DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

PREPARATION OF NATURAL FIBER REINFORCED SELF POLISHING PAINTS AND EVALUATION OF ANTIFOULING PERFORMANCES

by

Gudrat SAFAROV

October, 2021

İZMİR

PREPARATION OF NATURAL FIBER REINFORCED SELF POLISHING PAINTS AND EVALUATION OF ANTIFOULING PERFORMANCES

A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of Dokuz Eylül University
In Partial Fulfilment of the Requirements for the Degree of Master of Science
Department of Chemistry, Biochemistry Program

by

Gudrat SAFAROV

October, 2021

İZMİR

M. Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"PREPARATION OF NATURAL FIBER REINFORCED SELF POLISHING PAINTS AND EVALUATION OF ANTIFOULING PERFORMANCES"** completed by **GUDRAT SAFAROV** under supervision of **PROF. DR. LEVENT ÇAVAŞ** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Prof. Dr. Levent ÇAVAŞ

Supervisor

Prof. Dr. Mehmet Kadir YURDAKOÇ

(Jury Member)

Assoc.Prof. Dr. A. Kerem BAKIR

(Jury Member)

Prof. Dr. Özgür ÖZÇELİK

Director

Graduate School of Natural and Applied Sciences

ACKNOWLEDGMENTS

I am profoundly grateful to my supervisor Prof. Dr. Levent ÇAVAŞ for his support and guidance in this period. I also would like to thank Dokuz Eylül University, Department of Textile Engineering for providing natural fibers that were used in antifouling paints composition. I express my sincere thanks to LAPINUS company for providing commercial fibers. I deeply appreciate DYO company for supplying rosin which was main binder of the prepared paints. I thank Prof. Dr. Şermin AÇIK ÇINAR from Dokuz Eylül University, Institute of Marine Science and Technology for field studies of newly prepared fiber reinforced antifouling paint. I also thankful to Yeşim YILMAZ ABEŞKA, Cengizhan DAĞ, Nazlı MERT ÖZÜPEK for their supports. Finally, for their endless support and trust in me during this period, I would like to deeply thank my family.

Gudrat SAFAROV

PREPARATION OF NATURAL FIBER REINFORCED SELF POLISHING PAINTS AND EVALUATION OF ANTIFOULING PERFORMANCES

ABSTRACT

Biofouling can be described as the accumulation of living organisms on the surfaces that they get in contact with. Biofouling can increase parameters such as weight of ship, drag resistance, fuel consumption and decrease ship's maneuverability. Biofouling is prevented by using antifouling paints. Antifouling paints can be classified into two categories. One of them is based on release of chemically active substances from paint matrix. The other one does not require any kind of chemical release. Self-polishing antifouling paints are a class of paints that release chemically active substances from their matrices. Natural fibers such as Jute and Linen fibers and commercial fibers such as Rockforce MS730-Roxul 1000, Rockforce MS675-Roxul 1000 were used in paint formulations and the changes in self-polishing percentages were studied in this thesis. Biocidal agent econea, that was used in fiber-reinforced antifouling paint formulation, was analyzed by using High Performance Liquid Chromatography (HPLC). The eco-toxicity of econea was assessed by using an *Artemia salina*. Mechanical characteristics was studied by direct impact and crosscut tests. To gain information about antifouling performances of the paints field tests were made. In conclusion, natural fibers can be evaluated to develop eco-friendly self-polishing paints. Mechanically reinforced and ecofriendly paints can be formulated by using fibers in paint formulation.

Keywords: Biofouling, mechanical performances, self-polishing antifouling paint, toxicity.

DOĞAL LİFLERLE GÜÇLENDİRİLMİŞ KENDİ YÜZEYİNİ TEMİZLEYEN BOYALARIN HAZIRLANMASI VE ANTİFOULİNG PERFORMANSLARININ DEĞERLENDİRİLMESİ

ÖZ

Biyofouling, canlı organizmaların temas ettikleri yüzeylerde birikmesi olarak tanımlanabilir. Biofouling, geminin ağırlığı, sürtünme direnci, yakıt tüketimi gibi parametrelerini arrtırabilir ve geminin manevra kabiliyetinin azaltır. Antifouling boyalar kullanılarak biyofouling önlenir. Antifouling boyalar iki kategoriye ayrılabilir. Bunlardan biri, boya matrisinden kimyasal olarak aktif maddelerin salınımına dayanmaktadır. Diğeri ise herhangi bir kimyasal salınım gerektirmez. Kendi yüzeyini temizleyen antifouling boyalar, matrislerinden kimyasal olarak aktif maddeler salan bir boya sınıfıdır. Boya formülasyonlarında Jüt ve Keten gibi doğal lifler ve Rockforce MS730-Roxul 1000, Rockforce MS675- Roxul 1000 gibi ticari lifler kullanılmış ve kendi yüzeyini temizleme yüzdesindeki değişimler bu tezde incelenmiştir. Fiber takviyeli antifouling boya formülasyonunda kullanılan biyosidal ajan econea, Yüksek Performanslı Sıvı Kromatografisi (HPLC) kullanılarak analiz edilmiştir. Econea eko-toksisitesi, *Artemia salina* kullanılarak değerlendirilmiştir. Mekanik özellikler, doğrudan darbe ve çapraz kesme testleri ile incelenmiştir. Boyaların antifouling performansları hakkında bilgi edinmek için saha testleri yapılmıştır. Sonuç olarak, doğal lifler, çevre dostu kendinden cilalı boyalar geliştirmek için değerlendirilebilir. Boya formülasyonunda lifler kullanılarak mekanik olarak güçlü ve çevre dostu boyalar formüle edilebilir.

Anahtar kelimeler: Biyofouling, mekanik performans, kendi yüzeyini temizleyen antifouling boya, toksisite.

CONTENTS

Page

M. Sc THESIS EXAMINATION RESULT FORM ii

ACKNOWLEDGMENTS iii

ABSTRACT iv

ÖZ v

LIST OF FIGURES ix

LIST OF TABLES xvii

CHAPTER ONE - INTRODUCTION 1

1.1 Marine Biofouling 1

1.2 Effects of Marine Biofouling on a Maritime Industry 2

1.3 Historical Development of Antifouling Systems 2

1.4 Biofouling Protection Types 3

1.5 Types of Antifouling Paints 3

1.6 Less Toxic Alternatives 7

1.7 Fibers 9

1.7.1 Jute Fiber 10

1.7.2 Linen Fiber 11

1.8 Toxicity Tests 11

1.9 HPLC Analyses 12

1.10 Mechanical Performances of Paints 13

1.11 The Aims of the Thesis 14

CHAPTER TWO – MATERIALS AND METHODS 15

2.1 Materials 15

2.2 Preparation of the Natural Fibers for Use in Paints Formulation 16

2.2.1 Preparation of the Microscope Slides for Antifouling Paints Self Polishing Tests 17

2.3 Preparation of Free and Fiber Reinforced Antifouling Paints and Application on the Microscope Slides 17

2.4 Self Polishing Test 19

2.5 HPLC Analyses 19

2.6 Statistical Analysis 20

2.7 Eco-toxicity Test Using *Artemia salina* 20

2.8 Mechanical Tests 21

2.8.1 Direct Impact Test 21

2.8.2 Cross Cut Test 21

2.9 The Field Test 21

2.10 Fouling Criteria Assessment 23

CHAPTER THREE - RESULTS 24

3.1 The Results of the Self Polishing Tests 24

3.2 Results of the Eco-toxicity Test Using *Artemia salina* 216

3.3 Econea Analysis Using RP-HPLC 217

3.4 Results of Direct Impact and Cross Cut Tests 219

3.5 The Field Test Results 225

CHAPTER FOUR - DISCUSSION 236

CHAPTER FIVE - CONCLUSION 247

REFERENCES 250

LIST OF FIGURES

Page

Figure 1.1 Historical development of biofouling protection 3
Figure 1.2 Insoluble binder antifouling paint 4
Figure 1.3 Self-polishing antifouling paint 5
Figure 1.4 Tributyltin methacrylate (TBTM) and methyl methacrylate (MMA) 5
Figure 1.5 Tributyltin release mechanism 6
Figure 1.6 Self-polishing copolymer antifouling paint 6
Figure 1.7 Classification of plant-based fibers 10
Figure 2.1 Retach SM 100 mechanical cutter 17
Figure 2.2 Preparation of fiber free and fiber reinforced self-polishing antifouling paints 18
Figure 2.3 The apparatus for rotary tests 19
Figure 2.4 The Parameters affecting self-polishing percentage of antifouling paint 20
Figure 2.5 a) represents steel panel before paint preparation, b) represents steel panel covered by anticorrosive primer, c) represents steel panel covered by free or fiber reinforced antifouling paint 22
Figure 3.1 The effect of rotary rate and time on the self-polishing percentage of fiber free self-polishing antifouling paint at 20 °C 24
Figure 3.2 The effect of rotary rate and time on the self-polishing percentage of fiber free self-polishing antifouling paint at 30 °C 28
Figure 3.3 The effect of rotary rate and time on the self-polishing percentage of fiber free self-polishing antifouling paint at 40 °C 32
Figure 3.4 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 °C 36
Figure 3.5 The comparison of self-polishing percentages between control and linen fiber reinforced 1% (w/w) self-polishing antifouling paint for 3 hours test period at 20 ºC 37
Figure 3.6 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 °C 41

Figure 3.7 The comparison of self-polishing percentages between control and linen fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 °C 42
Figure 3.8 The effect of rotary rate and time on the self-polishing percentage of %1 (w/w) linen fiber reinforced self-polishing antifouling paint at 40 °C 46
Figure 3.9 The comparison of self-polishing percentages between control and linen fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 °C 47
Figure 3.10 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 20 °C ... 51
Figure 3.11 The comparison of self-polishing percentages between control and linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 20 °C 52
Figure 3.12 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 30 °C ... 56
Figure 3.13 The Comparison of self-polishing percentages between control and linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 °C 57
Figure 3.14 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 40 °C ... 61
Figure 3.15 The comparison of self-polishing percentages between control and linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 °C 62
Figure 3.16 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 °C . 66
Figure 3.17 The comparison of self-polishing percentages between control and linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 20 °C 67
Figure 3.18 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 °C . 71

Figure 3.19 The comparison of self-polishing percentages between control and linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 30 °C 72
Figure 3.20 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 °C . 76
Figure 3.21 The comparison of self-polishing percentages between control and linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 40 °C 77
Figure 3.22 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 °C 81
Figure 3.23 The comparison of self-polishing percentages between control and jute fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 20 °C..... 82
Figure 3.24 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 °C 86
Figure 3.25 The comparison of self-polishing percentages between control and jute fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 °C..... 87
Figure 3.26 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 °C 91
Figure 3.27 The comparison of self-polishing percentages between control and jute fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 °C..... 92
Figure 3.28 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 20 °C ... 96
Figure 3.29 The comparison of self-polishing percentages between control and jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 20 °C..... 97
Figure 3.30 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 30 °C . 101

Figure 3.31 The comparison of self-polishing percentages between control and jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC 102
Figure 3.32 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 40 °C . 106
Figure 3.33 The comparison of self-polishing percentages between control and jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC 107
Figure 3.34 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 °C 111
Figure 3.35 The comparison of self-polishing percentages between control and jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC 112
Figure 3.36 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 °C 116
Figure 3.37 The comparison of self-polishing percentages between control and jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC 117
Figure 3.38 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 °C 121
Figure 3.39 The comparison of self-polishing percentages between control and jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC 122
Figure 3.40 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 °C 126
Figure 3.41 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC 127
Figure 3.42 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 °C 131

Figure 3.43 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC 132
Figure 3.44 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 °C 136
Figure 3.45 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC 137
Figure 3.46 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint at 20 °C 141
Figure 3.47 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint for 3-hour test period 20 ºC 142
Figure 3.48 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint at 30 °C 146
Figure 3.49 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint for 3-hour test period at 30 ºC 147
Figure 3.50 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint at 40 °C 151
Figure 3.51 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint for 3-hour test period at 40 ºC 152
Figure 3.52 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 °C 156

Figure 3.53 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC 157
Figure 3.54 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 °C 161
Figure 3.55 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC 162
Figure 3.56 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 °C 166
Figure 3.57 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC 167
Figure 3.58 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 °C 171
Figure 3.59 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC 172
Figure 3.60 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 °C 176
Figure 3.61 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC 177
Figure 3.62 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 °C 181

Figure 3.63 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC 182
Figure 3.64 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 20 °C 186
Figure 3.65 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC 187
Figure 3.66 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 30 °C 191
Figure 3.67 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC 192
Figure 3.68 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 40 °C 196
Figure 3.69 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC 197
Figure 3.70 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 °C 201
Figure 3.71 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC 202
Figure 3.72 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 °C 206

Figure 3.73 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC 207
Figure 3.74 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 °C 211
Figure 3.75 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC 212
Figure 3.76 Results of the econea toxicity tests using model organism *Artemia salina* 216
Figure 3.77 HPLC chromatogram of 5 ppm econea 217
Figure 3.78 Time-dependent comparison HPLC chromatogram of 5 ppm econea at 88°C water 218
Figure 3.79 Detailed HPLC chromatogram of econea at 88°C 218

LIST OF TABLES

Page

Table 1.1 Some of booster biocides used in paint formulation 8
Table 2.1 Properties of jute fiber 15
Table 2.2 Properties of linen fiber 15
Table 2.3 Properties of MS730-Roxul 1000 fiber 16
Table 2.4 Properties of MS675- Roxul 1000 fiber 16
Table 2.5 Fiber free and fiber reinforced self-polishing antifouling paint formulations 18
Table 2.6 Antifouling paint formulations for field tests 22
Table 3.1 One-way ANOVA results related to the effects of rotary time and rate on self-polishing percentage of fiber free self-polishing antifouling paint at 30 ºC 25
Table 3.2 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour 25
Table 3.3 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours 26
Table 3.4 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours 27
Table 3.5 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of fiber free self-polishing antifouling paint at 30 ºC 29
Table 3.6 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour 29
Table 3.7 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours 30
Table 3.8 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours 31
Table 3.9 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of fiber free self-polishing antifouling paint at 40 ºC 33

Table 3.10 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour 33
Table 3.11 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours 34
Table 3.12 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours 35
Table 3.13 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 ºC 37
Table 3.14 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC 37
Table 3.15 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour 38
Table 3.16 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours 39
Table 3.17 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours 40
Table 3.18 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 ºC 42
Table 3.19 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC 42
Table 3.20 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour 43
Table 3.21 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours 44
Table 3.22 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours 45

Table 3.23 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 ºC 47
Table 3.24 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 ºC 47
Table 3.25 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour 48
Table 3.26 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours. 49
Table 3.27 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours 50
Table 3.28 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 20 ºC 52
Table 3.29 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC 52
Table 3.30 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour 53
Table 3.31 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours 54
Table 3.32 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours 55
Table 3.33 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 30 ºC 57
Table 3.34 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC 57
Table 3.35 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour 58

Table 3.36 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 2 hours..... 59
Table 3.37 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 3 hours..... 60
Table 3.38 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 40 °C..... 62
Table 3.39 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 °C 62
Table 3.40 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 1 hour 63
Table 3.41 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 2 hours..... 64
Table 3.42 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 3 hours..... 65
Table 3.43 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 °C..... 67
Table 3.44 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 °C 67
Table 3.45 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 1 hour 68
Table 3.46 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 2 hours..... 69
Table 3.47 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 3 hours..... 70
Table 3.48 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 °C..... 72

Table 3.49 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 °C 72
Table 3.50 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 1 hour 73
Table 3.51 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 2 hours..... 74
Table 3.52 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 3 hours..... 75
Table 3.53 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 °C..... 77
Table 3.54 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 °C 77
Table 3.55 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 1 hour 78
Table 3.56 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 2 hours..... 79
Table 3.57 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 3 hours..... 80
Table 3.58 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 °C..... 82
Table 3.59 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 °C 82
Table 3.60 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 1 hour..... 83
Table 3.61 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 2 hours 84

Table 3.62 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours 85
Table 3.63 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 ºC..... 87
Table 3.64 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC 87
Table 3.65 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour (Since the microscope slides were broken after the experiment, the photos of the 250 RPM rotary rate result are not shown.) 88
Table 3.66 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours (Since the microscope slides were broken after the experiment, the photos of the 250 RPM rotary rate result are not shown.) 89
Table 3.67 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours Since the microscope slides were broken after the experiment, the photos of the 250 RPM rotary rate result are not shown.) 90
Table 3.68 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 ºC..... 92
Table 3.69 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC 92
Table 3.70 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour..... 93
Table 3.71 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours 94
Table 3.72 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours 95

Table 3.73 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 20 ºC..... 97
Table 3.74 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC 97
Table 3.75 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour 98
Table 3.76 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours..... 99
Table 3.77 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours..... 100
Table 3.78 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 30 ºC..... 102
Table 3.79 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC 102
Table 3.80 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour 103
Table 3.81 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours..... 104
Table 3.82 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours..... 105
Table 3.83 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 40 ºC..... 107
Table 3.84 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 ºC 107
Table 3.85 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour 108

Table 3.86 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 2 hours..... 109
Table 3.87 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 3 hours..... 110
Table 3.88 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 °C..... 112
Table 3.89 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 °C 112
Table 3.90 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 1 hour 113
Table 3.91 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 2 hours..... 114
Table 3.92 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 3 hours..... 115
Table 3.93 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of 0.01% jute fiber reinforced self-polishing antifouling paint at 30 °C 117
Table 3.94 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 °C 117
Table 3.95 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 1 hour 118
Table 3.96 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 2 hours..... 119
Table 3.97 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 3 hours..... 120
Table 3.98 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 °C..... 122

Table 3.99 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 °C 122
Table 3.100 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 1 hour 123
Table 3.101 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 2 hours..... 124
Table 3.102 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 3 hours..... 125
Table 3.103 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 °C 127
Table 3.104 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 °C 127
Table 3.105 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 1 hour 128
Table 3.106 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 2 hours 129
Table 3.107 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 3 hours 130
Table 3.108 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 °C 132
Table 3.109 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 °C 132

Table 3.110 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 1 hour 133
Table 3.111 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 2 hours 134
Table 3.112 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 3 hours 135
Table 3.113 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 °C 137
Table 3.114 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 °C 137
Table 3.115 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 1 hour 138
Table 3.116 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 2 hours 139
Table 3.117 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 3 hours 140
Table 3.118 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint at 20 °C 142
Table 3.119 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 °C 142

Table 3.120 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 20 °C for 1 hour 143
Table 3.121 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 20 °C for 2 hours 144
Table 3.122 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 20 °C for 3 hours 145
Table 3.123 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint at 30 °C 147
Table 3.124 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 °C 147
Table 3.125 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 30 °C for 1 hour 148
Table 3.126 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 30 °C for 2 hours 149
Table 3.127 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 30 °C for 3 hours 150
Table 3.128 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint at 40 °C 152
Table 3.129 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 °C 152

Table 3.130 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 40 °C for 1 hour 153
Table 3.131 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 40 °C for 2 hours 154
Table 3.132 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 40 °C for 3 hours 155
Table 3.133 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 °C 157
Table 3.134 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 °C 157
Table 3.135 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 1 hour 158
Table 3.136 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 2 hours 159
Table 3.137 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 3 hours 160
Table 3.138 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 °C 162
Table 3.139 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 °C 162

Table 3.140 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 1 hour 163
Table 3.141 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 2 hours 164
Table 3.142 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 3 hours 165
Table 3.143 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 °C 167
Table 3.144 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 °C 167
Table 3.145 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 1 hour 168
Table 3.146 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 2 hours 169
Table 3.147 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 3 hours 170
Table 3.148 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 °C 172
Table 3.149 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 °C 172

Table 3.150 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 1 hour 173
Table 3.151 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 2 hours 174
Table 3.152 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 3 hours 175
Table 3.153 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 °C 177
Table 3.154 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 °C 177
Table 3.155 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 1 hour 178
Table 3.156 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 2 hours 179
Table 3.157 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 3 hours 180
Table 3.158 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 °C 182
Table 3.159 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 °C 182

Table 3.160 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 1 hour 183
Table 3.161 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 2 hours 184
Table 3.162 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 3 hours 185
Table 3.163 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 20 °C 187
Table 3.164 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 °C 187
Table 3.165 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 1 hour 188
Table 3.166 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 2 hours 189
Table 3.167 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 3 hours 190
Table 3.168 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 30 °C 192
Table 3.169 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 °C 192

Table 3.170 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 1 hour 193
Table 3.171 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 2 hours 194
Table 3.172 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 3 hours 195
Table 3.173 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 40 °C 197
Table 3.174 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 °C 197
Table 3.175 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 1 hour 198
Table 3.176 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 2 hours 199
Table 3.177 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 3 hours 200
Table 3.178 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing paint at 20 °C 202
Table 3.179 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 °C 202

Table 3.180 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 1 hour 203
Table 3.181 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 2 hours 204
Table 3.182 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 °C for 3 hours 205
Table 3.183 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 °C 207
Table 3.184 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 °C 207
Table 3.185 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 1 hour 208
Table 3.186 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 2 hours 209
Table 3.187 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 3 hours 210
Table 3.188 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 °C 212
Table 3.189 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 °C 212

Table 3.190 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 1 hour 213
Table 3.191 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 2 hours 214
Table 3.192 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 °C for 3 hours 215
Table 3.193 Results of the direct impact and crosscut test 220
Table 3.194 The metallic plate covered by only anticorrosive primer before and after immersion to sea 227
Table 3.195 The metallic plate covered by booster biocide (econea) and fiber free antifouling paint before and after immersion to sea 228
Table 3.196 The metallic plate covered by fiber free antifouling paint before and after immersion to sea 228
Table 3.197 The metallic plate covered by antifouling paint containing linen fiber 1% (w/w) before and after immersion to sea 229
Table 3.198 The metallic plate covered by antifouling paint containing linen fiber 0.1% (w/w) before and after immersion to sea 229
Table 3.199 The metallic plate covered by antifouling paint containing linen fiber 0.01% (w/w) before and after immersion to sea 230
Table 3.200 The metallic plate covered by antifouling paint containing jute fiber 1% (w/w) before and after immersion to sea 230
Table 3.201 The metallic plate covered by antifouling paint containing jute fiber 0.1% (w/w) before and after immersion to sea 231
Table 3.202 The metallic plate covered by antifouling paint containing jute fiber 0.01% (w/w) before and after immersion to sea 231
Table 3.203 The metallic plate covered by antifouling paint containing Rockforce MS730-Roxul 1000 fiber 1% (w/w) before and after immersion to sea 232

Table 3.204 The metallic plate covered by antifouling paint containing Rockforce MS730-Roxul 1000 fiber 0.1% (w/w) before and after immersion to sea 232
Table 3.205 The metallic plate covered by antifouling paint containing Rockforce MS730-Roxul 1000 fiber 0.01% (w/w) before and after immersion to sea 233
Table 3.206 The metallic plate covered by antifouling paint containing Rockforce MS675-Roxul 1000 fiber 1% (w/w) before and after immersion to sea233
Table 3.207 The metallic plate covered by antifouling paint containing Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) before and after immersion to sea 234
Table 3.208 The metallic plate covered by antifouling paint containing Rockforce MS675-Roxul 1000 fiber 0.01% (w/w) before and after immersion to sea 234
Table 3.209 Evaluation of fouling level of the metallic plates used in field test 235

CHAPTER ONE
INTRODUCTION

1.1 Marine Biofouling

An undesirable accumulation of biological matter on the surfaces that they get in contact with is known as biofouling. This event is observed in several areas such as medicine, industrial and maritime. The aggregation of aquatic species on artificial surfaces submerged in the marine environment can be classified as marine biofouling (Yebra et al., 2004; Almeida et al., 2007). The adhesion of organic and inorganic molecules to the artificial surface begins this process. Examples of early fouling matter are proteins, proteoglycans, and inorganic molecules. Organic molecule binding happens within 1-2 minutes. The major contributor to this event is physical forces such as Wander Waals forces and Brownian motion. For microorganisms that exist in the sea environment, surfaces rich in organic molecules are a perfect area (Kristensen et al., 2008).

When surface is covered by microorganisms such as microalgae or diatoms, it is known as primer colonization and takes around 1-24 h to complete. The biofilm layer is forming in this period and giving rise to the second stage of biofouling. At the second stage of biofouling macroalga spores and protozoa binds to the substrate and this is known as seconder colonization. The surface is coated with a rugged fouler at this point and this stage is permanent. Tertiary colonization occurs after 1 week of the secondary colonization stage and the macrofouling organism eggs accumulate and develop on the surface in this period (Qian et al., 2013). The degree of biofouling can be influenced by many parameters, such as geographical location, seawater temperature, seawater salinity, and season. Biofouling happens more rapidly in hot climates than in cold climates. The motion of molecules is more apparent when seawater is warm, and the number of organic molecules collected is expanding rapidly. This contributes to the formation of the organic film layer easily (Bixler et al., 2012).

1.2 Effects of Marine Biofouling on a Maritime Industry

Marine biofouling impacts the shipping sector by a variety of factors. Biomass accumulation in the ship's hulls increases the ship's weight and decreases maneuverability of ships, and it increases the fuel consumption and CO_2 emissions of ships (Yebra et al., 2004). The rigidness of the ship hulls is enhanced when coated with rigid biofouling layers which contributes to increased drag resistance. This kind of harsh biofilm coating makes the ship's hull and sea water friction more possible. High friction will lead to low ship maneuvering capability. As a result of the bioaccumulation of living organisms, the ship increases its fuel consumption drastically (Schultz et al., 2007). Higher consumption of fuels results in higher shipping prices and higher CO_2 emissions. Moreover, the introduction of new species through biofouling will contribute to significant ecological pollution. Ship hull-connected species (invasive species) may move in this way from one area to another (Davidson et al., 2009).

1.3 Historical Development of Antifouling Systems

Because of their importance in sea transport, ships have had to be shielded from biofouling since early age. The early techniques introduced in year 700 BC were to treat the underwater parts of the ships with wax-like materials, cover them with tin and copper. In 700 BC Phoenicians used wax-like substances under the ships. This type of coating helped to prevent biofouling to some degree. Vikings used tar-like materials to protect ship hulls from biofouling in 1000 AD. in 1600 Ship hulls were coated with copper. This type of coating prevented organisms from attachment to the surface. But coating ship hulls with copper was an expensive and labor-intensive process. In 19 centuries, the bottom of the ships started to be covered with antifouling paints. Antifouling paints provided higher biofouling protection and were cheaper than their predecessors. In the XX century, it became important to cover the underwater parts of the ships with antifouling paints. In the 1950s, the use of triorganotin derivatives in the ships provided superior antifouling performance. The use of triorganotin derivatives was banned in 2008 after the realization of harmful effect of triorganotin derivatives on the ecosystem (Jones, 2009).

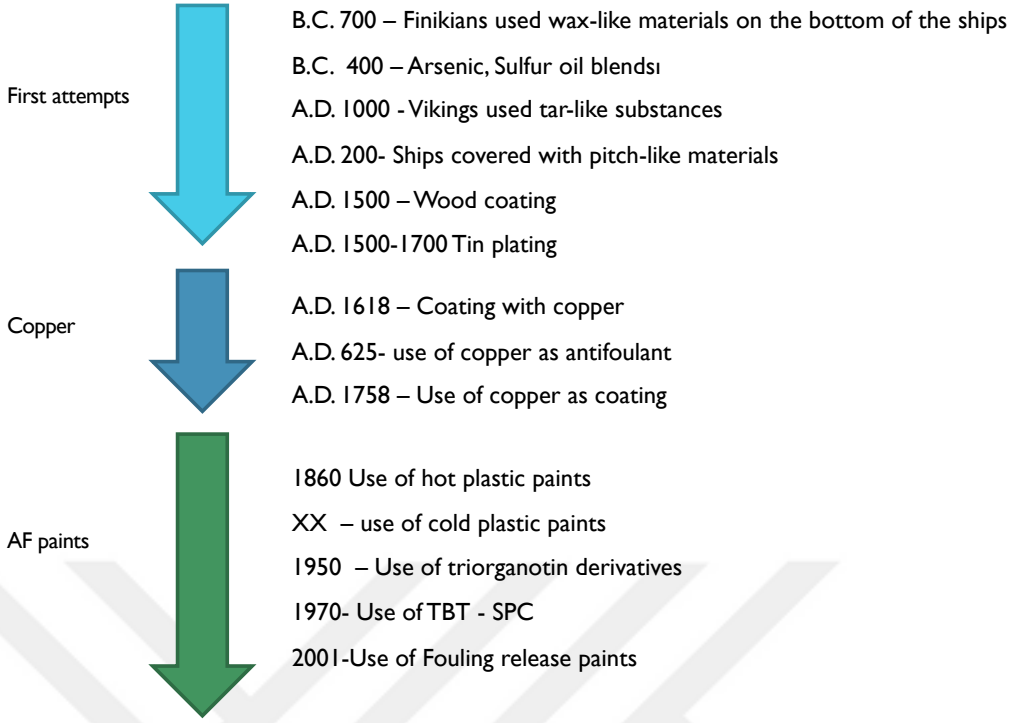


Figure 1.1 Historical development of biofouling protection (Inspired from Jones, 2009)

1.4 Biofouling Protection Types

It is important to separate antifouling techniques into two major groups. Prevention of biofouling with coating and non-coating. The electrochemical procedure and dry-docking washing of the ship hulls consist of non-coating biofouling prevention. Dry-docking is a procedure that is labor intensive and costly. For this cause, ship hull protection is a very necessary factor. Using antifouling paints for biofouling prevention is a reliable strategy. By using this type of paints ships can sail for a period as long as 1-4 years (Chambers et al., 2006).

1.5 Types of Antifouling Paints

It is possible to group the coating used in biofouling prevention via two major groups. The first group is based upon the release from the paint binder of chemically active substances. This class also consists of two categories (Almeida et al., 2007; Yebra et al., 2004). Soluble binder paints and insoluble binder paints are in these

categories. Insoluble binder antifouling paints shows good performance in the prevention of bioaccumulation on coatings surface (Figure 1.2). However insoluble binder paints also have disadvantages. Porous textures are formed when biocides are released from the insoluble paint binder. Microorganisms may adopt these pores as living and hiding areas. These kind of drawbacks pointed out the need for an alternative way of protection against biofouling (Kwon et al., 2020).

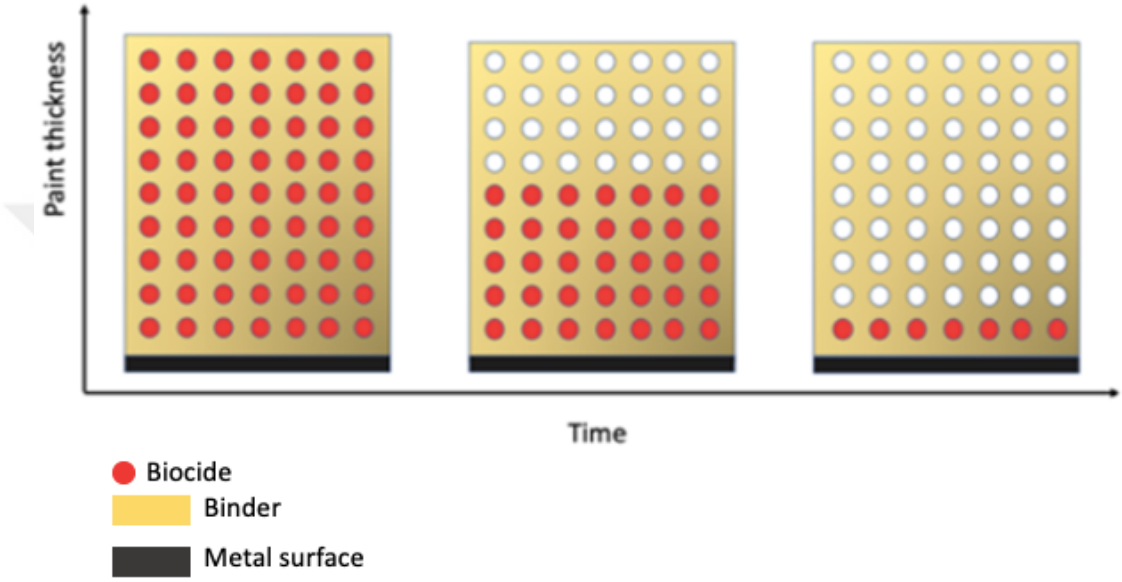


Figure 1.2 Insoluble binder based antifouling paint (Inspired from Almedia et al., 2007)

Soluble binder paints are consisting of self-polishing and self-polishing copolymer antifouling paints. As biocides are released from the binder of self-polishing antifouling paints, the binder frequently erodes and gradually becomes thinner (Figure 1.3). This type of protection is desirable but when the surface of the coating is eroded recessed protruding surfaces are forming. This rough surface also can act as a protection and living area for organisms. Trialkylsilyl-based methacrylate, Cu-based acrylate, Zn-based acrylate binders are used as a binder in self polishing antifouling paints. In the preparation of self-polishing anti-fouling paints, rosin could also be used. The good degree of polishing and natural occurrences of rosin, enables it to be used as a binder material in self-polishing antifouling paints (Dafforn et al., 2011).

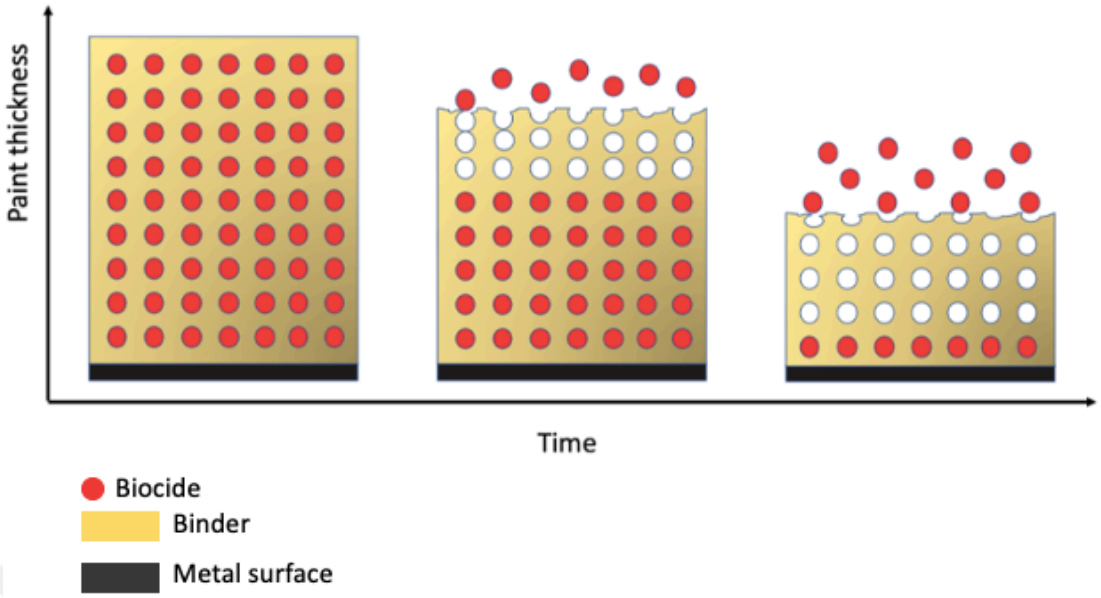


Figure 1.3 Self-polishing antifouling paint (Inspired from Almedia et al., 2007)

The use of self-polishing copolymer type antifouling paints has shown excellent performance. When the surface of the coating gets in contact with the seawater surface deteriorates layer by layer (Figure 1.6). When a layer of paint is hydrolyzed from paint binder, a new and biocide packed layer is forms. Tributyltin self-polishing copolymer (TBT) was mainly used in this type of paints. The chemical structure of TBT containing copolymer can be seen in Figure 1.4.

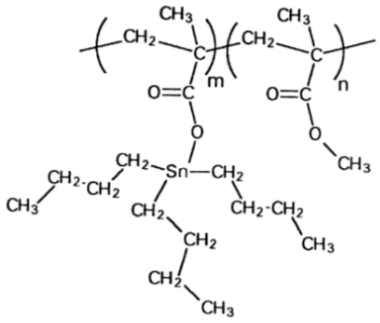


Figure 1.4 Tributyltin methacrylate (TBTM) and methyl methacrylate (MMA)

Tributyltin moiety is linked to the acrylate backbone of the polymer. When polymer backbone contacts with water ester bonds is cleaved and TBT moiety is released away from polymer backbone. TBT release reaction can be seen in Figure 1.5.

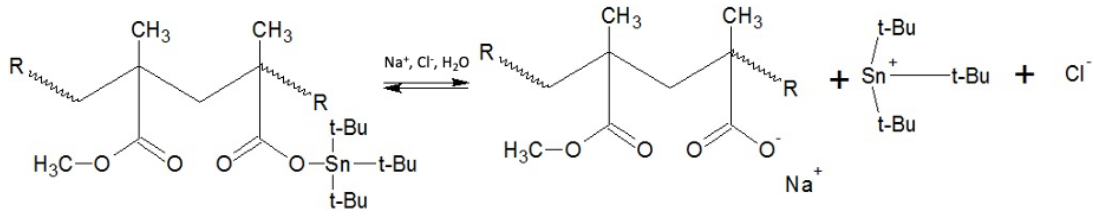


Figure 1.5 Tributyltin release mechanism (Inspired from Almeida et al., 2007)

Although antifouling paints containing tributyltin derivatives showed the best performance of their time, in 2003 production of these paints were restricted and in 2008 use of them were totally banned after understanding the damage caused to the environment. TBT caused imposex in many shellfish, and its accumulation in sea sediments was reported (da Costa et al., 2017; Maciel et al., 2018).

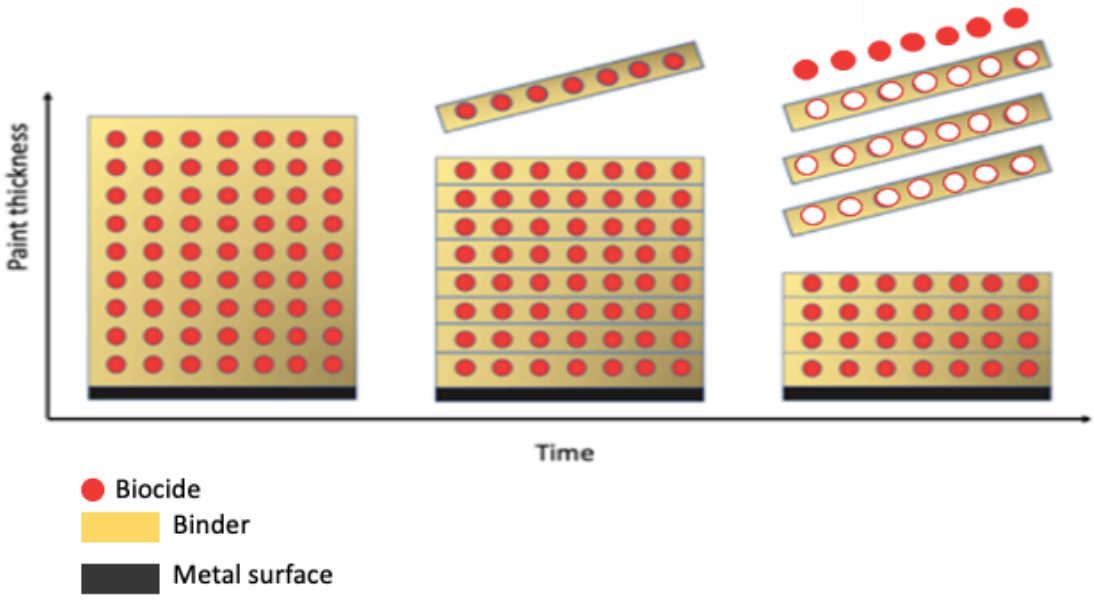


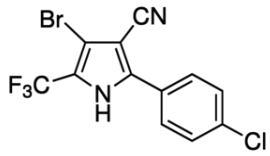
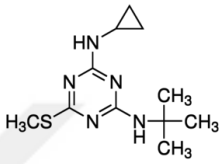
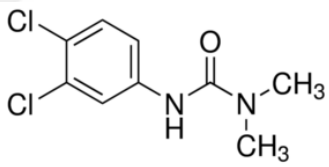
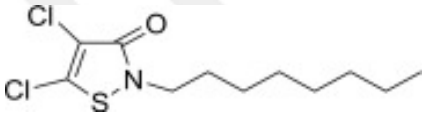
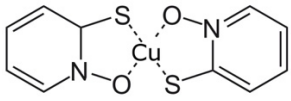
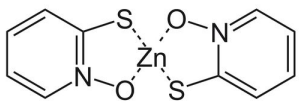
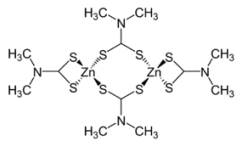
Figure 1.6 Self-polishing copolymer antifouling paint (Inspired from Almeida et al., 2007)

1.6 Less Toxic Alternatives

Biocide-containing antifouling paints have been shown to damage the ecosystem. Paints containing copper and zinc already caused the rise in the concentration of heavy metals in the seas. The search for more environmentally friendly solutions is the priority of the industry. The use of booster biocides gives an opportunity to obtain less harmful paint formulations. Booster biocides are used in paint formulation in combination with other biocides such as heavy metal containing biocides (Zinc pyrithione, Copper pyrithione, Ziram, Zineb). The use of booster biocides gives reliable protection against biofouling. Some of the widely used booster biocides are shown in Table 1.1. Although the use of booster biocides is a more environmentally friendly option compared to the use of TBT, regulations have been implemented as a result of understanding the damage caused by some booster biocides to the environment. Irgarol 1051 and diuron are among these booster biocides. The use of these booster biocides was banned in the UK in 2000. The use of Irgarol 1051 and Diuron was also banned in Denmark in 2000. In Australia, the use of Irgarol 1051 in antifouling paint structures is prohibited as of the 1990s (Cresswell et al., 2006; Readman et al., 2006; Dafforn et al., 2011). For biofouling protection, naturally occurring compounds may also be used in paint formulation. Secondary metabolites produced by many marine animals act as natural antifoulants. The use of these antifoulants in the formulation of antifouling paints can give biofouling protection for some time. However, various problems such as ease of availability and raw material sustainability increase the cost of production. These kind of drawbacks make it hard to produce sustainable paints (Qian et al., 2009; Satheesh et al., 2016; Sathicq et al., 2019). The use of nonstick technologies gained popularity in recent years. Fouling release type paints are a class of nonstick antifouling paint that does not require any biocide release. Fluoropolymers and silicone-based polymers used for this purpose. Fouling release type paints protect surface by reducing surface energy of the coating and making it harder for organisms to attach. Static surfaces cannot be fully protected by fouling release paints because this type of paint needs movement to clean its surface. Although the use of fouling release type paints gives reliable protection weak

mechanical characteristics of this paint makes it hard to use in severe sea conditions (Lejars et al., 2012).

Table 1.1 Some of booster biocides used in paint formulation

Econea (4-bromo-2-(4-chlorophenyl)-5-(trifluoromethyl)-1H-pyrrole-3-carbonitrile)	
Irgarol 1051 (2-methylthio-4-*tert*-butylamino-6-cyclopropylamino-*s*-triazine)	
Diuron (3-(3,4-dichlorophenyl)-1,1-dimethylurea)	
Sea-Nine 211 (4,5-dichloro-2-*n*-octyl-3(2H)-isothiazolone)	
Copper pyrithione (copper complex of 2-mercaptopyridine-1-oxide)	
Zinc pyrithione (zinc complex of 2-mercaptopyridine-1-oxide)	
Ziram (zinc bis(dimethylthiocarbamates))	

1.7 Fibers

Fibers are thin thread of a natural or artificial substances. Natural fibers, synthetic organic fibers, and synthetic inorganic fibers are the three primary forms of fibers. Cotton, silk, wool-like fibers, plant or animal-based fibers are examples of natural fibers. Aramid and polyethylene, which have the broadest application range, belong to the synthetic organic fiber category. Glass fiber, alumina, boron, carbon, and silicon are the most widely used examples of manufactured inorganic fibers (Lilholt et al., 2000).

Natural fibers are fibers obtained from sources such as plants, animals and minerals. Plant-based natural fibers are fibrous materials produced by plants during photosynthesis. Since 8,000 BC, natural fibers have been utilized in many areas. In ancient days, linen and hemp fabrics were used. A growing awareness that non-renewable resources are finite and exhaustible began to develop around the beginning of the 21st century. Plant-based natural fibers are utilized as reinforcement in a variety of polymers and composites (Faruk et al., 2012). Natural fibers are composite materials with complex three-dimensional structures and are generally composed of cellulose, hemicellulose, lignin and pectin. Cellulose, the linear polymer of anhydro glucose, forms the main structure of natural fibers and gives structural stability and stiffness to the natural fiber. Cellulose is highly crystalline form. Hemicellulose is found in fiber structure with cellulose and has a branched polymer structure. Unlike cellulose, which is crystalline, hemicellulose is amorphous. Lignin consists of cross-linked hydroxy or methoxylated phenylpropane polymer structures and is amorphous. Pectin is complex polysaccharides found in natural fiber structure and consists of rhamnose residues and glucuronic acid in its main chain. Side chain structures are generally composed of rhamnose, arabinose and galactose sugars (Clemons et al.,2005). Fibers derived from plant sources can be classified into five categories. Wood, steam/bast, leaf, seed/fruit and grass are main sources of natural fiber (Chandramohan et al., 2011). Classification of fibers and examples of fibers can be seen in Figure 1.7.

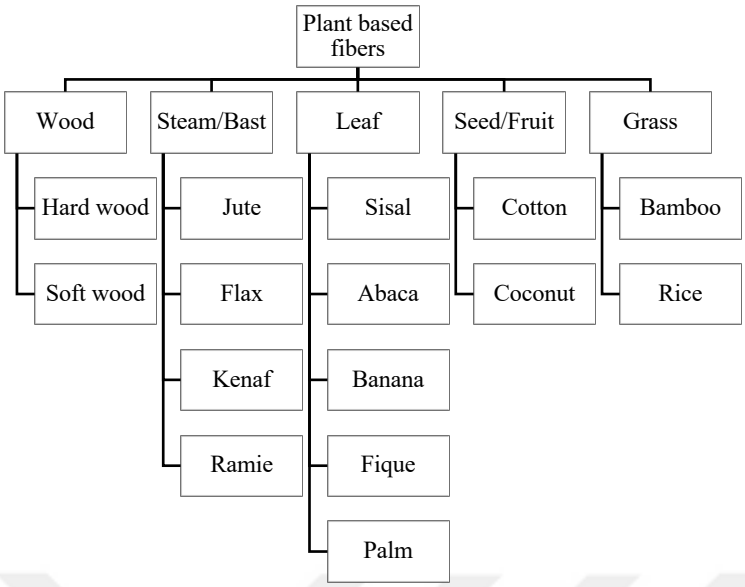


Figure 1.7 Classification of plant-based fibers (Inspired from Chandramohan et al., 2011)

Natural fibers derived from renewable resources have gained popularity as reinforcement in plastic materials in recent years. The benefits of plant fibers over glass fiber and carbon fiber are as follows: low cost, low density, acceptable specific strength, high toughness, good thermal characteristics, reduced skin and respiratory tract irritation, and biodegradability. In comparison to glass fibers, natural fibers have exceptionally high sound absorption capabilities and low specific gravity. Manufacturing industries are becoming significantly more aware of industrial uses of natural fiber. Natural fibers are being used for polymer composites to satisfy varied end uses in transport, low-cost construction, and other construction industries (Sanjay et al., 2016).

1.7.1 Jute Fiber

Jute is derived from plants of the *Corchorus genus*, which has around 100 species. It's one of the most affordable natural fibers, and it's also the most widely produced. The jute plant is the most widely used of all the bark fibers in the textile industry. The trees are between 2.5 and 3.5 meters tall. After cotton, it is the most widely grown plant on the planet. It is native to India and thrives in a tropical environment. India, Bangladesh, and Pakistan account for around 80% of global output. The fiber cells in the body of the jute are arranged in bundles. When looking at the cross section, angular cells in the shapes of a pentagon and a hexagon may be noticed (Wang et al., 2019).

Several studies had been conducted to improve parameters of jute fiber and jute fiber containing composites. It has been observed that the use of jute fiber in the structures of composite materials significantly increases the tensile, bending and impact power of the material (Hossain et al., 2011; Liu et al., 2009).

1.7.2 Linen Fiber

Linum usitatissimum, also known as linen (flax), is a bast fiber. It is a temperate-zone crop that is one among the world's oldest fiber crops. Linen fibers' tensile mechanical characteristics are estimated based on their diameter and position in the stems. Linen fiber production accounts for 0.4 percent of total global fiber output. The use of linen fiber gained popularity after an increase in the use of ecofriendly materials (Yan et al., 2014).

There are several publications examining the effects of linen fiber on the mechanical behavior of composite materials (Arbelaiz et al., 2005; Lodha et al., 2005; Holbery et al., 2006; Van de Weyenberg et al., 2006; Liu et al., 2008; John et al., 2009; Barkoula et al., 2010; Modniks et al., 2010; Andersons et al., 2011; Miao et al., 2011; Liang et al., 2012). In addition to the changes in the physical properties of polypropylene materials reinforced with linen, the changes in the thermal and crystalline structures of the composite material after this reinforcement have been investigated in a series of publications. The use of linen fibers instead of inorganic fibers in composite materials is a more environmentally friendly solution. The tensile properties of glass fiber and linen fiber reinforced composites were investigated (Assarar et al., 2011). Looking at the results of research, the tensile strength of the linen fiber reinforced composite is up to 350 MPa, and thus it can be used as an alternative to glass fiber.

1.8 Toxicity Tests

It is necessary to investigate the damage caused by heavy metals released from materials commonly used in industry such as antifouling paints. This type of research is done using toxicity tests. By understanding the toxic effects of the chemicals used in paints formulation new, eco-friendly and nontoxic alternatives can be produced.

Toxicity tests are generally classified according to the duration of the tests. Toxicity tests consist of acute, subacute, sub chronic, chronic and special toxicity tests. The toxicity used for aquatic environments differs from other types of toxicity. Although the effects of the substance on a single species are examined when the toxicity is calculated in mammals, eco-toxicity differs according to the diversity of the living species in the environment (Mitchell et al.,2002).

There are studies in the literature on the environmental damage caused by heavy metals used in the formulation of antifouling paints (Amara et al., 2018). For this reason, it is necessary to investigate the damage of these chemicals to the environment. This information is obtained using ecotoxicity tests. Toxic effects of biocides used in formulations were investigated by using model organisms such as zebra mussels, sea urchins, oysters etc. Due to the long-standing interest in aquatic toxicity testing, a variety of test species and test types have been used. *Artemia salina* (brine shrimp)*, Nitzschia linearis* (diatom)*, Crangon crangon* (sand shrimp)*, Ceriodaphnia dubia* (water flea) etc. can be given as examples for model organisms to asses ecotoxicity of the chemicals used in paint formulations (Amara et al., 2018; Bao et al., 2011).

1.9 High Performance Liquid Chromatography Analyses

With the increase in the use of antifouling paints, it has become important to determine the level and occurrence of the chemicals released from the paints. It is important to determine the fate of the biocides used in paint structures after they are released into the environment. Various methods have been developed to determine the amount of biocide in seawater samples taken near the port or offshore (Rodríguez et al., 2011). Among these methods, the methods using High Performance Liquid Chromatography (HPLC) draw attention with both the rapidity of the method and the short duration of the experiment. HPLC is a type of liquid chromatography and gives fast and reliable results. HPLC consists of a stationary and a mobile phase. According to the characteristics of the stationary and mobile phases, HPLC is classified as normal and reversed phase. In normal phase HPLC, the stationary phase polar mobile phase is nonpolar, whereas in reverse phase HPLC, the opposite, stationary phase nonpolar mobile phase is polar.

The use of HPLC for the determination of biocides used in antifouling paint formulations has also taken its place in the literature (Rodríguez et al., 2011; Tsang et al., 2009; Thomas, 1999). A new and robust method for the determination of booster biocide Econea (tralopyril) levels was carried out by using RP-HPLC (Mert et al., 2014). In another publication, HPLC was used coupled with atmospheric-pressure chemical-ionization mass spectrometry for the determination of booster biocides diuron, İrgarol, dichlofluanid etc. (Martinez et al., 2001).

1.10 Mechanical Performances of Paints

Mechanical tests are necessary to understand how paints will behave in real life conditions. If the paint does not have mechanical strength, cracks, cuts, spills, etc. that will occur on the surface will affect the performance of the paint. This becomes even more important if the paint in question is antifouling paints applied to the hulls of marine vessels. Damage to the paint surface may occur because of the ship hull rubbing against any artificial. This damage may cause sea water to penetrate the inner layers of the paint later, resulting in a decrease in paint performance and even make the surface useless. Therefore, it is necessary to conduct tests regarding mechanical behavior while producing paint and to produce paint in accordance with the test results. There are several methods for measuring paint mechanical performance. Among these methods, tests such as a mandrel, direct impact, crosscut and knife-cut are among commonly used tests. The results obtained in these tests give information about the paint performance (Yebra et al., 2009).

1.11 The Aims of the Thesis

The aim of the thesis study is to prepare self-polishing paints reinforced with natural fibers and to investigate the self-polishing percentages and antifouling performances of the prepared paints. It is aimed to investigate the effects of the fibers used in the paint formulation on the self-polishing percentages of the paints.

The objectives of the thesis:

- Investigation of effects of natural and commercial fibers on the self-polishing percentages of antifouling paints
- Investigation of ecotoxicity of booster biocide econea using model organism *Artemia salina*
- Purity check of booster biocide econea using HPLC
- Investigation of mechanical characteristics of prepared fiber reinforced antifouling paints using direct impact and crosscut tests
- Investigation of antifouling performances of prepared fiber reinforced antifouling paints via field trials

CHAPTER TWO
MATERIALS AND METHODS

2.1 Materials

Rosin was used as the main binder chemical in fiber-reinforced antifouling paints formulation. Rosin was kindly provided by DYO company in Turkey. Natural fibers such as linen fiber and jut fiber were provided by Dokuz Eylül University, Department of Textile Engineering. Properties of natural fibers are shown in Table 2.1 and Table 2.2. Paints containing commercial fibers such as Rockforce MS730-Roxul 1000 and Rockforce MS675- Roxul 1000 were also prepared. These commercial fibers were provided by Lapinus Company in Netherland. Properties of the commercial fibers are shown in Table 2.3 and Table 2.4. Data were obtained from Lapinus database (Lapinus | Part of the ROCKWOOL Group, n.d.).

Table 2.1 Properties of jute fiber

Length (average)	2 mm
Width (average)	20 µm
Density	2.3-1.5 g/cm^3
Tensile strength	393-773 MPa
Young's module	13-26.25 GPa
Elongation at brake	7-8 %

Table 2.2 Properties of linen fiber

Length (average)	33 mm
Width (average)	19 µm
Density	1.4-1.5 g/cm^3
Tensile strength	45-1100 MPa
Young's module	27.6 GPa
Elongation at brake	2.7-3.2 %

Table 2.3 Properties of MS730-Roxul 1000 fiber.

Parameter	Average/Tolerance
Moisture Content	max. 0.1 %wt
Ignition Loss	max. 0.3 %wt
Fiber Length	225 ± 50 micron
Fiber diameter (mass wt. av.)	approx. 9.0 micron
Fiber diameter (num. av.)	approx. 5.5 micron
Specific surface area	approx. 0.20 m^2/g
Hardness	6 Moh
Melting Point	> 1000 ºC
Specific Density	2.75 ± 0.15 g/cm^3
Color	Grey/Green

Table 2.4 Properties of MS675- Roxul 1000 fiber.

Parameter	Average/Tolerance
Moisture Content	max. 0.1 %wt
Ignition Loss	max. 0.3 %wt
Fiber Length	500 ± 150 micron
Fiber diameter (mass wt. av.)	approx. 9.0 micron
Fiber diameter (num. av.)	approx. 5.5 micron
Specific surface area	approx. 0.20 m^2/g
Hardness	6 Moh
Melting Point	> 1000 ºC
Specific Density	2.75 ± 0.15 g/cm^3
Color	Grey/Green

2.2 Preparation of the Natural Fibers for Use in Paints Formulation

Natural fibers that were in long fiber form were cut to desired dimensions with the help of the Dokuz Eylül University, Department Textile Engineering by using the

Retach SM 100 mechanical cutter. Long fibers were fed to a mechanical cutter and fibers that had dimensions of approximately 500 μm was obtained. Retach SM 100 mechanical cutter were used, and photo of this instrument can be seen in the Figure 2.1.

Figure 2.1 Retach SM 100 mechanical cutter

2.2.1 Preparation of the Microscope Slides for Antifouling Paints Self Polishing Tests

Free and fiber-reinforced antifouling paints were applied to the surfaces of the microscope slides. Surfaces of microscope slides that had dimensions of 26x76 mm were dried and cleaned before paint application. Microscope slides were weighted before and after application of free and fiber-reinforced antifouling paints.

2.3 Preparation of Free and Fiber Reinforced Antifouling Paints and Application on the Microscope Slides

To prepare fiber reinforced rosin-based antifouling paint, rosin was dissolved in 50 ml beaker by using xylene at 60 °C temperature on the heater by stirring at a constant rate (150 RPM). After obtaining a homogeneous form, $CaCO_3$, ZnO and Cu_2O were added to the mixture one by one. The mixture was stirred for 15 min at 60 °C to obtain the desired texture. After obtaining homogeneous texture econea and fibers in 1, 0.1

and 0.01 (w/w %) ratio were added to the mixture and stirred for additional 15 minutes. Illustration of paint preparation can be seen at Figure 2.2. Free and fiber reinforced antifouling paints formulations are shown in Table 2.5. Afterwards microscope slides were dipped to paint and dried overnight, become ready for self-polishing test.

Table 2.5 Fiber free and fiber reinforced self-polishing antifouling paint formulations

Paint Components	Control (w/w%)	I (w/w%)	II (w/w%)	III (w/w%)
Rosin	40	39	39	39
Xylene	40	40	39.9	39.09
ZnO	10	10	10	10
CaCO3	6	6	6	6
Cu_2O	4	4	4	4
Fiber	0	1	0.1	0.01

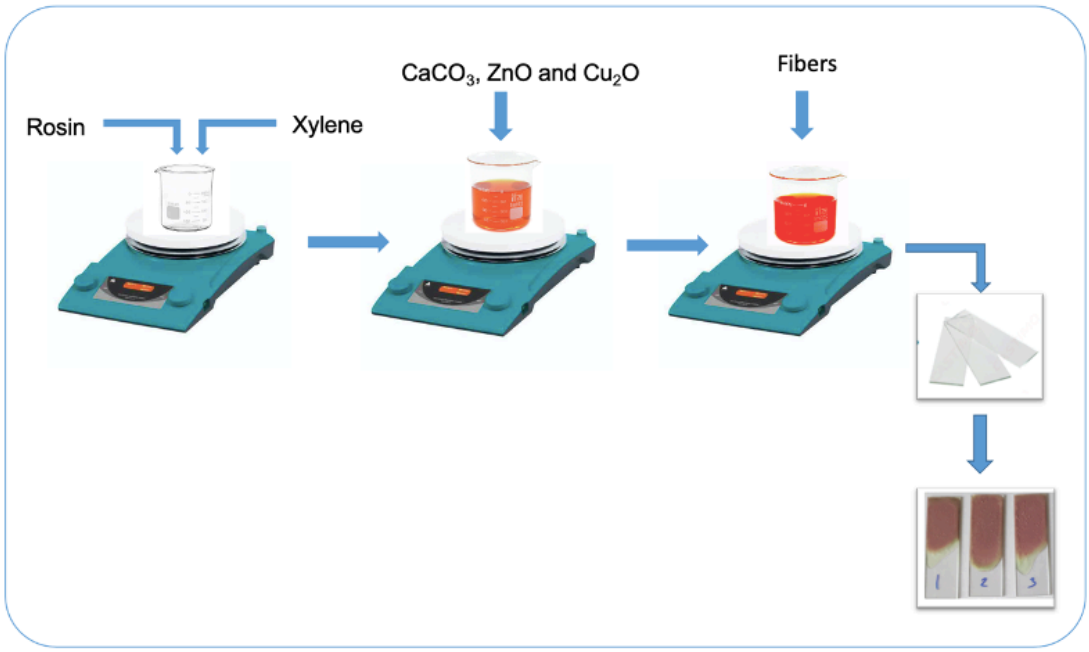


Figure 2.2 Preparation of fiber free and fiber reinforced self-polishing antifouling paints

2.4 Self-Polishing Test

To obtain information on paint's self-polishing percentage, self-polishing test was carried out. The self-polishing test was conducted by using the rotary test apparatus which is shown in Figure 2.3. The rotary test apparatus was consisted of a magnetic stirrer, rubber disk, 500 ml beaker and microscope slides which can be seen from Figure 2.3. Before the test, painted glass slides were weighted individually. Afterward, coated microscope slides were mounted to a rubber disk vertically and the disk was dipped into a beaker that contained tap water. The rotary tests were carried out at 250-1000 RPM for 1-3 hours. The temperature range was between 20 °C to 40 °C. After the self-polishing test microscope slides were dried at room temperature and the final weight of the slides was measured.

Figure 2.3 The apparatus for rotary tests

2.5 HPLC Analyses

Econea (tralopyril), the booster biocide used in self polishing antifouling paint formulation, was analyzed using HPLC. HPLC analysis was used to examine the purity of econea. The econea solution was heated to 88 ºC and then a sample was taken at 30 – 150 min time period in 30 min intervals. These samples were then used in HPLC analysis. 5 µg mL^{-1} econea solution was prepared using acetonitrile (ACN). The sample was passed through a 0.45µm membrane filter before HPLC injection. Inertsil C18 column (150x4.6mm, 5µm) was used in HPLC as stationary phase. ACN: Water: o-phosphoric acid (50:49.95:0.05 v/v) isocratic elution was prepared as mobile phase.

HPLC conditions are as follow: wavelength 280 nm; flow rate: 2mL/min, column temperature:35°C injection volume: 20 µL, loop volume: 20 µL.

2.6 Statistical Analysis

Due to a large number of obtained data statistical analyses were examined. Statistical analysis was done by using MATLAB R2021a software. The parameters affecting self-polishing degree of fiber reinforced self-polishing antifouling paint such as fiber type fiber ratio, rotary rate, rotary time, and temperature can be seen from Figure 2.4. Data obtained by self-polishing tests were evaluated by one-way ANOVA and Tukay tests.

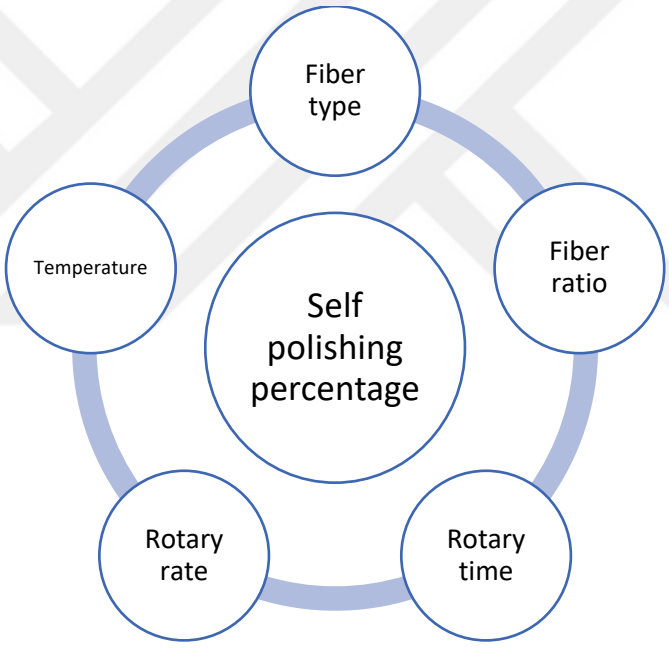


Figure 2.4 The Parameters affecting self-polishing percentage of antifouling paint

2.7 Eco-toxicity Test Using *Artemia salina*

Artemia salina is well known model test organism. *A.salina* has short hatching period and can be found easily commercially. To hatch *A.salina*, eggs were placed to artificial seawater for 1 day period under constant illumination and aeration. Artificial seawater was prepared by adding NaCl (3.5% w/w) to purified water. After 1 day

period 20 µL total volume 10 swimming *A.salina* larvae were placed to 96 well plate and then total volume of plates were fixed to 270 µL by adding biocide (Econea) solutions in different concentrations. Experiments were done with 3 repeats. Survival of *A.salina* was calculated by counting swimming individuals at the plates at 30, 60, 90, 120, 150, 180, 210, 240 and 270 minutes.

2.8 Mechanical Tests

2.8.1 Direct Impact Test

A Direct impact test was done to gain information about the mechanical performance of the prepared paint. For this purpose, metallic plates were first covered by anticorrosive primer and then covered by antifouling paint. Paint formulation is given in Table 2.5.

After painting metallic plates by antifouling paint plate let dry for a 5-day period. After obtaining a dry surface metal ball weighed 70 g was dropped from 50 cm high. After the drop test surface was analyzed and scored (Urban et al., 2003).

2.8.2 Cross Cut Test

Cross cut test is done to determine the mechanical performance of the paint. For this reason, cuts spaced 3mm were done on the surface of the paint. After that tape was attached to that area. It's important to fully attach tape to the surface. After that tape was pulled rapidly. After that spacing between cuts must be analyzed for paint deformations (Murdan et al., 2005; Yebra et al., 2009). For the cross cut test, generally, ISO 2409 standard is used.

2.9 The Field Test

To gain information of the paints antifouling performance field test was conducted. Paints were prepared by the formulations given in Table 2.8. The steel panels were

cleaned and covered with anticorrosive primer. After drying for one day steel panels were painted with prepared antifouling paints and let dry in room temperature for three-day period (Figure 2.5). After preparation of samples field test was conducted for one-month period in Dokuz Eylül University, Institute of Marine Sciences and Technology in İnciralti, İzmir.

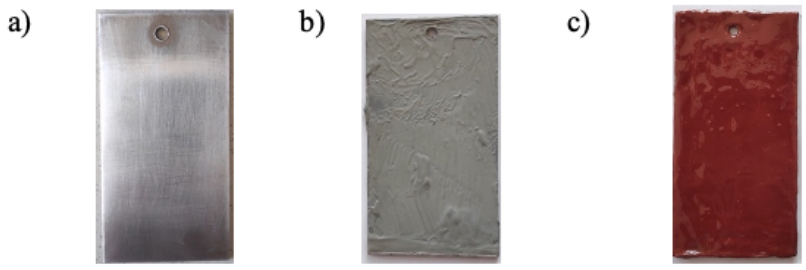


Figure 2.5 a) represents steel panel before paint preparation, b) represents steel panel covered by anticorrosive primer, c) represents steel panel covered by free or fiber reinforced antifouling paint

Table 2.6 Antifouling paint formulations for field tests

Paint Components	Fiber free (w/w%)	Booster biocide and fiber free (w/w%)	I (w/w%)	II (w/w%)	III (w/w%)
Rosin	40	40	39	39	39
Xylene	40	40	40	39.9	39.09
ZnO	7	10	7	7	7
Econea	5	0	5	5	5
CaCO3	4	5	4	4	4
Cu_2O	4	5	4	4	4
Fiber	0	0	1	0.1	0.01

2.10 Fouling Criteria Assessment

Fouling evaluation is done to evaluate the performance of antifouling paints used in the marine field. The categorization is evaluated according to the abundance of micro and macro-organisms attached to the surface. There are examples in the literature on how to make such categorization of fouling (Arimura et al., 2004; Alyuruk 2012; Mert et al., 2014).

Level 1. No fouling organisms on the surface

Level 2. There is microfilm layer formation occurs on artificial surface

Level 3. There is microfilm layer on the surface and macro fouling is at beginning stage

Level 4. Micro and Macro organisms observed on artificial surface

Level 5. The surface is heavily fouled by macro-organisms

CHAPTER THREE
RESULTS

3.1 The Results of the Self Polishing Tests

Figure 3.1 represents the results of the self-polishing test of fiber-free self-polishing antifouling paint at 20 ºC. The tests were made at four different rotary rates ranged between 250-1000 RPM and 3 different time intervals ranged between 1 to 3 hours. As can be seen from the self-polishing test results represented in Figure 3.1 the highest self-polishing percentage was observed at 1000 RPM rotary rate for a 3-hour test period. The means of the test results of the 1-hour self-polishing test did not show any statistical differences among four different rotary rates ($p>0.05$). The tests that were made for 3-hour rotary time at 250 RPM were not statistically different from tests that were made at 500-1000 RPM rates ($p>0.05$). As can be seen from Table 3.1 rotary rate and temperature affected self-polishing percentage remarkably ($p<0.05$). The photos of microscope slides coated by fiber-free antifouling paint that were used in self-polishing tests can be seen from Table 3.2- Table 3.4.

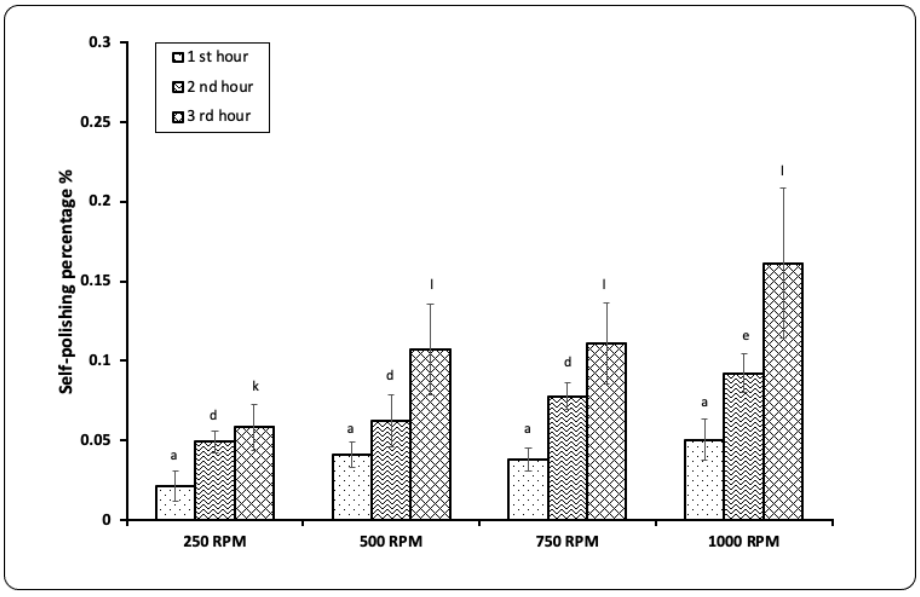


Figure 3.1 The effect of rotary rate and time on the self-polishing percentage of fiber free self-polishing antifouling paint at 20 °C

Table 3.1 One-way ANOVA results related to the effects of rotary time and rate on self-polishing percentage of fiber free self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.05145	11	0.00468	11.77	3.63847e-07
Error	0.00954	24	0.0004		
Total	0.06099	35			

Table 3.2 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour

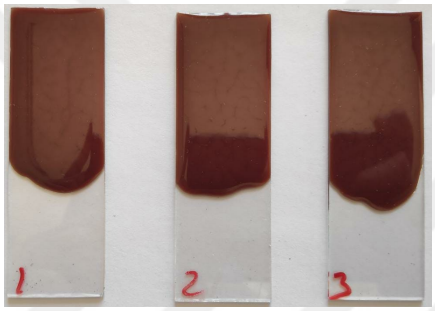
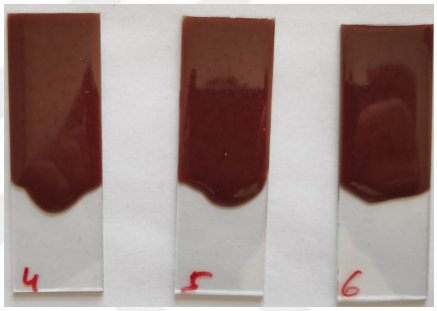
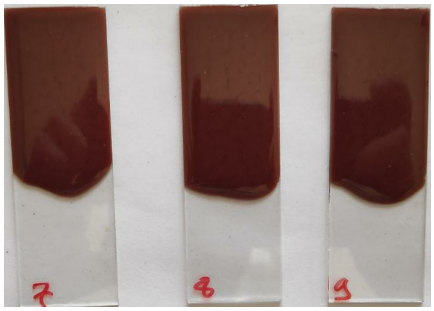
 250 RPM	 500 RPM
 750RPM	1000 RPM

Table 3.3 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours

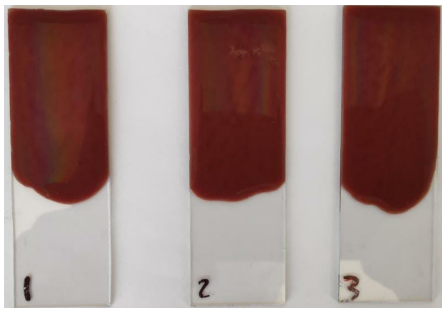
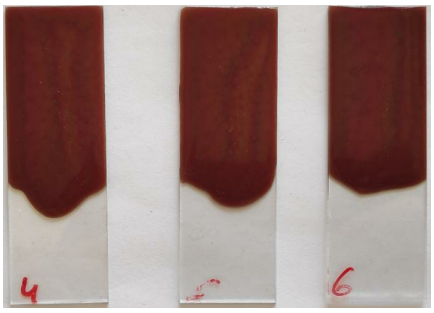
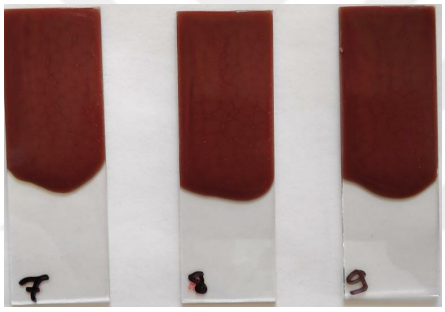
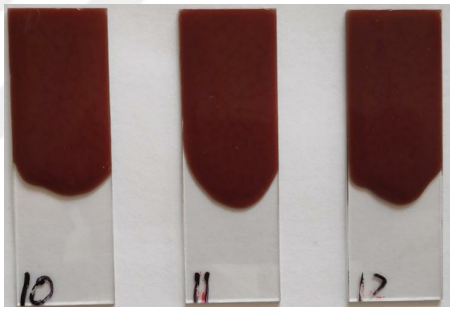
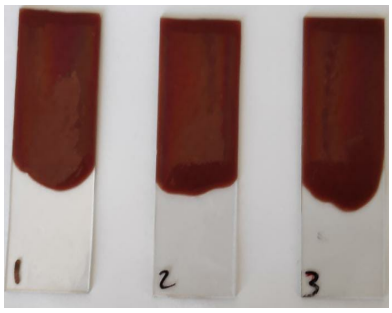
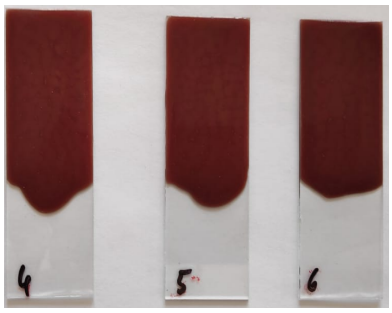
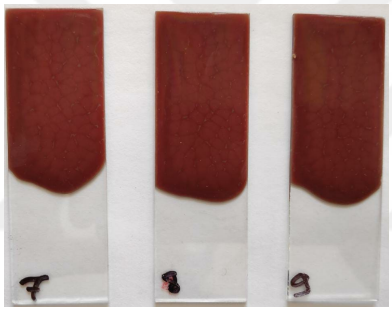
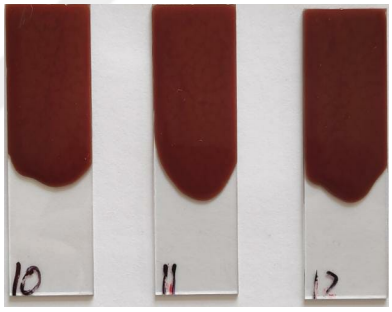
 250 RPM	 500 RPM
 750RPM	 1000 RPM

Table 3.4 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The self-polishing percentages of the fiber-free self-polishing antifouling paint done at 30 ºC are shown in Figure 3.2. Minimum and maximum self-polishing percentages were observed at 250 RPM for 1-hour and 1000 RPM for 3-hour tests respectively. The self-polishing percentages were not statistically different through 1 hour test period at 250-500 RPM and 750-1000 RPM rotary rates ($p>0.05$). The results of the 2-hour polishing tests that were made at 250 RPM were statistically different from tests that were done at 500, 750 and 1000 RPM rotary rates ($p<0.05$). The self-polishing percentages of the test that were made for 2 hours at 500 RPM and 750 RPM rotary rates were not statistically different either ($p>0.05$). When the data in Table 3.5 is analyzed, it can be seen that the p-value is smaller than 0.05 and it indicates a remarkable effect of rotary rate and time on self-polishing percentages. The photos of microscope slides coated by fiber-free antifouling paint that were used in self-polishing tests can be seen from Table 3.6 - Table 3.8.

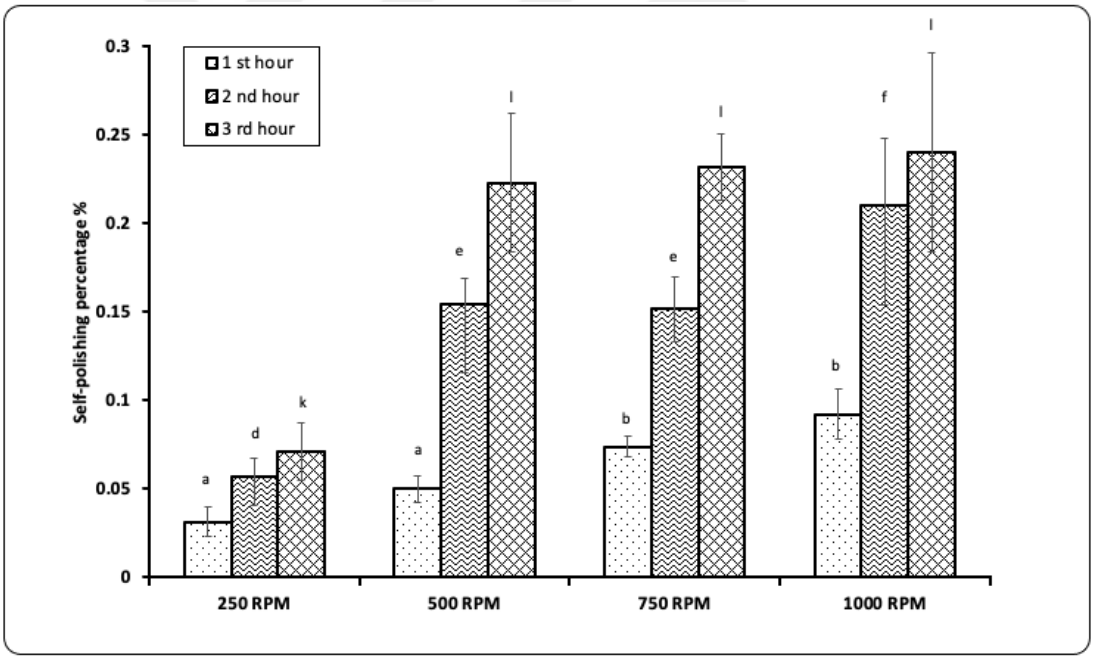


Figure 3.2 The effect of rotary rate and time on the self-polishing percentage of fiber free self-polishing antifouling paint at 30 °C

Table 3.5 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of fiber free self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.2025	11	0.01841	21.71	7.72735e-10
Error	0.02035	24	0.00085		
Total	0.22285	35			

Table 3.6 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour

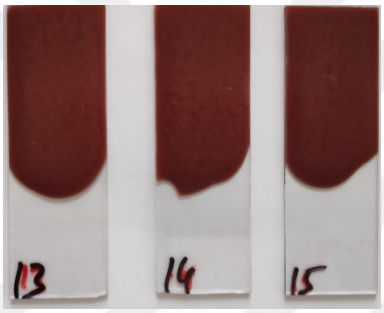
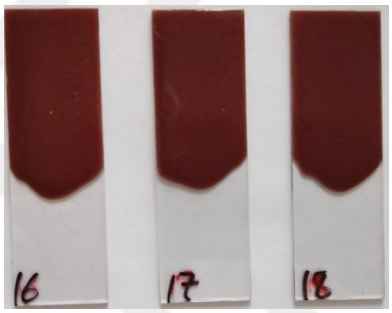
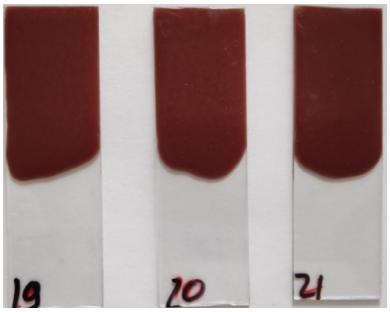
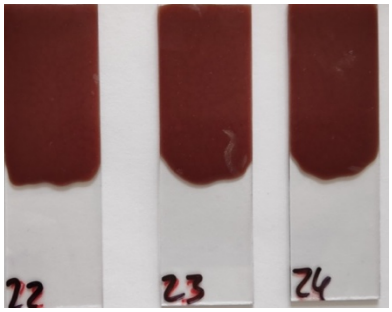
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.7 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours

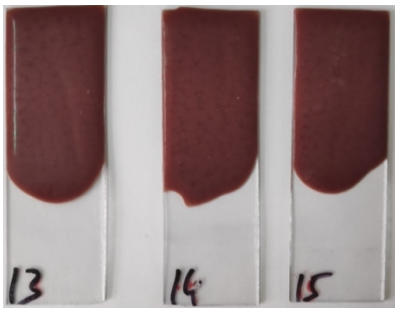
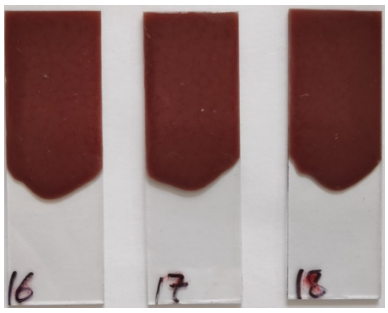
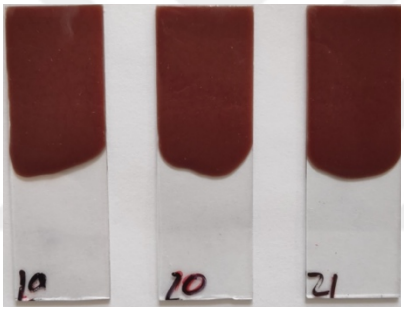
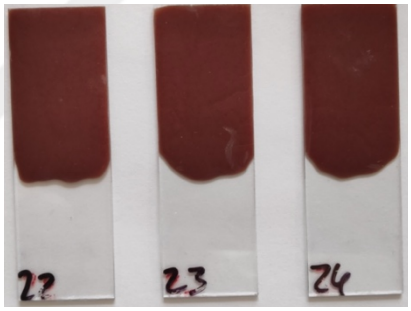
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.8 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours

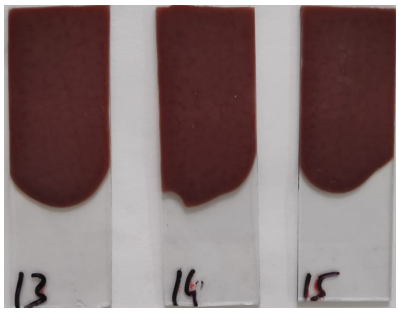
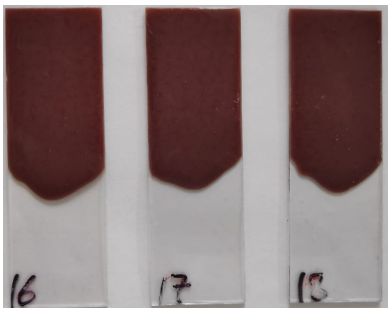
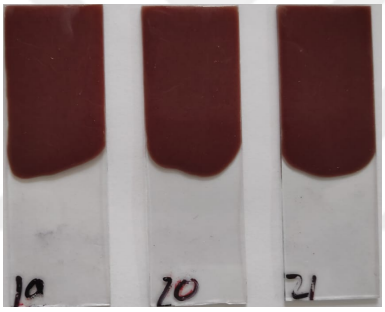
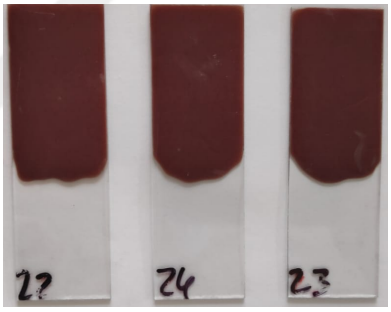
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Figure 3.3 represents the results of the self-polishing tests of the fiber-free self-polishing antifouling paint that were made at 40 °C. The maximum self-polishing percentage was observed at a 3-hour 1000 RPM test period as was expected. The means of the self-polishing percentages for 1 hour test period did not show statistical differences at all RPM rates ($p<0.05$). When analyzing the data obtained from the 2-hour self-polishing test no statistical differences were found for 500 and 750 RPM rotary rates ($p>0.05$). The self-polishing tests that were made for 3 hours did not show statistical differences between 500, 750 and 100 RPM rotary rates ($p>0.05$) but were different from 250 RPM rotary rate ($p<0.05$). The results of the one-way ANOVA test are shown in Table 3.9 and from it, we can understand that the self-polishing percentages were different between four different RPM rates and four different time periods. The photos of microscope slides coated by the fiber-free antifouling paint that were used in self-polishing tests can be seen from Table 3.10 - Table 3.12. The discolorations and the cracks on the surface of fiber-free self-polishing antifouling paint occurred and it can be seen from Table 3.12.

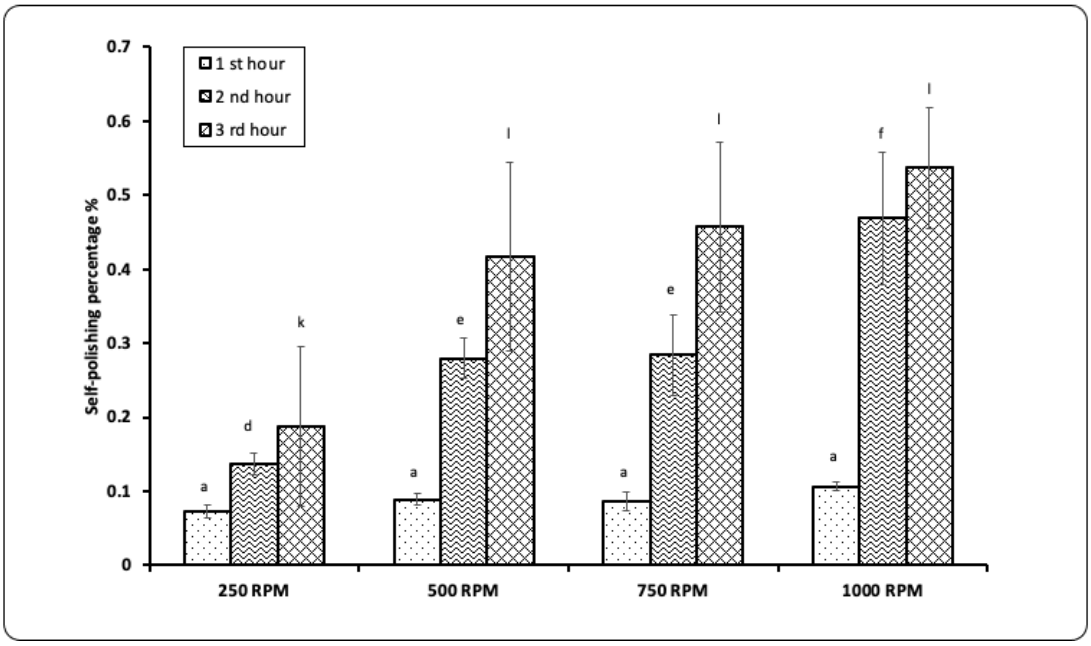


Figure 3.3 The effect of rotary rate and time on the self-polishing percentage of fiber free self-polishing antifouling paint at 40 °C

Table 3.9 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of fiber free self-polishing antifouling paint at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.96863	11	0.08806	17.67	6.56583e-09
Error	0.11961	24	0.00498		
Total	1.08824	35			

Table 3.10 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour

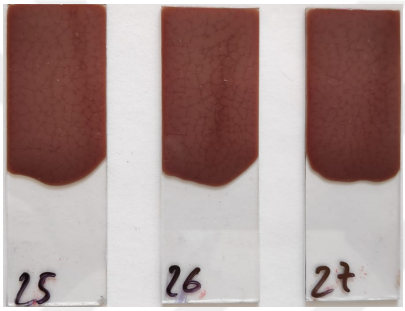
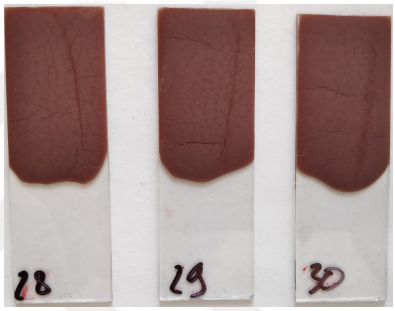
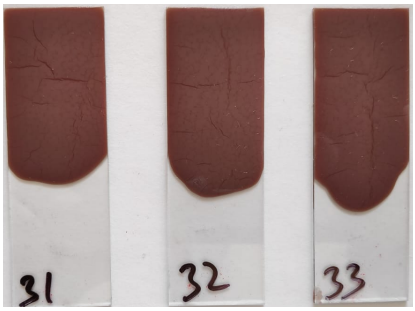
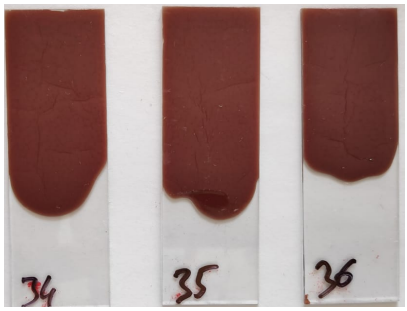
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.11 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours

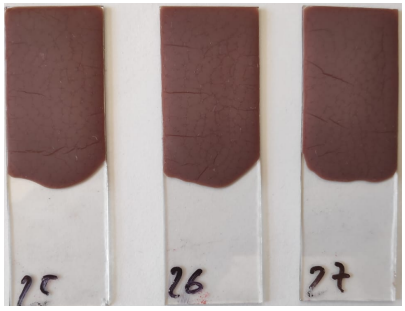
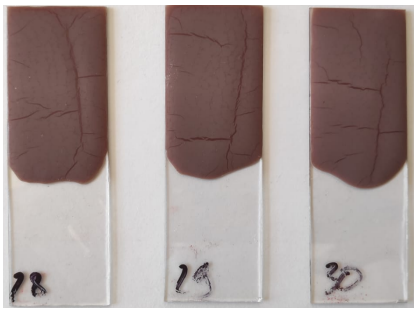
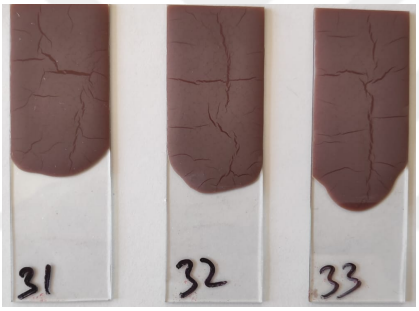
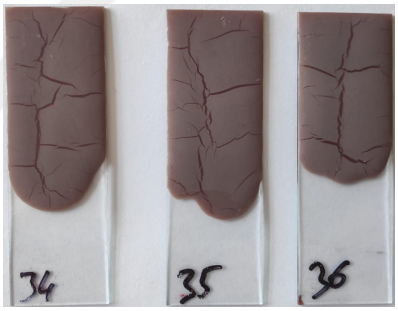
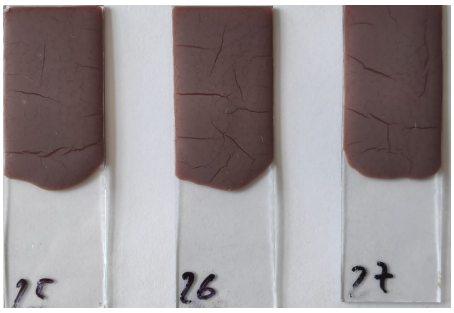
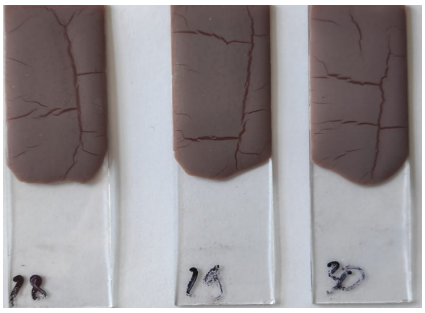
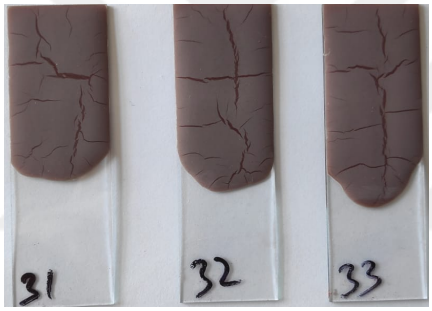
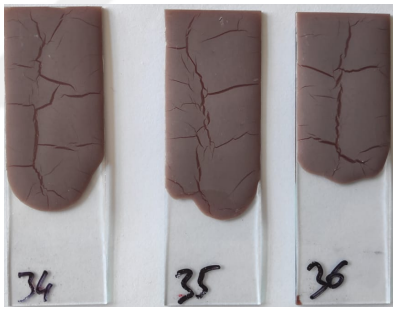
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.12 The photos of the fiber free self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

From Figure 3.4 the results of the self-polishing test of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint that were done at 20 °C can be seen. The highest and the lowest polishing percentages were observed at 1000 RPM 3-hour and 250 RPM 1-hour conditions, respectively. The results of the tests that were done for 1 hour did not show significant differences at 250, 500 and 750 RPM rotary rates ($p>0.05$) but different at 1000 RPM rotary rate ($p<0.05$). 2-hour test results were not statistically different at 250, 500 and 750 RPM rotary rates ($p>0.05$) but different at 1000 RPM rotary rate ($p<0.05$). Table 3.13 represents the results of the one-way ANOVA test and from it, we can see that the p-value is much smaller than 0.05. Figure 3.5 depicts the comparison of self-polishing percentages between the fiber-free (control) and the 1% (w/w) linen fiber-reinforced self-polishing antifouling paint. As can be seen from Figure 3.5 linen fiber 1% (w/w) reinforcement decreased self-polishing percentage but a significant difference was not observed ($p>0.05$). The results of the one-way ANOVA tests related to mean comparison of the 1% (w/w) linen fiber-reinforced self-polishing antifouling paint and the control paint represented in Table 3.14 and from it can be seen that the self-polishing percentage means of compared paints did not show statistical differences between them ($p>0.05$). The photos of microscope slides used in the self-polishing test which was covered by 1% (w/w) linen fiber-reinforced self-polishing antifouling paint can be seen from Table 3.15- 3.17.

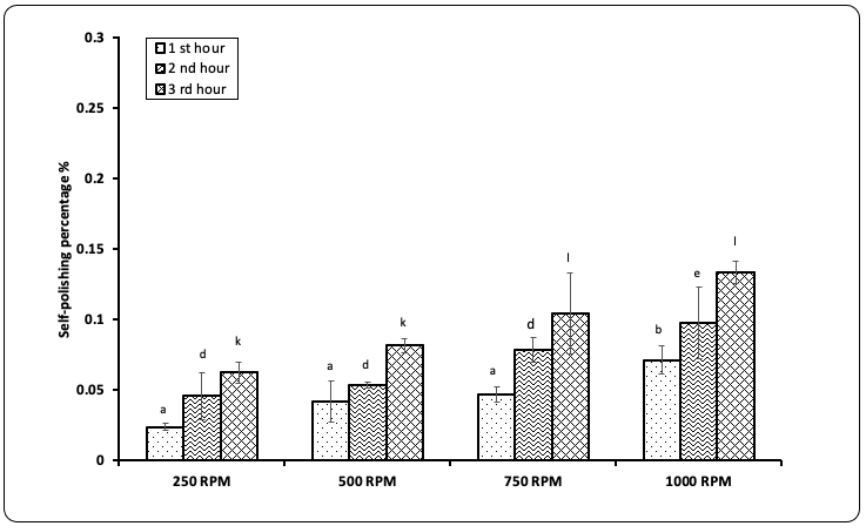


Figure 3.4 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 °C

Table 3.13 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.03167	11	0.00288	14.82	3.8536e-08
Error	0.00466	24	0.00019		
Total	0.03633	35			

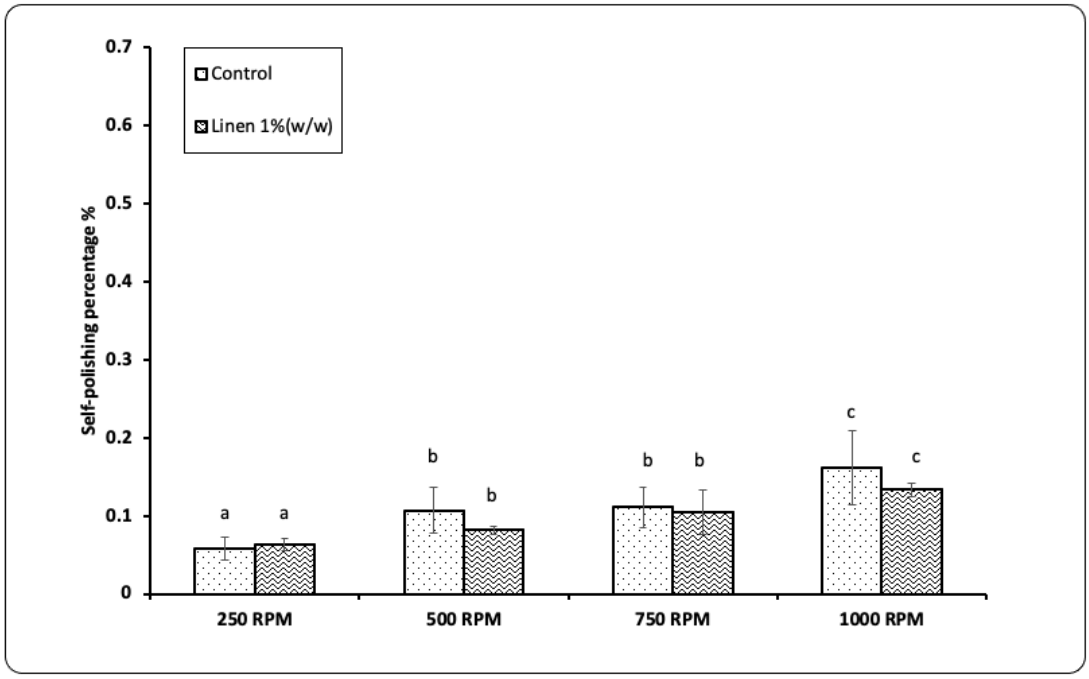


Figure 3.5 The comparison of self-polishing percentages between control and linen fiber reinforced 1% (w/w) self-polishing antifouling paint for 3 hours test period at 20 ºC

Table 3.14 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.00114901	1	0.00114901	0.7420492	0.39829721
Error	0.0340653	22	0.00154842		
Total	0.03521431	23			

Table 3.15 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour

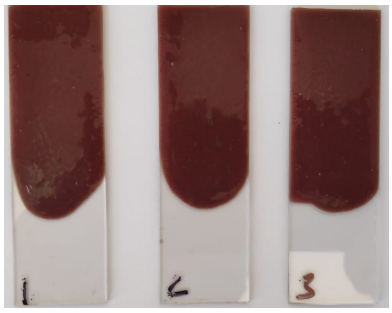
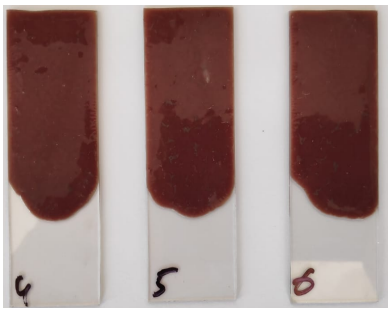
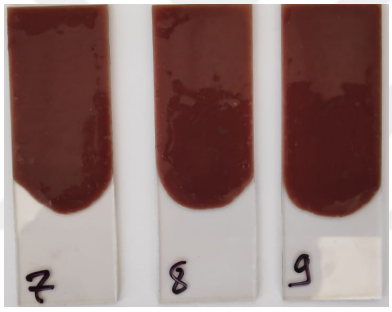
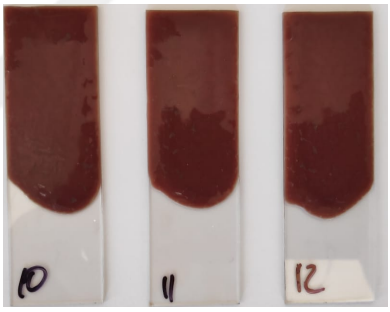
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.16 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours

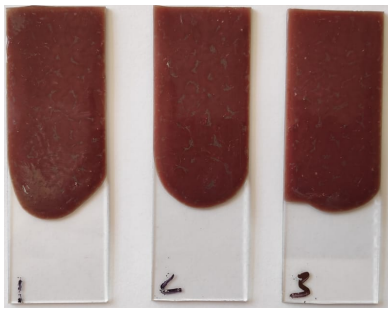
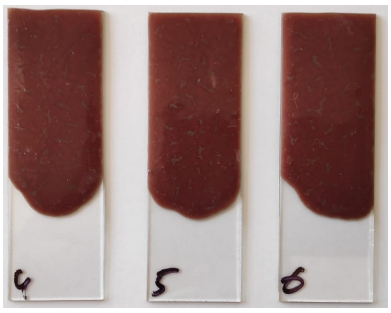
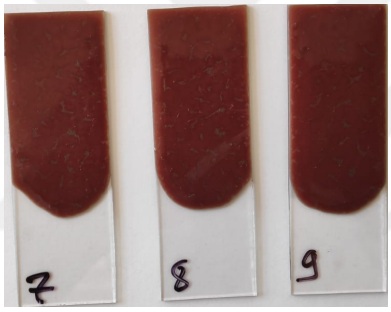
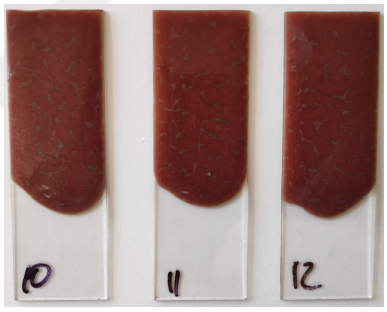
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.17 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours

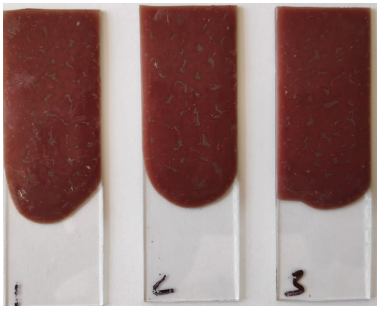
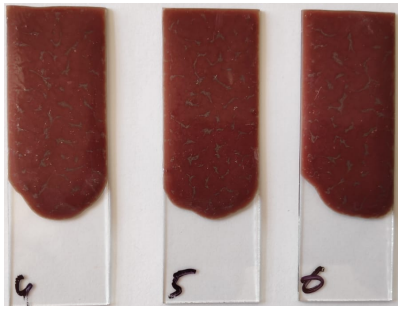
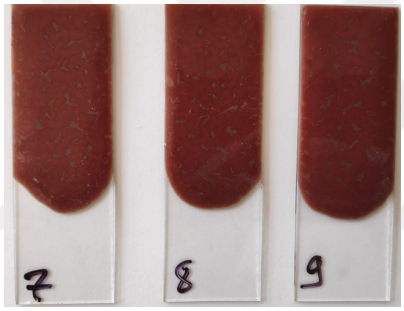
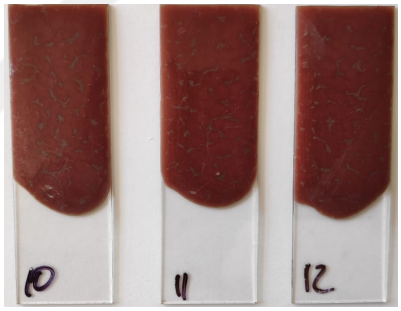
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Figure 3.6 represents the results related to the self-polishing test of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint that were done at 30 °C. As can be seen from Figure 3.5 highest and lowest self-polishing percentages were observed at 1000 RPM 3-hour test period and 250 RPM 1 hour test period, respectively. The means of the results of the tests that were done for 1 hour were not statistically different for 250, 500 and 750 RPM rotary rate ($p>0.05$) but different at 1000 RPM rotary rate ($p>0.05$). Self-polishing percentages obtained from tests that were made at 250 and 500 RPM rotary rate for 2 hours were statistically different from tests that were done at 750 and 1000 RPM rotary rates ($p<0.05$). When tests were done for a 3-hour period, data obtained from 250-500 RPM and 750-1000 RPM did not show a significant difference among them ($p>0.05$). The results of the one-way ANOVA tests can be seen in Table 3.18. As can be seen from Figure 3.7, linen fiber %1 (w/w) reinforcement decreased the self-polishing percentage in some content but this decline in self-polishing percentage was not statistically meaningful ($p>0.05$). Comparison of the self-polishing percentage's means for the linen fiber reinforced 1% (w/w) antifouling paint and the control paint which was not reinforced by any fiber can be seen from Table 3.19. The photos of microscope slides used in the self-polishing test which was covered by 1% (w/w) linen fiber-reinforced self-polishing antifouling paint can be seen from Table 3.20-Table 3.22.

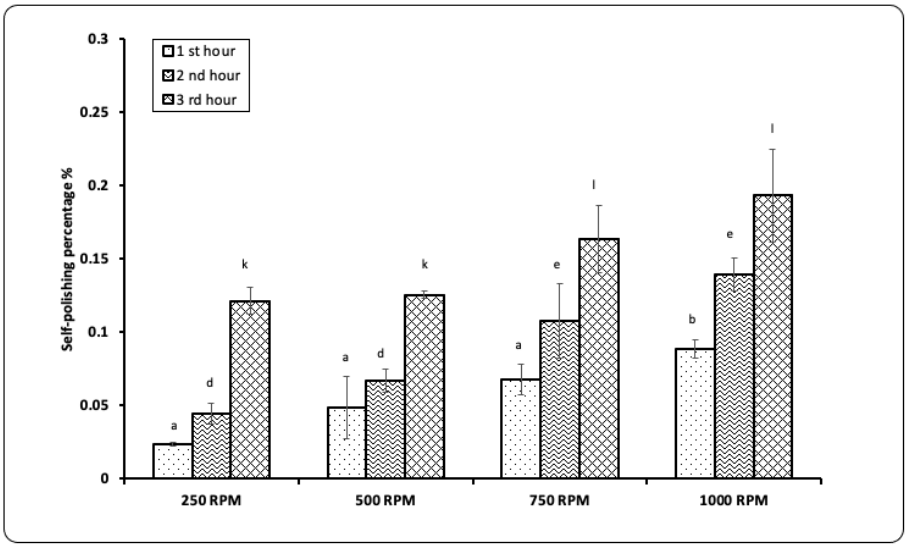


Figure 3.6 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 °C

Table 3.18 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.08754	11	0.00796	30.79	1.81091e-11
Error	0.0062	24	0.00026		
Total	0.09375	35			

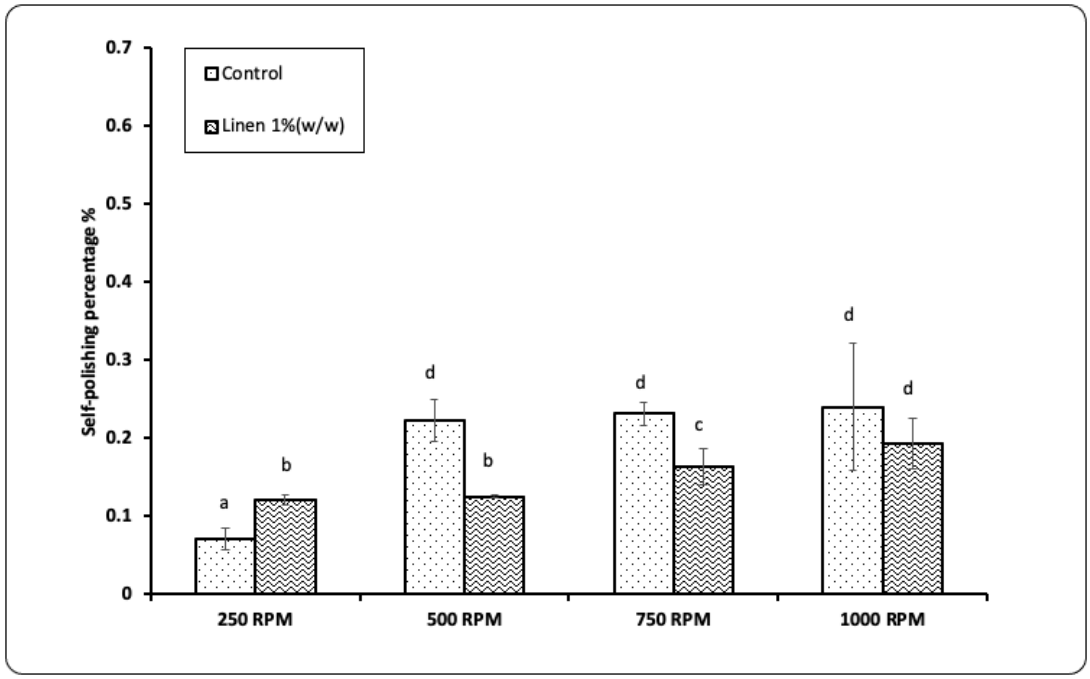


Figure 3.7 The comparison of self-polishing percentages between control and linen fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC

Table 3.19 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.89259683	1	0.89259683	174.480049	6.16E-12
Error	0.11254657	22	0.00511575		
Total	1.0051434	23			

Table 3.20 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour

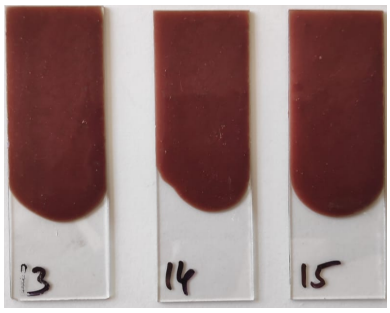
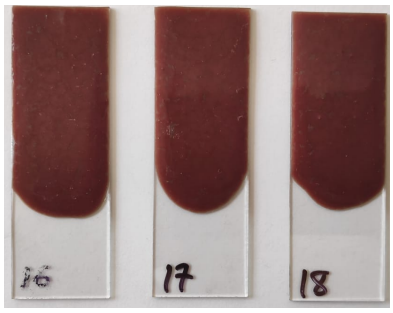
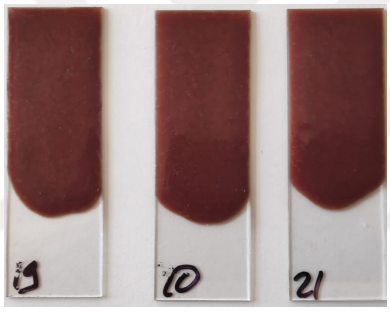
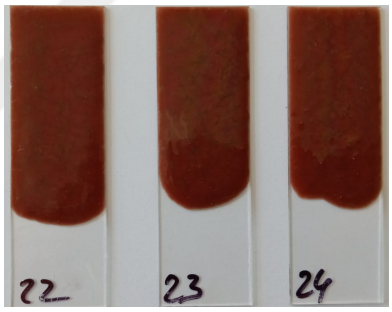
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.21 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours

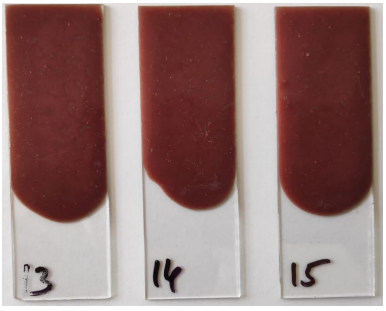
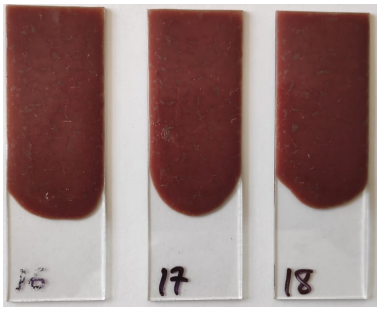
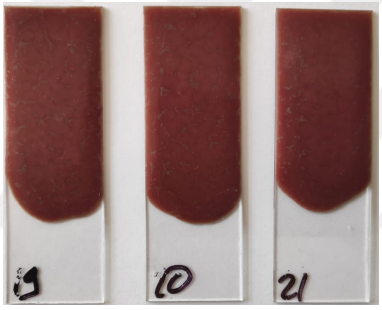
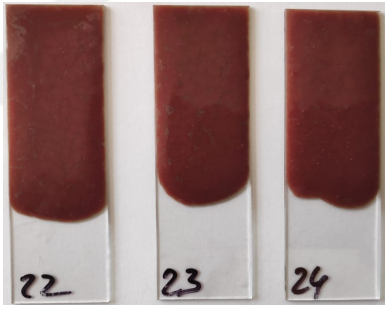
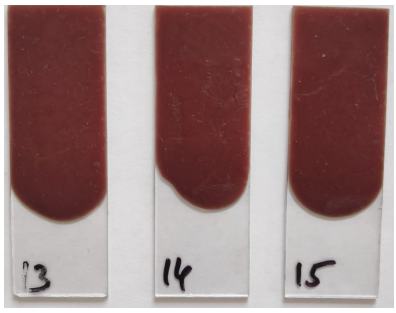
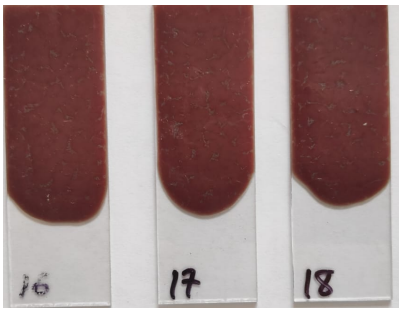
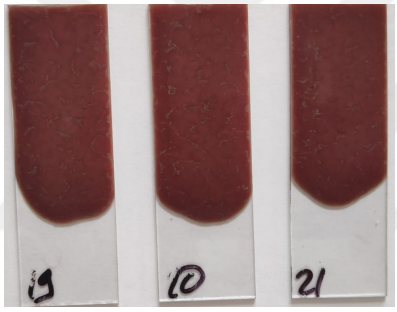
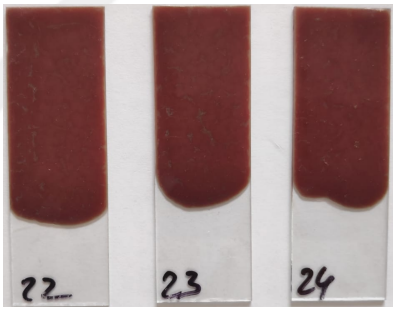
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.22 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Self-polishing percentages of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint are shown in Figure 3.8. The tests were made at 40 °C temperature. Self-polishing percentages of the tests that were made for a 1-hour period did not show significant differences for 500, 750 and 1000 RPM rotary rates ($p>0.05$). The results of the test that were done for 2 hours also did not show any significant differences between 250, 750 and 1000 RPM rotary rates ($p<0.05$). Data obtained from the tests that were done for a 3-hour period did not show any statistical difference among 500, 750 and 1000 RPM rotary rates either ($p>0.05$). When Table 3.23 is analyzed, changes in the self-polishing percentages by the effect of rotary time and rotary rate among groups can be seen ($p<0.05$). When Figure 3.9 is examined, it can be seen that the linen fiber reinforcement did not decrease the self-polishing percentage. The results related to one-way ANOVA analyses of the self-polishing percentages mean comparison for the control and linen fiber1% (w/w) reinforced antifouling paint can be seen in Table 3.24. The photos of microscope slides used in the self-polishing tests which were covered by the linen fiber reinforced 1% (w/w) self-polishing antifouling paint can be seen from Table 3.25-Table 3.27. The discolorations and the cracks occurred on the surface of the paint after the test period, and it can be seen in Table 3.27

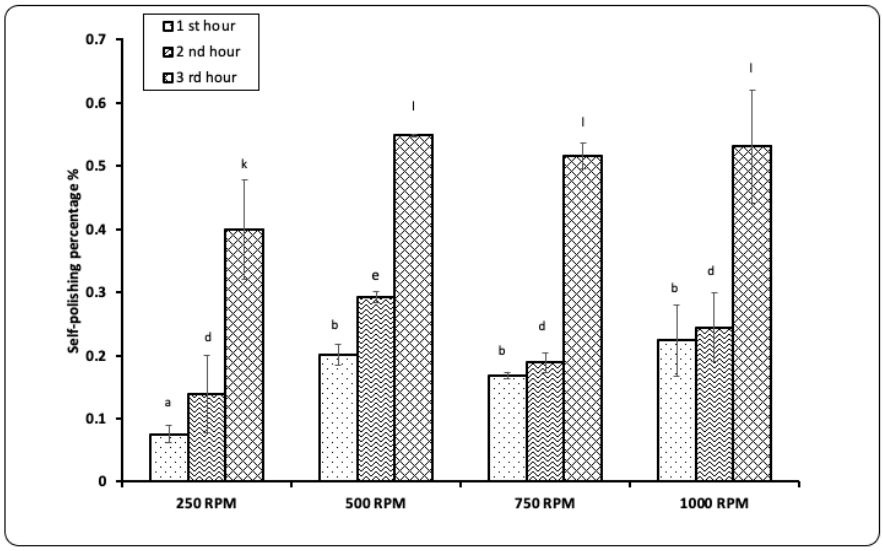


Figure 3.8 The effect of rotary rate and time on the self-polishing percentage of %1 (w/w) linen fiber reinforced self-polishing antifouling paint at 40 °C

Table 3.23 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.91328	11	0.08303	19.7	2.14226e-09
Error	0.10117	24	0.00422		
Total	1.01445	35			

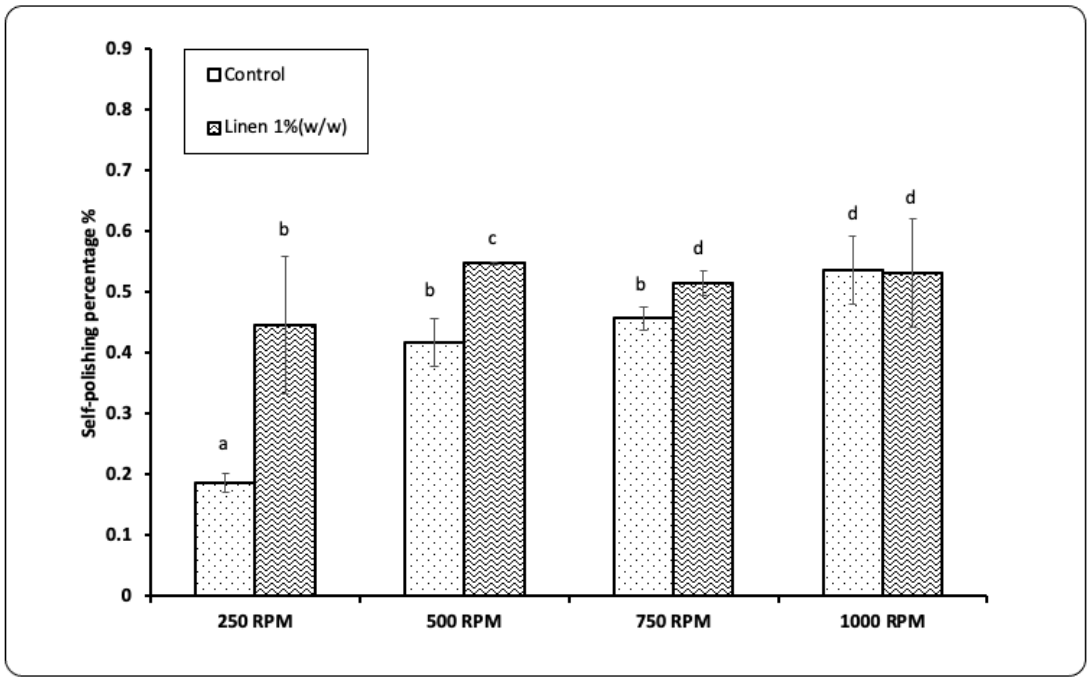


Figure 3.9 The comparison of self-polishing percentages between control and linen fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC

Table 3.24 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.07364459	1	0.07364459	4.50744005	0.04523754
Error	0.35944595	22	0.01633845		
Total	0.43309055	23			

Table 3.25 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour

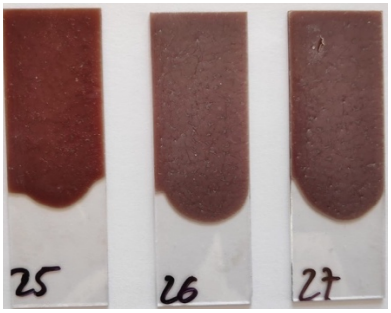
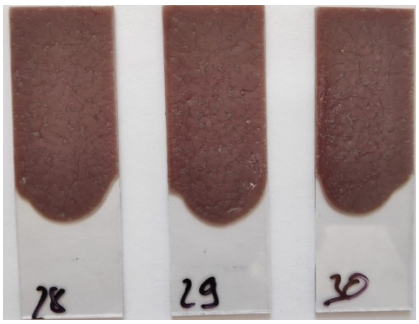
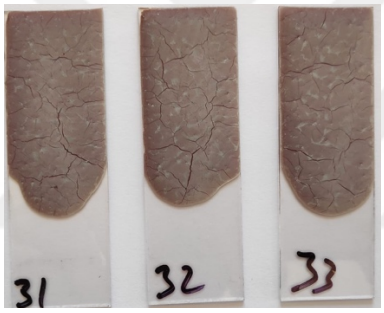
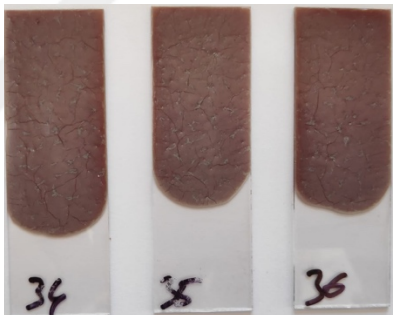
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.26 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours.

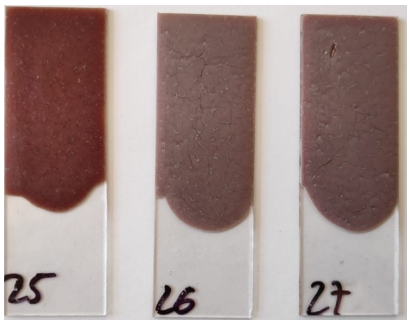
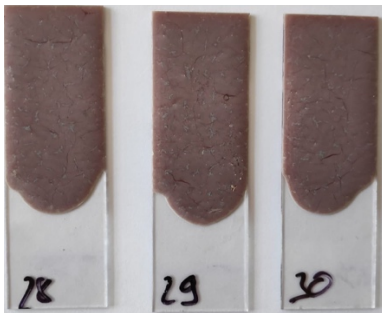
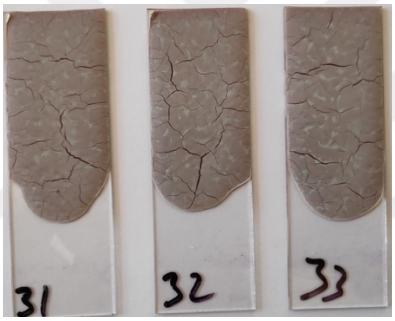
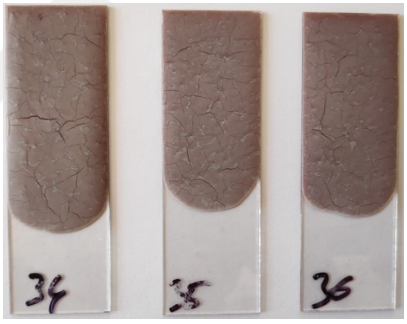
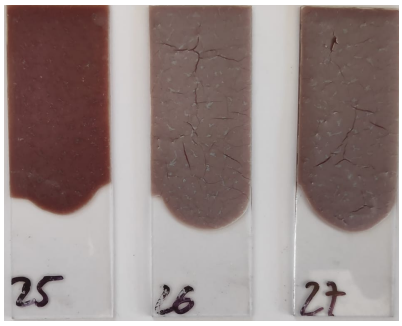
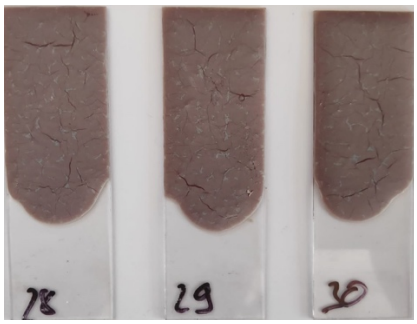
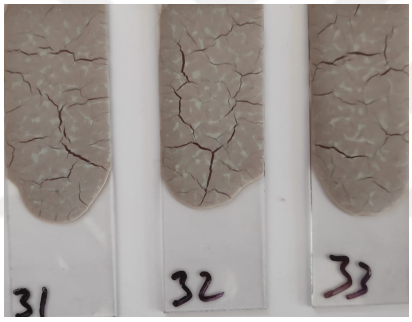
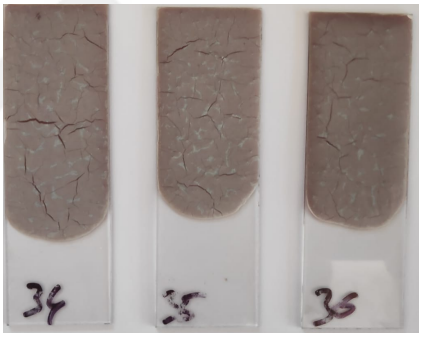
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.27 The photos of the linen fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Self-polishing percentages of the linen fiber reinforced 0.1% (w/w) self-polishing paint are depicted in Figure 3.10. The tests were done at 20 °C temperature. The highest self-polishing percentage was observed at 1000 RPM rotary rate for a 3-hour test period. The results of the test that were done for 1 hour did not show any significant differences between all rotary rates. The tests result that were done for 2 hours did not show significant differences at 250-500 RPM and 750-1000 RPM rotary rates. The results of the one-way ANOVA test can be seen in Table 3.28. When we look at Figure 3.11, we can see that the linen fiber 0.1 % (w/w) reinforcement increased the self-polishing percentage of the paint. Although fiber reinforcement increased the paint's self-polishing percentage, statistical difference was not observed between means of the control and linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint's self-polishing percentages. The results of the one-way ANOVA analyses of mean comparison for the self-polishing percentage of the linen fiber reinforced 0.1% (w/w) and control paint can be seen from Table 3.29. The photos of microscope slides used in the self-polishing test which was covered by the linen fiber0.1% (w/w) reinforced self-polishing antifouling paint can be seen from Table 3.30-Table 3.32.

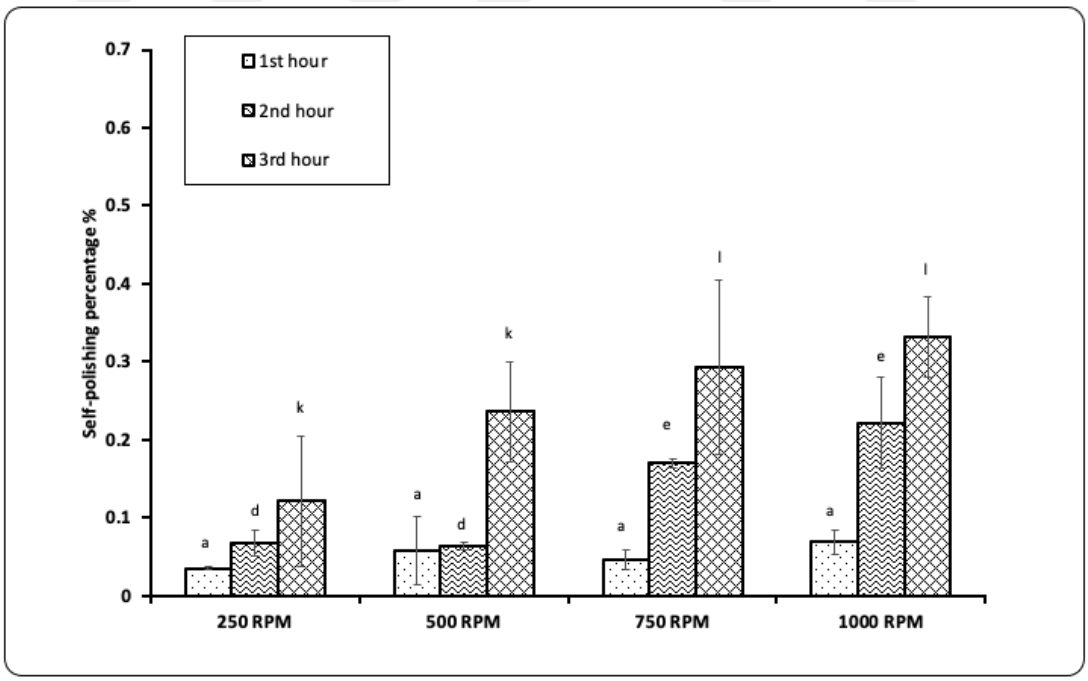


Figure 3.10 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 20 °C

Table 3.28 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 20 ºC.

Source	SS	df	MS	F	Prob>F
Columns	0.36011	11	0.03274	12.22	2.53751e-07
Error	0.0643	24	0.00268		
Total	0.42441	35			

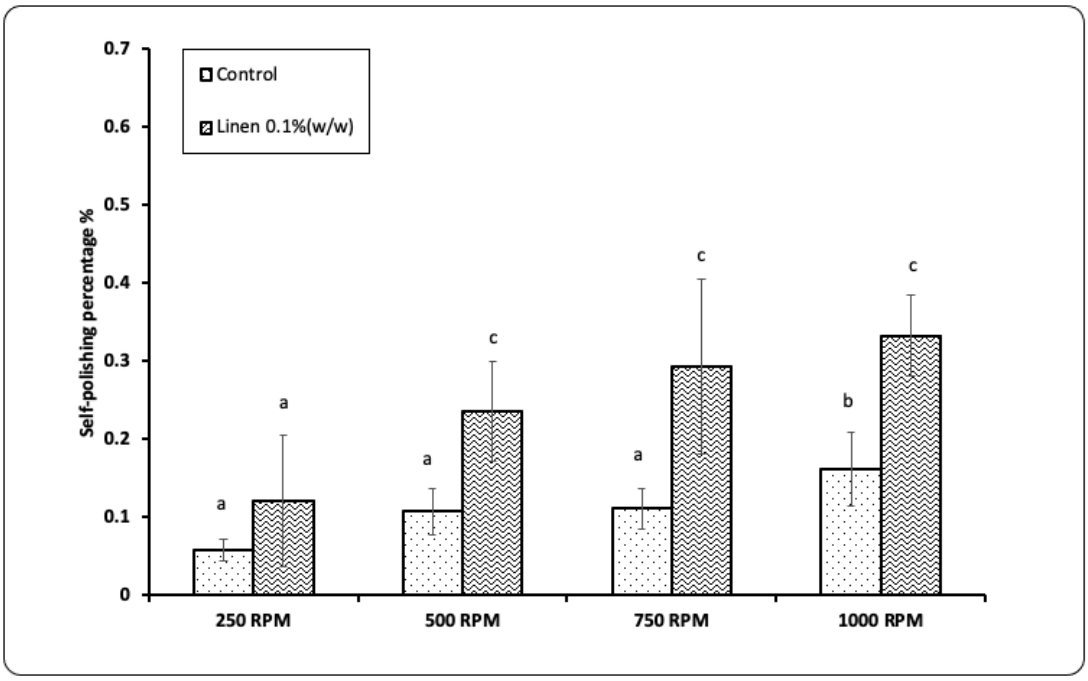


Figure 3.11 The comparison of self-polishing percentages between control and linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC

Table 3.29 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.11123306	1	0.11123306	16.0864368	0.00058749
Error	0.15212364	22	0.00691471		
Total	0.26335669	23			

Table 3.30 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour

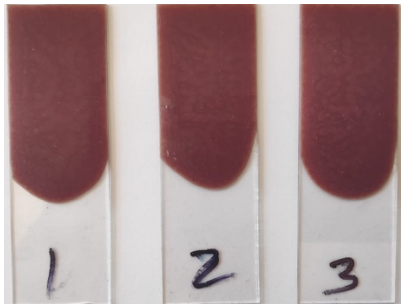
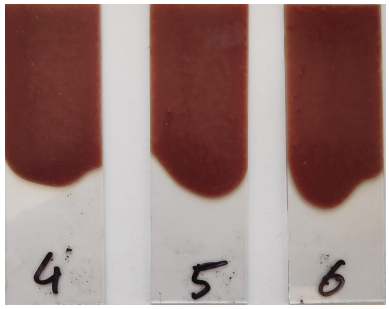
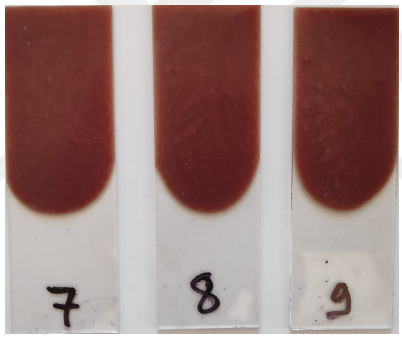
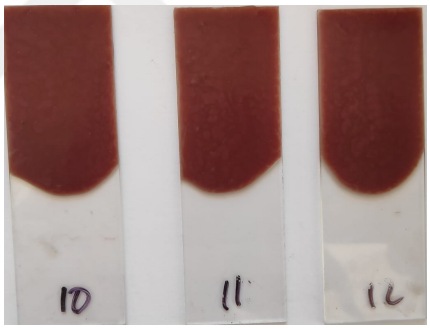
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.31 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours

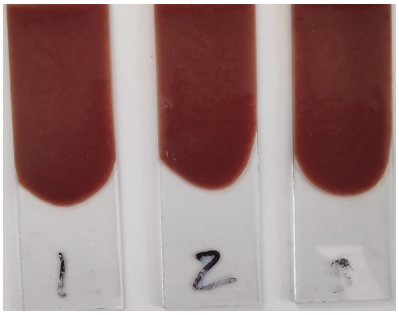
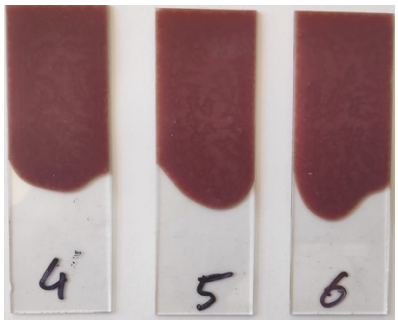
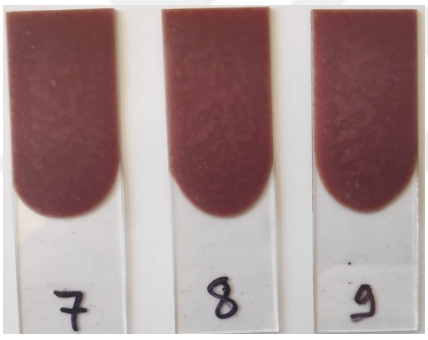
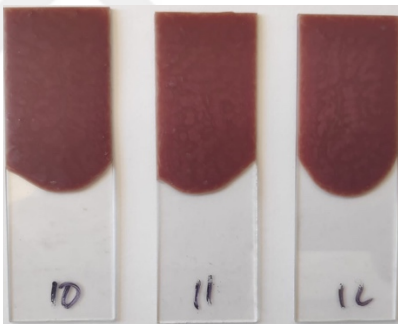
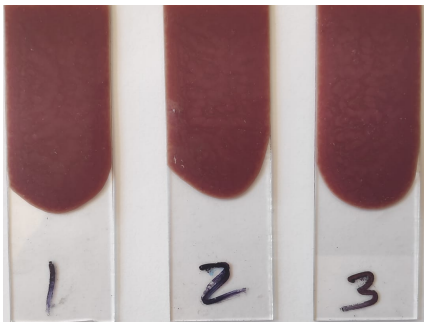
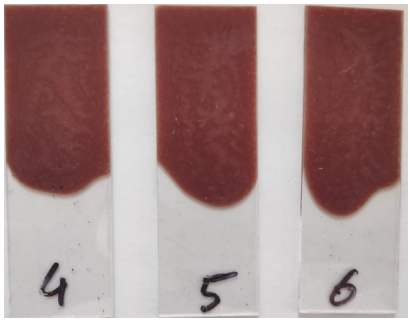
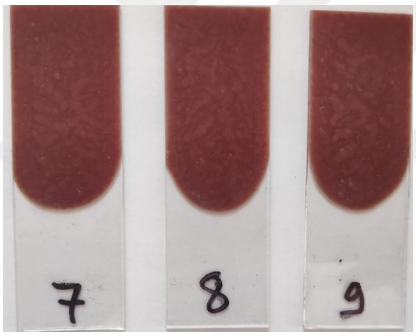
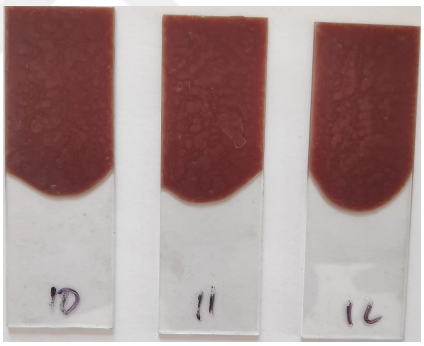
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.32 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results obtained from the self-polishing test of the linen fiber reinforced 0.1% (w/w) self-polishing rosin-based antifouling paint are shown in Figure 3.12 The tests were done at 30 °C temperature. The highest self-polishing percentage was observed at 1000 RPM for a 3-hour test period. 1-hour polishing test results related to 500-1000 RPM rotary rate speeds were not statistically different among them ($p>0.05$). The self-polishing percentages did not show significant differences between 500-1000 RPM rotary rates at a 2-hour test period. The results of the test that were done for 3 hours at 500, 750 and 1000 RPM rotary rates did not show any significant differences ($p<0.05$). The results of the one-way ANOVA test can be seen in Table 3.33. The increase in the self-polishing percentage after fiber reinforcement can be seen in Figure 3.13. Statistical difference was observed between control and fiber-reinforced paints polishing percentages ($p<0.05$) and one-way ANOVA test results can be seen from Table 3.34. The photos of microscope slides used in the self-polishing test which was covered by the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint can be seen from Table 3.35-Table 3.37.

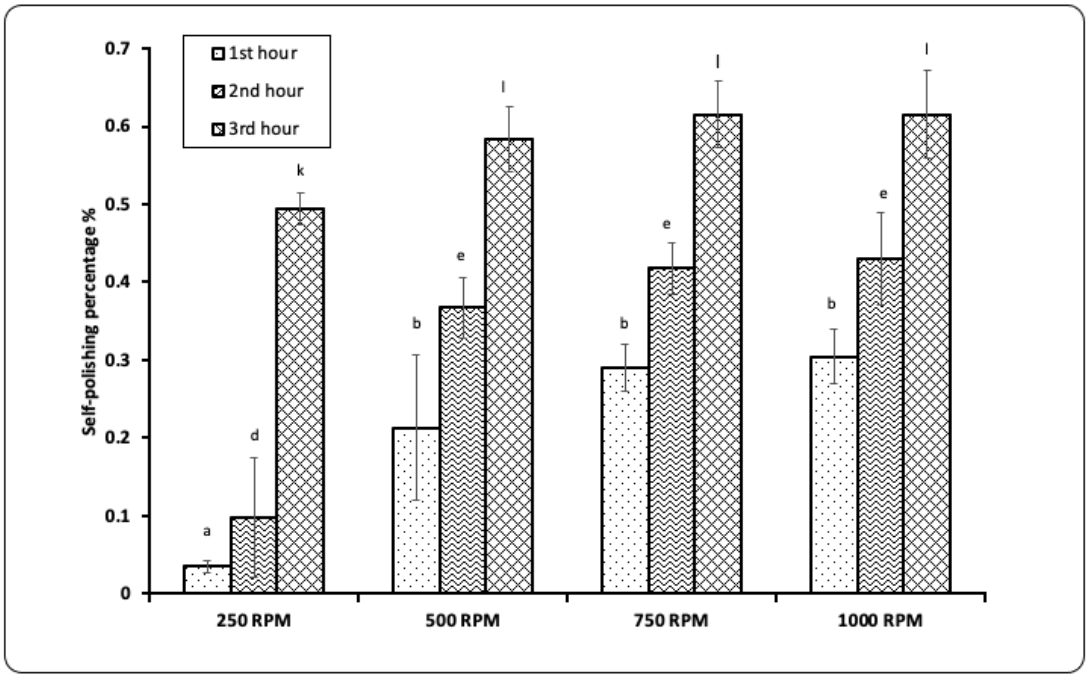


Figure 3.12 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 30 °C

Table 3.33 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	1.2283	11	0.11166	44.38	3.13764e-13
Error	0.06039	24	0.00252		
Total	1.28869	35			

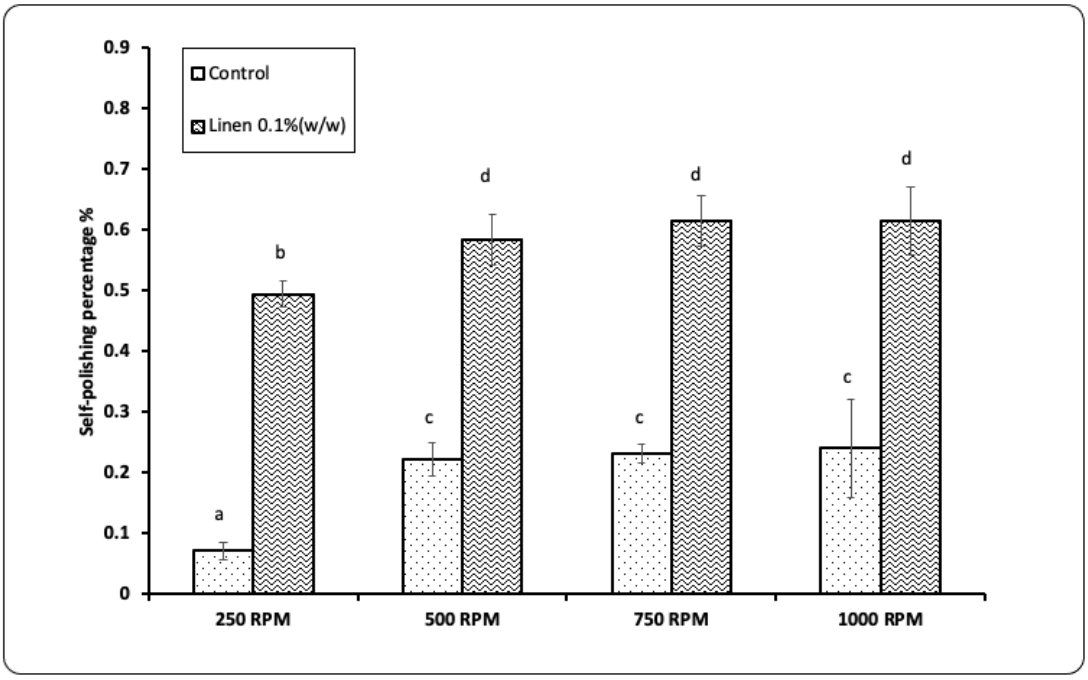


Figure 3.13 The comparison of self-polishing percentages between control and linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC

Table 3.34 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.89259683	1	0.89259683	174.480049	6.16e-12
Error	0.11254657	22	0.00511575		
Total	1.0051434	23			

Table 3.35 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour

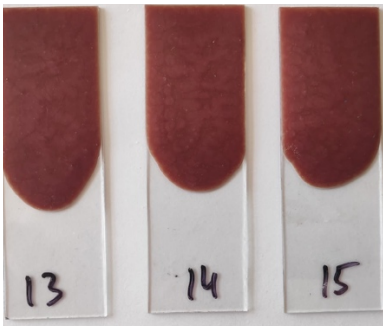
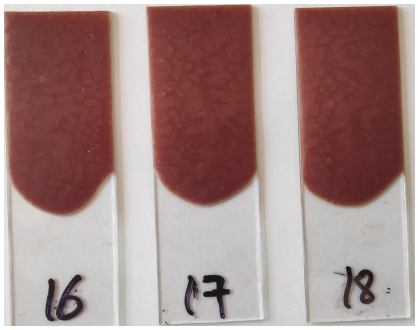
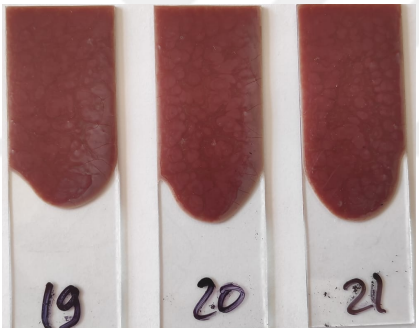
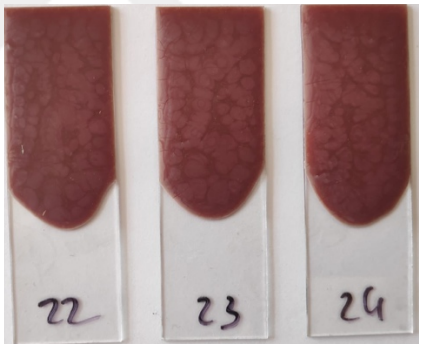
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.36 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours

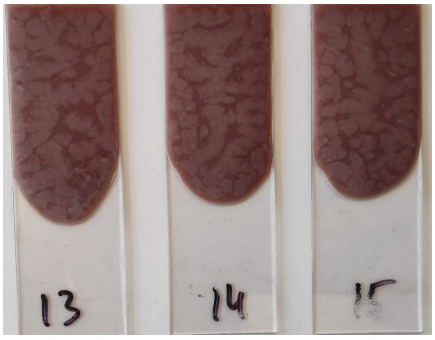
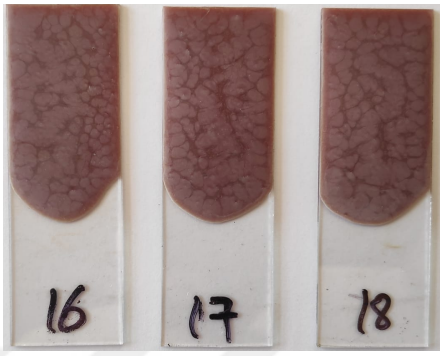
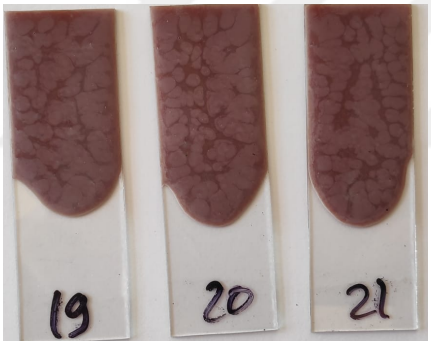
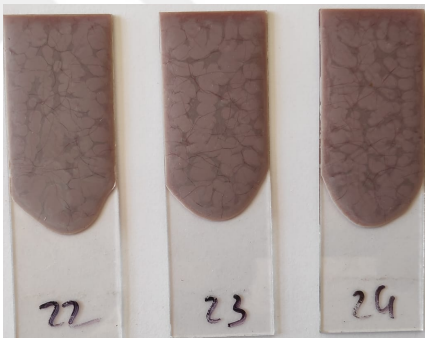
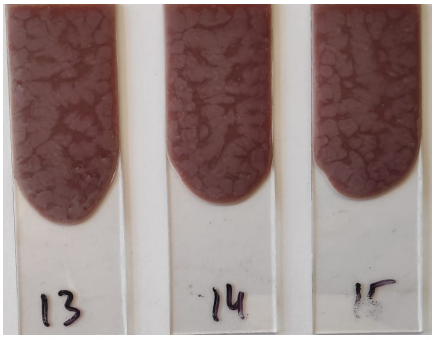
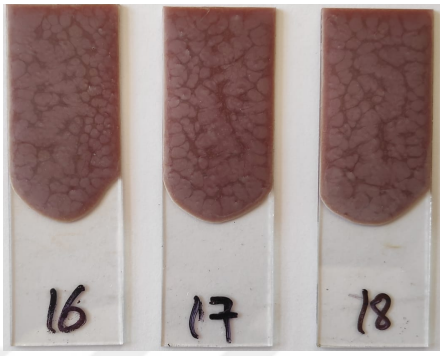
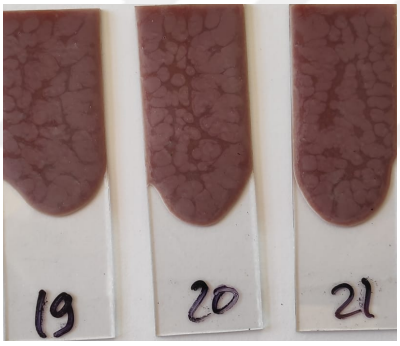
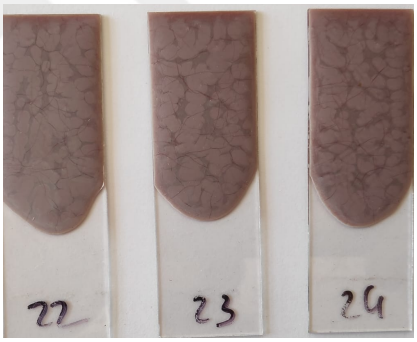
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.37 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing test of linen fiber the 0.1% (w/w) reinforced self-polishing paint are shown in Figure 3.14 The tests were made at 40 ^{o}C temperature. The self-polishing percentages of the tests that were done for a 3-hour time period did not show any significant differences for all rotary rates ($p>0.05$). The results of the test that were done for 1 hour also did not show any significant differences between all rotary rates either ($p>0.05$). The results of the one-way ANOVA tests can be seen from Table 3.38 and as can be seen from the table self-polishing percentage changed based on rotary rate and rotary rime ($p<0.05$). Figure 3.15 represents a comparison of self-polishing percentages between the control and the linen fiber reinforced 0.1% (w/w) antifouling paint. As can be seen from Figure 3.15 fiber reinforcement increased the polishing percentage. One-way ANOVA test results of comparison of self-polishing percentages means can be seen in Table 3.39. As can be seen from the table statistical differences were not observed between self-polishing percentages means ($p>0.05$). The photos of microscope slides used in the self-polishing test which was covered by the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint can be seen from Table 3.40-Table 3.42.

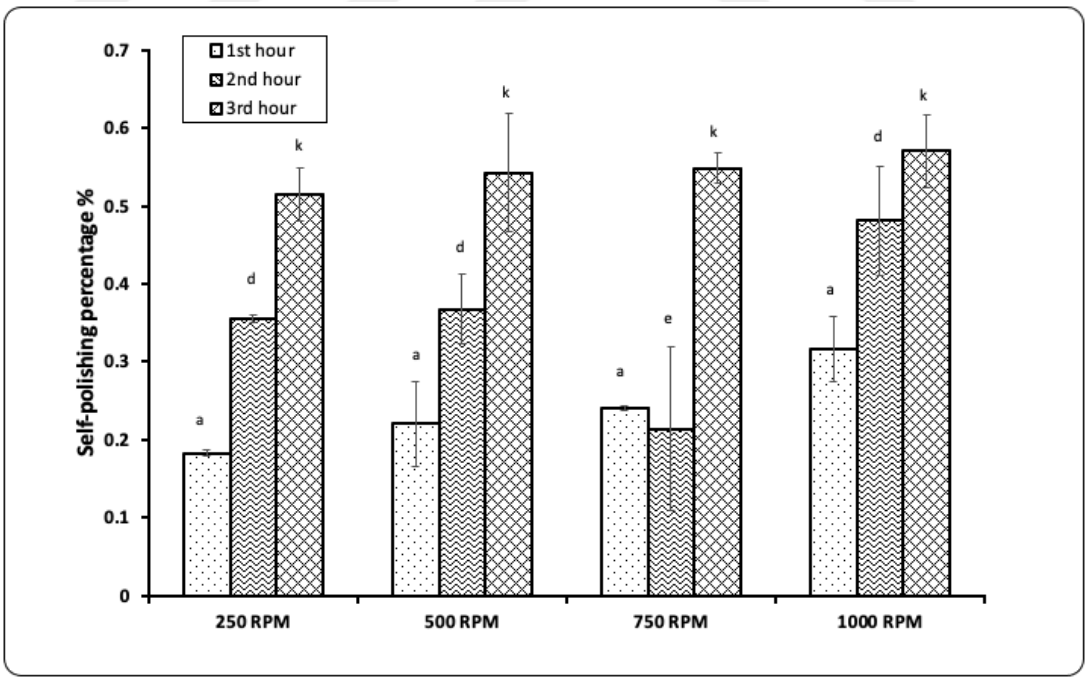


Figure 3.14 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 40 °C

Table 3.38 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.70666	11	0.06424	24.01	2.65769e-10
Error	0.06421	24	0.00268		
Total	0.77087	35			

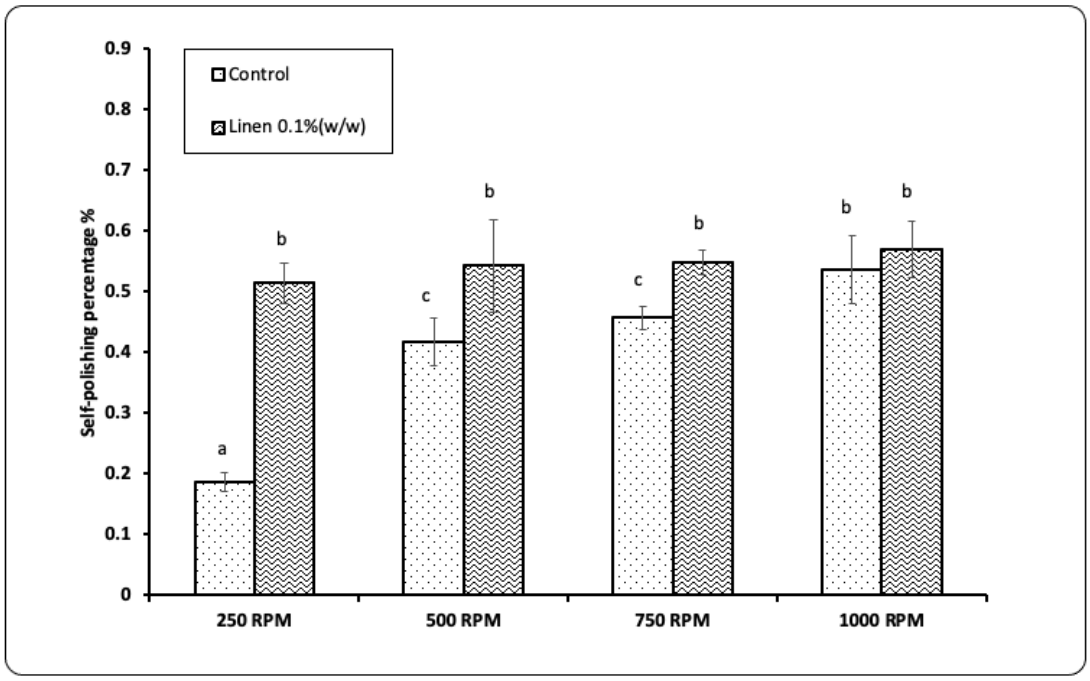


Figure 3.15 The comparison of self-polishing percentages between control and linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC

Table 3.39 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.12528331	1	0.12528331	8.54422995	0.00787692
Error	0.3225841	22	0.01466291		
Total	0.44786741	23			

Table 3.40 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour

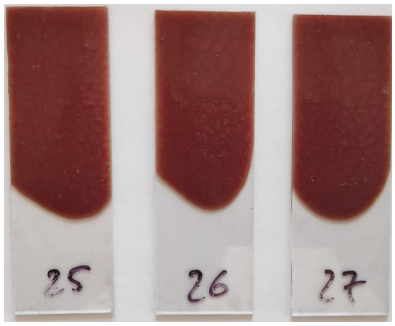
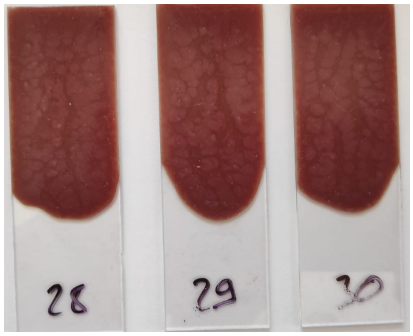
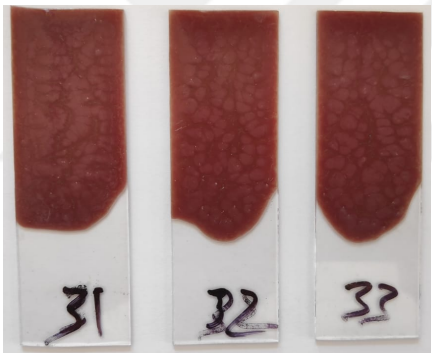
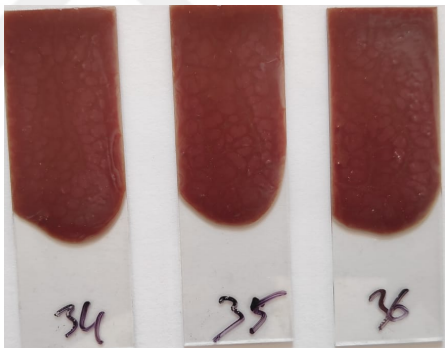
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.41 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours

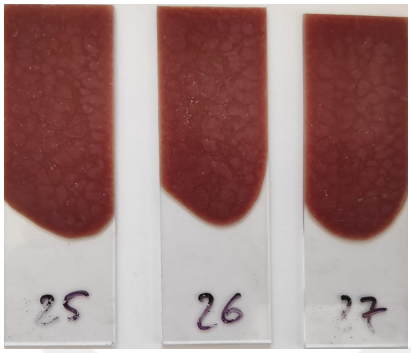
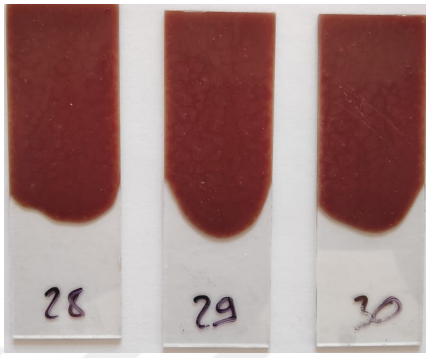
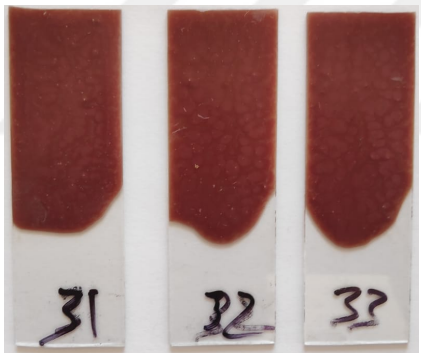
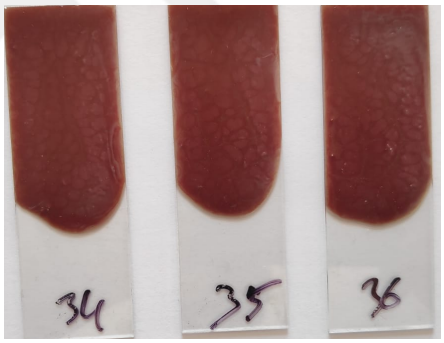
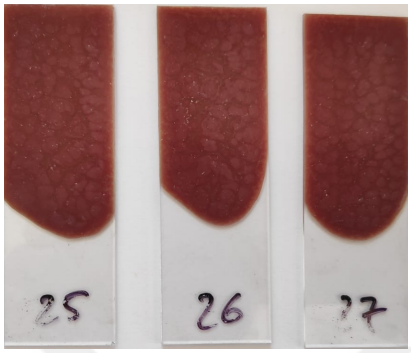
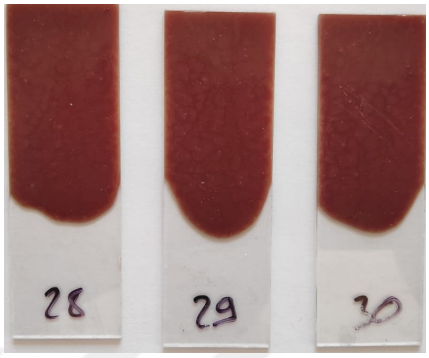
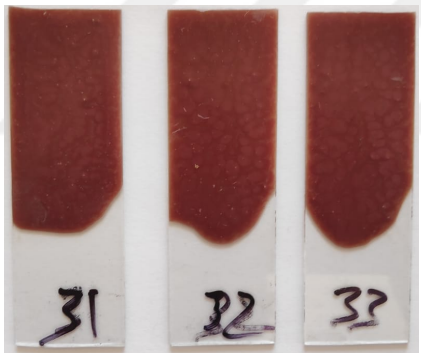
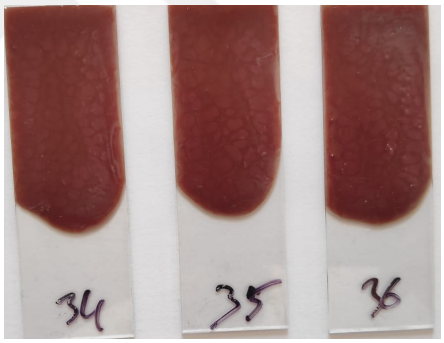
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.42 The photos of the linen fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The self-polishing test results of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint are shown in Figure 3.16. The tests were made at 20 °C temperature. One-way ANOVA test results are given in Table 3.43. The self-polishing percentages of the tests that were done for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between all RPM rotary rates ($p>0.05$). Self-polishing percentages obtained from the tests that were done for 3-hour 1000 RPM rate were significantly different from tests that were made at 250-750 RPM ($p<0.05$). The highest self-polishing percentage was observed at 1000 RPM rotary rate for a 3-hour test period. As it can be seen from Figure 3.17 the means of the fiber-reinforced paints self-polishing percentages did not show any significant differences from the control group. One-way ANOVA tests results related to the mean comparison of self-polishing percentages between fiber-reinforced paint and control paint are shown in Table 3.44. The photos of microscope slides used in the self-polishing test which was covered by the linen fiber reinforced 0.01% (w/w) paint can be seen from Table 3.45-Table 3.47.

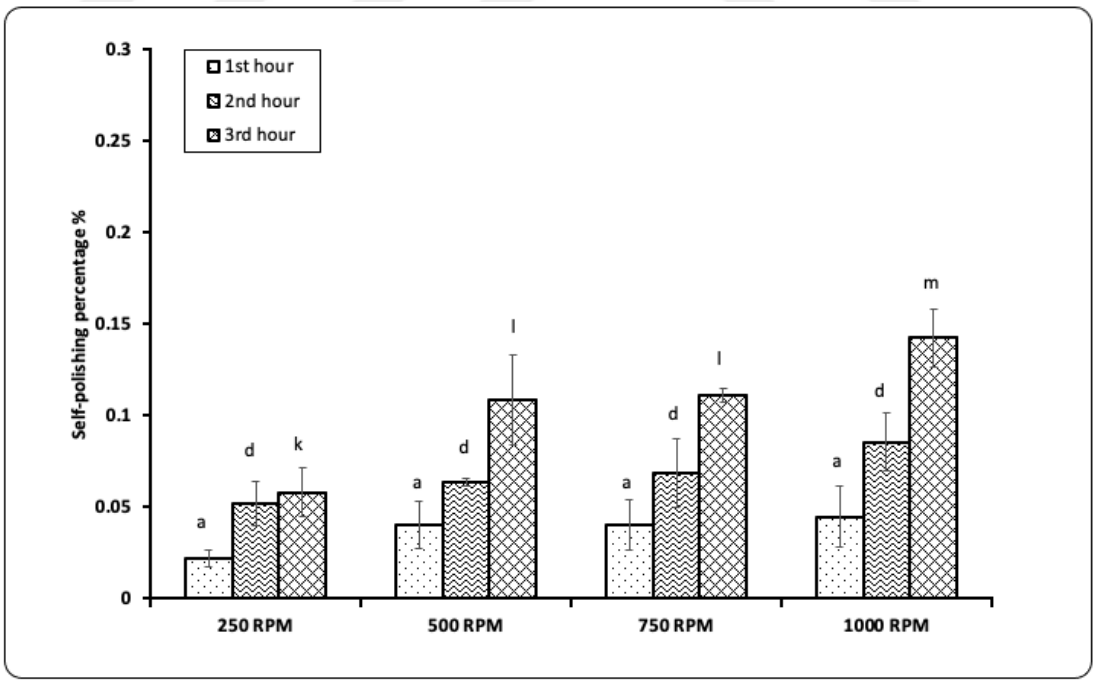


Figure 3.16 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 °C

Table 3.43 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.04168	11	0.00379	18.38	4.37381 e-09
Error	0.172	24	0.00072		
Total	0.20877	35			

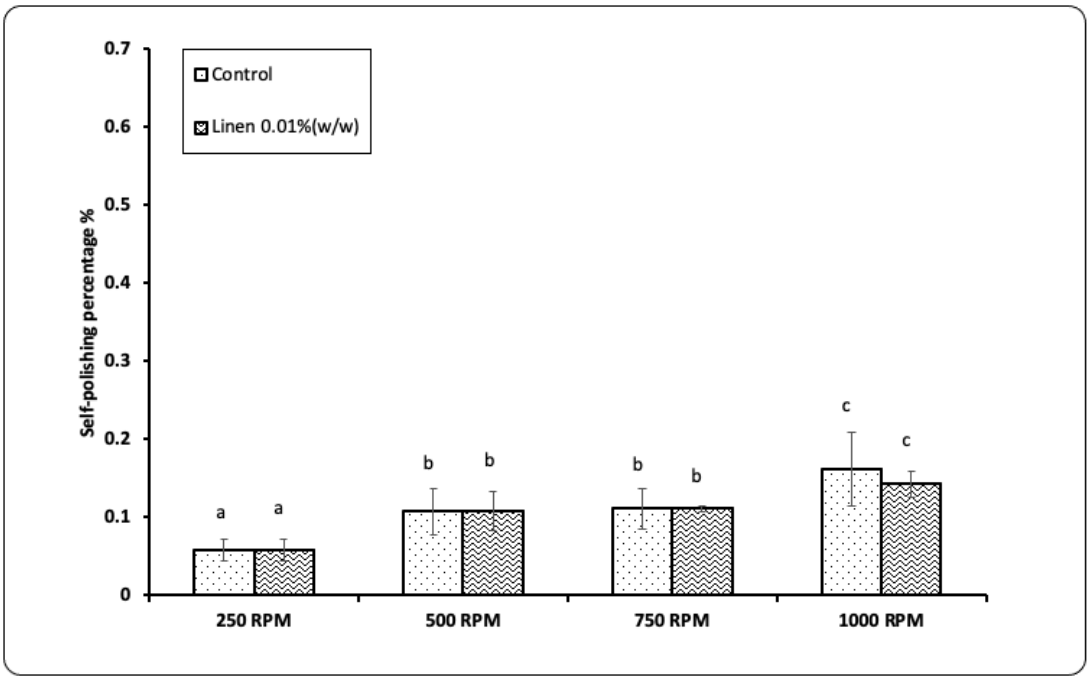


Figure 3.17 The comparison of self-polishing percentages between control and linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC

Table 3.44 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.00011698	1	0.00011698	0.06984491	0.79402274
Error	0.03684772	22	0.0016749		
Total	0.03696471	23			

Table 3.45 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour

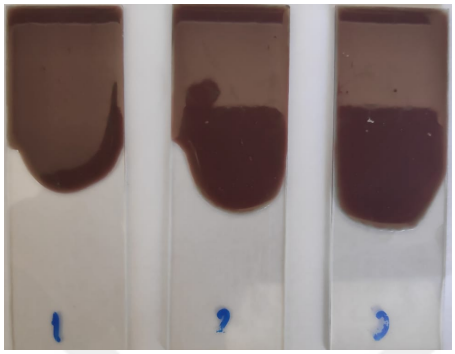
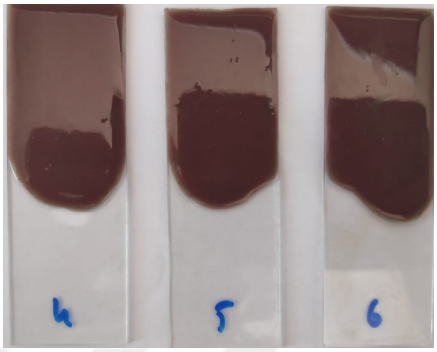
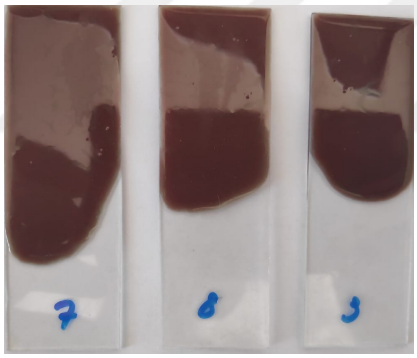
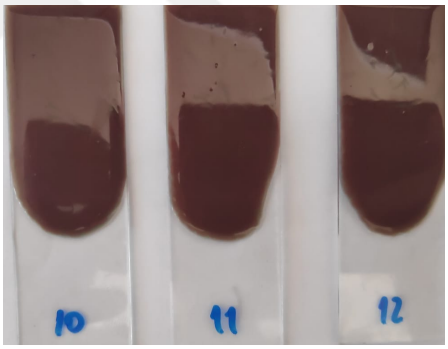
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.46 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours

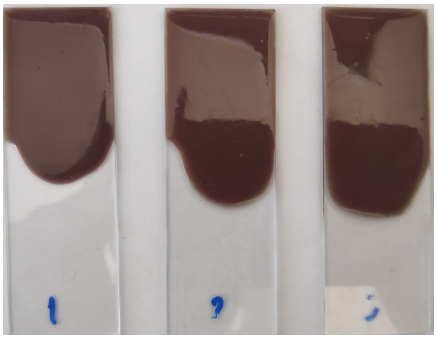
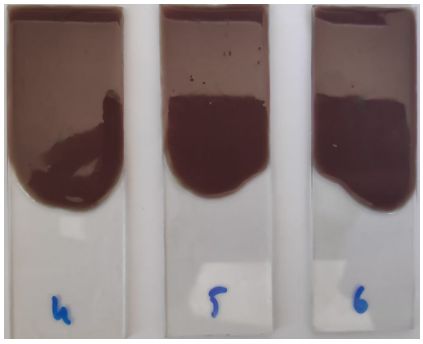
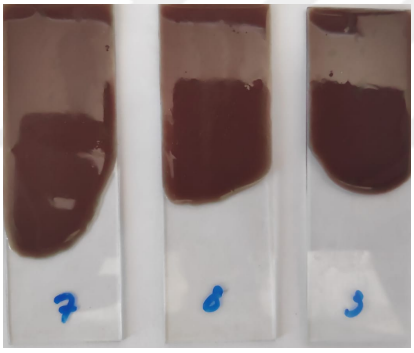
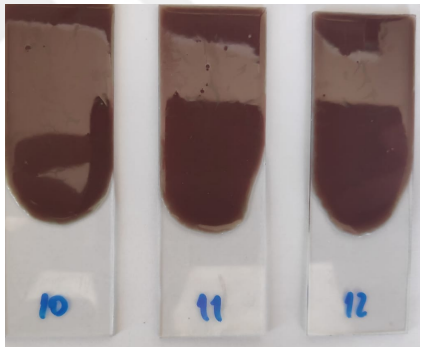
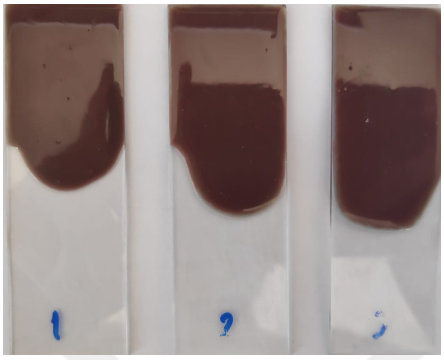
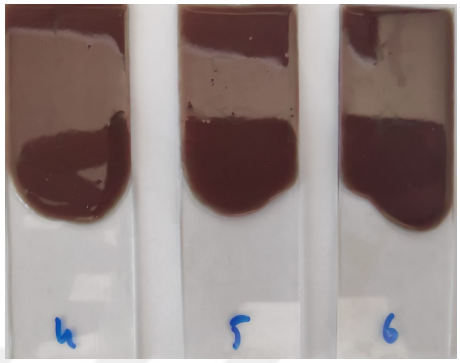
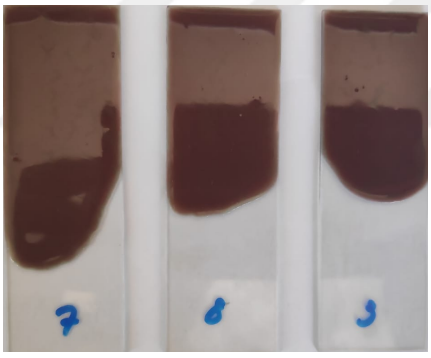
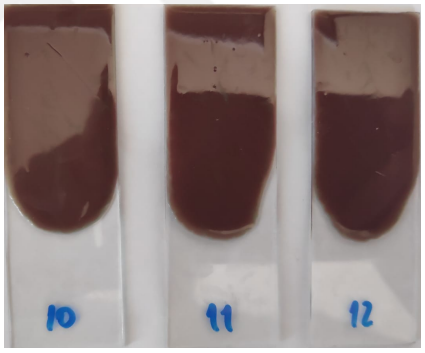
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.47 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

In Figure 3.18 self-polishing test results of the linen fiber reinforced 0.01% (w/w) antifouling paint are depicted. The tests were made at 30 °C temperature. The results related to the one-way ANOVA test can be seen in Table 3.48. Self-polishing percentages of tests that were made for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). The highest self-polishing percentage was observed at 1000 RPM 3-hour test period. The results of the test that were done for 2 hours did not show any significant differences between 500, 750 and 1000 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour period did not show any statistical differences either for 500, 750 or 1000 RPM ($p>0.05$). As can be seen from Figure 3.19, linen fiber 0.1% (w/w) reinforcement did not affect the self-polishing percentage significantly ($p>0.05$). Means of self-polishing percentages for the fiber-reinforced and the control paint did not show significant differences ($p>0.05$) among them, and it can be seen in Table 3.49. The photos of microscope slides used in the self-polishing test which was covered by the 0.01% (w/w) linen fiber-reinforced antifouling paint can be seen from Table 3.50-Table 3.52.

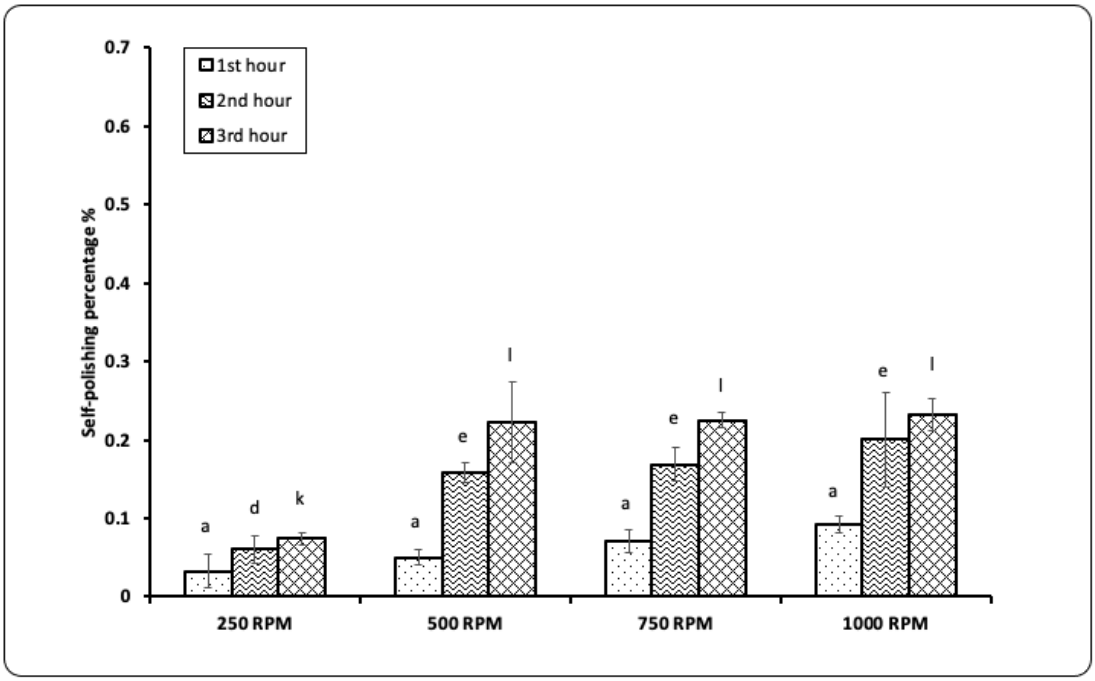


Figure 3.18 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 °C

Table 3.48 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.191157	11	0.01742	24.3	2.34453 e-10
Error	0.172	24	0.00072		
Total	0.20877	35			

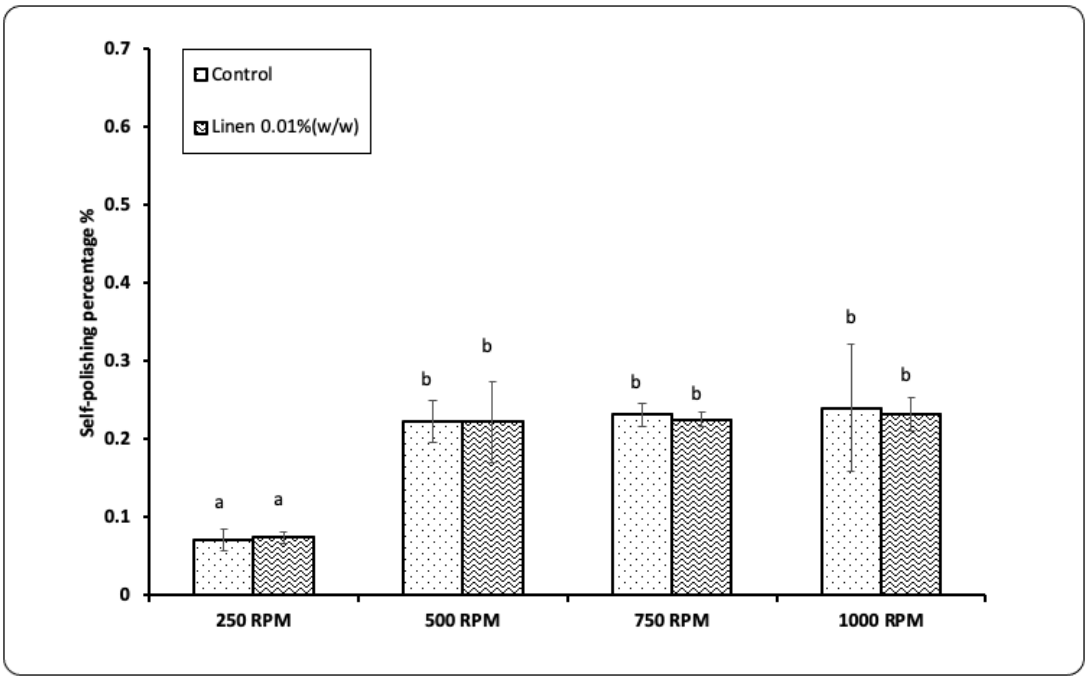


Figure 3.19 The comparison of self-polishing percentages between control and linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC

Table 3.49 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	6.29e-05	1	6.29e-05	0.01084026	0.91802018
Error	0.12763149	22	0.00580143		
Total	0.12769438	23			

Table 3.50 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour

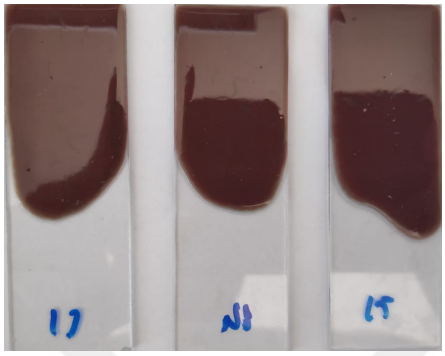
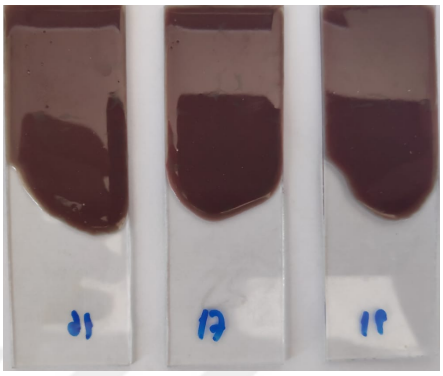
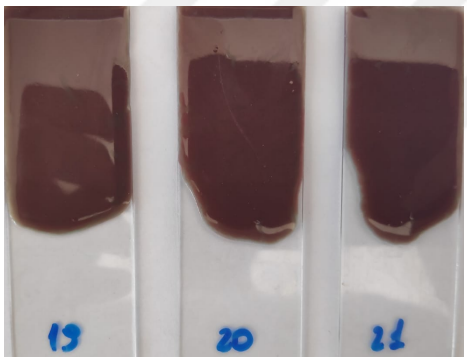
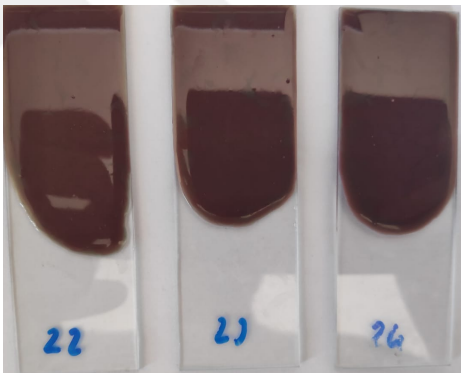
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.51 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours

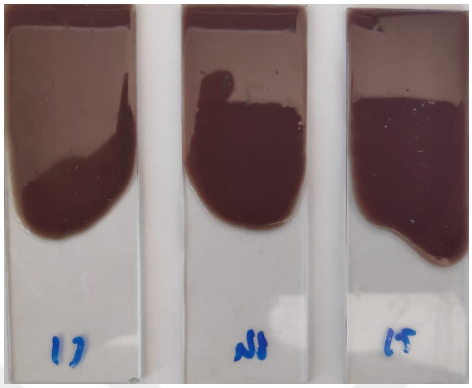
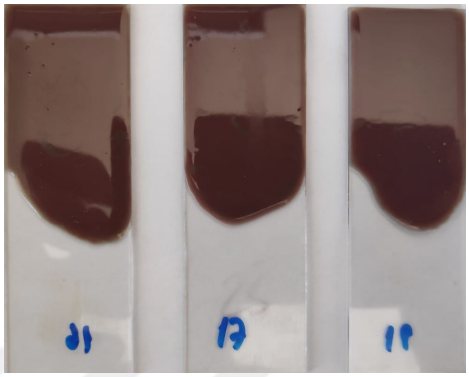
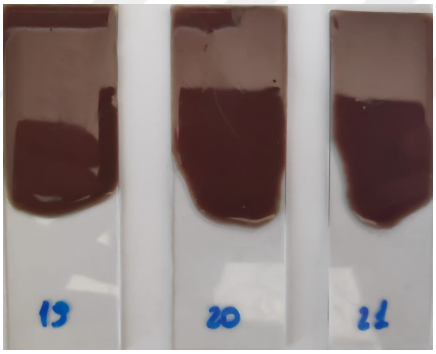
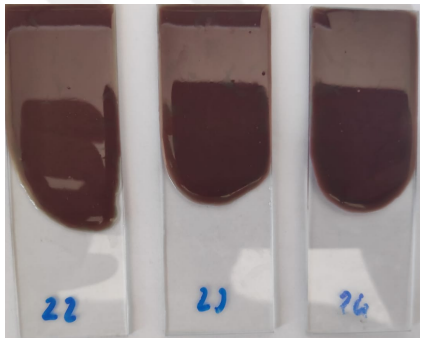
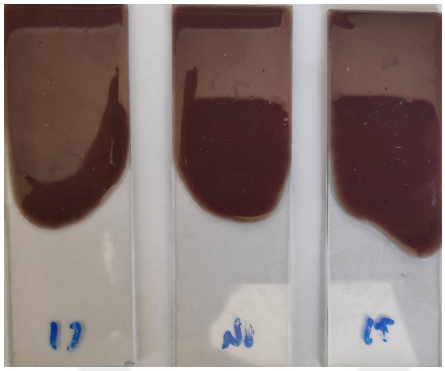
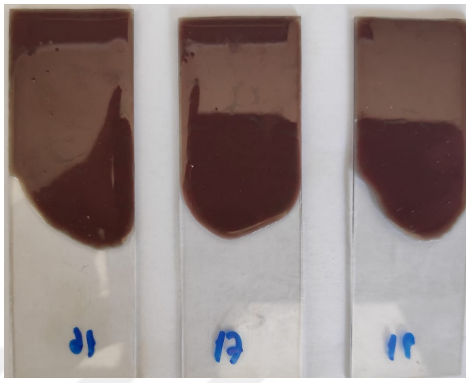
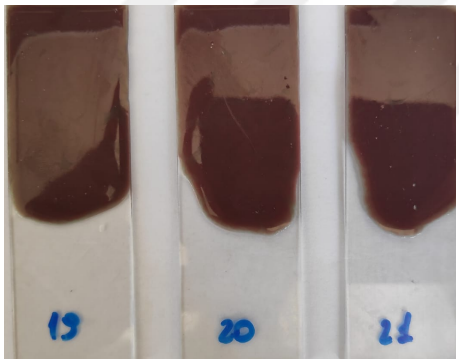
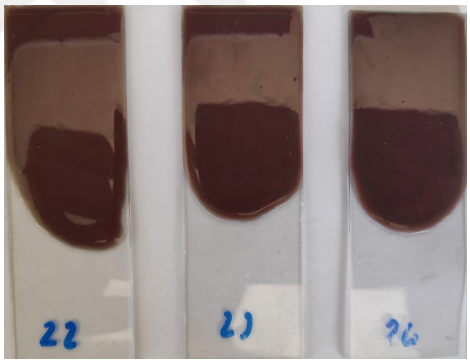
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.52 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The self-polishing test results of the 0.01% (w/w) linen fiber-reinforced antifouling paint can be seen in Figure 3.20. The tests were made at 40 °C temperature. The results related to the effect of rotary time and speed one-way ANOVA test can be seen in Table 3.53 and as it can be seen from the table the rotary rate and rotary time affected self-polishing percentage ($p<0.05$). The highest self-polishing percentage was observed at a 3-hour test period for 1000 RPM rotary rate. Self-polishing percentages of tests that were done for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). The tests result of the 2-hour test period were not significantly different for 500 and 750 RPM rotary rates ($p>0.05$). Self-polishing percentages of 3-hour tests were not significantly different for 500 and 750 RPM rotary rates ($p>0.05$). Significant differences were not observed between control and the 0.01% (w/w) linen fiber-reinforced self-polishing antifouling paints self-polishing percentages, and it can be seen from Figure 3.21. The results of the mean comparisons of self-polishing percentages for the control and the fiber-reinforced paints one-way ANOVA test can be seen in Table 3.54. Photos of microscope slides used in the self-polishing test which was covered by 0.01% (w/w) linen fiber-reinforced paint can be seen from Table 3.55-Table 3.57.

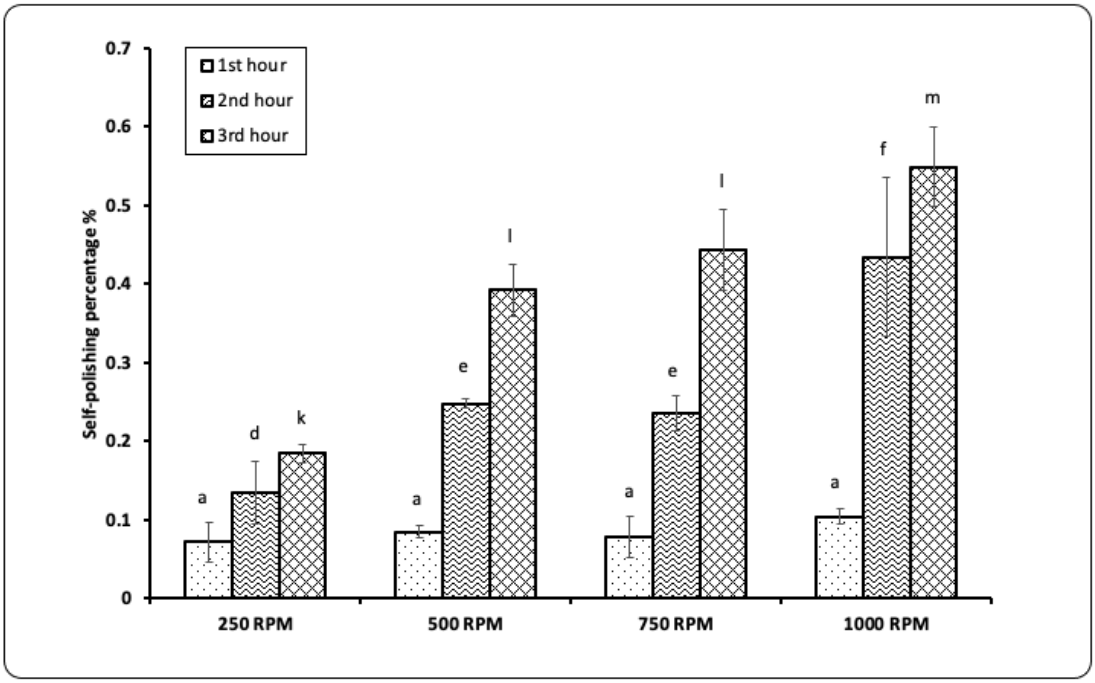


Figure 3.20 The effect of rotary rate and time on the self-polishing percentage of linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 °C

Table 3.53 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.92618	11	0.0842	50.1	7.98941 e-14
Error	0.04034	24	0.00168		
Total	0.96652	35			

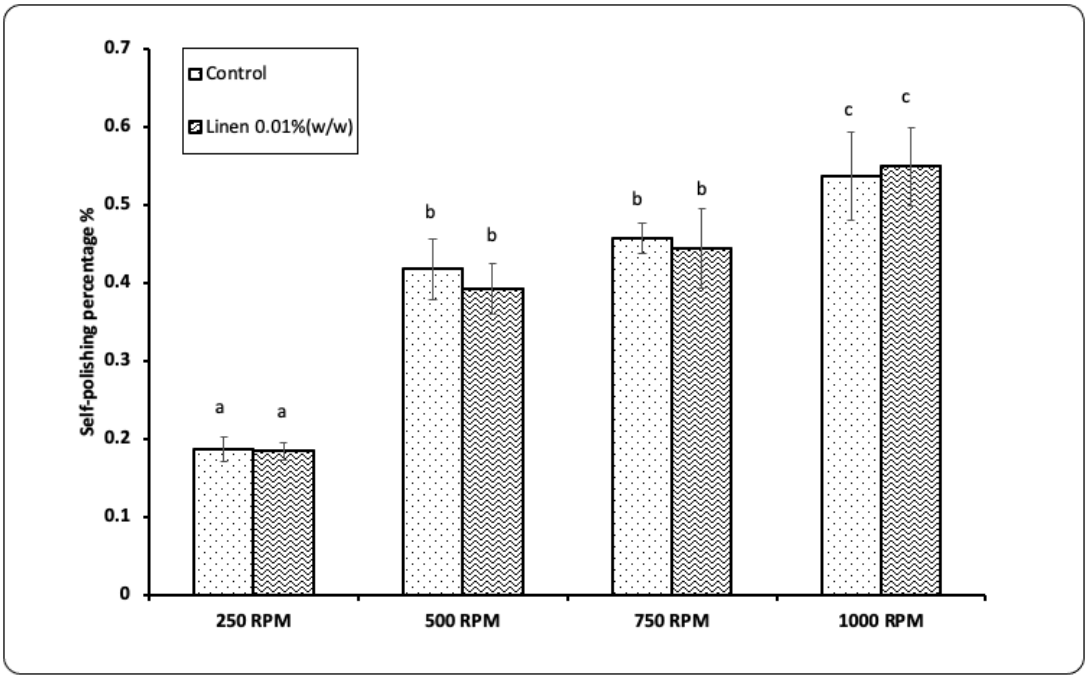


Figure 3.21 The comparison of self-polishing percentages between control and linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC

Table 3.54 One-way ANOVA results related to mean comparison of control and linen fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.00034515	1	0.00034515	0.01453347	0.90513789
Error	0.52247369	22	0.0237488		
Total	0.52281884	23			

Table 3.55 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour

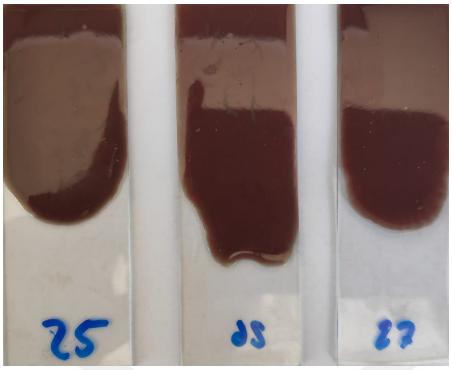
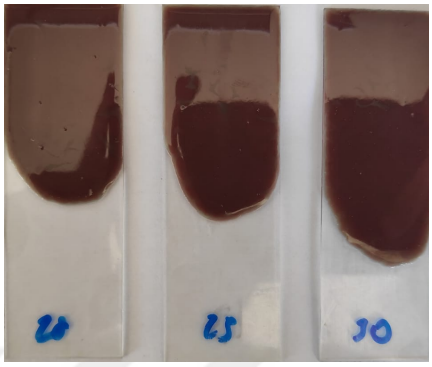
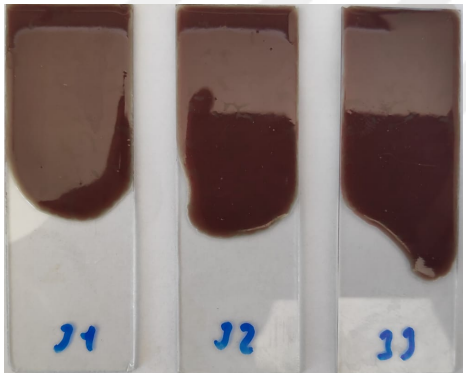
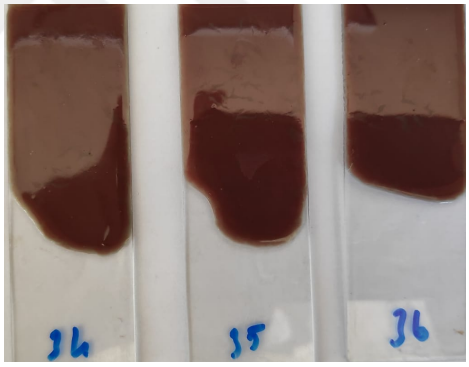
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.56 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours

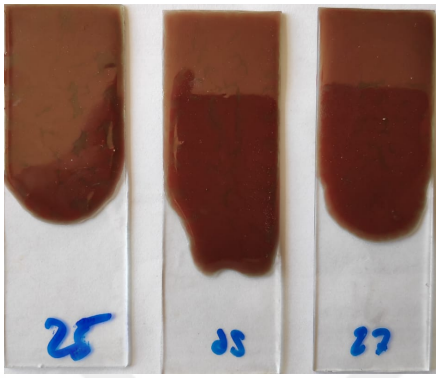
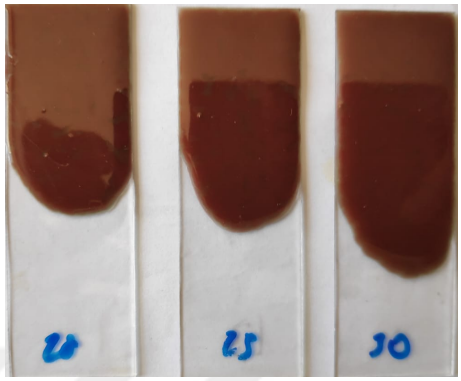
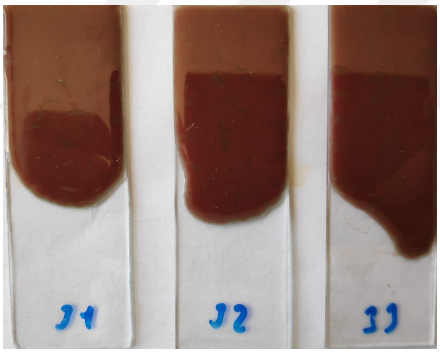
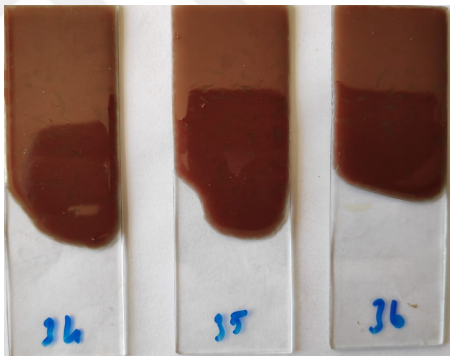
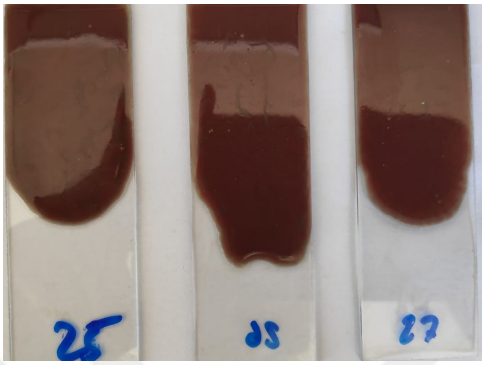
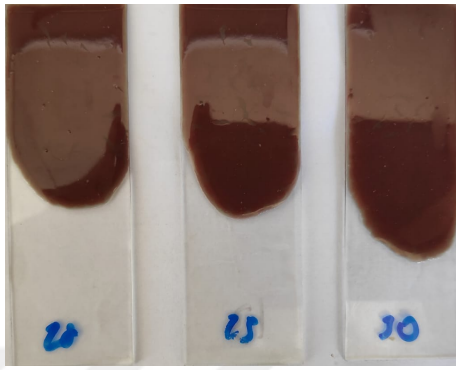
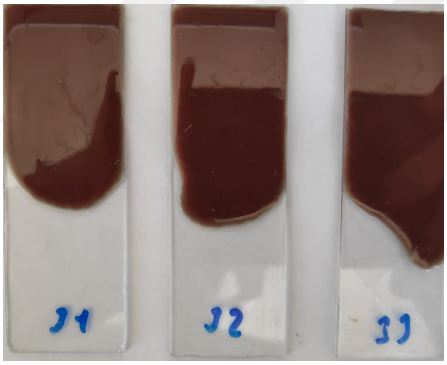
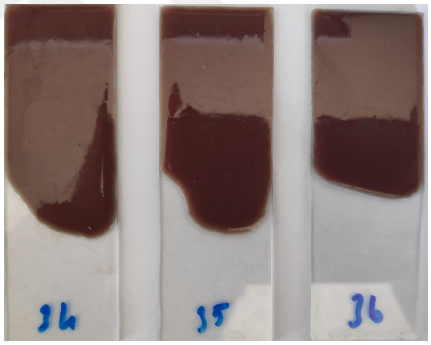
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.57 The photos of the linen fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Self-polishing percentages of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint are shown in Figure 3.22. The tests were made at 20 °C temperature. One-way ANOVA analyses of the self-polishing tests can be seen in Table 3.58. As it can be seen from Table 3.58 rotary rate and rotary time affected self-polishing percentage remarkably ($p<0.05$). The highest self-polishing percentage was observed at the test that was done for a 3-hour period at 1000 RPM rotary rate but did not have significant differences between 500 and 750 RPM rotary rates ($p>0.05$). Jute fiber reinforcement increased self-polishing percentage and it can be seen in Figure 3.23. The results of the one-way ANOVA tests related to the comparison of fiber-reinforced and control paints self-polishing percentages can be seen in Table 3.59. The photos of microscope slides used in the self-polishing test which were covered by the jute fiber reinforced 1% (w/w) self-polishing antifouling paint can be seen from Table 3.60-Table 3.62. Visible cracks and discoloration occurred in the paint structure, and it can be seen from Table 3.62.

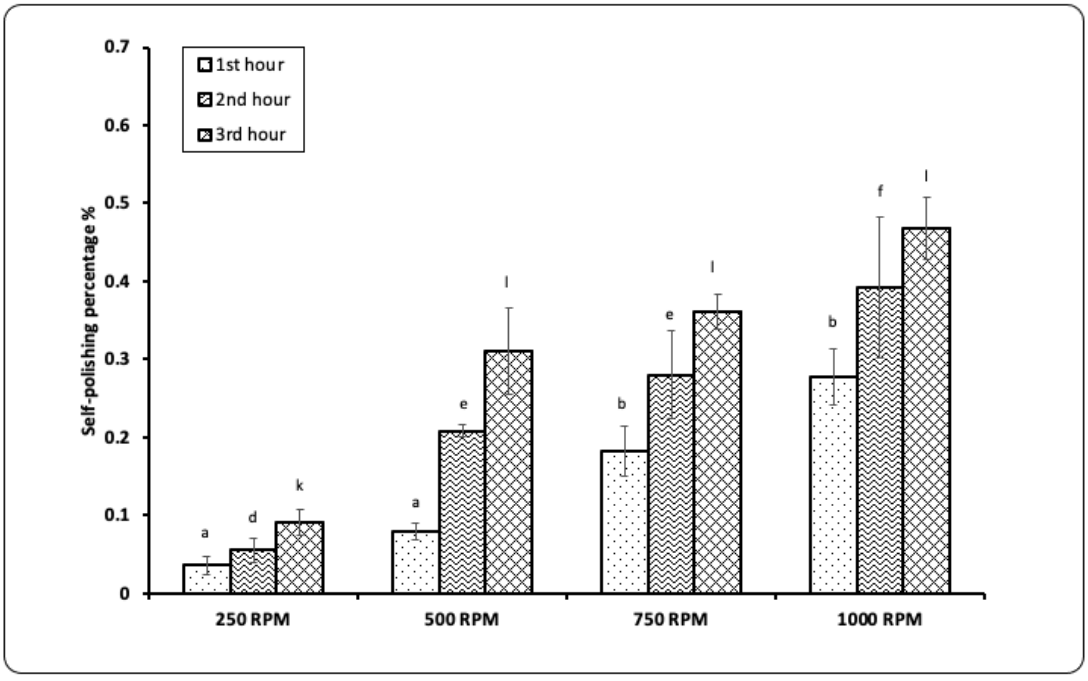


Figure 3.22 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 °C

Table 3.58 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.67189	11	0.06108	37.31	2.18309e-12
Error	0.03929	24	0.00164		
Total	0.71118	35			

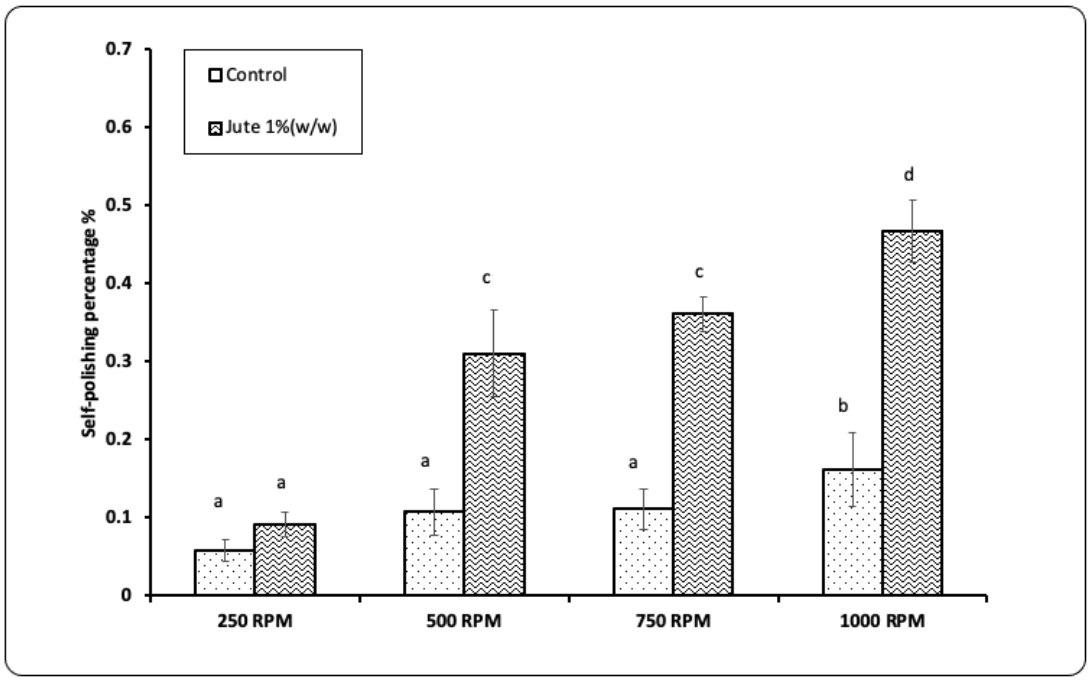


Figure 3.23 The comparison of self-polishing percentages between control and jute fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC

Table 3.59 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.23539114	1	0.23539114	19.9184727	0.00019469
Error	0.25999007	22	0.01181773		
Total	0.4953812	23			

Table 3.60 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour

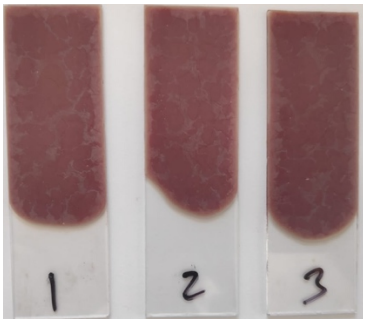
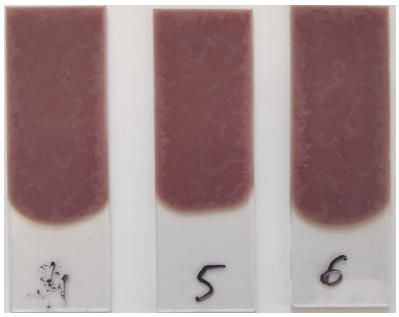
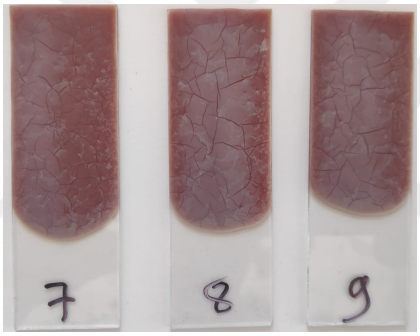
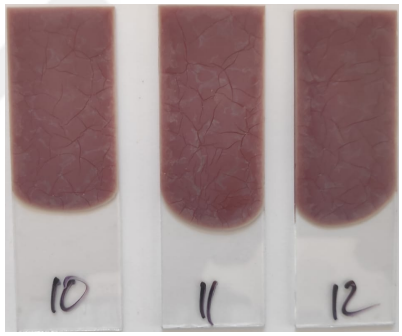
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.61 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours

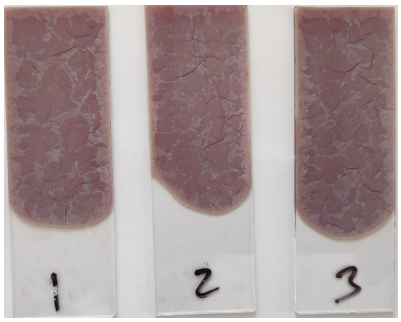
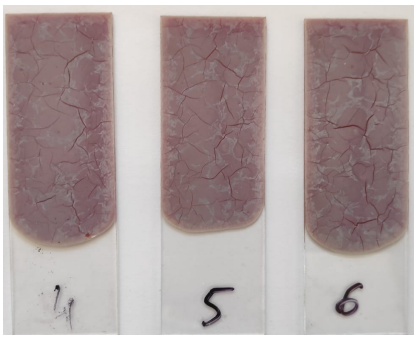
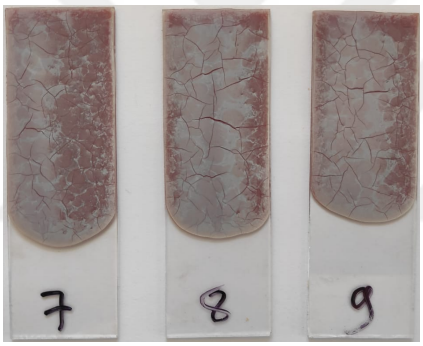
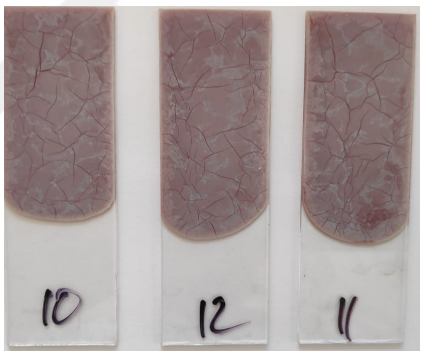
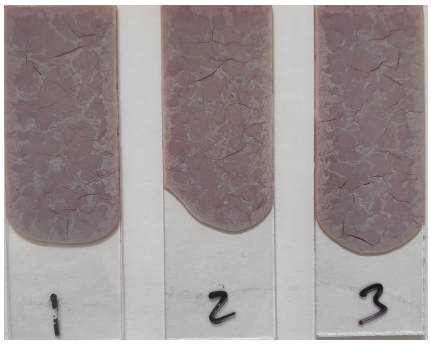
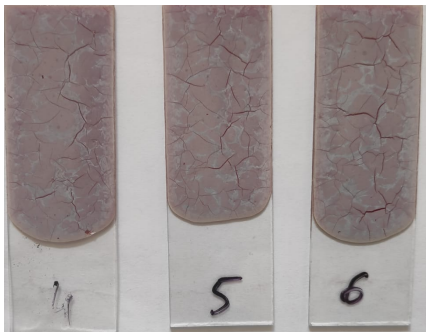
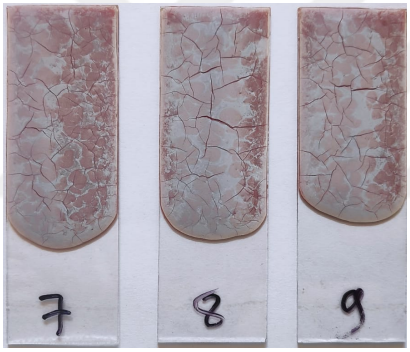
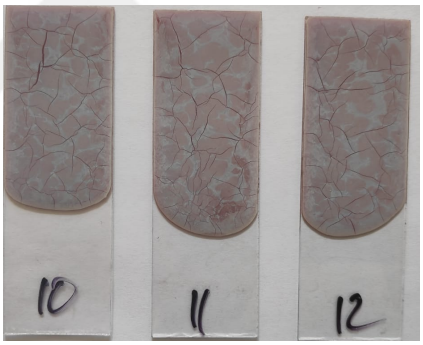
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.62 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Self-polishing percentages of the jute fiber reinforced 1% (w/w) self-polishing rosin-based self-polishing antifouling paint are shown in Figure 3.24. The tests were made at 30 ºC temperature. One-way ANOVA test results of the polishing test can be seen in Table 3.63. The results of self-polishing tests for 1 hour period were not significantly different at 250-750 RPM range. 2-hour tests self-polishing percentages results were not statistically different for 250-750 RPM range. Self-polishing percentages of tests that were made for a 3-hour period were not significantly different for 500, 750 and 1000 RPM rotary rates ($p>0.05$). The lowest self-polishing degree was observed at 250 RPM rotary rate for 1 hour test period. As can be seen from Figure 3.25 jute fiber reinforcement increased the self-polishing percentage. One-way ANOVA test related to comparison of self-polishing percentage means can be seen in Table 3.64. The photos of microscope slides used in the self-polishing test which was covered by jute fiber reinforced 1% (w/w) self-polishing antifouling paint can be seen from Table 3.65-Table 3.67. The cracks and the discoloration occurred in the paint structure, and it can be seen from Table 3.67

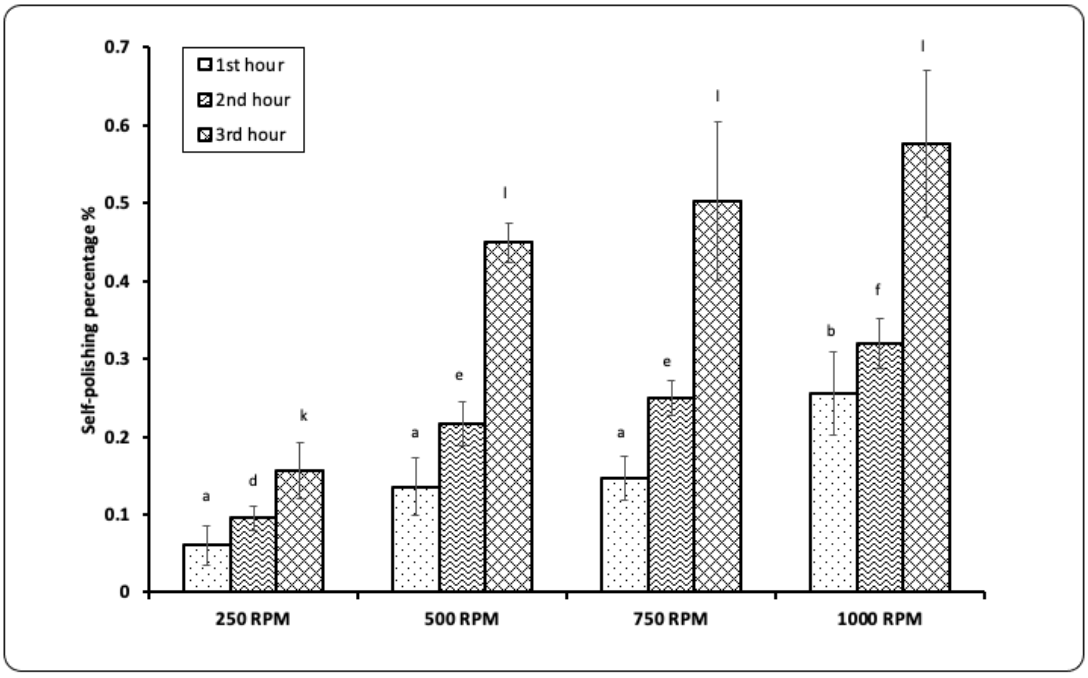


Figure 3.24 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 °C

Table 3.63 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.91651	11	0.08332	33.99	6.11867e-12
Error	0.05883	24	0.00245		
Total	0.97534	35			

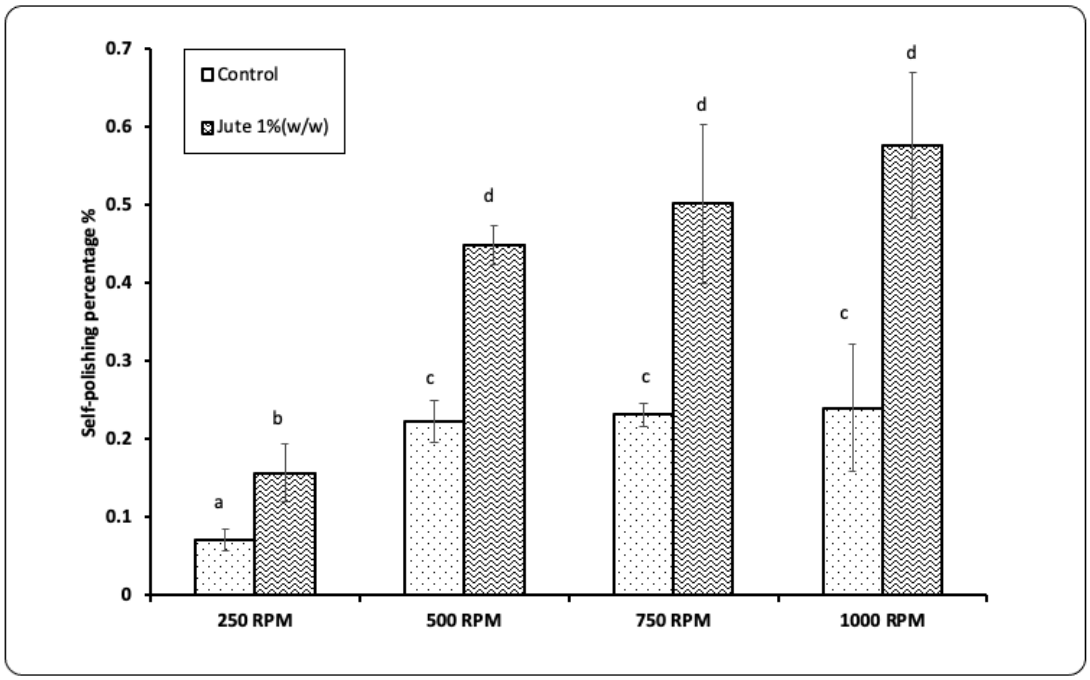


Figure 3.25 The comparison of self-polishing percentages between control and jute fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC

Table 3.64 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.31606244	1	0.31606244	16.7181345	0.00048571
Error	0.41591804	22	0.01890537		
Total	0.73198048	23			

Table 3.65 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour (Since the microscope slides were broken after the experiment, the photos of the 250 RPM rotary rate result are not shown.)

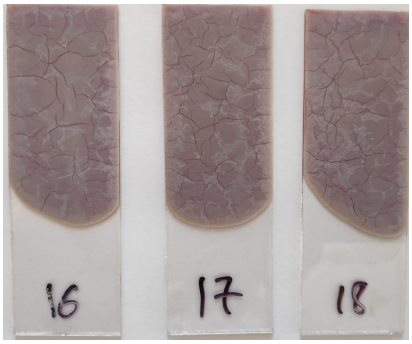
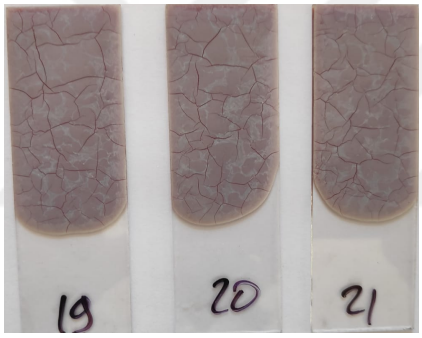
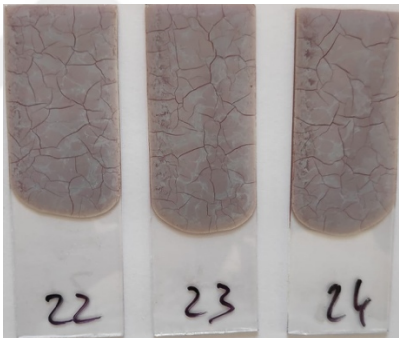
250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.66 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours (Since the microscope slides were broken after the experiment, the photos of the 250 RPM rotary rate result are not shown.)

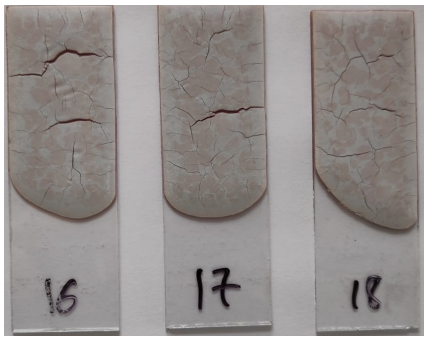
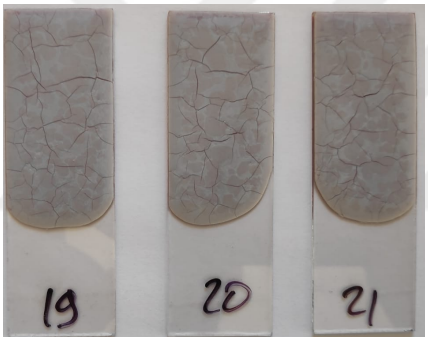
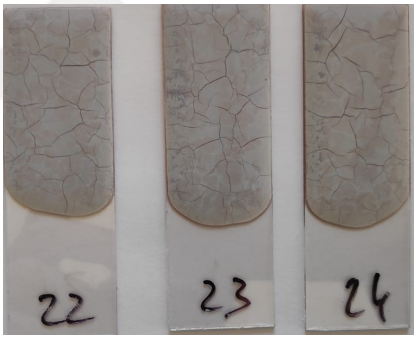
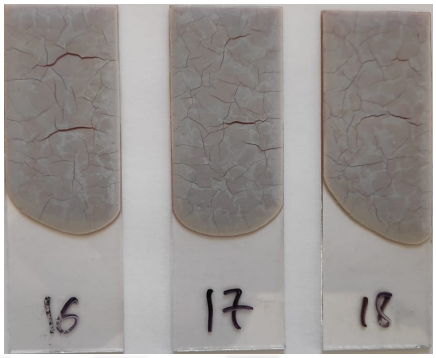
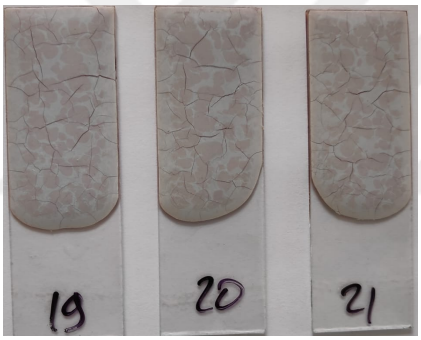
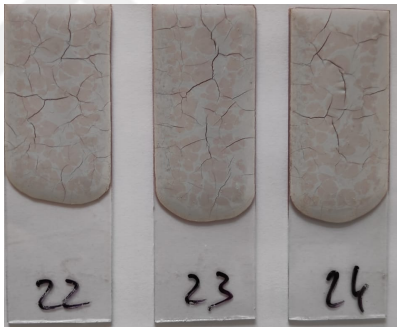
250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.67 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours Since the microscope slides were broken after the experiment, the photos of the 250 RPM rotary rate result are not shown.)

250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing test of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint are shown in Figure 3.26. The tests were made at 40 °C temperature. The results of one-way ANOVA analyses can be seen in Table 3.68. The results of the self-polishing tests for 1-hour were not significantly different for 500-1000 RPM rotary rates ($p>0.05$). Self-polishing percentages of the tests that were held for a 2-hour period were similar for 250, 500 and 750 RPM rates ($p>0.05$). The results of the test that were done for 3 hours at 1000 RPM rotary rate was highest and it was significantly different from 250, 500 and 750 RPM rotary rates ($p<0.05$). When the comparison graph which is shown in Figure 3.27 is examined, it can be seen that jute fiber reinforcement did not decrease the self-polishing percentage. Comparisons for means of self-polishing percentages for control and fiber-reinforced paints one-way ANOVA results can be seen in Table 3.69. The photos of microscope slides used in the self-polishing test which was covered by jute fiber reinforced 1% (w/w) paint can be seen from Table 3.70-Table 3.72 and from tables it can be seen that paints had deformations such as discoloration and the visible cracks on the surfaces.

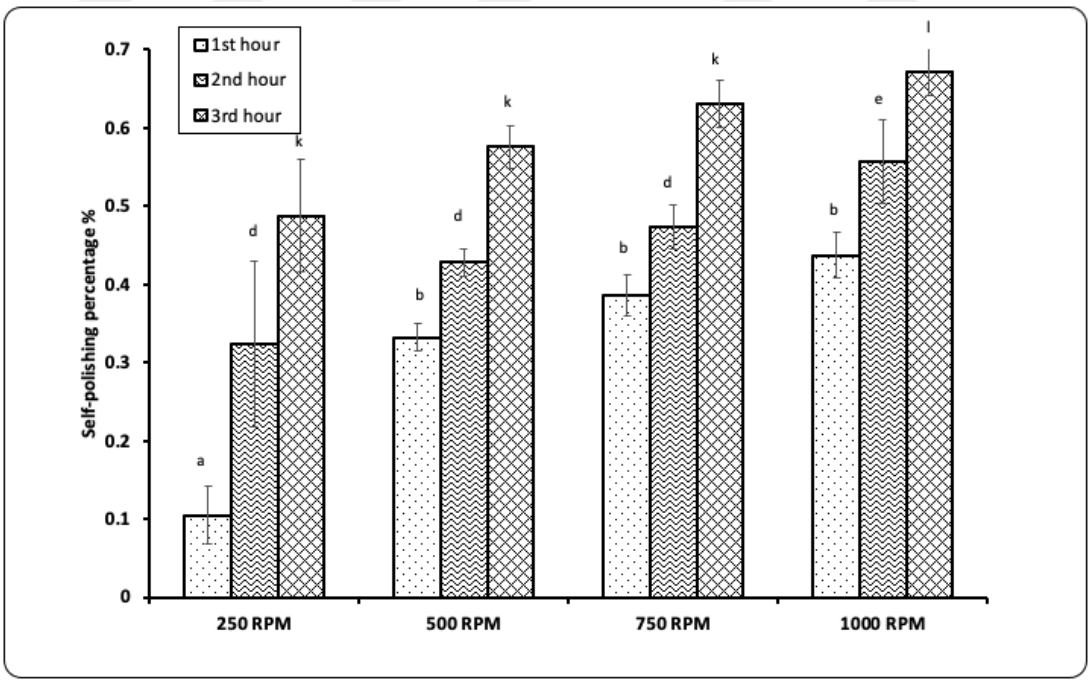


Figure 3.26 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 °C

Table 3.68 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.79342	11	0.07213	33.2	7.94315e-12
Error	0.05215	24	0.00217		
Total	0.84557	35			

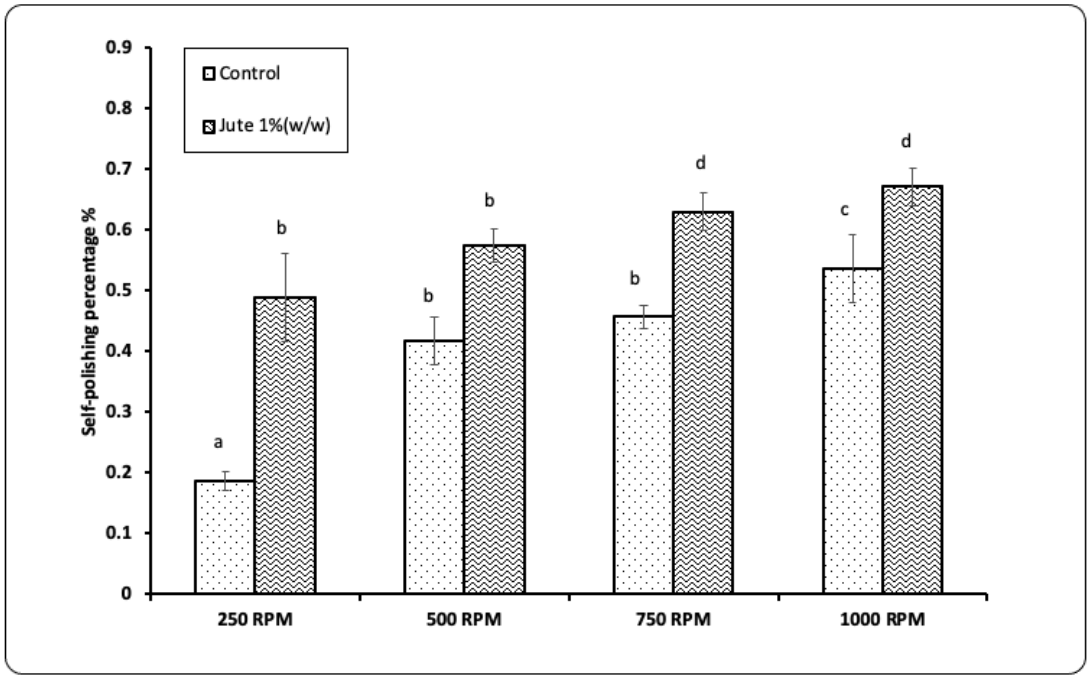


Figure 3.27 The comparison of self-polishing percentages between control and jute fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC

Table 3.69 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.22033789	1	0.22033789	13.0573956	0.00154052
Error	0.37124047	22	0.01687457		
Total	0.59157836	23			

Table 3.70 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour

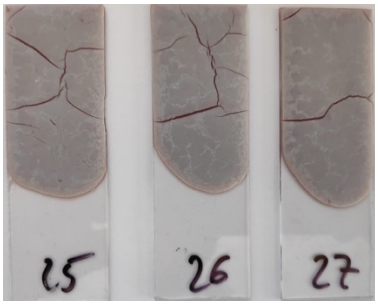
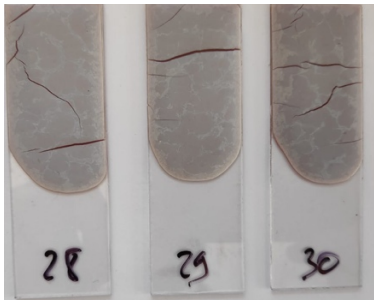
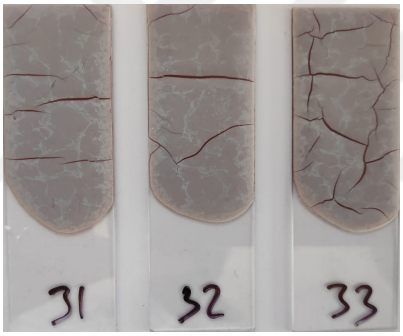
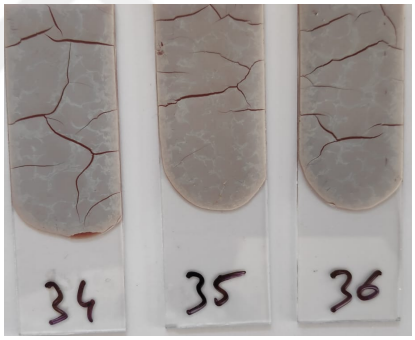
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.71 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours

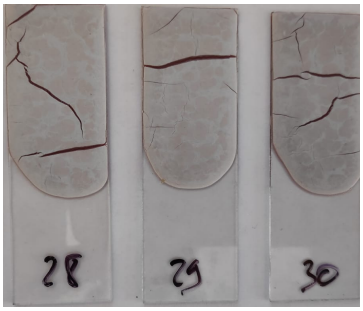
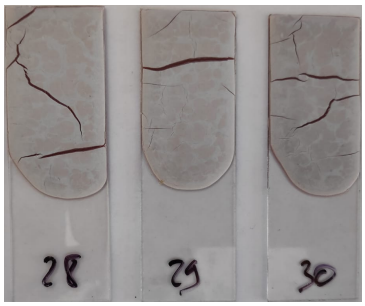
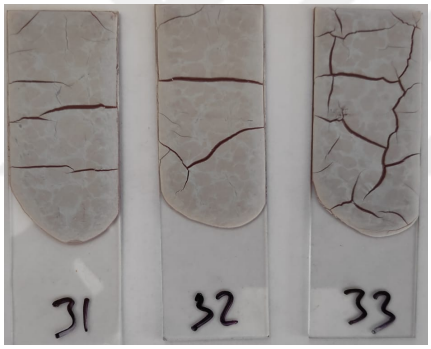
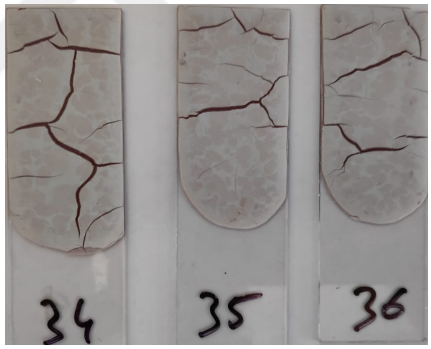
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.72 The photos of the jute fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours

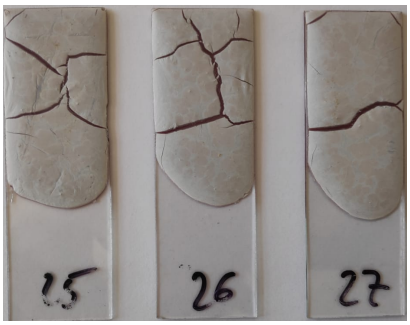
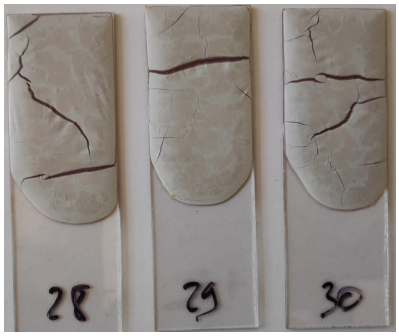
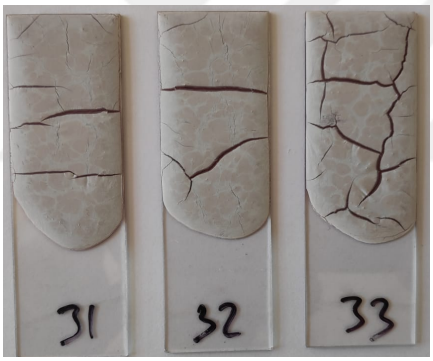
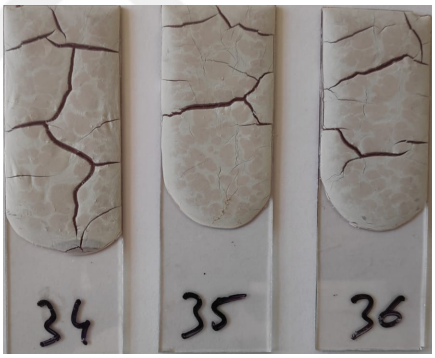
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Figure 3.28 depicts the results of the self-polishing tests of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint. The tests were done at 20 °C. The highest self-polishing degree was observed at 1000 RPM rotary rate for a 3-hour test period. The results of the one-way ANOVA test can be seen in Table 3.73. Self-polishing percentages of the tests that were held for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). Self-polishing percentages were not significantly different for 250 and 750 RPM also 500 and 1000 RPM rotary rates for a 2-hour test period ($p>0.05$). The results of the test that were done for 3 hours did not show any significant differences between 500 and 750 RPM rotary rates ($p>0.05$). When the result for comparison of control and jute fiber reinforced paints self-polishing percentage which is shown in Figure 3.29 analyzed, it can be seen that the fiber reinforcement did not affect the self-polishing percentage significantly ($p>0.05$). One-way ANOVA test results related to comparison of self-polishing percentages means for the control and the fiber-reinforced paint can be seen in Table 3.74. The photos of microscope slides used in the self-polishing test which was covered by reinforced by jute fiber 0.1% (w/w) can be seen from Table 3.75-Table 3.77.

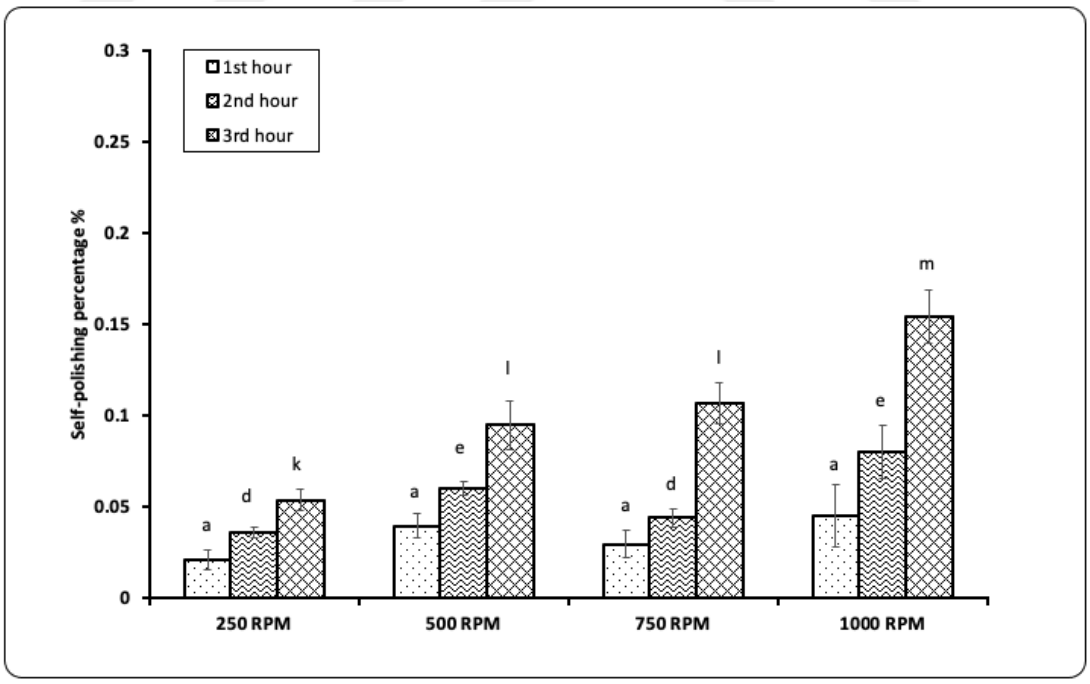


Figure 3.28 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 20 °C

Table 3.73 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.04945	11	0.0045	44.29	3.20574 e-13
Error	0.00244	24	0.0001		
Total	0.05188	35			

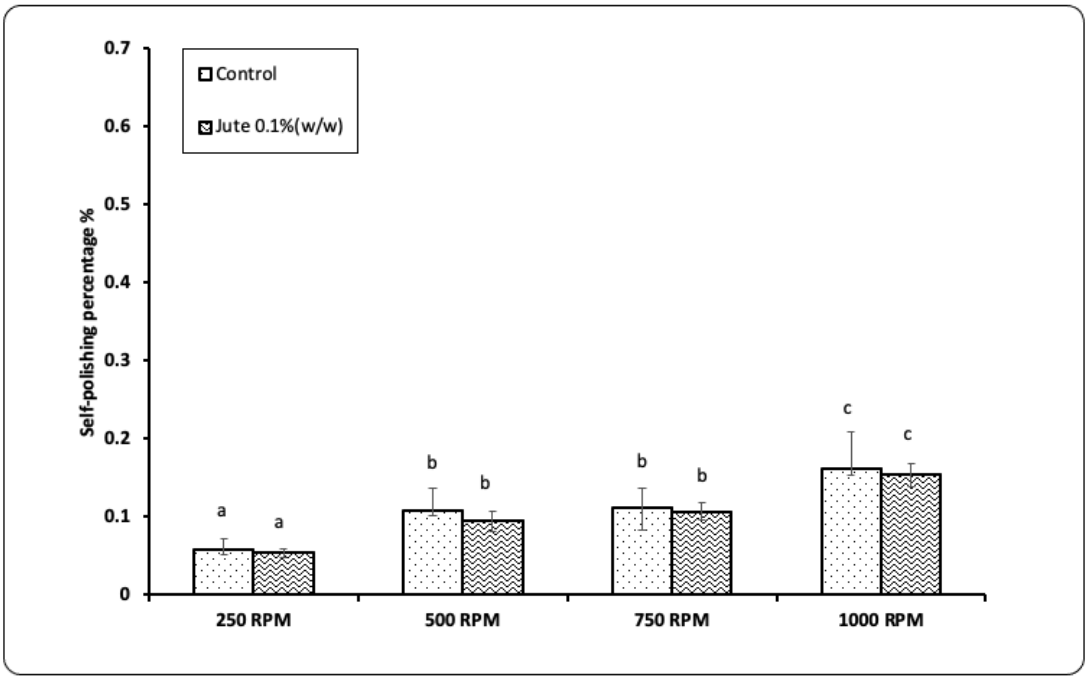


Figure 3.29 The comparison of self-polishing percentages between control and jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC

Table 3.74 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.00033531	1	0.00033531	0.18370576	0.67237515
Error	0.04015618	22	0.00182528		
Total	0.0404915	23			

Table 3.75 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour

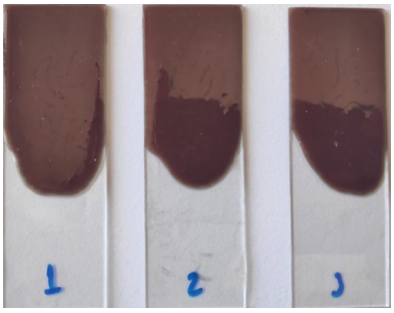
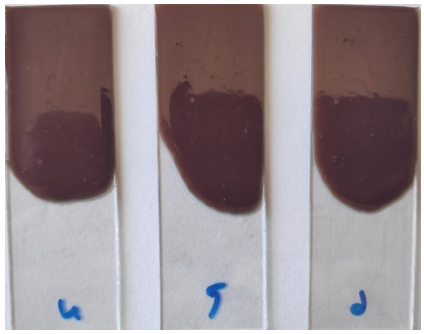
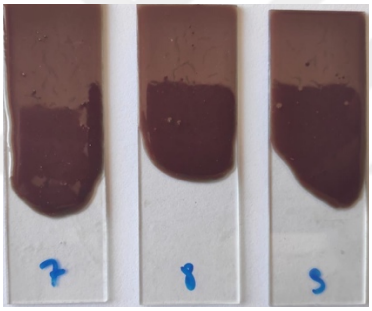
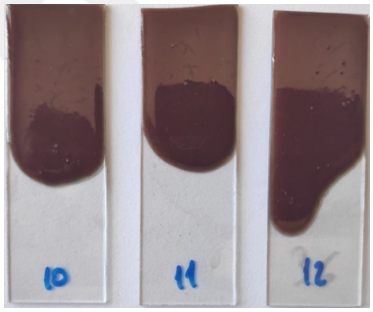
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.76 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours

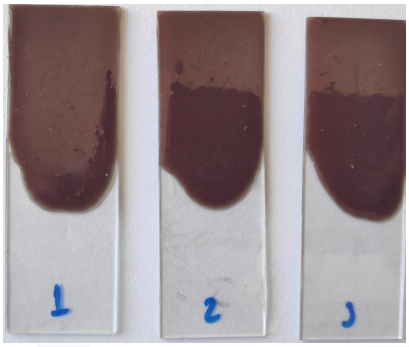
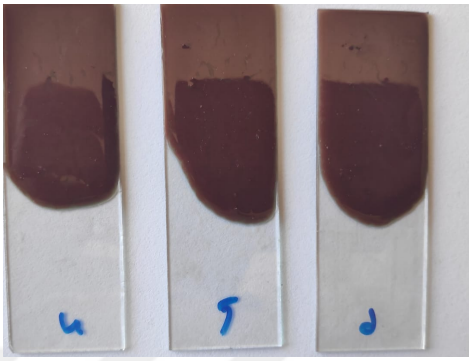
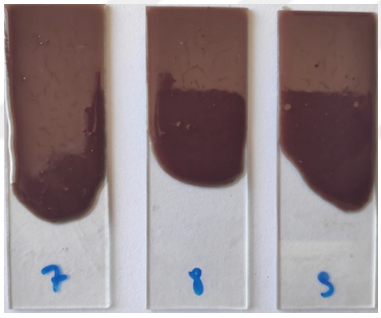
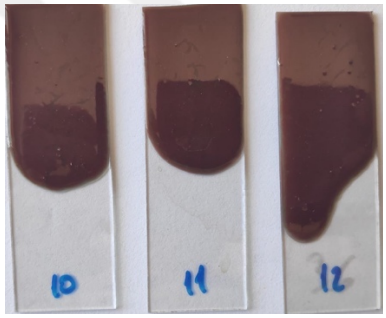
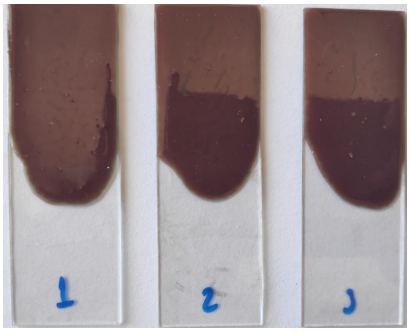
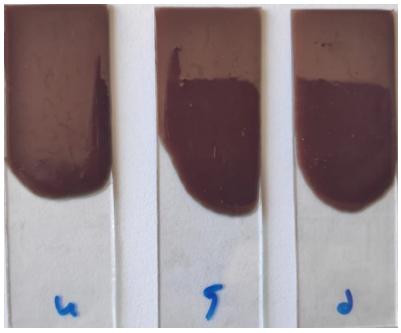
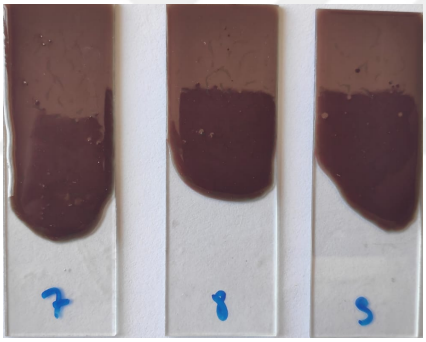
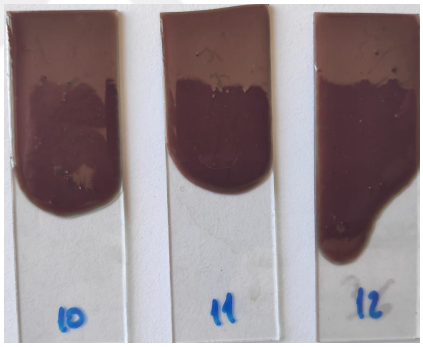
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.77 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing test for the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint are shown in Figure 3.30 The tests were made at 30 °C temperature. The highest self-polishing percentage was observed at a 3-hour test period at 1000 RPM rotary rate. The self-polishing test's one-way ANOVA results are depicted in Table 3.78. Self-polishing percentages of the tests that were held for a 1-hour period were not significantly different for 250, 500 and 750 RPM rotary rates ($p>0.05$). The results of the tests that were done for 2 hours did not show any significant differences between 500, 750 and 1000 RPM rotary rates ($p>0.05$). Data obtained from the tests that were done for a 3-hour period did not show any statistical differences either for 500, 750 or 1000 RPM ($p>0.05$). When Figure 3.31 examined, it can be seen that the jute fiber 0.1 % (w/w) reinforcement did not decrease the self-polishing percentage significantly ($p>0.05$). Control and fiber-reinforced paints self-polishing percentages mean comparisons one-way ANOVA results are shown in Table 3.79. The photos of microscope slides used in the self-polishing test which was covered by the jute fiber reinforced 0.1% (w/w) paint can be seen from Table 3.80-Table 3.82.

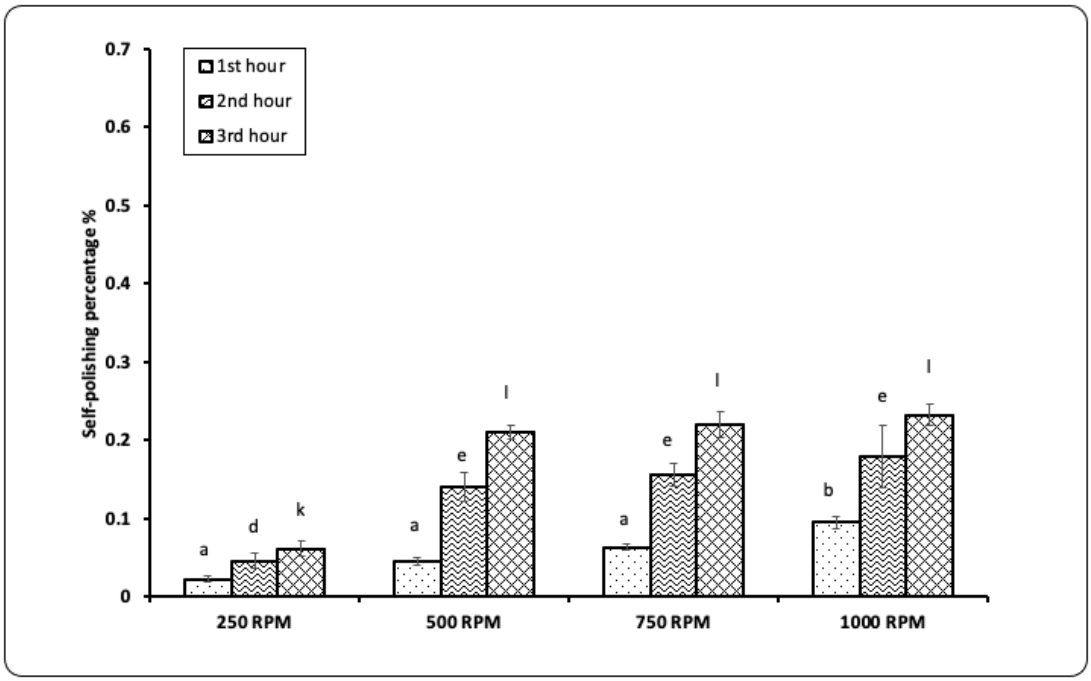


Figure 3.30 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 30 °C

Table 3.78 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.19056	11	0.01732	69.8	1.80878 e-15
Error	0.00596	24	0.00025		
Total	0.19651	35			

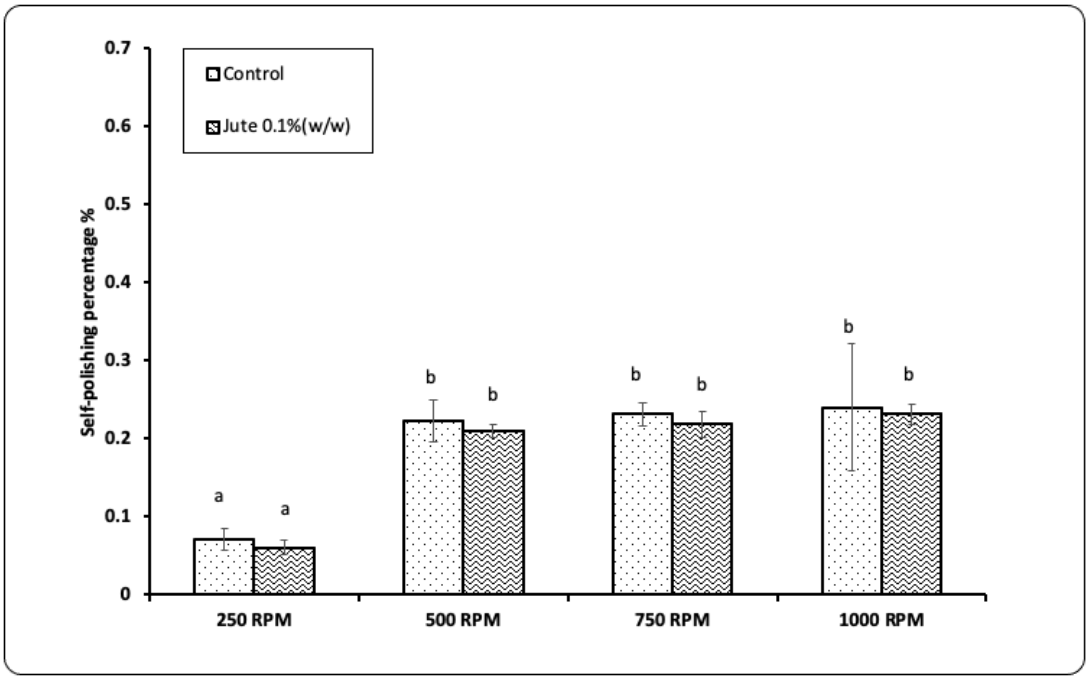


Figure 3.31 The comparison of self-polishing percentages between control and jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC

Table 3.79 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.0007533	1	0.0007533	0.12961714	0.72226256
Error	0.12785814	22	0.00581173		
Total	0.12861144	23			

Table 3.80 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 1 hour

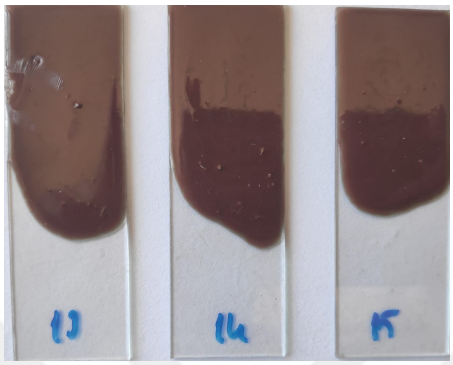
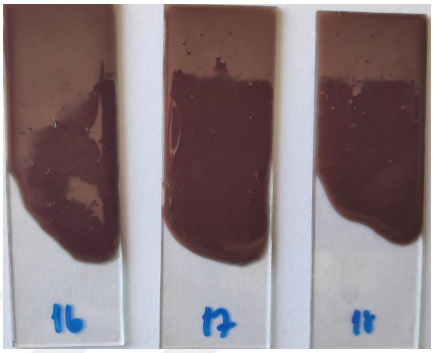
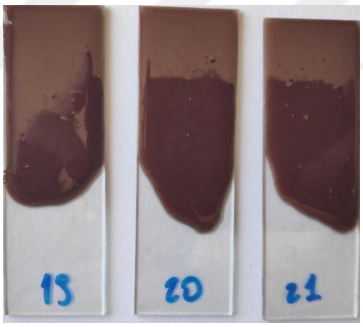
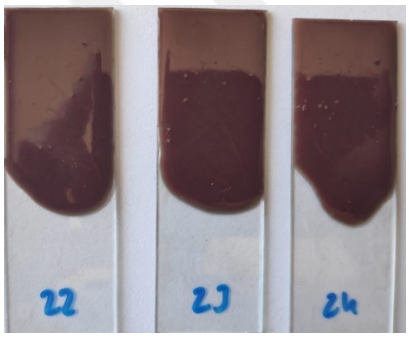
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.81 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 2 hours

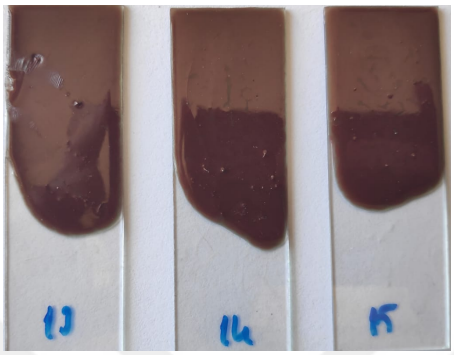
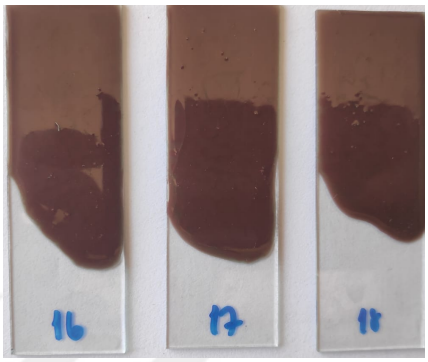
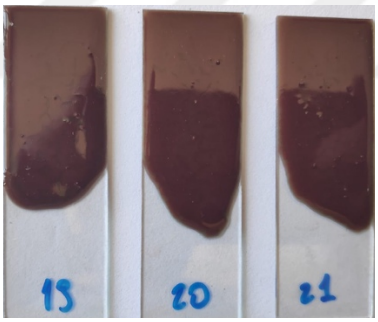
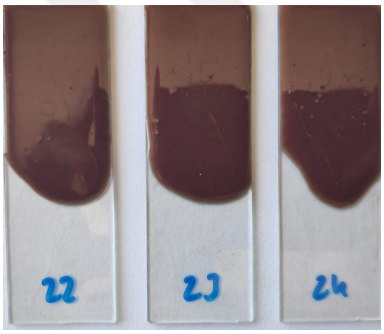
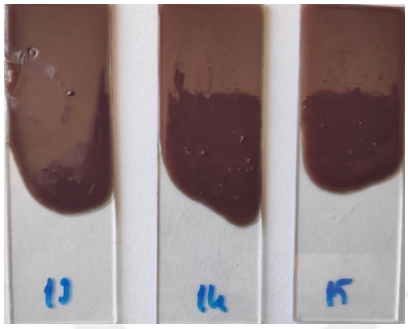
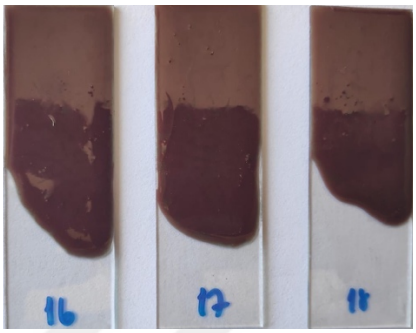
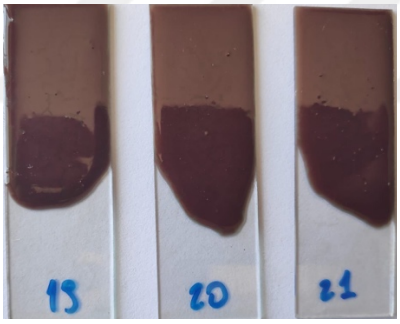
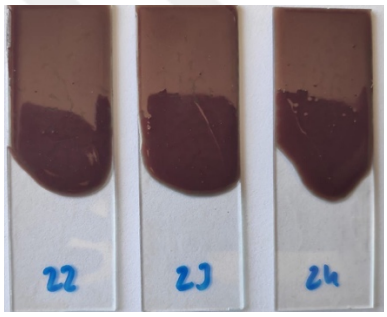
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.82 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 °C for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Self-polishing test results of jute fiber reinforced 0.1% (w/w) antifouling paint are depicted in Figure 3.32. The tests were held at 40 °C. The highest self-polishing percentage was observed at 1000 RPM rotary rate 3-hour test period. The results of the one-way ANOVA test can be seen in Table 3.83. Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500 and 750 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour period did not show any statistical differences either for 500 or 750 RPM rotary rates ($p>0.05$). When Figure 3.33 is examined, it can be seen that the jute fiber reinforcement 0.1% (w/w) decreased self-polishing percentage compared to the control group, but this decrease was not statistically meaningful. The results of self-polishing percentages mean comparison of the control and the fiber-reinforced paint's one-way ANOVA analyses can be seen in Table 3.84. The photos of microscope slides used in the self-polishing test which were covered by jute fiber reinforced 0.1% (w/w) antifouling paint can be seen from Table 3.85-Table 3.87.

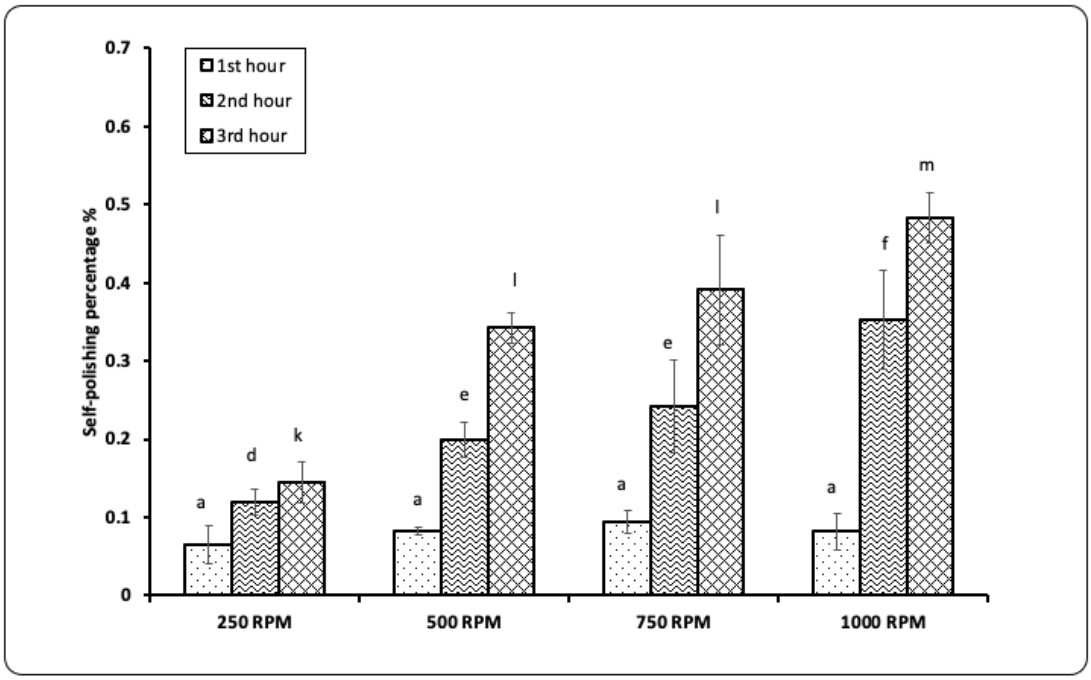


Figure 3.32 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 40 °C

Table 3.83 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.67454	11	0.06132	44.28	3.2161 e-13
Error	0.03324	24	0.00138		
Total	0.70778	35			

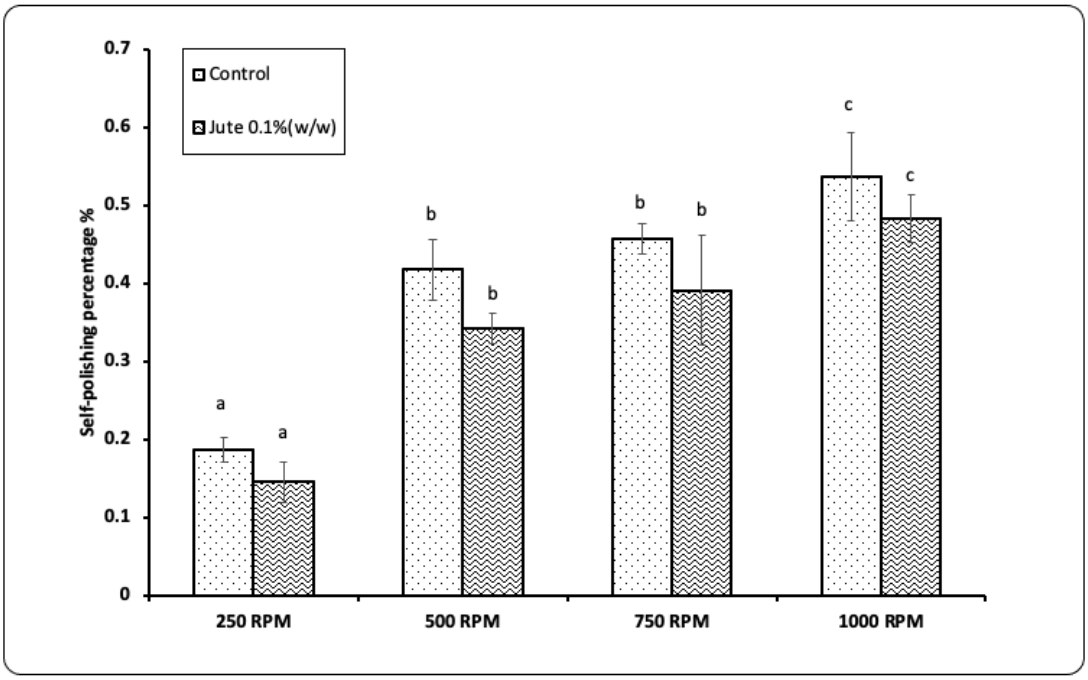


Figure 3.33 The comparison of self-polishing percentages between control and jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC

Table 3.84 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.02106952	1	0.02106952	0.9352398	0.34401688
Error	0.49562633	22	0.02252847		
Total	0.51669586	23			

Table 3.85 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour

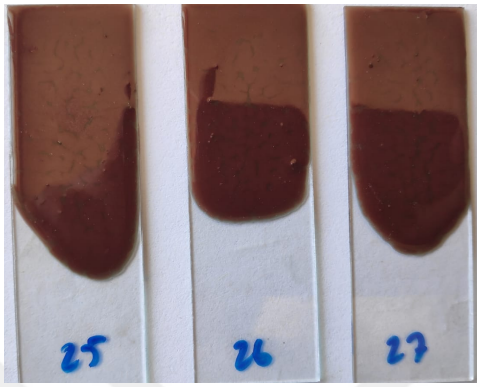
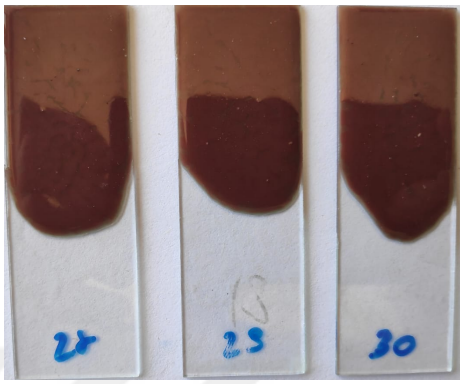
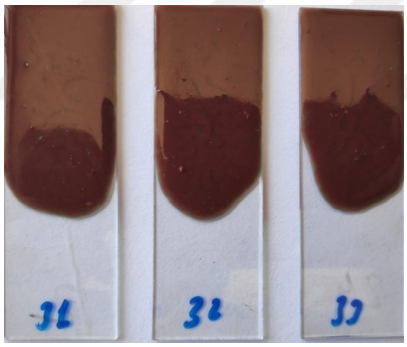
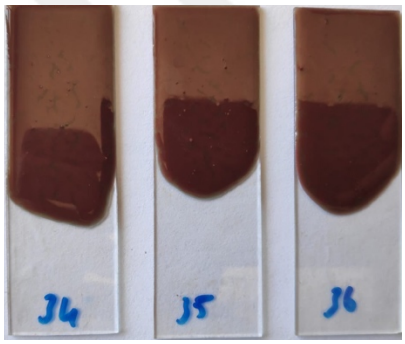
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.86 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours

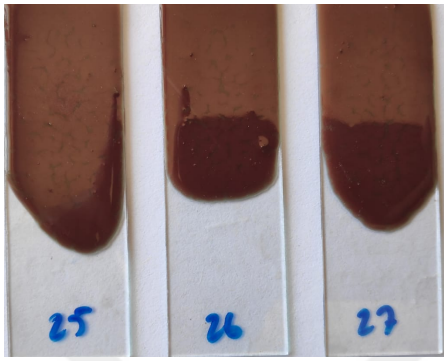
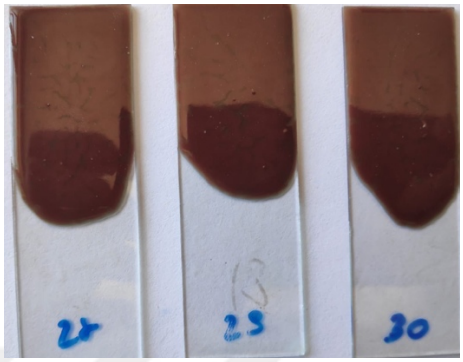
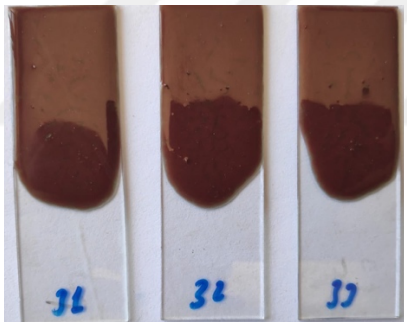
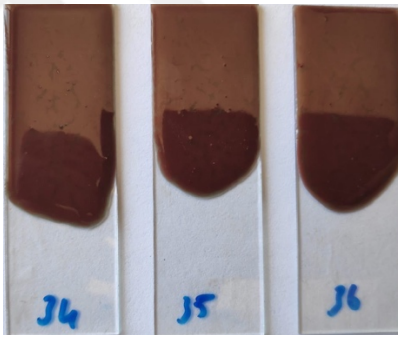
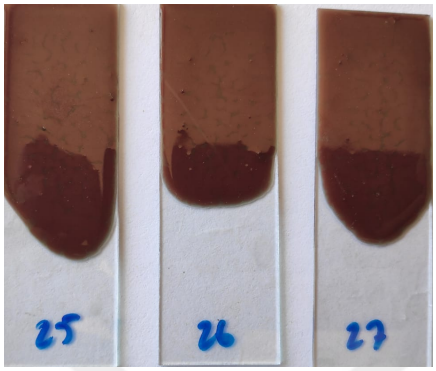
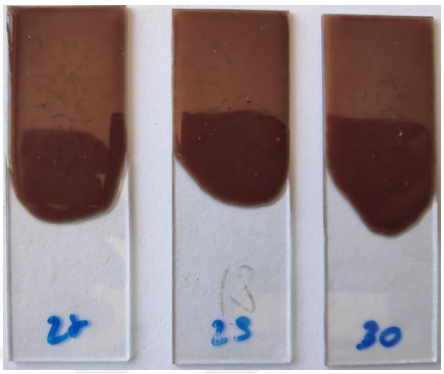
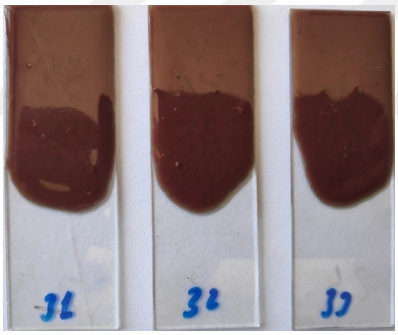
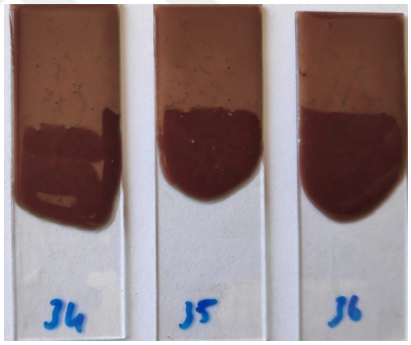
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.87 The photos of the jute fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Data obtained from the self-polishing test of the jute fiber reinforced 0.01% (w/w) antifouling paint depicted in Figure 3.34. The tests were made at 20 °C temperature. The highest self-polishing percentage was observed at 1000 RPM rotary rate 3-hour test period. Self-polishing percentages of tests that were done for a 1-hour period were not significantly different for 500, 750 and 1000 RPM rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500 and 750 RPM rotary rates ($p>0.05$). The self-polishing percentages obtained from tests that were done for a 3-hour period at 1000 RPM rotary rate were significantly different from tests that were done for a 3-hour period 250-750 RPM rotary rates ($p<0.05$). The results of self-polishing tests one-way ANOVA analyses can be seen in Table 3.88. When data shown in Figure 3.35 is analyzed, it can see that the jute fiber reinforcement did not affect the self-polishing percentage significantly ($p>0.05$). One-way ANOVA analyses results related to mean comparison can be seen in Table 3.89. The photos of microscope slides used in the self-polishing test which was covered by jute fiber reinforced 0.01% (w/w) antifouling paint can be seen from Table 3.90-Table 3.92.

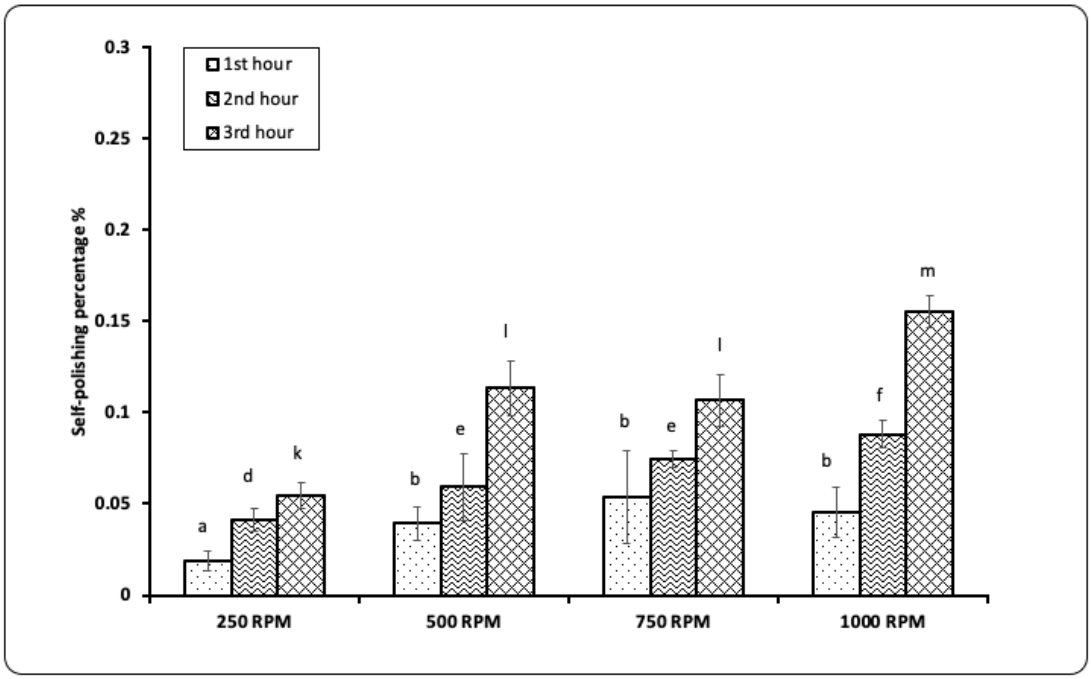


Figure 3.34 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 °C

Table 3.88 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.04939	11	0.00449	27.29	6.73532 e-11
Error	0.00395	24	0.00016		
Total	0.05334	35			

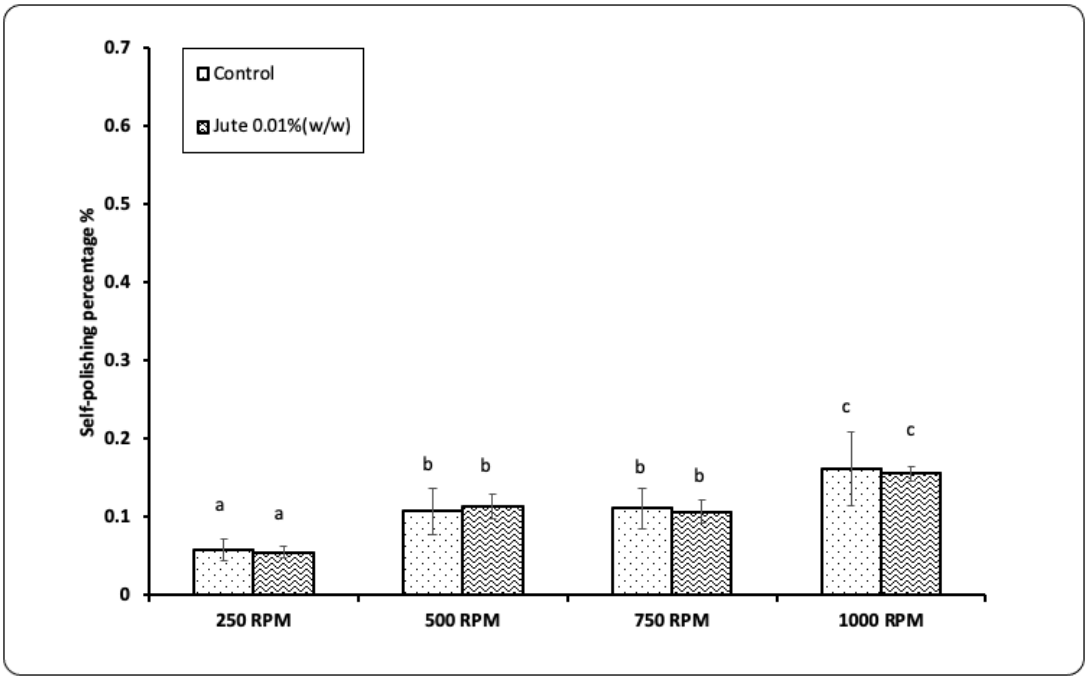


Figure 3.35 The comparison of self-polishing percentages between control and jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC

Table 3.89 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	2.23e-05	1	2.23e-05	0.01218457	0.91310583
Error	0.04019164	22	0.00182689		
Total	0.0402139	23			

Table 3.90 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour

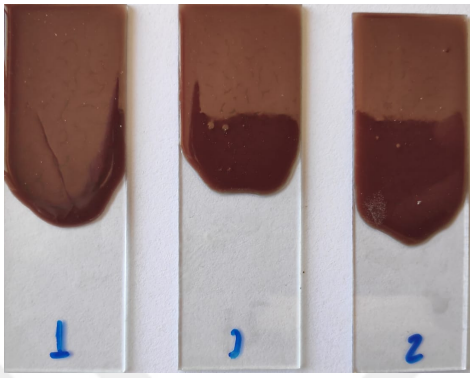
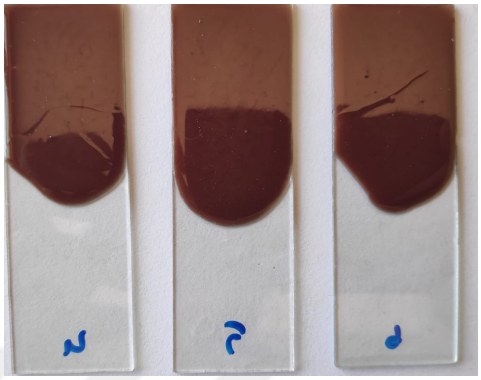
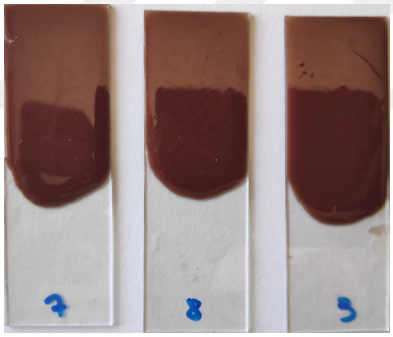
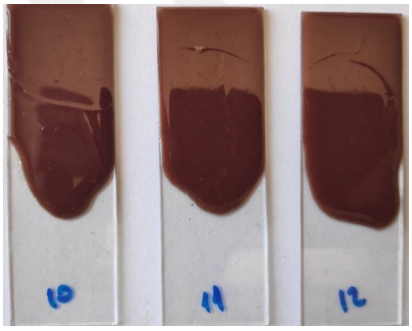
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.91 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours

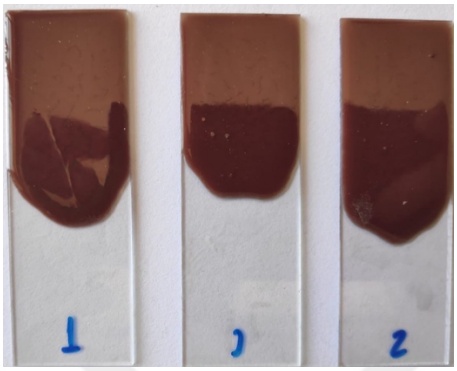
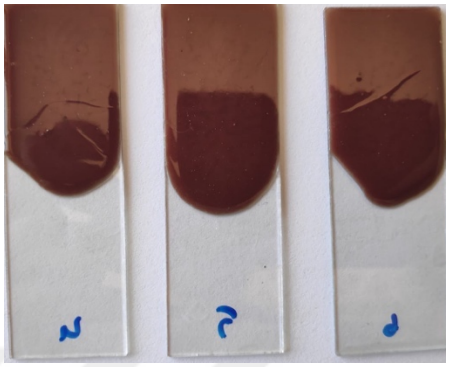
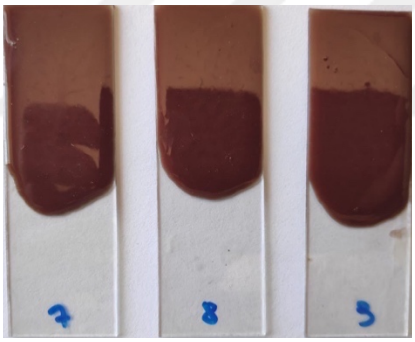
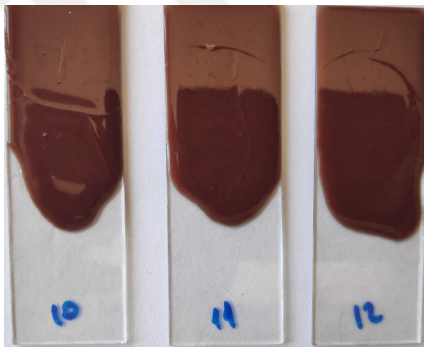
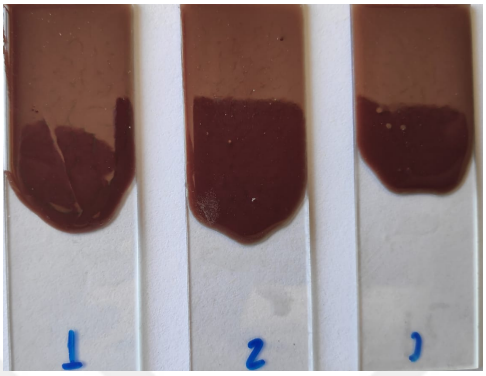
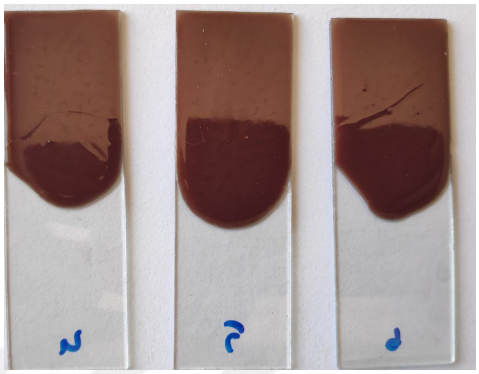
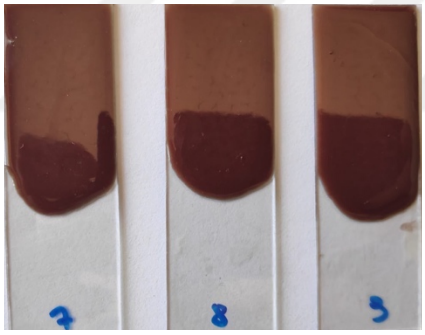
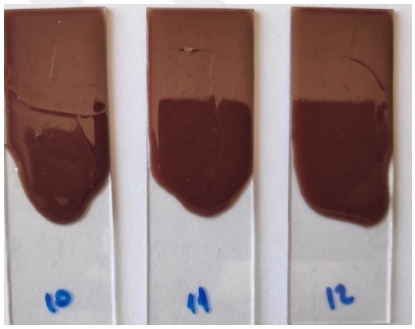
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.92 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing test of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint are shown in Figure 3.36 Tests were held at 30 °C temperature. The highest self-polishing percentage was observed at 1000 RPM rotary rate for a 3-hour test period. Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500, 750 and 1000 RPM rotary rates ($p>0.05$). Data obtained from the tests that were done for a 3-hour time period did not show any statistical differences either for 500, 750 or 1000 RPM ($p>0.05$). The results of self-polishing tests one-way ANOVA analyses are given in Table 3.93. The 0.01 (w/w) jute fiber reinforcement did not affect the self-polishing percentage significantly ($p>0.05$) and it can be seen from Figure 3.37. Self-polishing percentage's mean comparisons for fiber the reinforced and the control paints one-way ANOVA analyses can be seen in Table 3.94. The photos of microscope slides used in the self-polishing test which was covered by jute fiber reinforced 0.01% (w/w) paint can be seen from Table 3.95-Table 3.97.

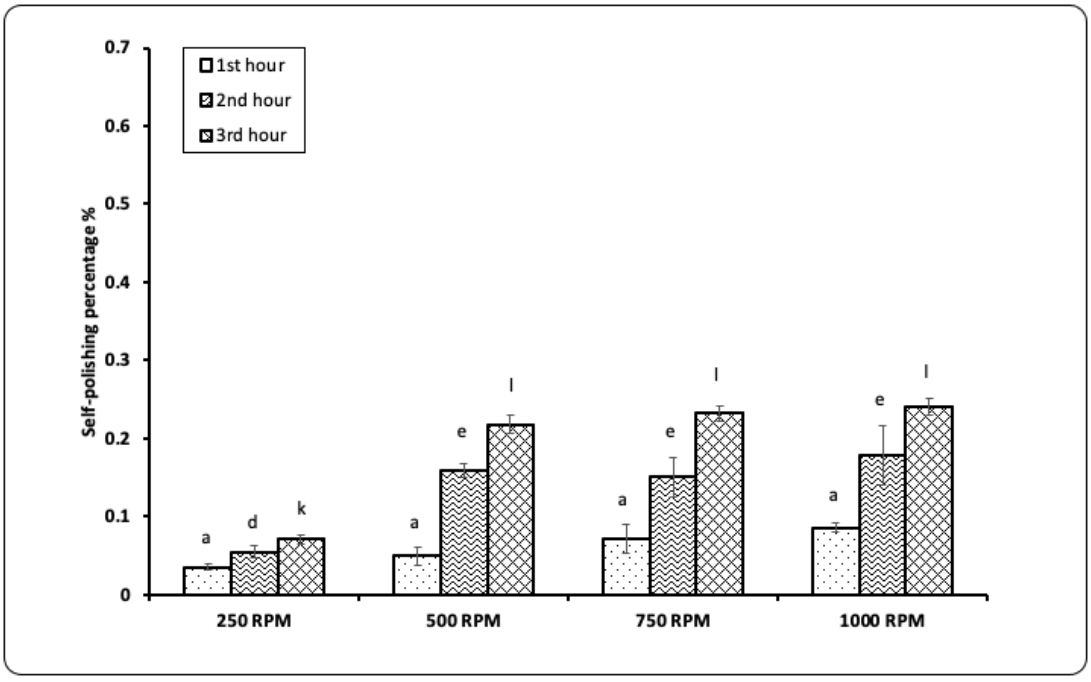


Figure 3.36 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 °C

Table 3.93 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of 0.01% jute fiber reinforced self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.19263	11	0.01751	66.04	3.41629 e-15
Error	0.00636	24	0.00027		
Total	0.199	35			

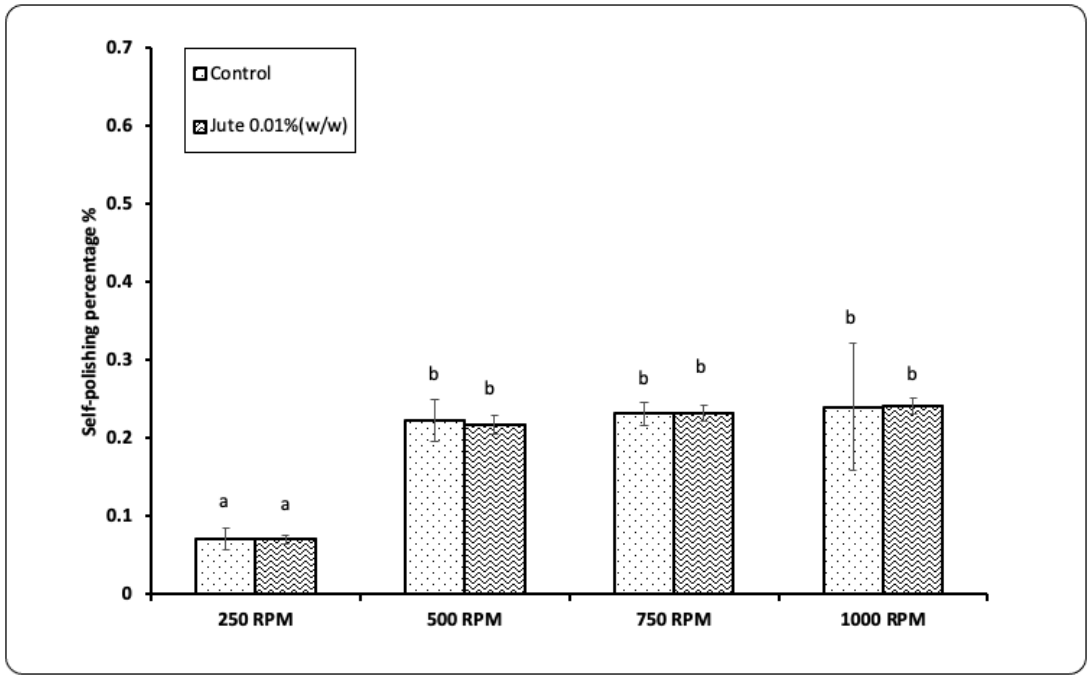


Figure 3.37 The comparison of self-polishing percentages between control and jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC

Table 3.94 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	8.85e-06	1	8.85E-06	0.00152273	0.96922461
Error	0.12788491	22	0.00581295		
Total	0.12789376	23			

Table 3.95 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour

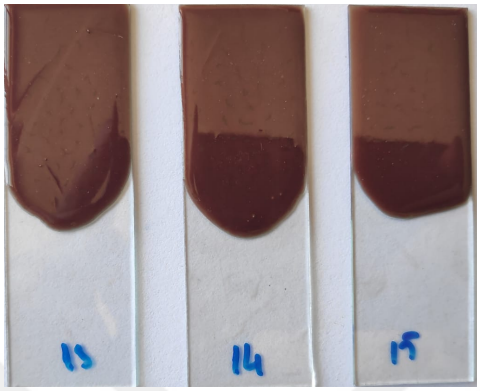
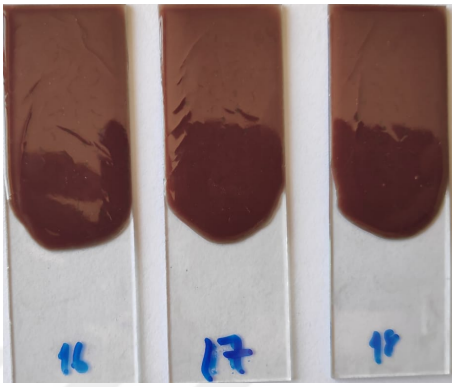
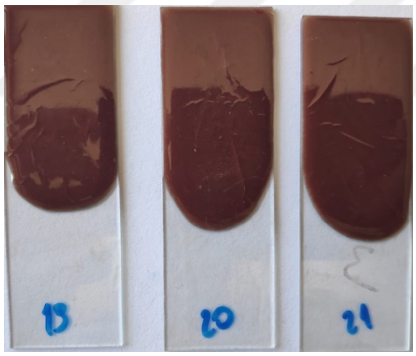
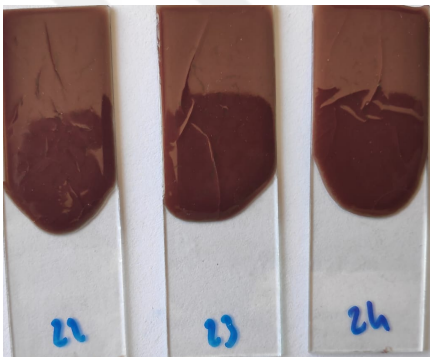
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.96 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours

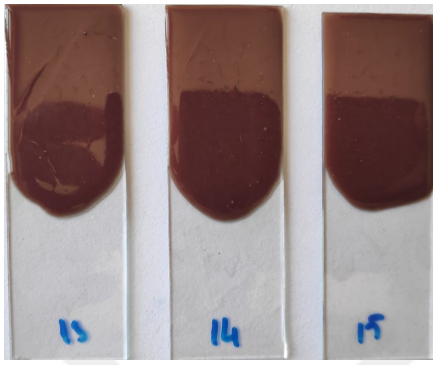
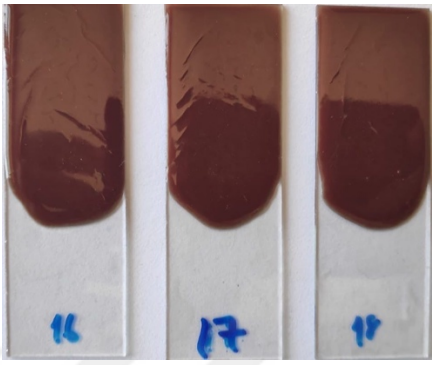
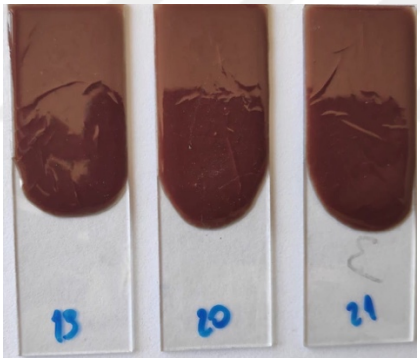
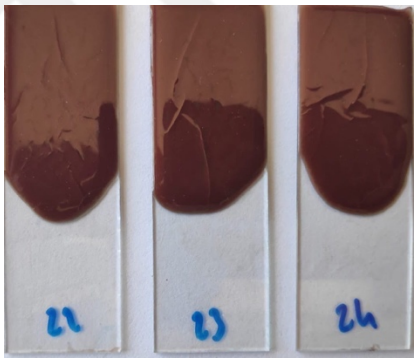
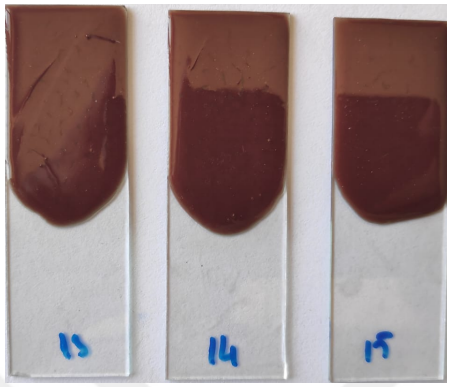
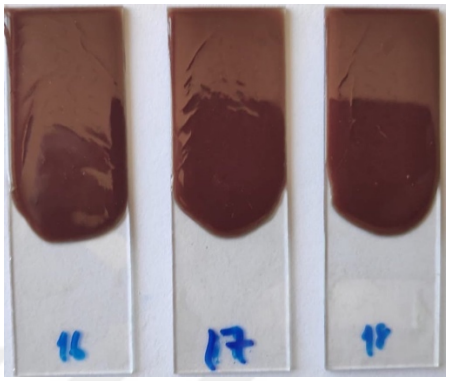
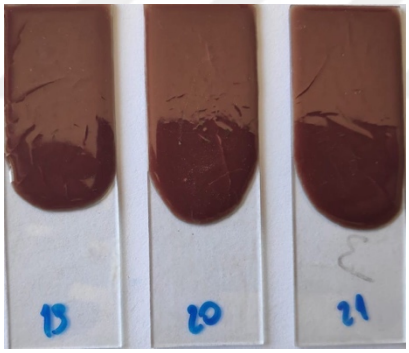
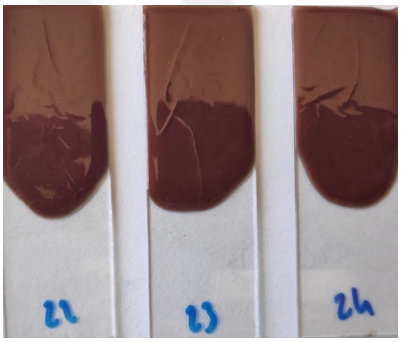
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.97 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing test of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint are shown in Figure 3.38. The tests were done at 40 °C temperature. The highest self-polishing percentage was observed at 1000 RPM rotary rate 3-hour test period. The results of tests One-way ANOVA analyses can be seen in Table 3.98. As it can be seen from Table 3.98 all experimental conditions affected self-polishing percentage ($p<0.05$). Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500 and 750 RPM rotary rates ($p>0.05$). Data obtained from the tests that were done for a 3-hour time period did not show any statistical differences either for 500 or 750 ($p>0.05$). When Figure 3.39 is analyzed, it can be seen that fiber reinforcement did not affect self-polishing percentage meaningfully ($p>0.05$). One-way ANOVA analyses of self-polishing percentage's mean comparison are given in Table 3.99. The photos of microscope slides used in the self-polishing test which was covered by jute fiber reinforced 0.01% (w/w) paint can be seen from Table 3.100-Table 3.102.

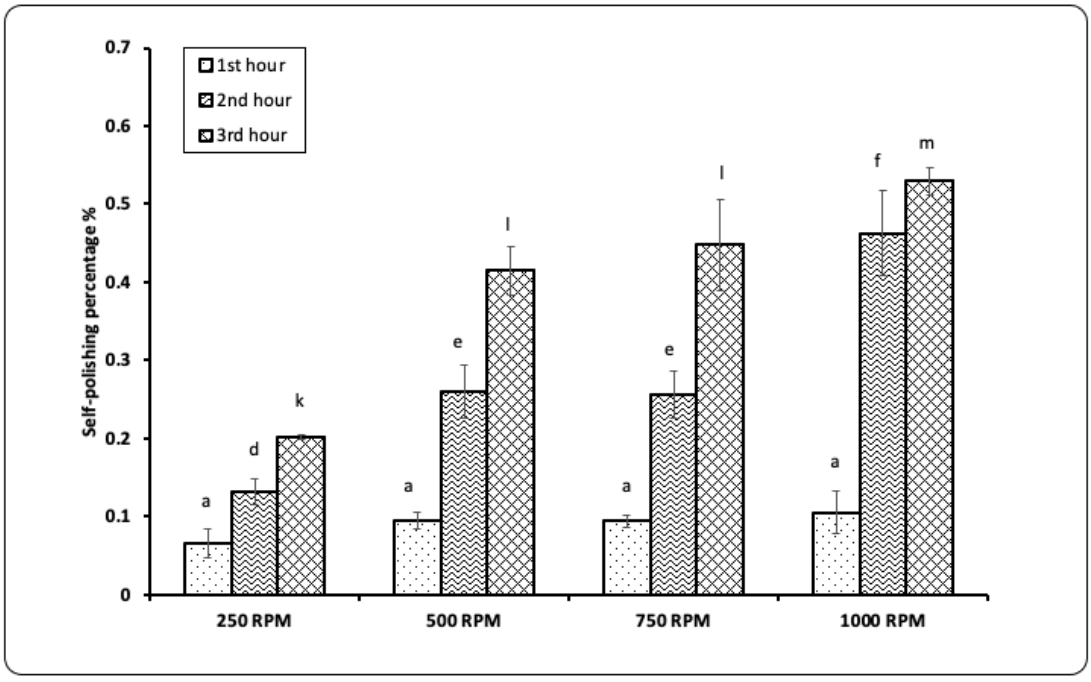


Figure 3.38 The effect of rotary rate and time on the self-polishing percentage of jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 °C

Table 3.98 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.92757	11	0.08432	90.29	9.21307 e-17
Error	0.02242	24	0.00093		
Total	0.94998	35			

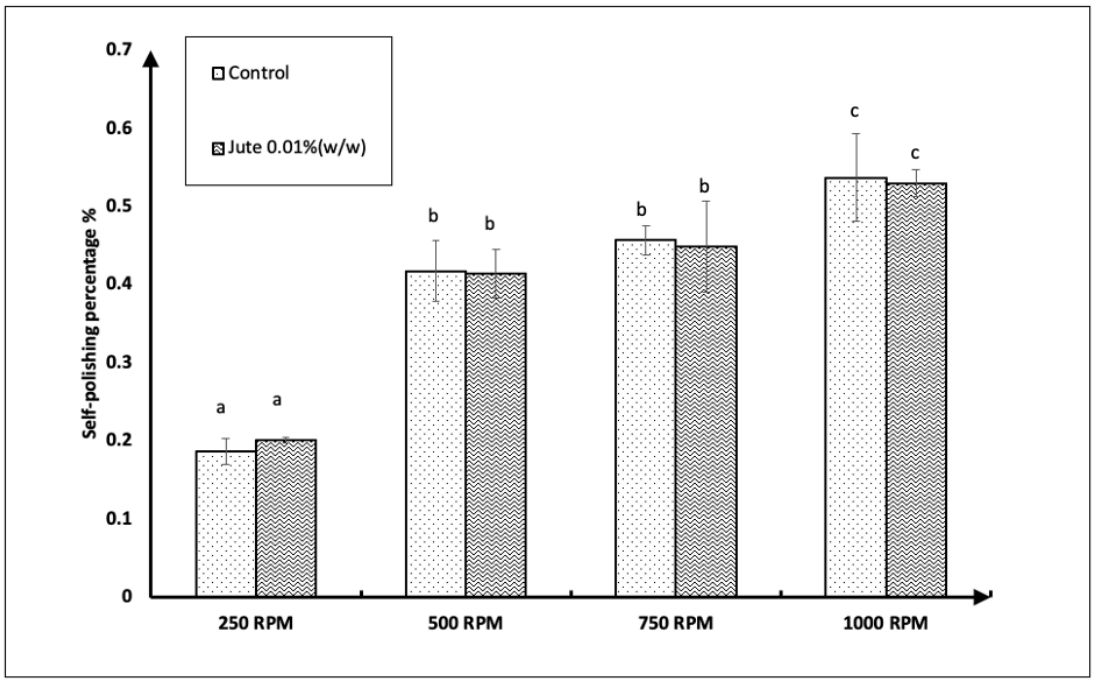


Figure 3.39 The comparison of self-polishing percentages between control and jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC

Table 3.99 One-way ANOVA results related to mean comparison of control and jute fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.26247286	1	0.26247286	16.1350138	0.00057888
Error	0.35788026	22	0.01626728		
Total	0.62035312	23			

Table 3.100 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour

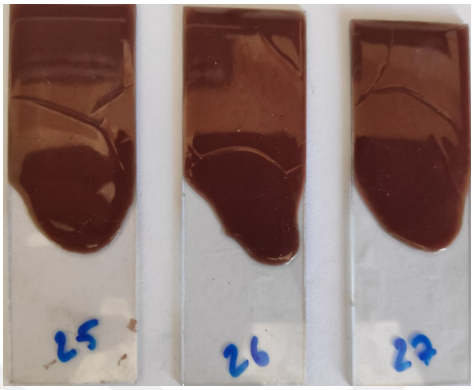
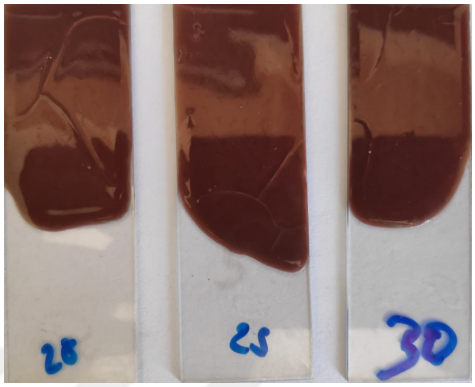
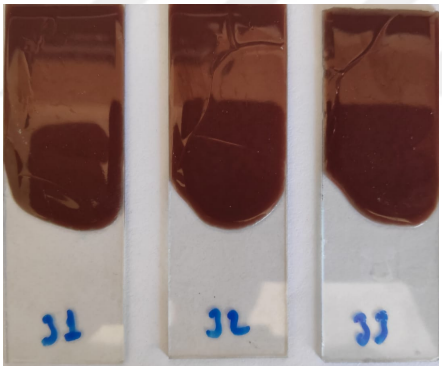
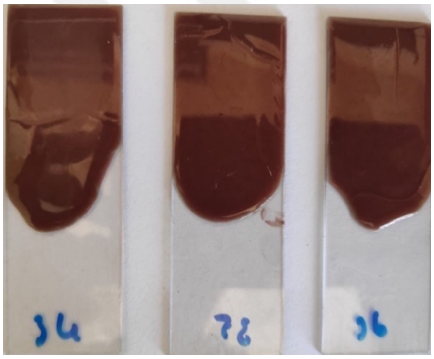
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.101 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours

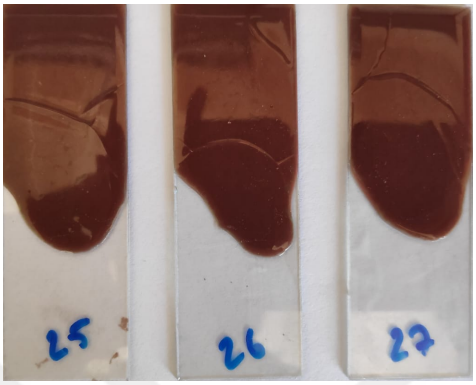
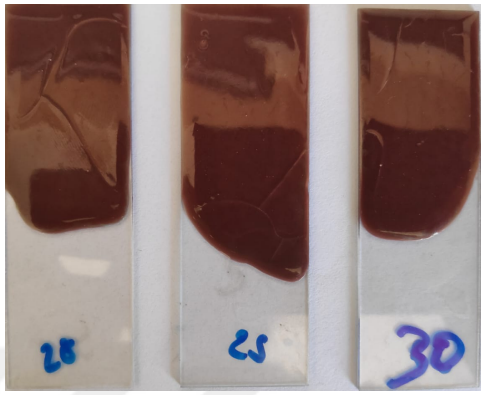
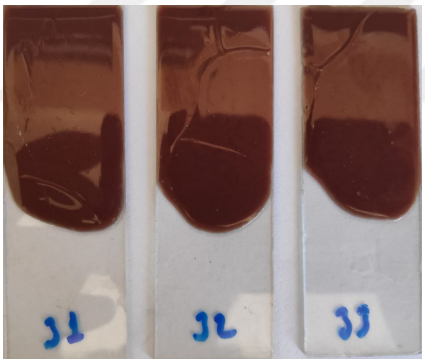
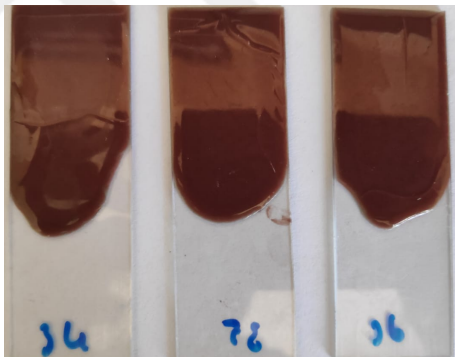
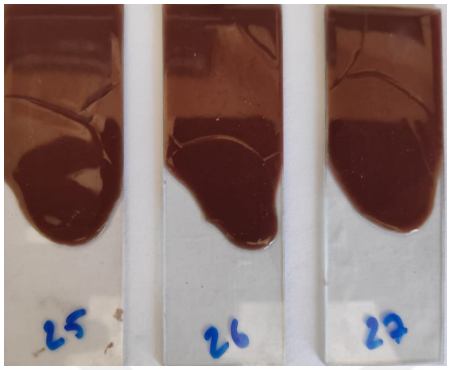
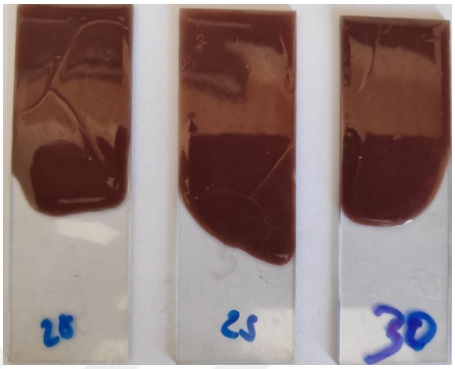
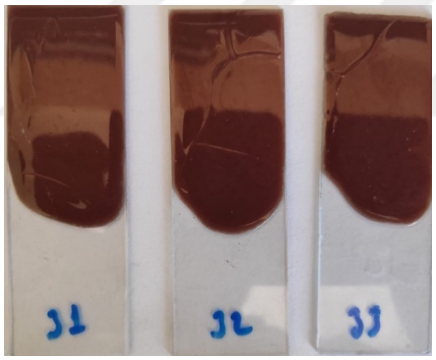
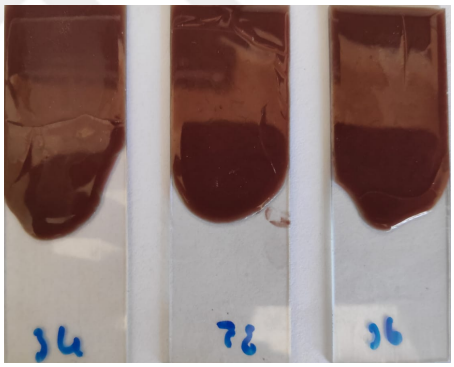
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.102 The photos of the jute fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Self-polishing percentages of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing rosin-based paint are shown in Figure 3.40. The tests were done at 20 °C temperature. The highest and the lowest self-polishing percentages were observed a1000 RPM and 250 RPM rotary rates respectively. One-way ANOVA analyses of self-polishing tests can be seen in Table 3.103. Self-polishing percentages of tests that were held for a 1-hour period were not statistically different for 250-500 RPM and 750-1000 RPM rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 250-500 RPM and 750-1000 RPM rotary rates ($p>0.05$) Data obtained from tests that were made for a 3-hour period were not significantly different at 500 and 750 RPM rotary rates ($p>0.05$) but different at 1000 RPM rotary rate. The self-polishing percentage's mean comparisons One-way ANOVA analyses results can be seen in Table 3.104. When data from Figure 3.41 is analyzed, it can be seen that fiber reinforcement did not decrease the self-polishing percentage. The photos of microscope slides used in the self-polishing test can be seen from Table 3.105-Table 3.107.

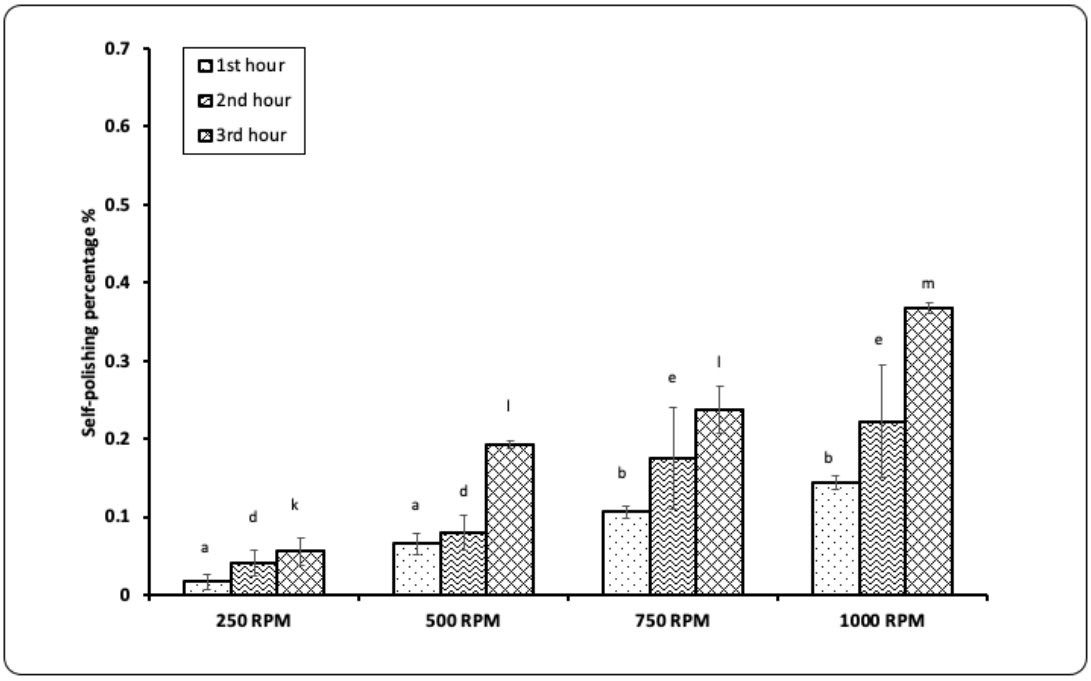


Figure 3.40 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 °C

Table 3.103 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.05767	11	0.00524	15.83	1.99709 e-08
Error	0.00795	24	0.00033		
Total	0.06562	35			

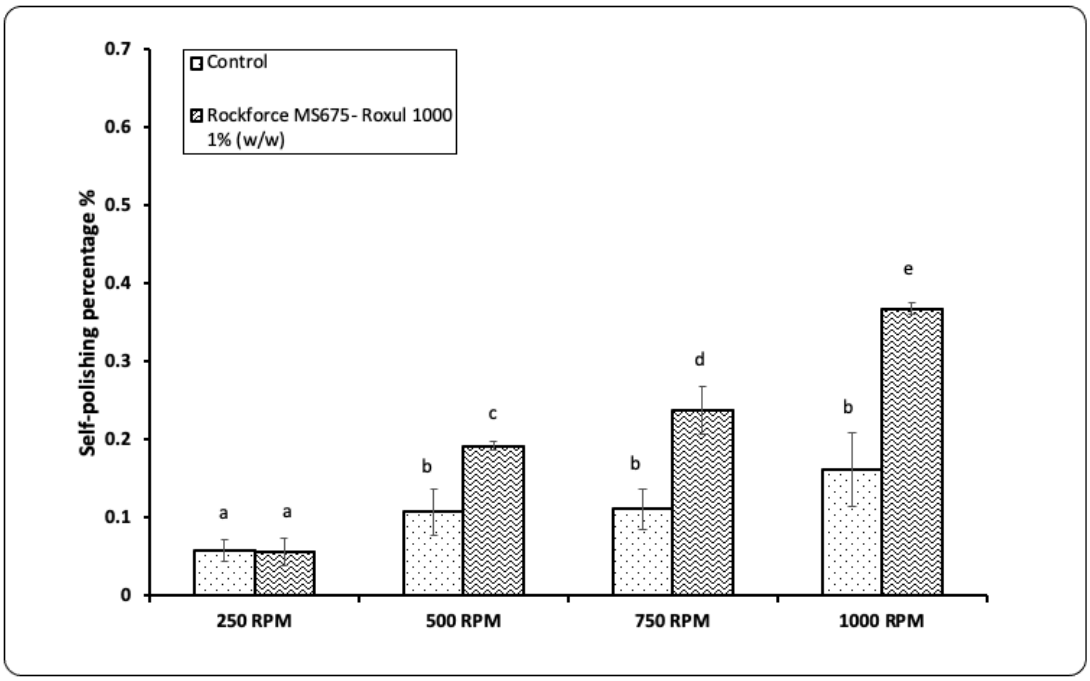


Figure 3.41 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC

Table 3.104 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.06446142	1	0.06446142	8.06493345	0.00953011
Error	0.17584165	22	0.0079928		
Total	0.24030306	23			

Table 3.105 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour

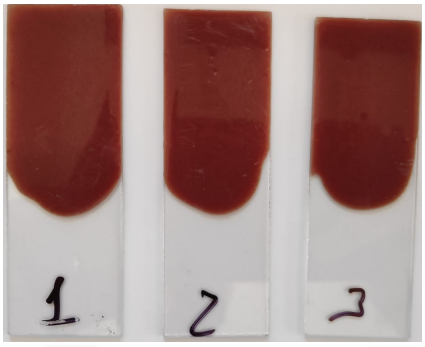
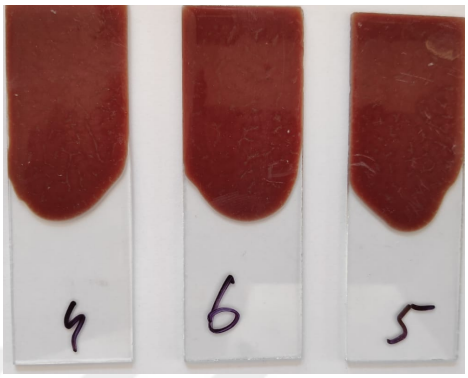
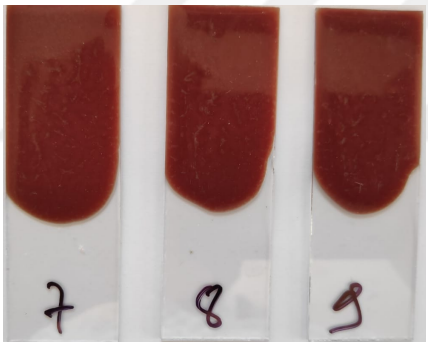
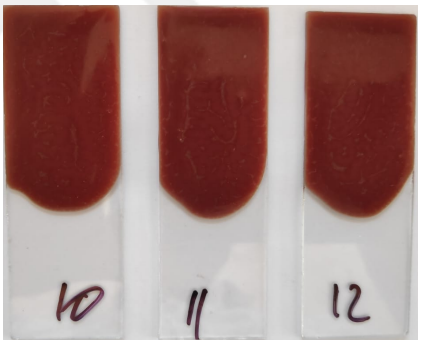
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.106 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours

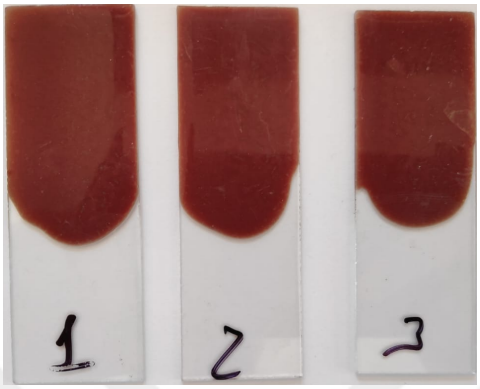
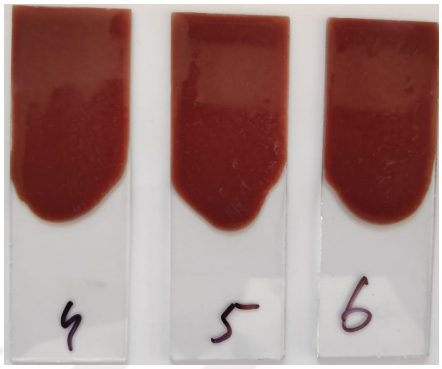
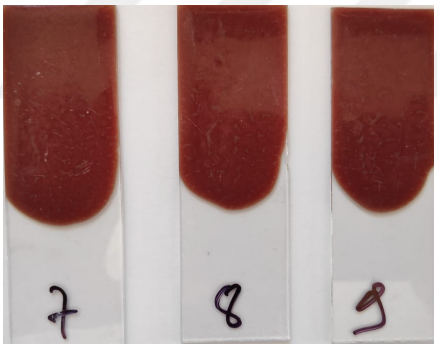
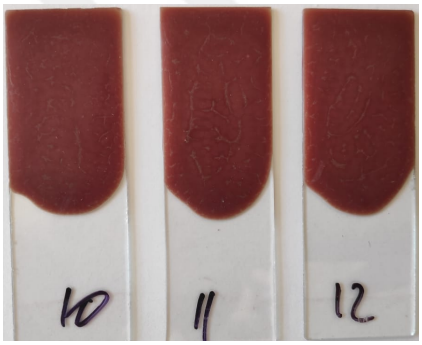
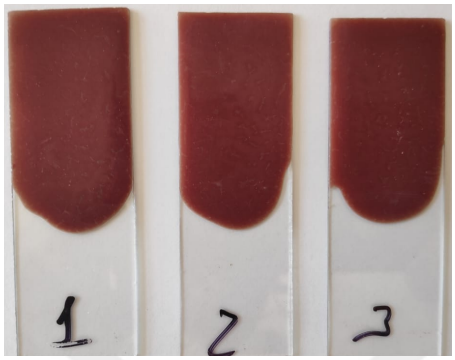
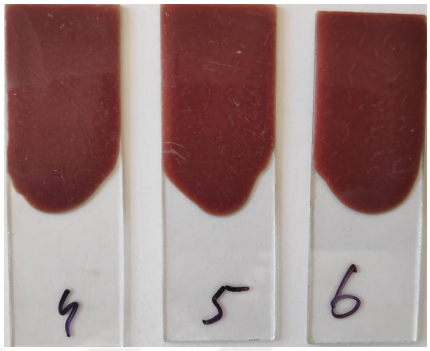
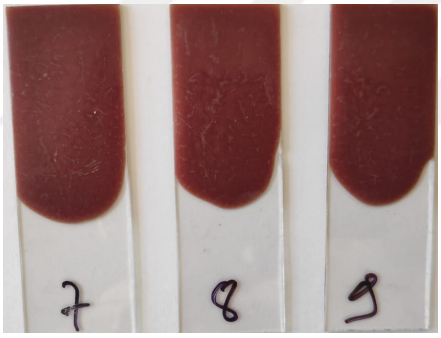
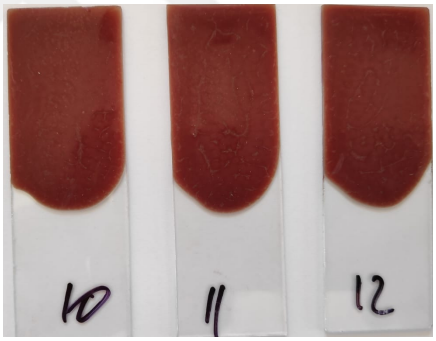
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.107 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Self-polishing percentages of the Rockforce MS675-Roxul 1000 fiber 1% (w/w) -reinforced self-polishing paint obtained from the polishing test are shown in Figure 3.42 Tests were held at 30 °C temperature. One-way ANOVA analyses of tests can be seen in Table 3.108. Self-polishing percentages of the tests that were made for a 1-hour period were not statistically different for all rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 250, 500 and 7550 RPM rotary rates too ($p>0.05$). Data obtained from the tests that were done for a 3-hour period at 1000 RPM rotary rate had the highest self-polishing percentage value. When Figure 3.43 is analyzed, it can be seen that the fiber reinforcement did not decrease the self-polishing percentage at all RPM rates ($p>0.05$). One-way ANOVA analyses of self-polishing percentage's mean comparison are seen in Table 3.109. The photos of microscope slides used in the self-polishing tests which were covered by the Rockforce MS675-Roxul 1000 fiber 1% (w/w) -reinforced self-polishing antifouling paint can be seen from Table 3.110-Table 3.112.

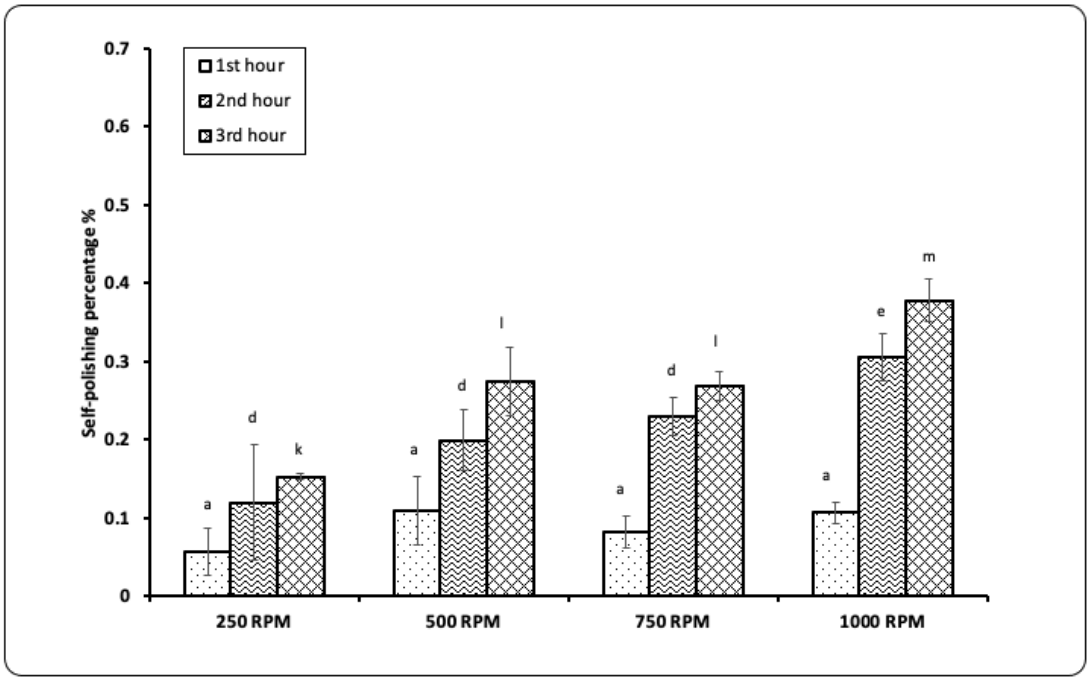


Figure 3.42 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 °C

Table 3.108 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.33947	11	0.03086	25	1.73086e-10
Error	0.02963	24	0.00123		
Total	0.3691	35			

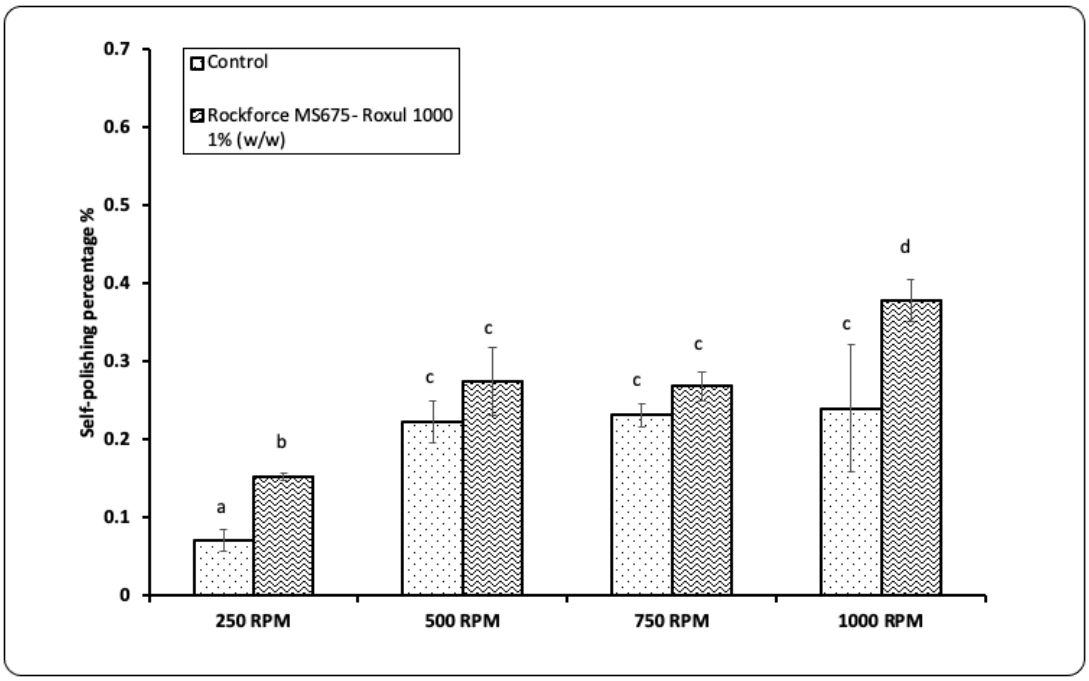


Figure 3.43 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC

Table 3.109 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.03524642	1	0.03524642	5.12169838	0.03383926
Error	0.15139924	22	0.00688178		
Total	0.18664565	23			

Table 3.110 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour

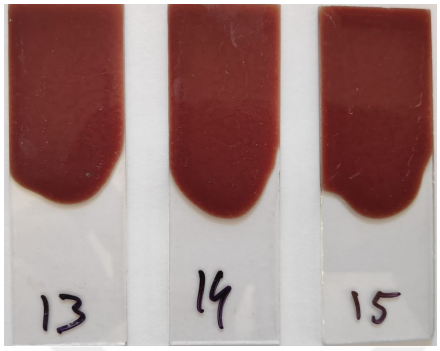
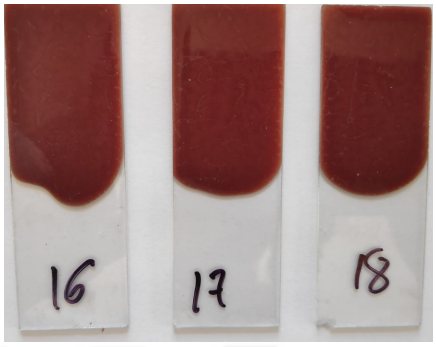
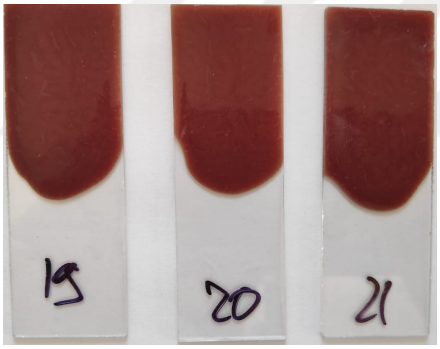
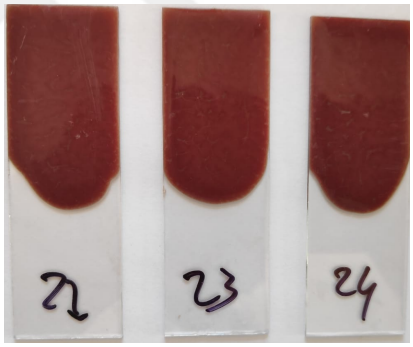
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.111 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours

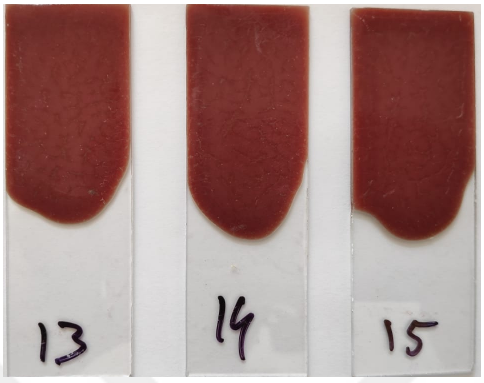
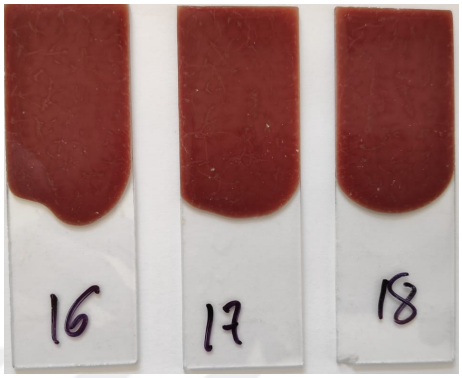
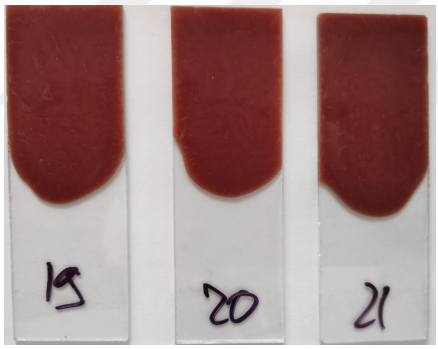
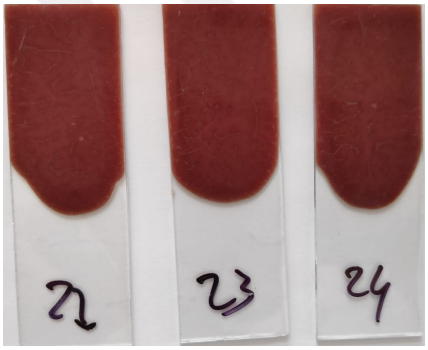
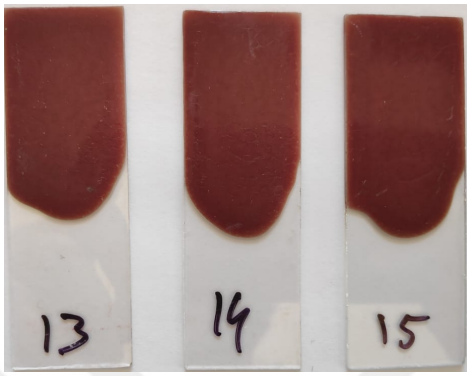
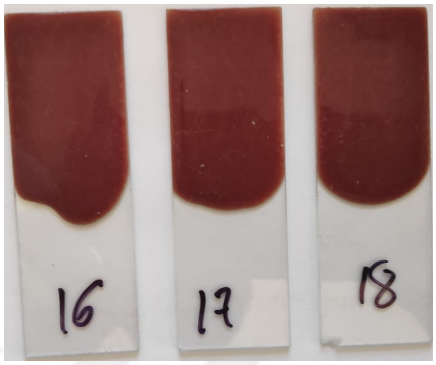
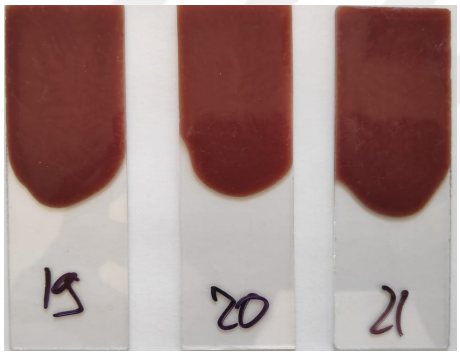
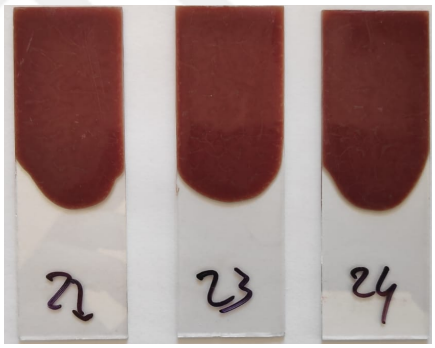
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.112 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing test of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint are shown in Figure 3.44. The tests were held at 40 °C. The self-polishing test's one-way ANOVA analyses results are given in Table3.113. The highest self-polishing percentage was observed at 1000 RPM rotary rate for a 3-hour test period. Self-polishing percentages of the tests that were done for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500, 750 and 1000 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour time period did not show any statistical differences either for 500, 750 or 1000 RPM ($p>0.05$). When Figure 3.45 is analyzed, which depicts the comparison of self-polishing percentages, it can be seen that the decrease in the self-polishing percentage was not statistically meaningfully after fiber reinforcement ($p>0.05$). The results of the self-polishing percentage's mean comparisons one-way ANOVA test can be seen in Table 3.114. The photos of microscope slides used in the self-polishing test which was covered by the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) antifouling paint can be seen from Table 3.115-Table 3.117.

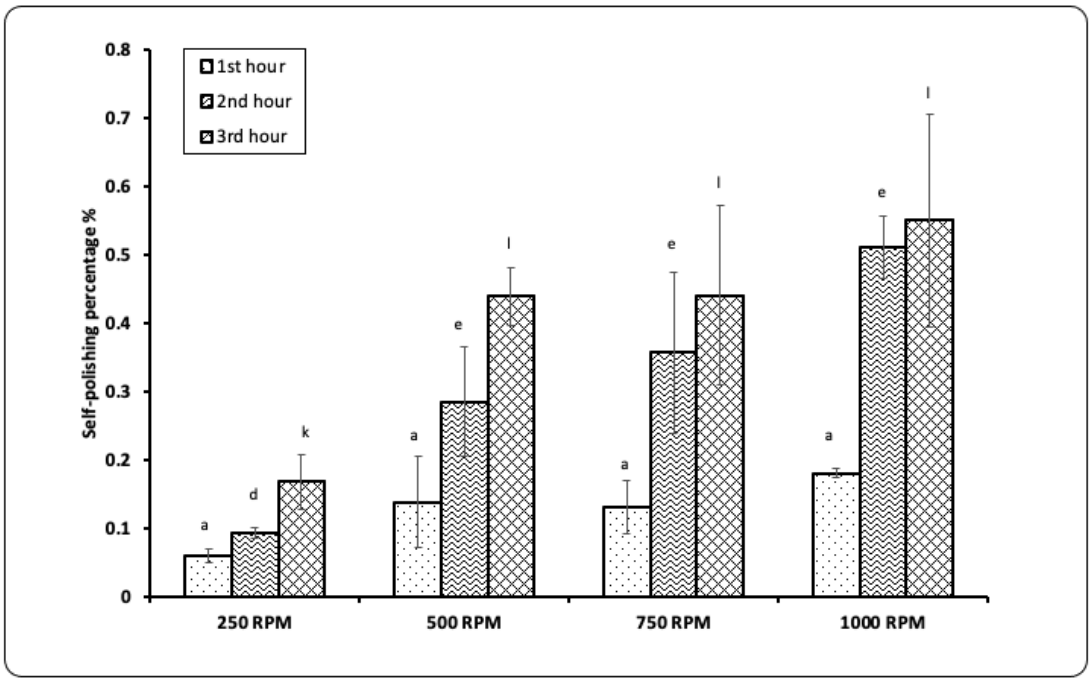


Figure 3.44 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 °C

Table 3.113 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.99371	11	0.09034	14.79	3.95811e-08
Error	0.14664	24	0.00611		
Total	1.14036	35			

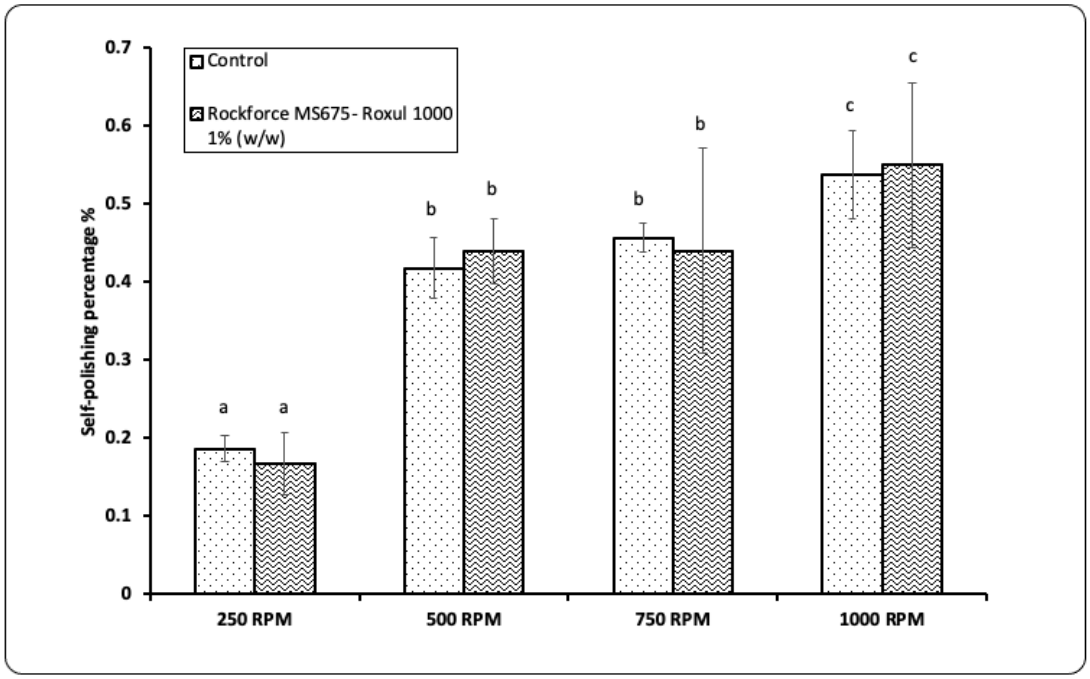


Figure 3.45 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC

Table 3.114 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	6.64e-07	1	6.64e-07	2.33E-05	0.99619597
Error	0.62789394	22	0.02854063		
Total	0.62789461	23			

Table 3.115 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour

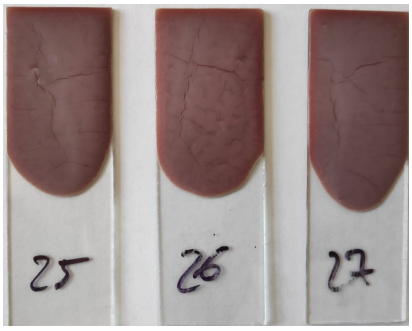
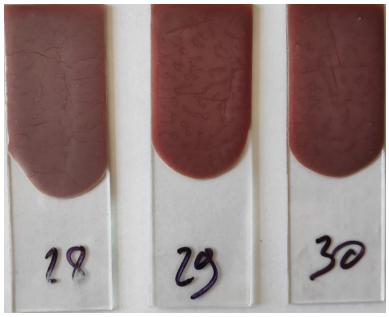
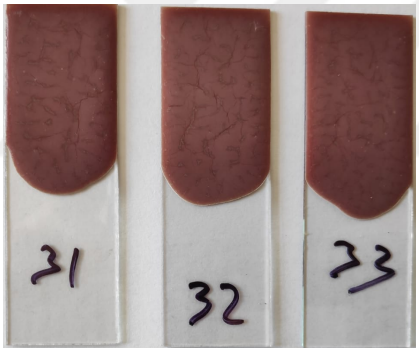
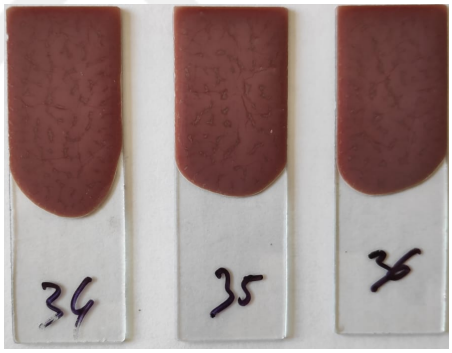
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.116 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours

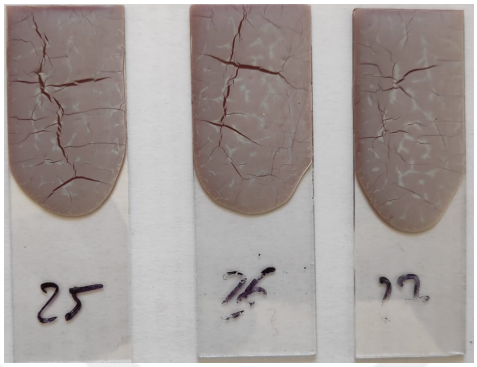
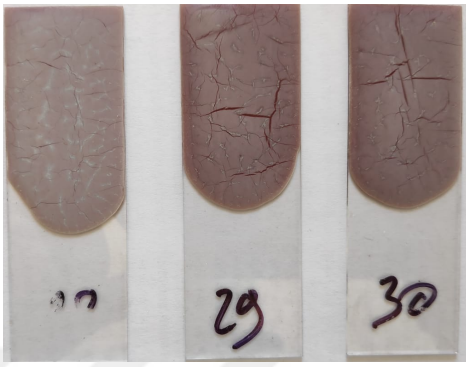
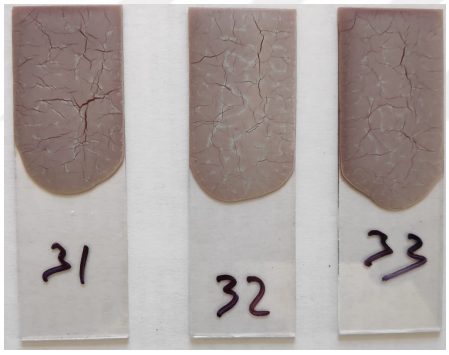
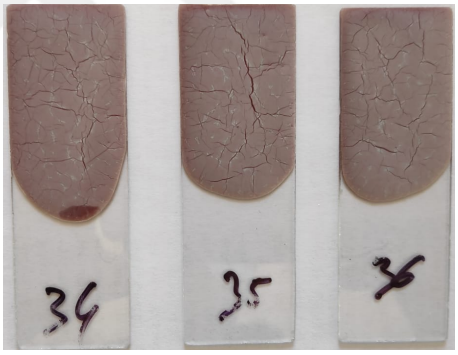
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.117 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours

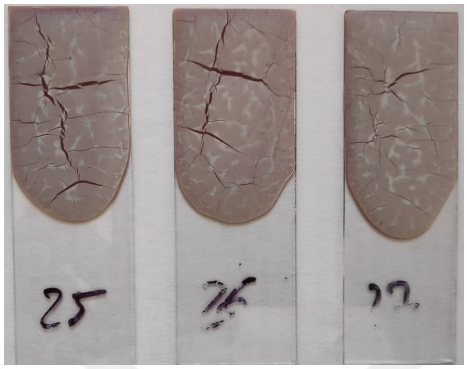
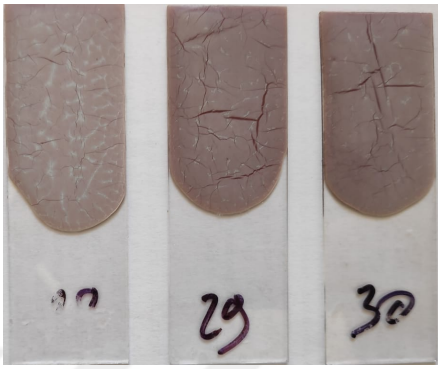
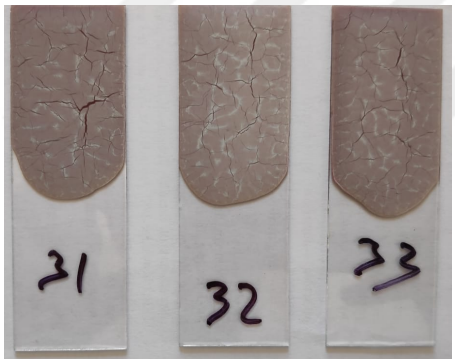
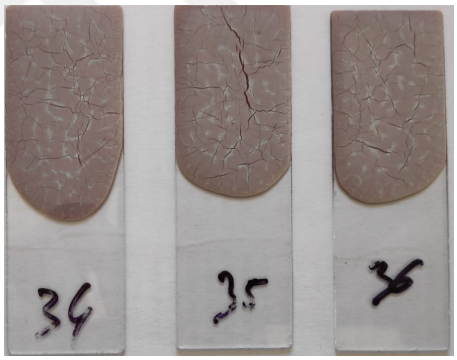
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Figure 3.46 represents the results of the self-polishing tests of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint. The tests were done at 20 ^{o}C temperature. The results of one-way ANOVA analyses of self-polishing tests are shown in Table 3.118. The highest self-polishing percentage was observed at 1000 RPM rotary rate 3-hour test period. Self-polishing percentages of tests that were made for a 1-hour period were not significantly different for 250,500 and 750 RPM rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 250, 500 and 750 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour time period did not show any statistical differences either for 500 or 750 RPM rates ($p>0.05$). The results of the comparison of self-polishing percentages between the control and the fiber-reinforced antifouling paint are shown in Figure 3.47. As can be seen from Figure 3.47 the fiber reinforcement did not affect self-polishing percentage significantly ($p>0.05$). One-way ANOVA analyses results for comparison of self-polishing percentages means can be seen in Table 3.119. The photos of microscope slides used in the self-polishing test which was covered by Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint can be seen from Table 3.120-Table 3.122.

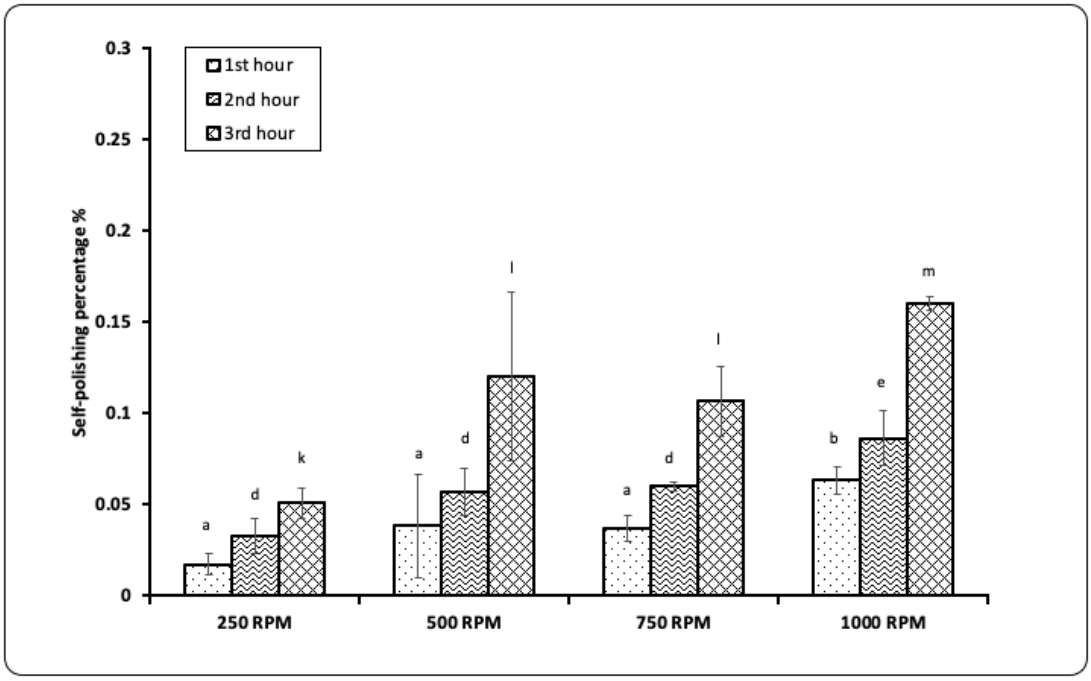


Figure 3.46 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint at 20 °C

Table 3.118 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.05767	11	0.00524	15.83	1.99709 e-08
Error	0.00795	24	0.00033		
Total	0.06562	35			

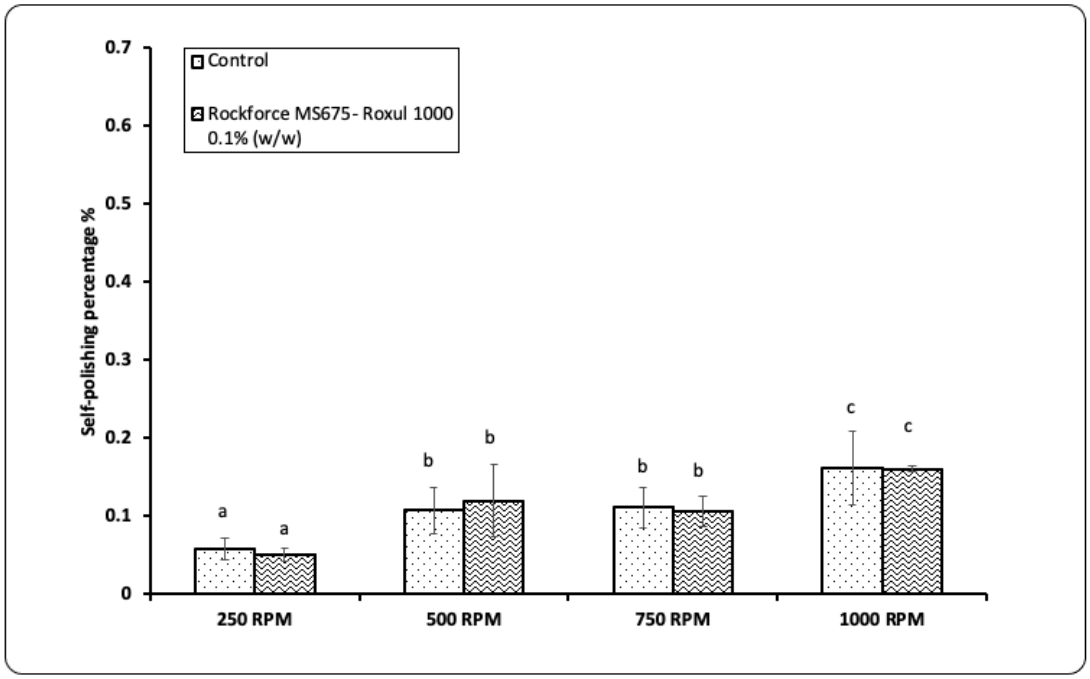


Figure 3.47 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint for 3-hour test period 20 ºC

Table 3.119 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	6.67e-08	1	6.67e-08	3.10E-05	0.9956082
Error	0.04732051	22	0.00215093		
Total	0.04732057	23			

Table 3.120 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour

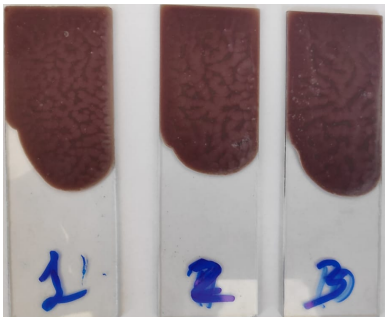
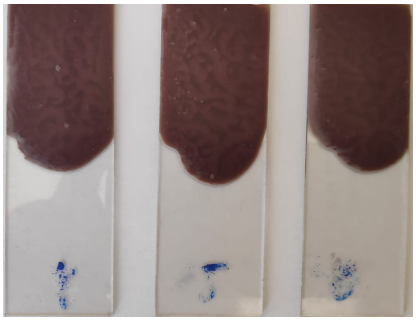
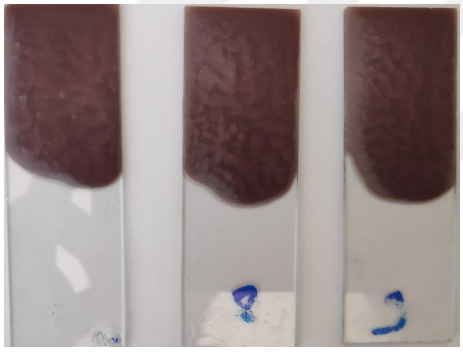
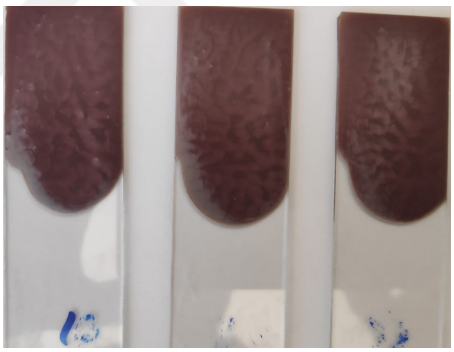
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.121 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours

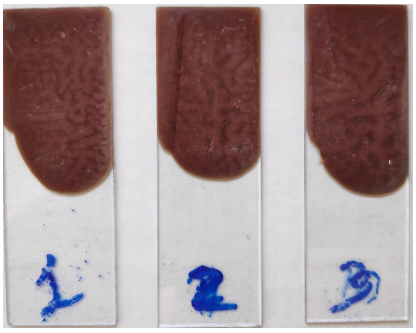
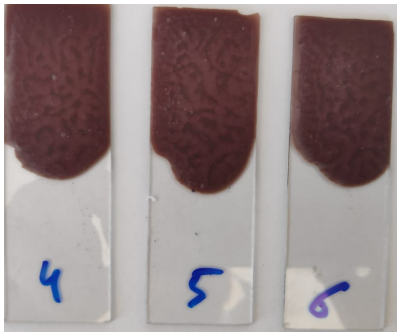
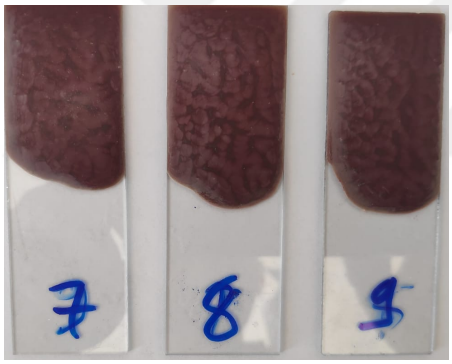
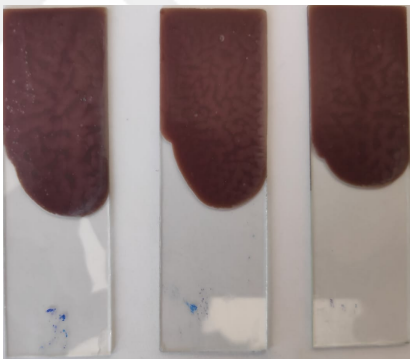
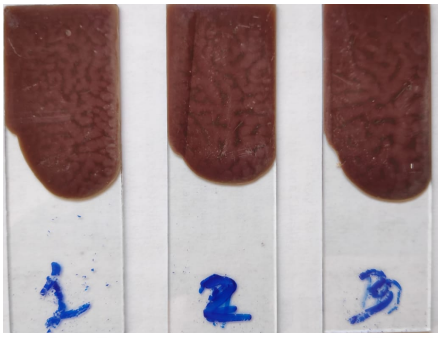
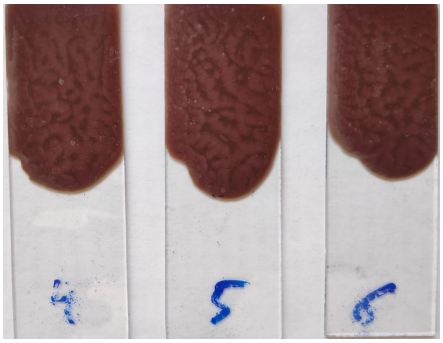
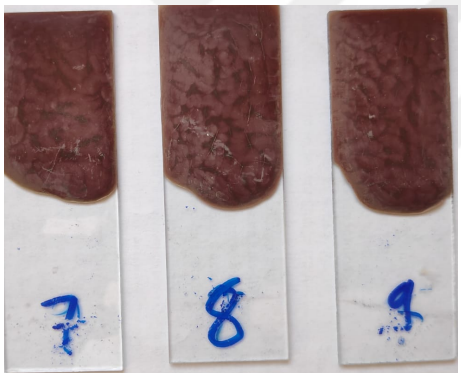
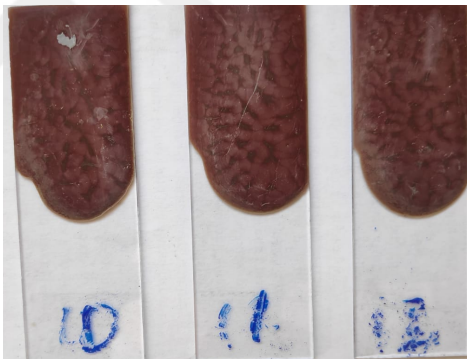
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.122 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing test of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint are shown in Figure 3.48. The tests were done at 30 °C. One-way ANOVA analyses of self-polishing tests are given in Table 3.123. The highest and the lowest self-polishing percentages were observed at 1000 RPM rotary rate and 250 RPM rotary rate. Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for 250-500 RPM and 750-1000 RPM rotary rates ($p>0.05$). Self-polishing percentages of tests that were done for 2 hours did not show significant differences at 500 and 750 RPM rotary rates ($p>0.05$). It can be seen from Figure 3.49 that the fiber reinforcement did not decrease the polishing degree meaningfully. Table 3.124 depicts one-way ANOVA analyses results of self-polishing percentage's mean comparison of the control and the fiber-reinforced paint. The photos of microscope slides used in the self-polishing test which was covered by the Rockforce MS675-Roxul 1000 fiber reinforced 0.1% (w/w) paint can be seen from Table 3.125-Table 3.127.

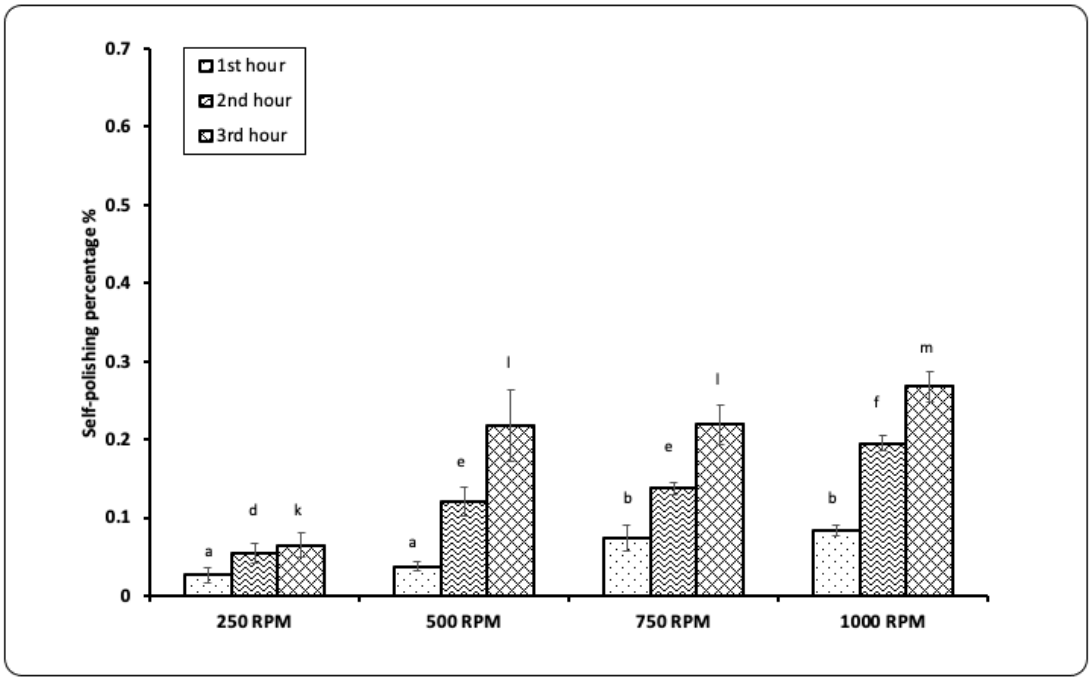


Figure 3.48 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint at 30 °C

Table 3.123 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.21874	11	0.01989	52.99	4.22711 e-14
Error	0.00901	24	0.00038		
Total	0.22775	35			

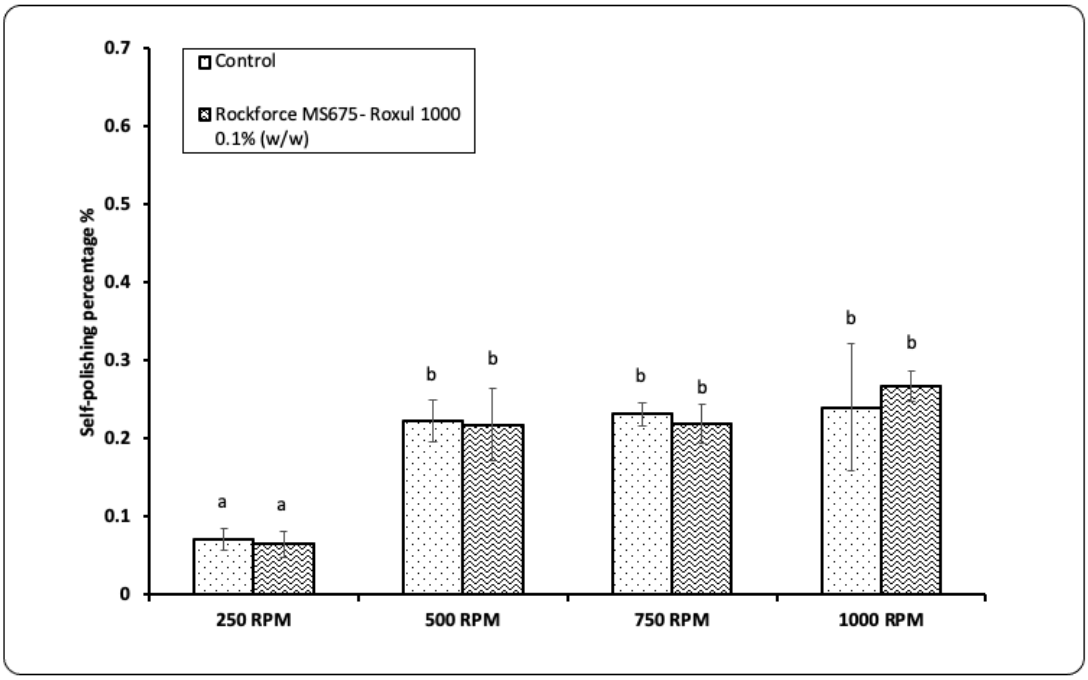


Figure 3.49 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint for 3-hour test period at 30 ºC

Table 3.124 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	3.29e-06	1	3.29e-06	0.00049856	0.98238721
Error	0.14517598	22	0.00659891		
Total	0.14517927	23			

Table 3.125 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour

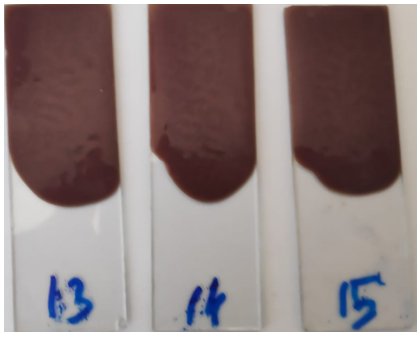
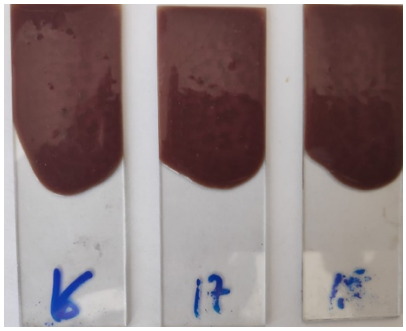
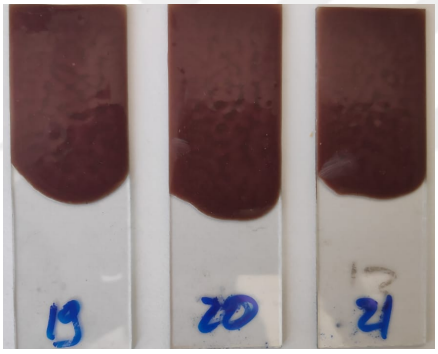
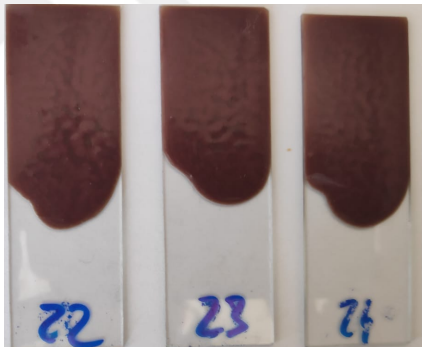
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.126 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours

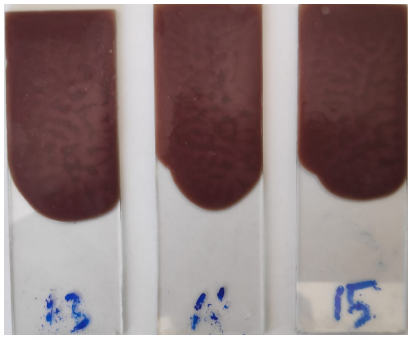
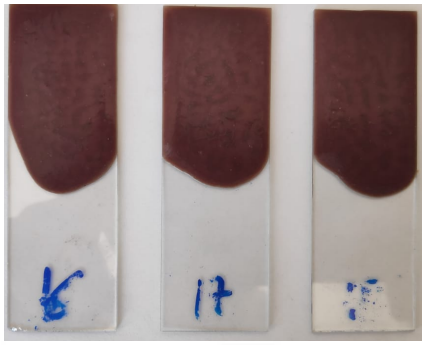
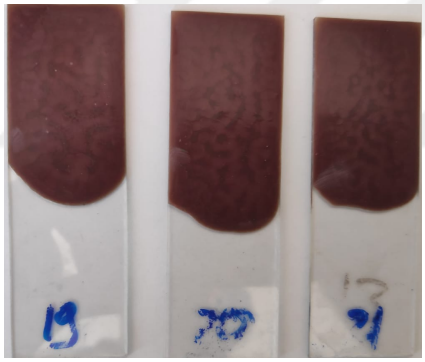
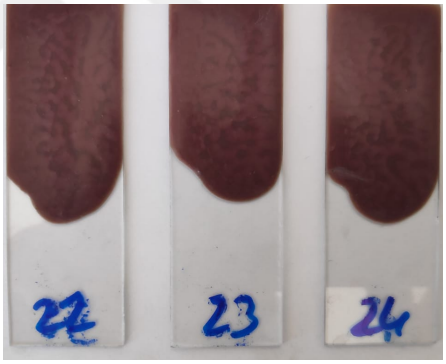
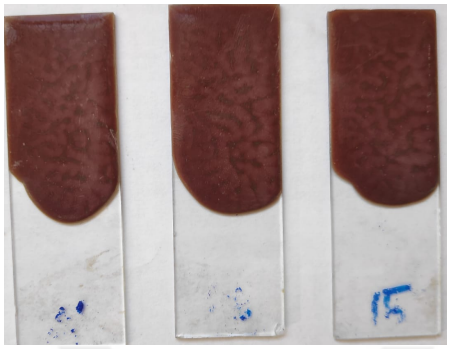
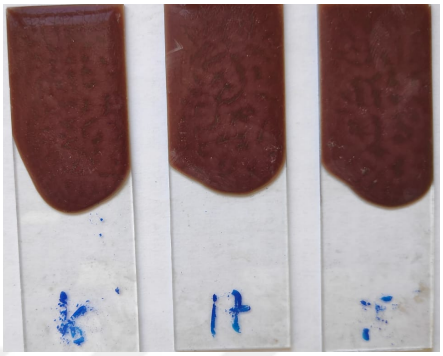
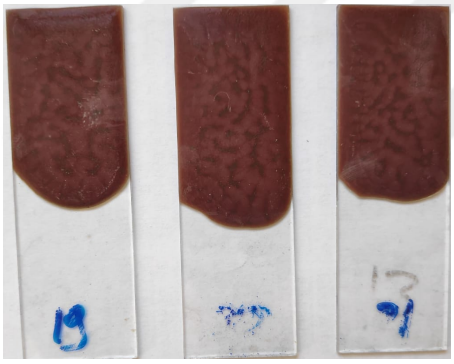
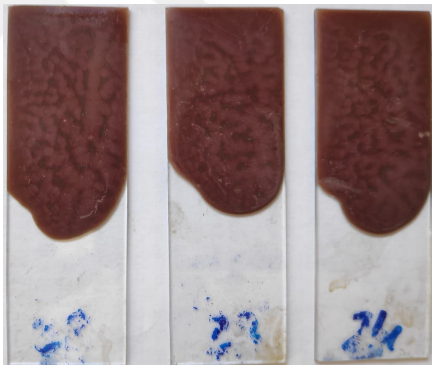
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.127 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Data obtained from the self-polishing test of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w)-reinforced self-polishing antifouling paint is shown in Figure 3.50. The tests were made at 40 °C temperature. Data related to self-polishing tests one-way ANOVA analyses can be seen in Table 3.128. The highest self-polishing percentage was observed at 1000 RPM rotary rate for a 3-hour test period. Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500 and 750 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour time period did not show any statistical differences either for 500, 750 or 1000 RPM ($p>0.05$). When Figure 3.51 is analyzed, it can be seen that the self-polishing percentage for all RPM rates been decreased. Data related to one-way ANOVA analyses for mean comparison of self-polishing percentages can be seen in Table 3.129. The photos of microscope slides used in the self-polishing test which were covered by the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced paint can be seen from Table 3.130-Table 132.

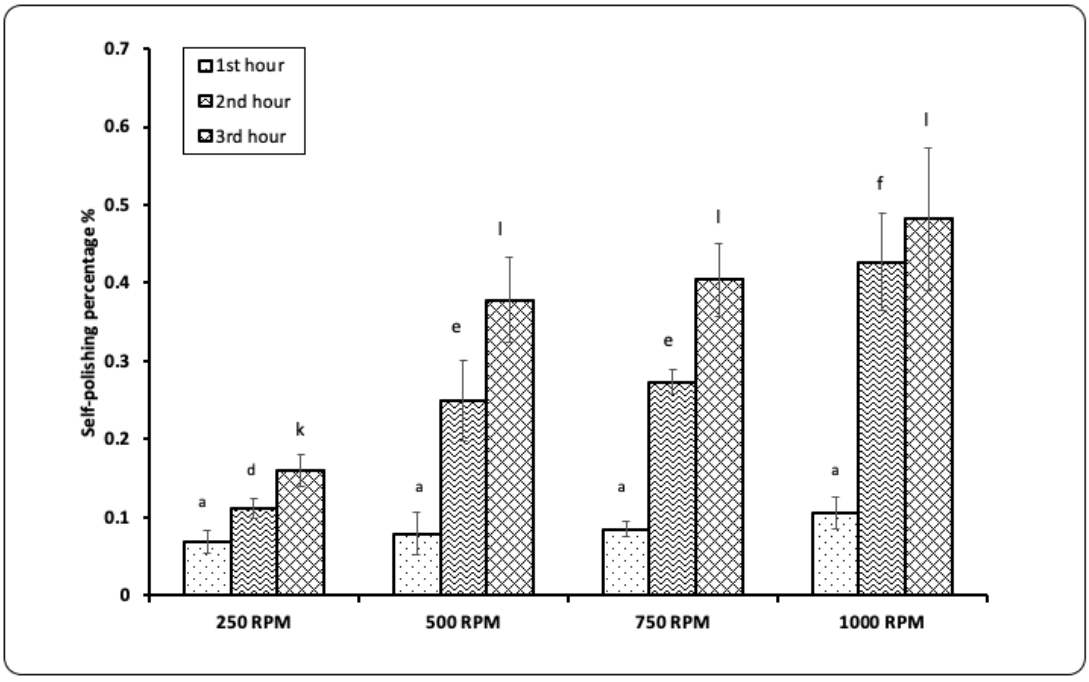


Figure 3.50 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint at 40 °C

Table 3.128 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.78246	11	0.07113	38.5	1.53705 e-12
Error	0.04434	24	0.00185		
Total	0.8268	35			

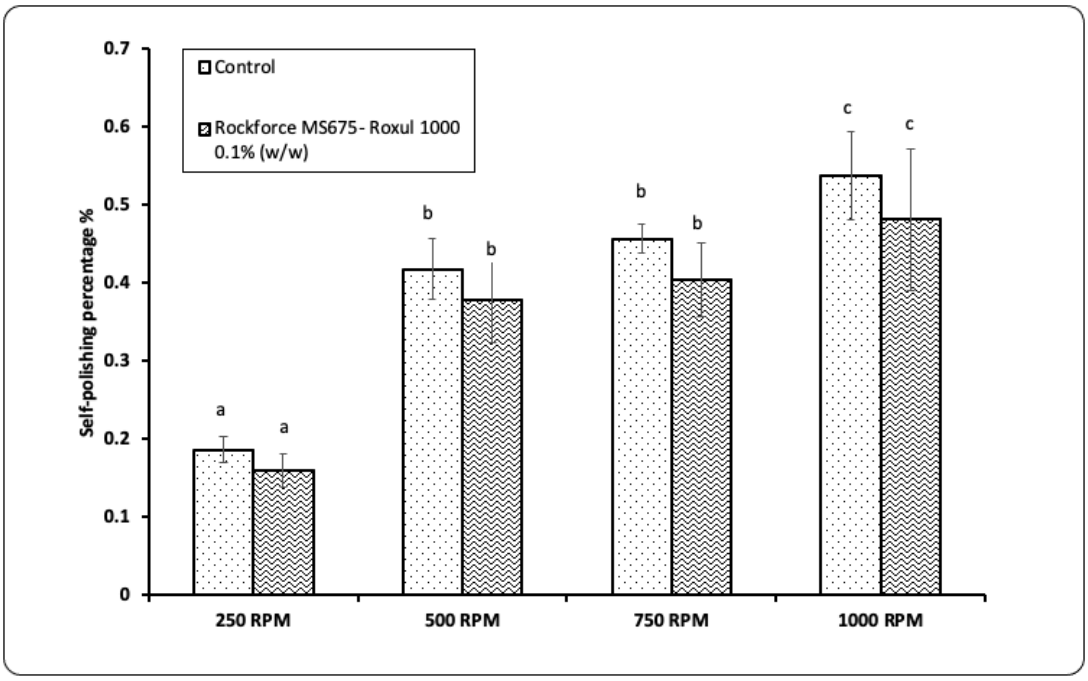


Figure 3.51 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint for 3-hour test period at 40 ºC

Table 3.129 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.0113401	1	0.0113401	0.50188772	0.48611124
Error	0.49708767	22	0.02259489		
Total	0.50842777	23			

Table 3.130 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour

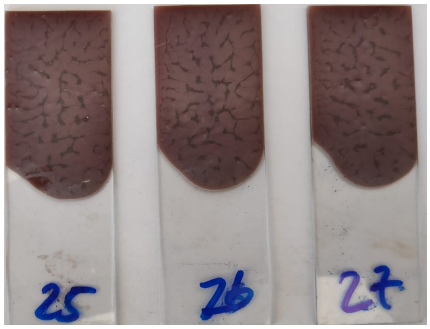
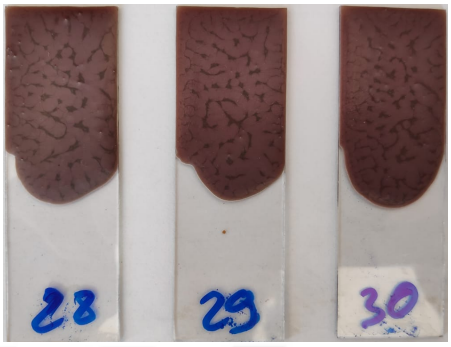
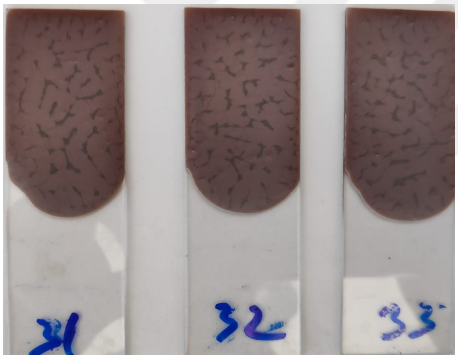
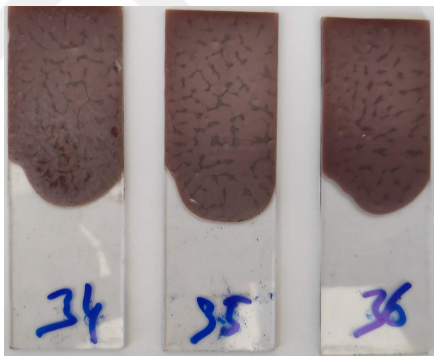
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.131 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours

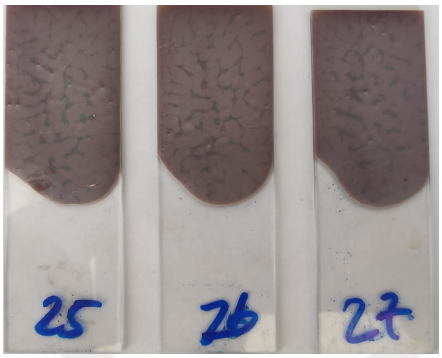
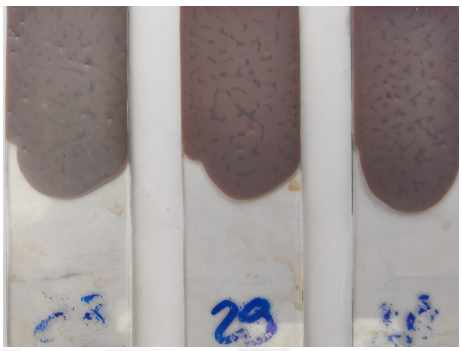
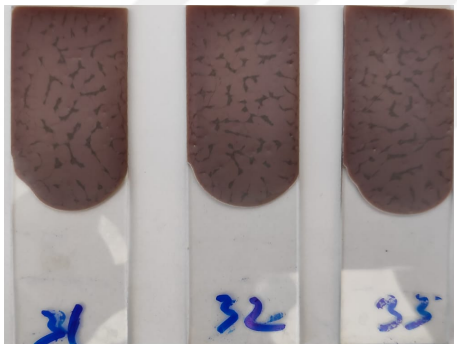
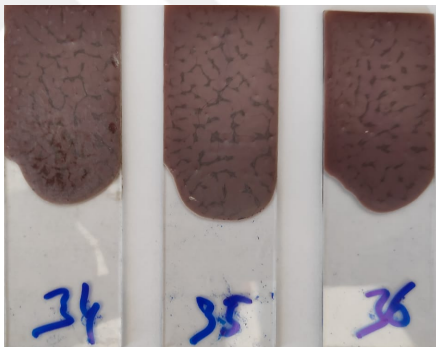
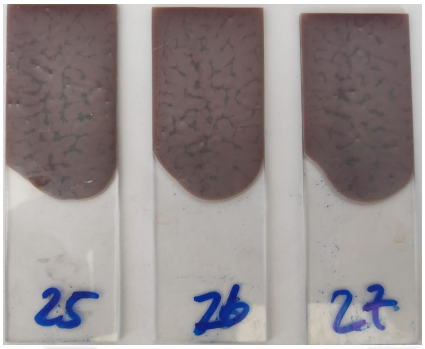
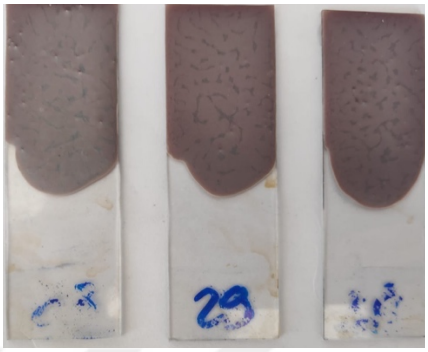
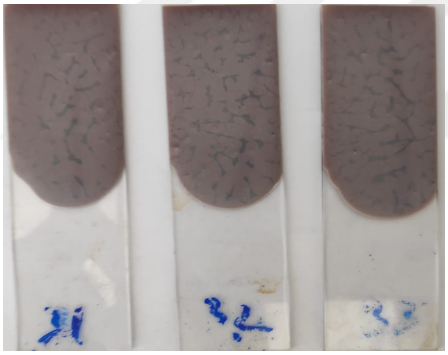
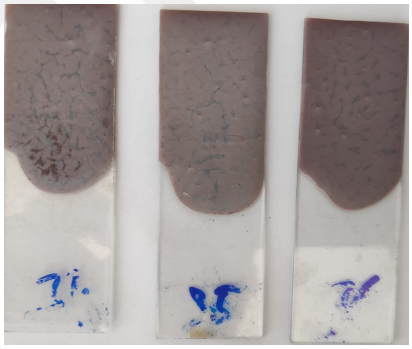
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.132 The photos of the Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing test of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint are shown in Figure 3.52. The tests were done at 20 ºC. One-way ANOVA analyses results are given in Table 3.133. The highest self-polishing percentage was observed at a 3-hour test period at 1000 RPM rotary rate. Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for 500, 750 and 1000 RPM rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 250 - 500 RPM and 750-1000 RPM rotary rates ($p>0.05$). When Figure 3.53 is analyzed, it can be seen that the 0.01 % (w/w) fiber reinforcement did not affect the self-polishing percentage significantly. As can be seen from the results of the one-way ANOVA analyses for the self-polishing percentage's means comparison in Table 3.134, no significant difference was observed between means of self-polishing percentages of the control and the fiber-reinforced antifouling paints. The photos of microscope slides used in the self-polishing test which was covered by the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint can be seen from Table 3.135-Table 3.137.

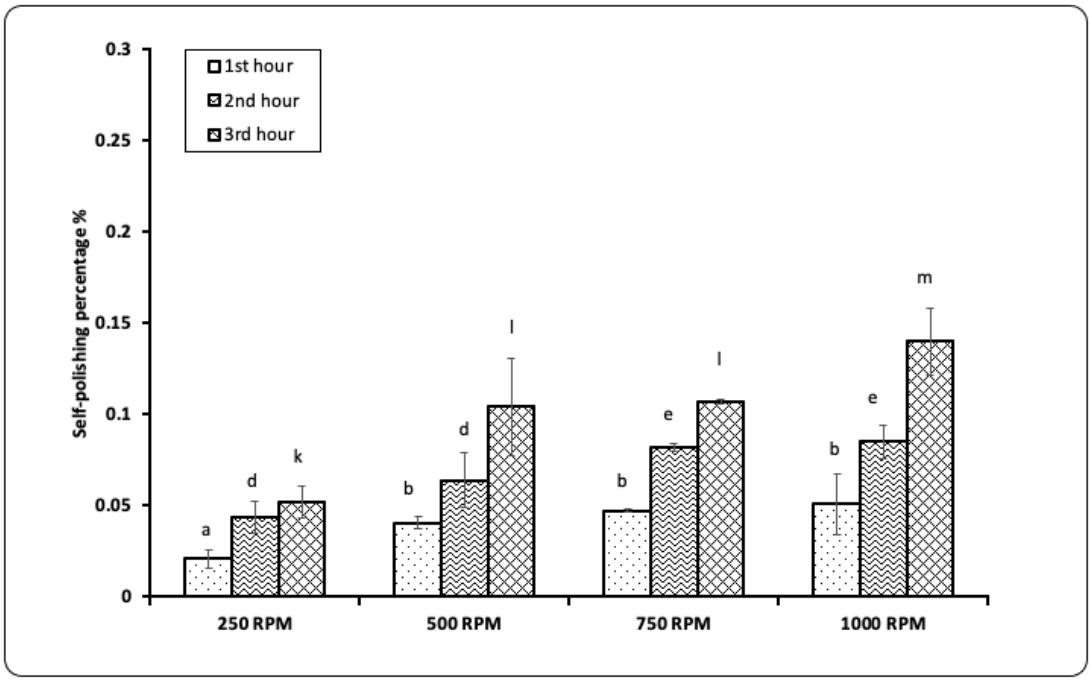


Figure 3.52 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 °C

Table 3.133 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.03902	11	0.00355	23.22	3.80568 e-10
Error	0.00367	24	0.00015		
Total	0.04268	35			

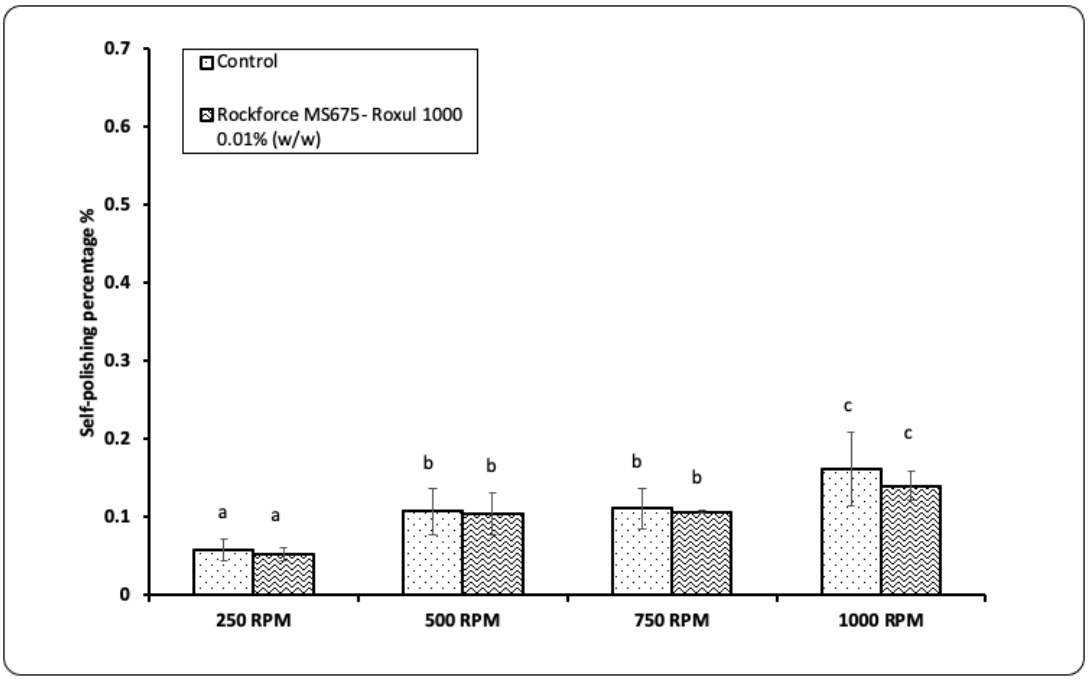


Figure 3.53 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC

Table 3.134 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.00045442	1	0.00045442	0.2644383	0.61221443
Error	0.03780573	22	0.00171844		
Total	0.03826015	23			

Table 3.135 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour

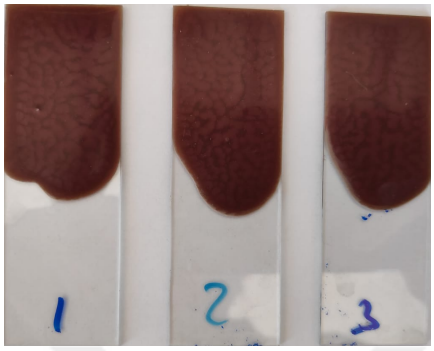
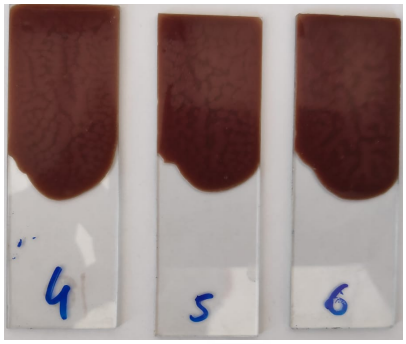
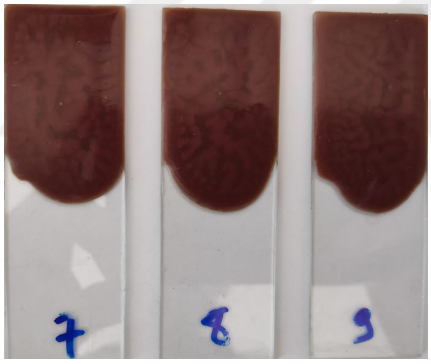
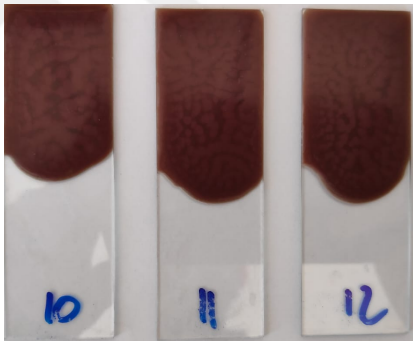
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.136 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours

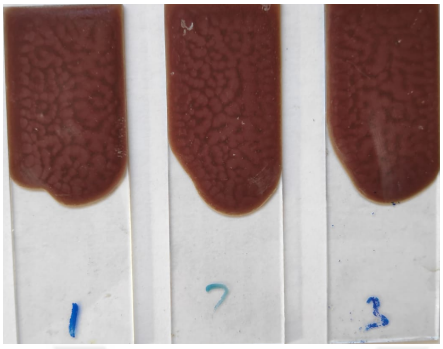
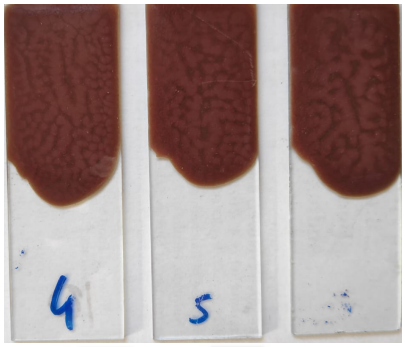
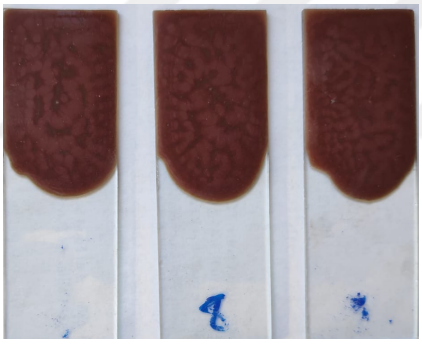
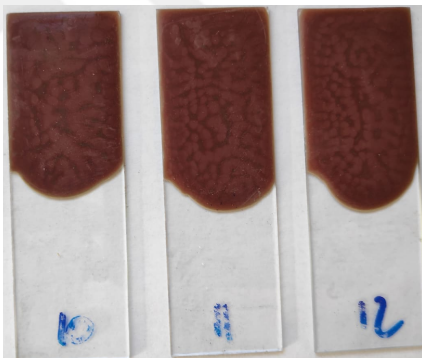
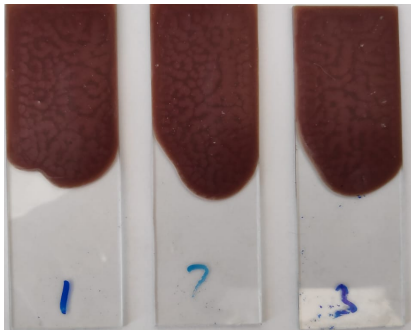
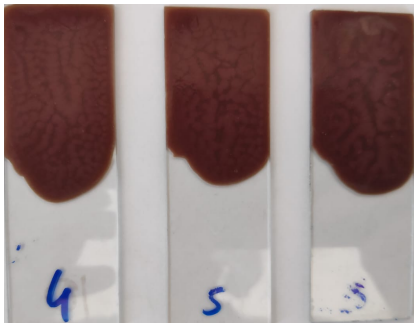
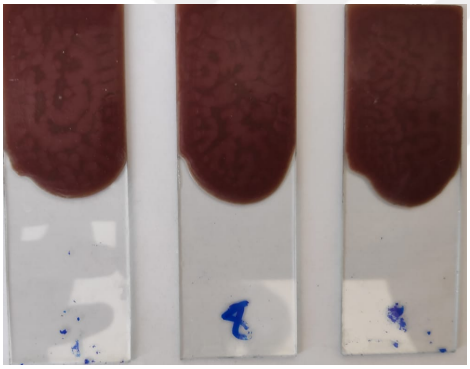
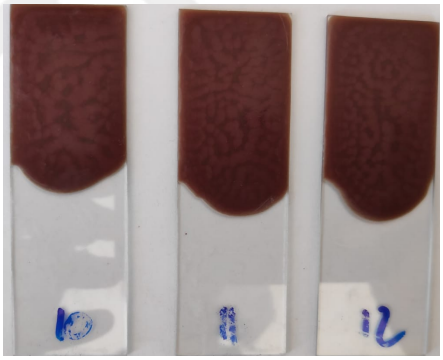
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.137 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing test of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint are shown in Figure 3.54. The tests were held at 30 ºC. The highest self-polishing percentage was observed at 1000 RPM rotary rate for a 3-hour test period. Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for 500 and 750 RPM rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500, 750 and 1000 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour time period did not show any statistical differences either for 500, 750 or 1000 RPM ($p>0.05$). Self-polishing tests one-way ANOVA analyses results are given in Table 3.138. When Figure 3.55 is examined, it can be seen that the fiber reinforcement did not affect the self-polishing percentage significantly for all rotary rates ($p>0.05$). One-way ANOVA analyses of comparison of self-polishing percentage's means for the control and the fiber-reinforced antifouling paint are given in Table 3.139. The photos of microscope slides used in the self-polishing test which were covered by the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint can be seen from Table 3.140-Table 3.142.

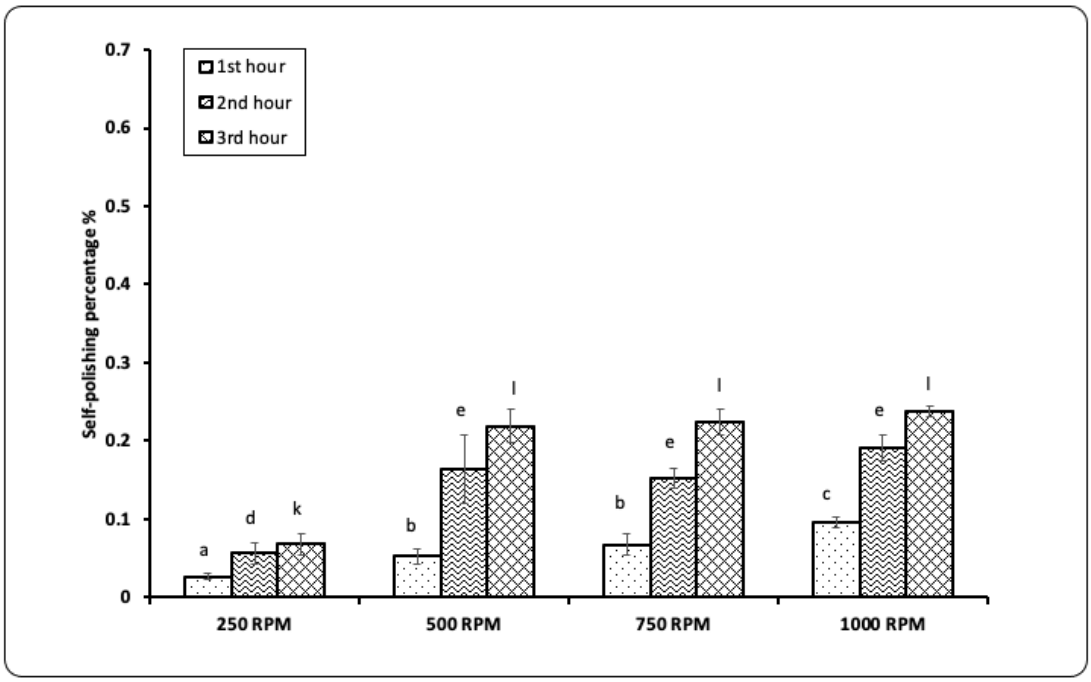


Figure 3.54 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 °C

Table 3.138 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.19424	11	0.01766	55.41	2.54123 e-14
Error	0.00765	24	0.00032		
Total	0.20189	35			

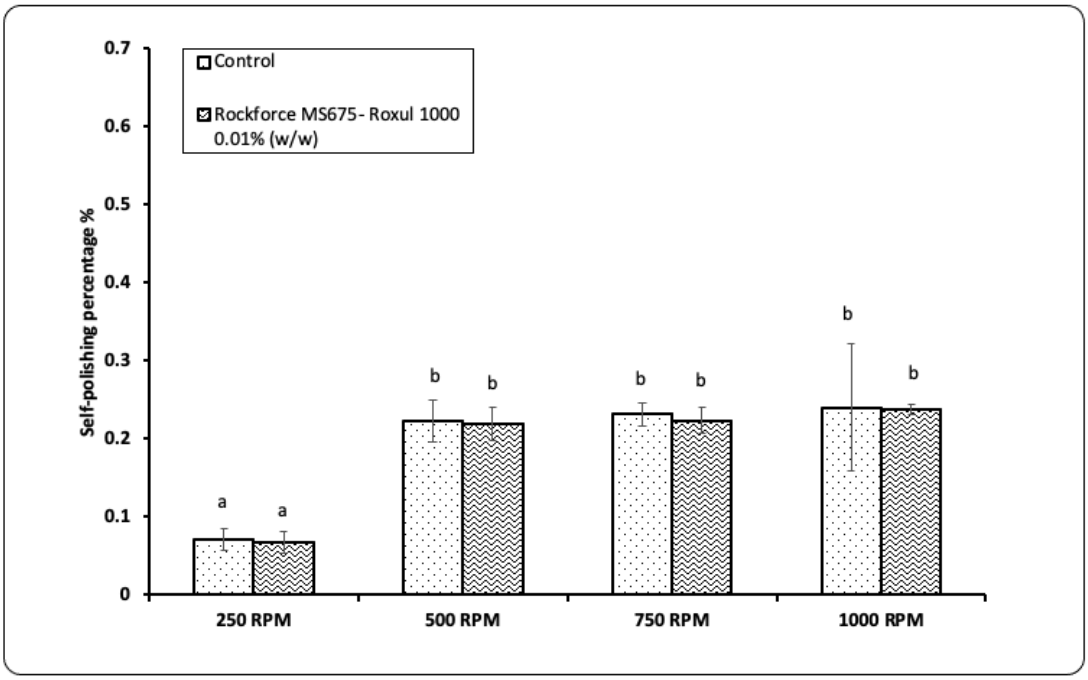


Figure 3.55 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC

Table 3.139 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.0001138	1	0.0001138	0.01953252	0.89012216
Error	0.12817066	22	0.00582594		
Total	0.12828446	23			

Table 3.140 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour

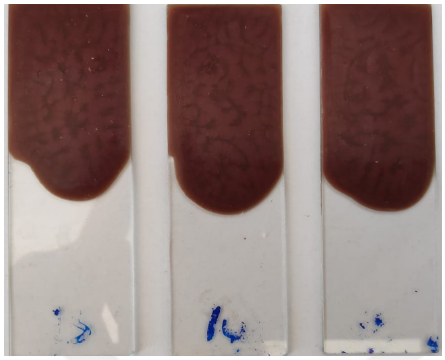
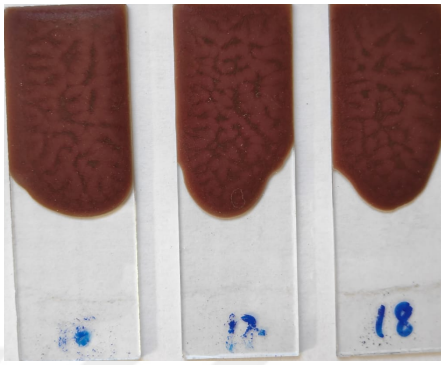
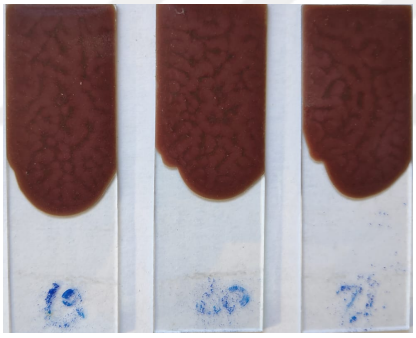
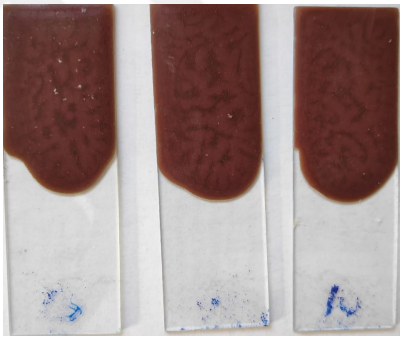
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.141 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours

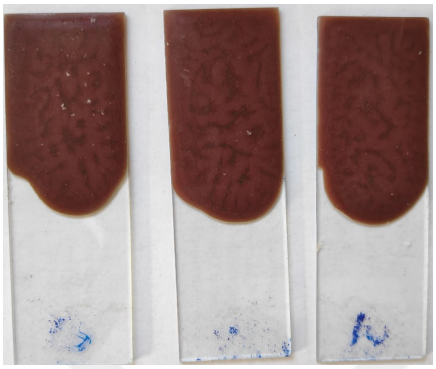
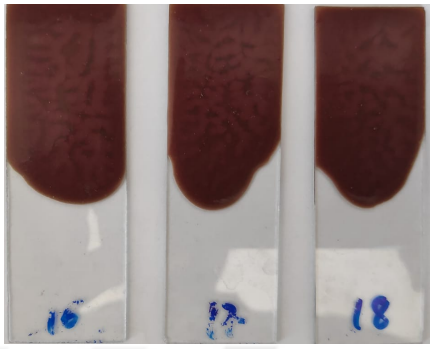
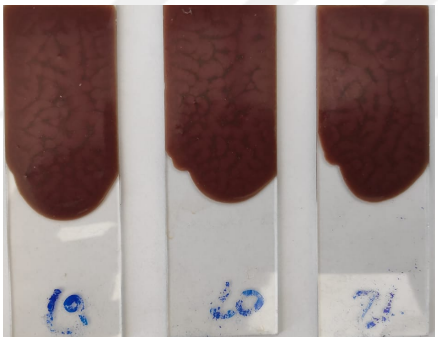
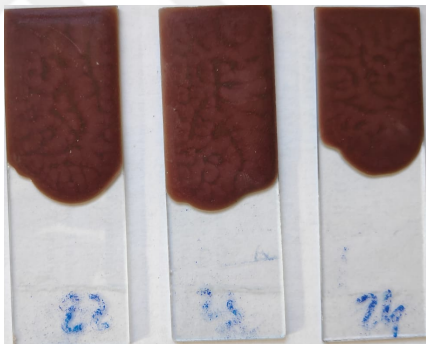
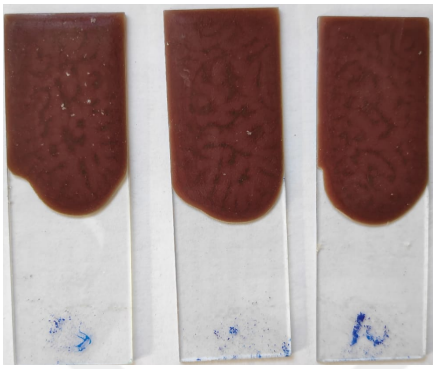
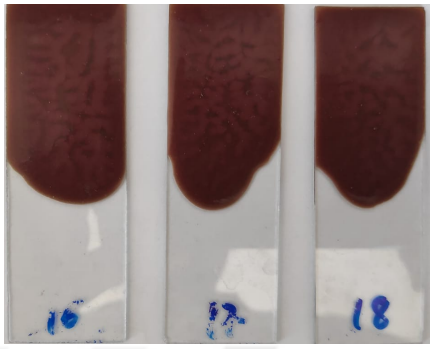
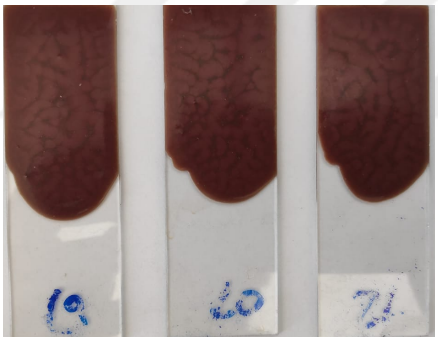
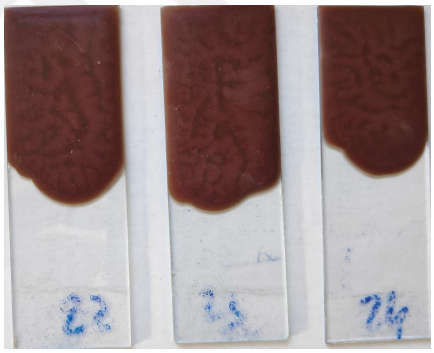
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.142 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Test results of the self-polishing test for the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint are shown in Figure 3.56. The tests were made at 40 °C. The highest self-polishing percentage was observed at 1000 RPM rotary rate for a 3-hour period. Self-polishing tests one-way ANOVA analysis results can be seen in Table 3.143. Self-polishing percentages of tests that were made for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500, 750 and 1000 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour time period did not show any statistical differences either for 500, 750 or 1000 RPM ($p>0.05$). From Figure 3.57 it can be seen that the fiber reinforcement decreased the self-polishing percentage, but this decline was not statistically meaningful for all rotary rates. Comparison of self-polishing percentages means one-way ANOVA analyses are shown in Table 3.144. The photos of microscope slides used in the self-polishing test which was covered by Rockforce MS675-Roxul 1000 fiber 0.01% (w/w) reinforced self-polishing antifouling paint can be seen from Table 3.145-Table 3.147.

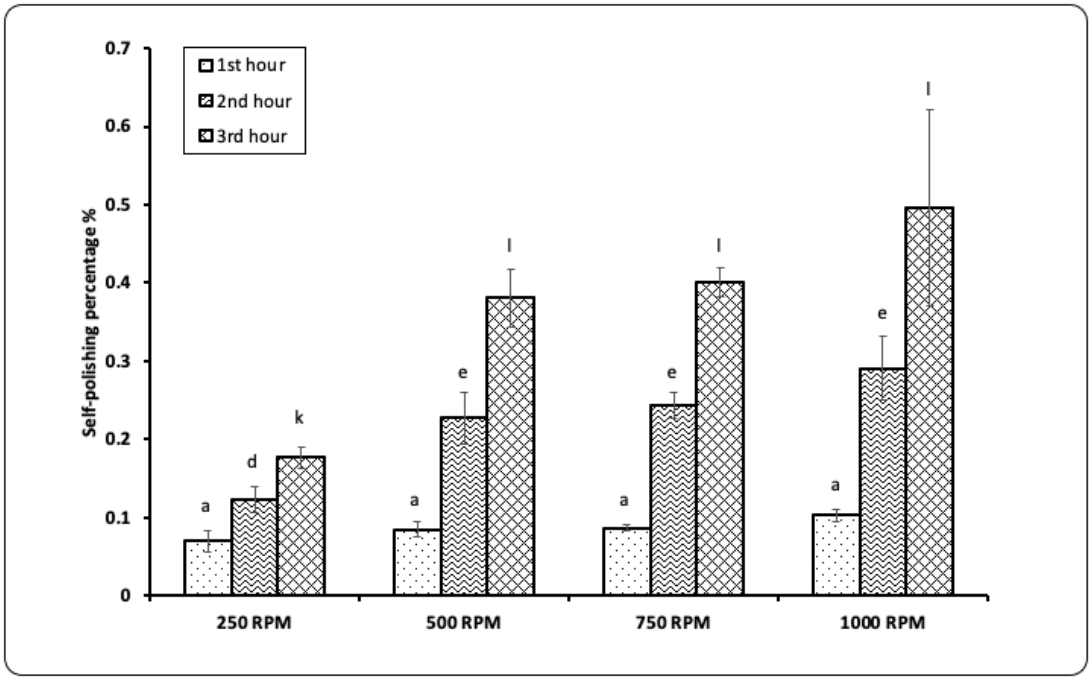


Figure 3.56 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 °C

Table 3.143 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.67193	11	0.06108	34.64	4.95984 e-12
Error	0.04232	24	0.00176		
Total	0.71425	35			

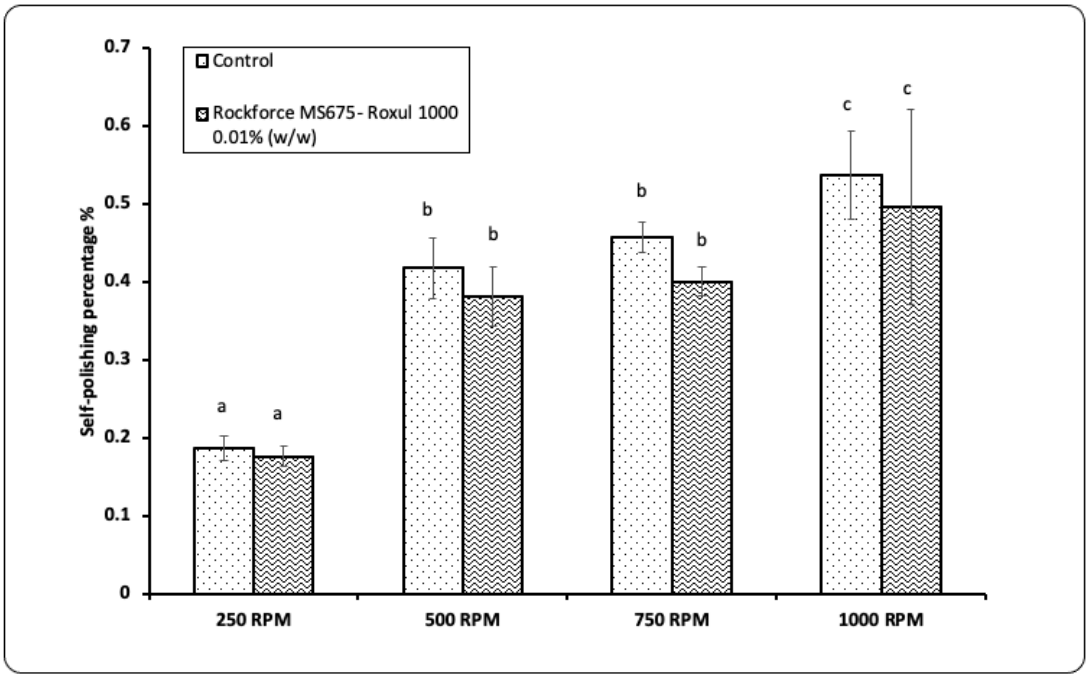


Figure 3.57 The comparison of self-polishing percentages between control and Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC

Table 3.144 One-way ANOVA results related to mean comparison of control and Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.00778842	1	0.00778842	0.34506056	0.5629037
Error	0.49656567	22	0.02257117		
Total	0.50435409	23			

Table 3.145 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour

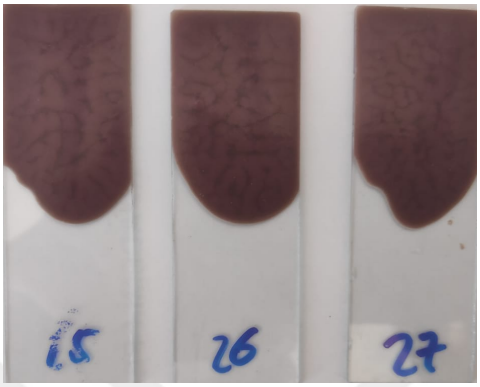
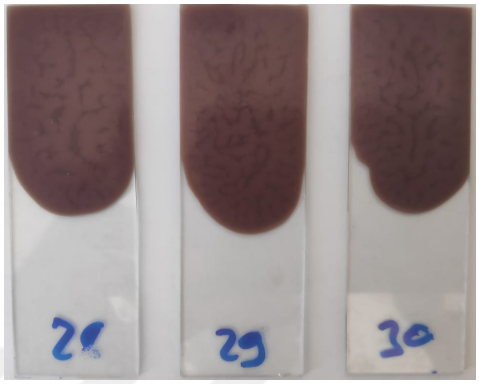
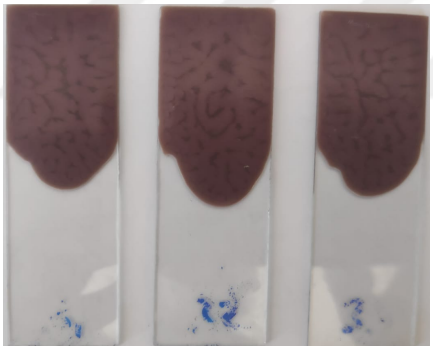
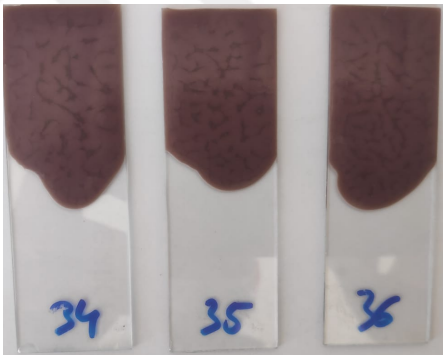
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.146 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours

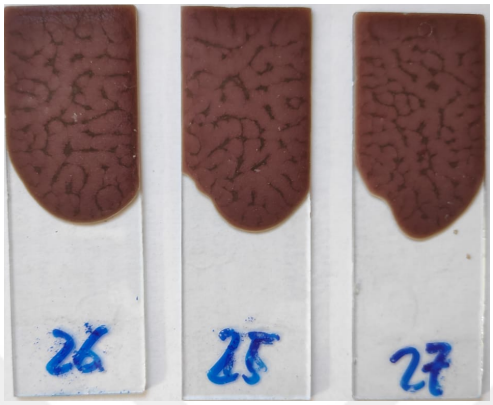
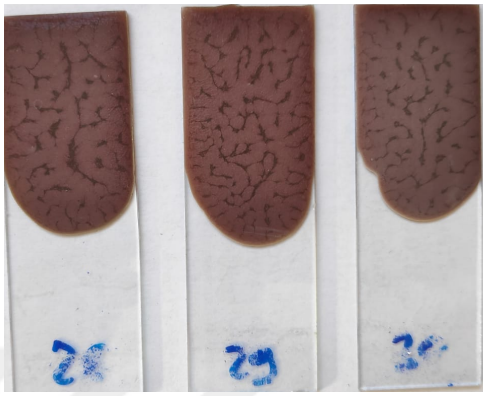
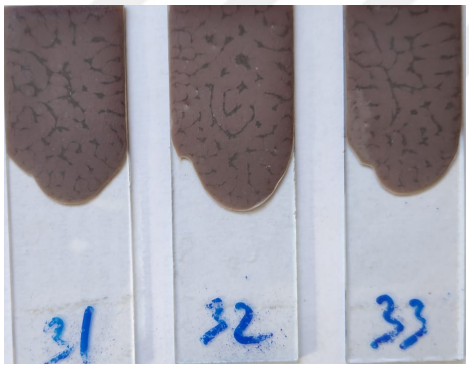
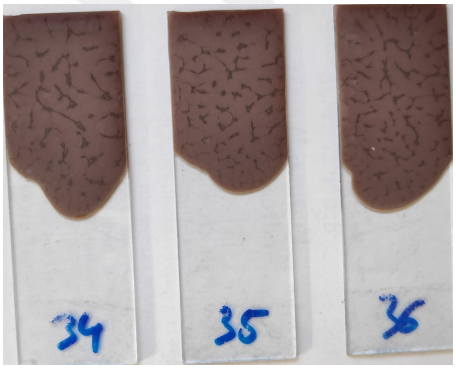
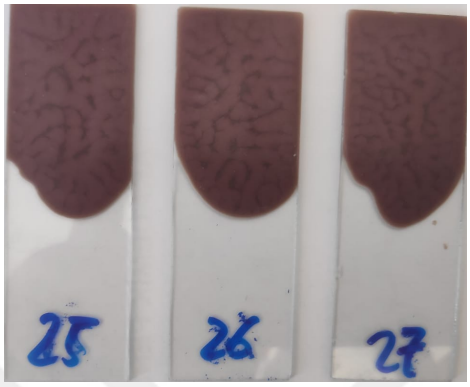
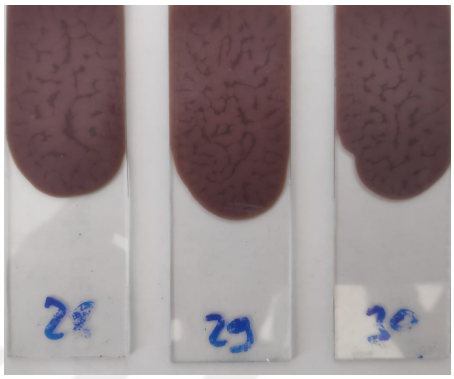
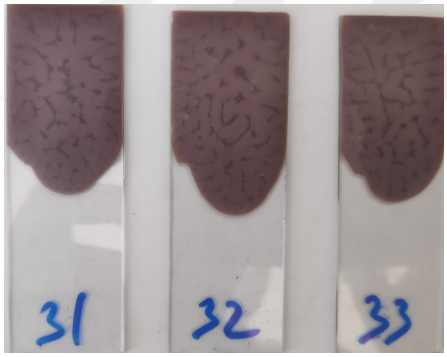
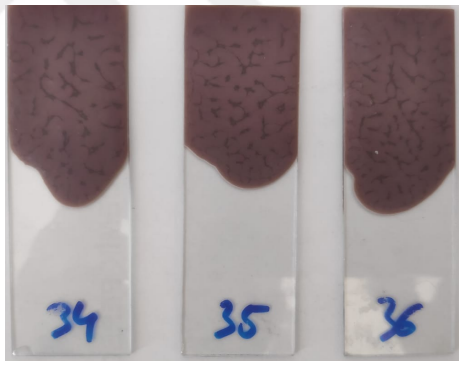
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.147 The photos of the Rockforce MS675-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The self-polishing test results of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint are shown in Figure 3.58. Tests were made at 20 °C. One-way ANOVA analyses results of the tests can be seen in Table 3.148. The highest self-polishing percentage was observed at a 3-hour test period at 1000 RPM rate. Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for 500-1000 RPM rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 250-500 and 750-1000 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour time period did not show any statistical differences either for 500, 750 or 1000 RPM ($p>0.05$). As can be seen from Figure 3.59, the Rockforce MS730-Roxul 1000 fiber 1% (w/w) reinforcement decreased the self-polishing percentage. Self-polishing percentage's mean comparison of the control and the fiber-reinforced antifouling paint can be seen in Table 3.149. The photos of microscope slides used in the self-polishing test which were covered by the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint can be seen from Table 3.150-Table 3.152.

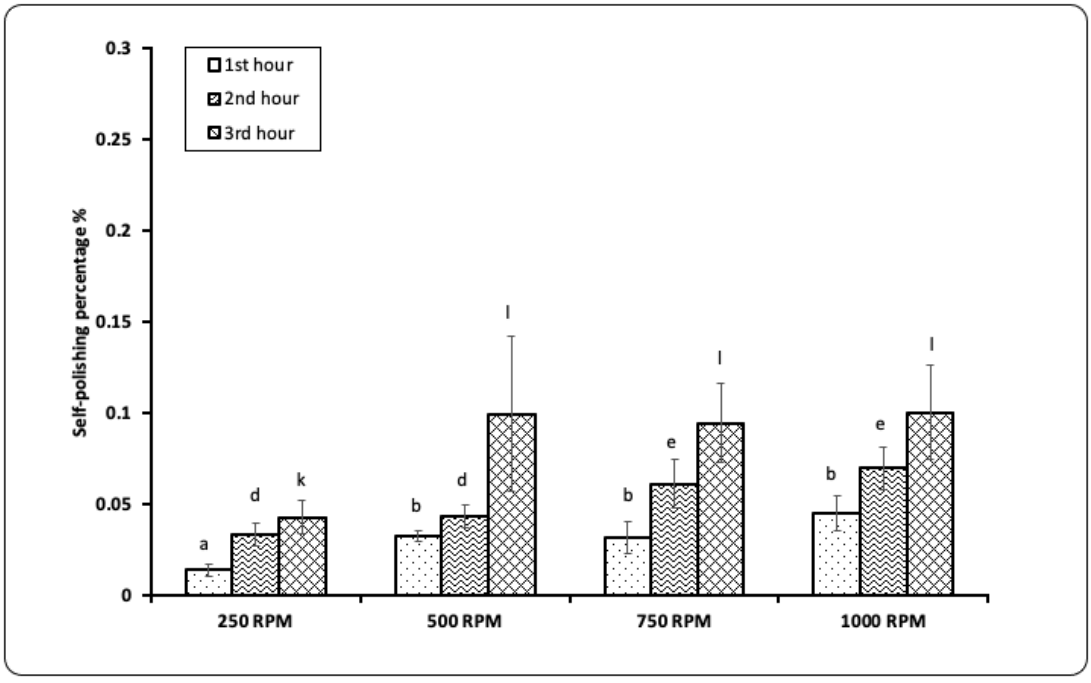


Figure 3.58 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 °C

Table 3.148 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.02825	11	0.00257	8.62	6.27006 e-06
Error	0.00715	24	0.0003		
Total	0.0354	35			

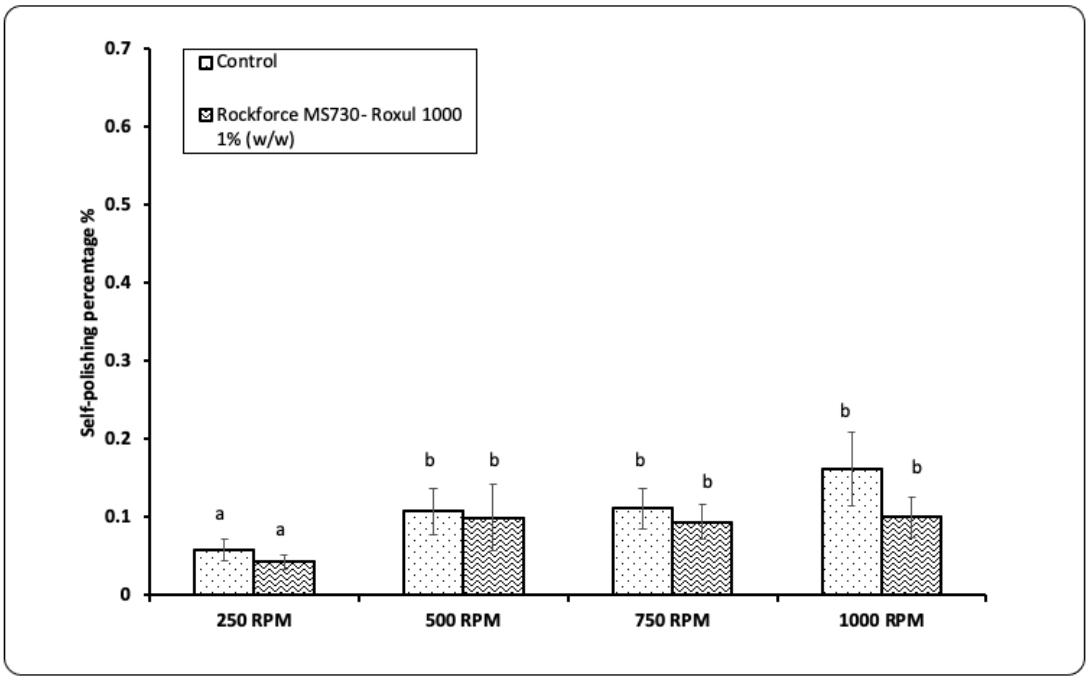


Figure 3.59 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC

Table 3.149 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.00388457	1	0.00388457	2.32792567	0.14131993
Error	0.03671103	22	0.00166868		
Total	0.0405956	23			

Table 3.150 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour

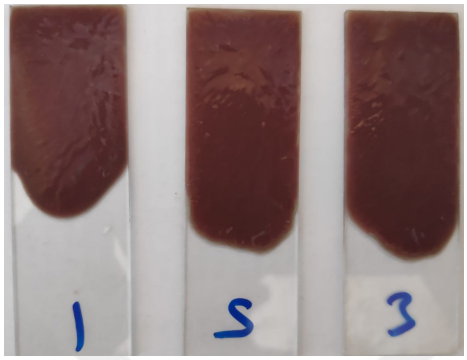
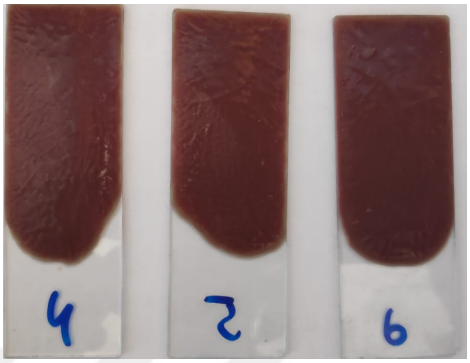
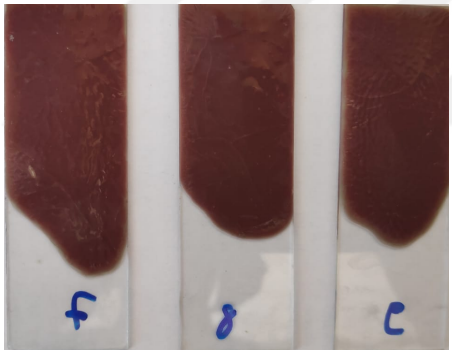
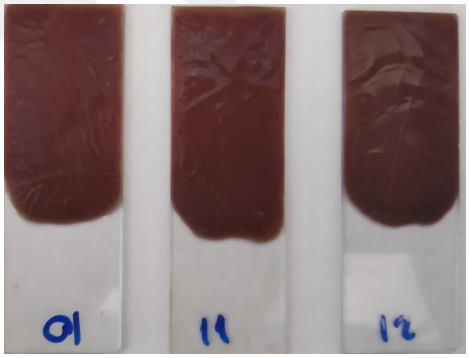
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.151 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours

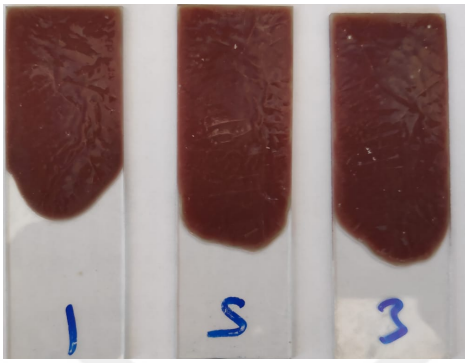
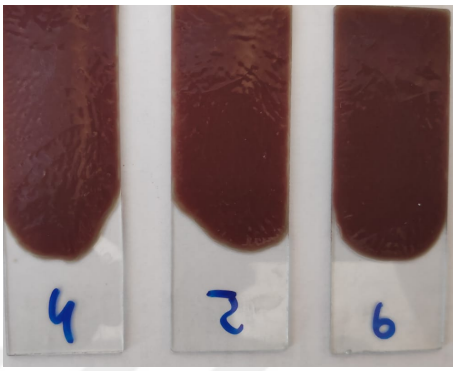
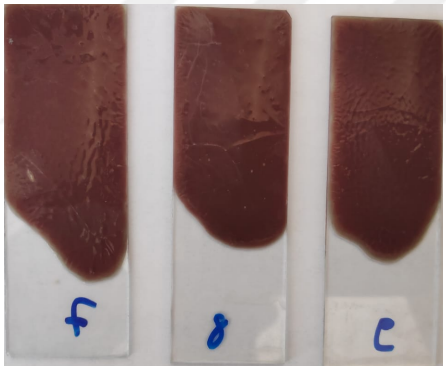
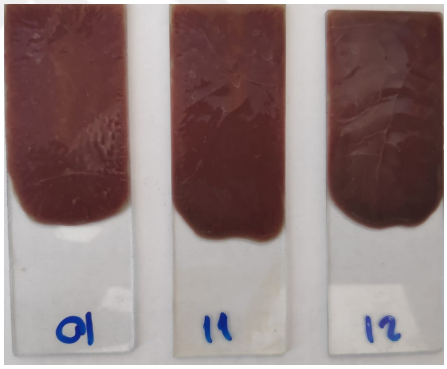
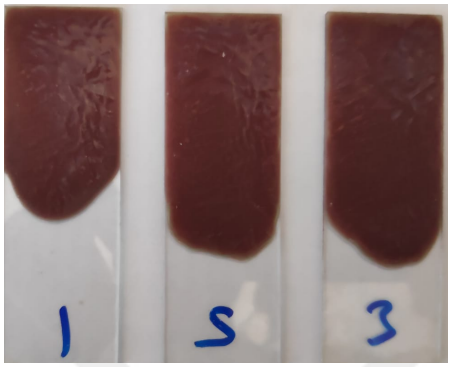
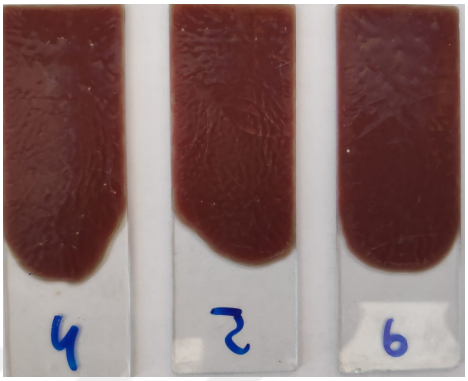
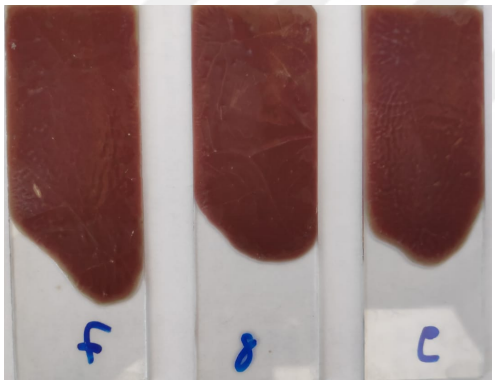
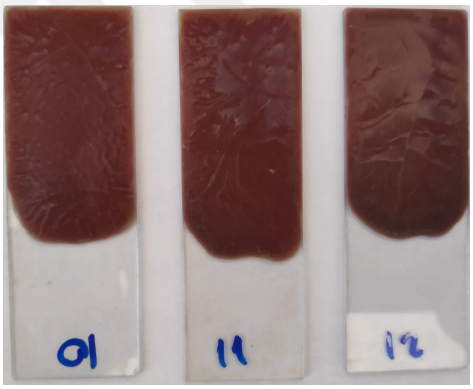
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.152 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing test of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint are shown in Figure 3.60. Tests were done at 30 °C temperature. One-way ANOVA analyses results of self-polishing tests are given in Table 3.153. The highest self-polishing percentage was observed at a 3-hour test period at 1000 RPM rotary rate. Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for 250-750 RPM rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500-750 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour time period did not show any statistical differences for 500, 750 or 1000 RPM ($p>0.05$). When Figure 3.61 is examined, a decrease in self-polishing percentage can be seen, but this decrease was not statistically meaningful ($p<0.05$). One-way ANOVA tests related to self-polishing percentage's mean comparison for the control and the fiber-reinforced paint are given in Table 3.154. The photos of microscope slides used in the self-polishing tests which were covered by Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint can be seen from Table 3.155-Table 3.157.

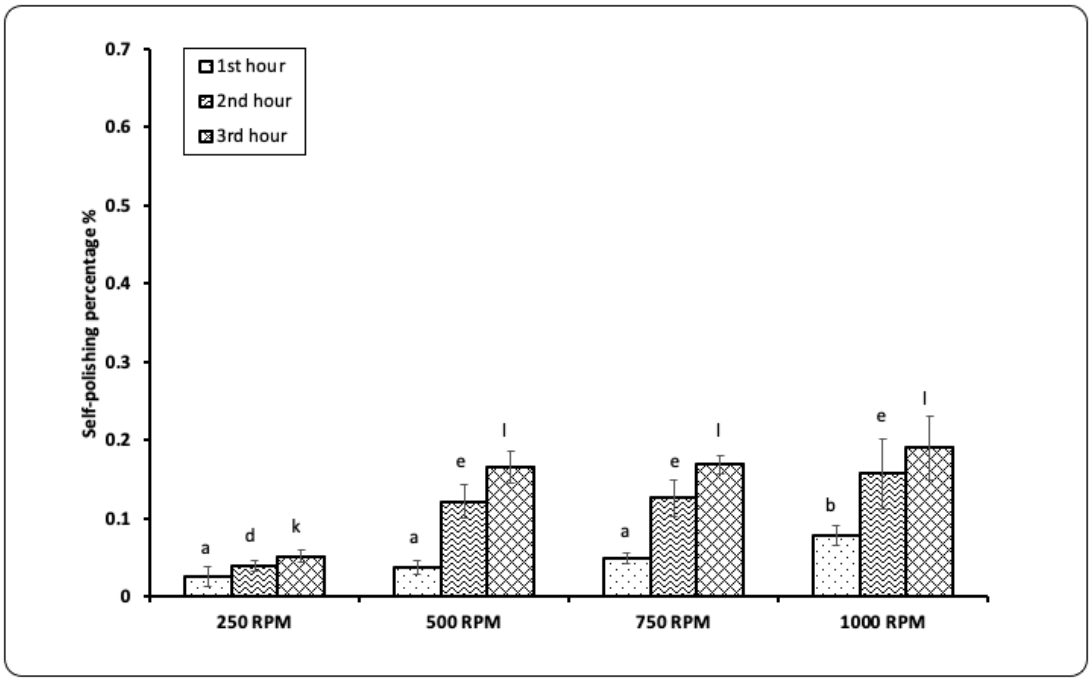


Figure 3.60 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 °C

Table 3.153 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.12103	11	0.011	23.02	4.16614 e-10
Error	0.01147	24	0.00048		
Total	0.1325	35			

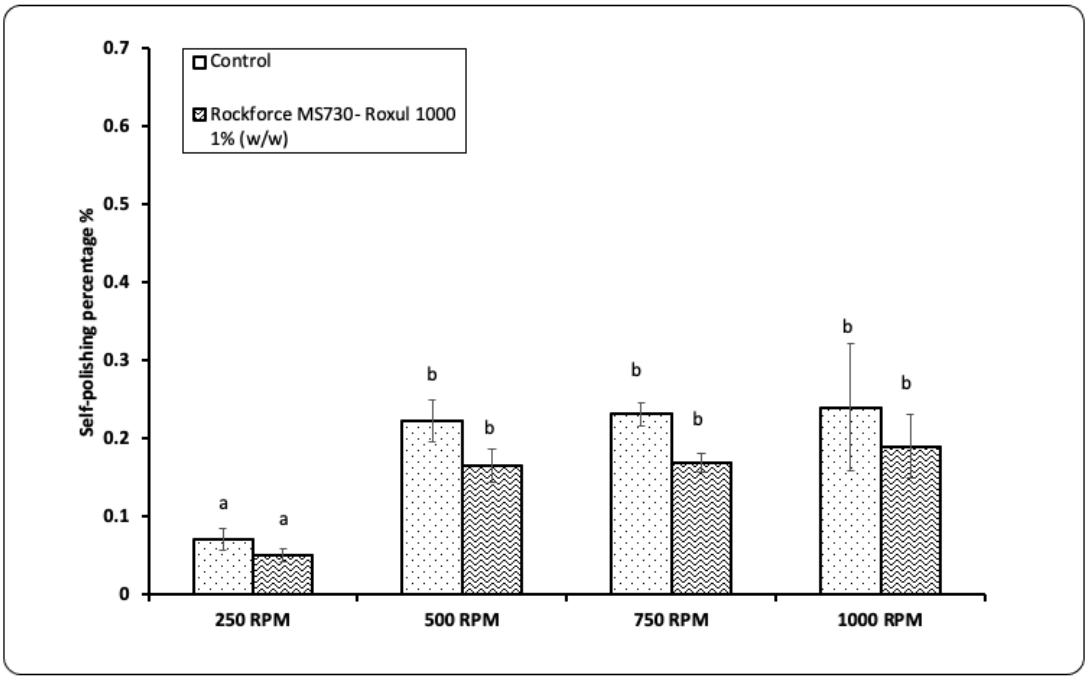


Figure 3.61 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC

Table 3.154 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.01366187	1	0.01366187	2.75651699	0.11104675
Error	0.10903656	22	0.00495621		
Total	0.12269843	23			

Table 3.155 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour

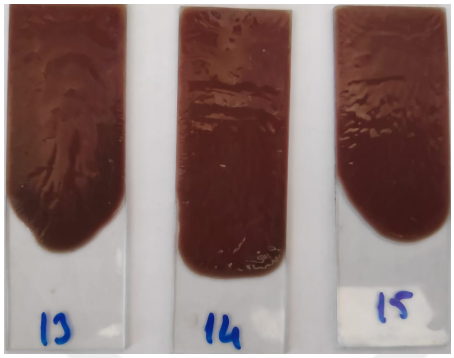
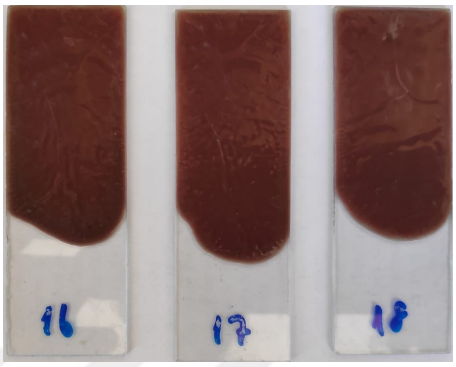
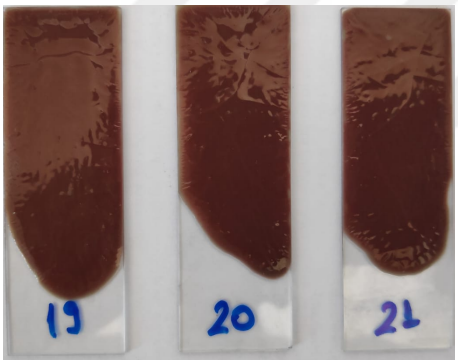
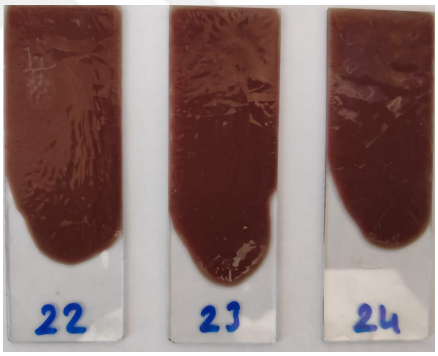
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.156 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours

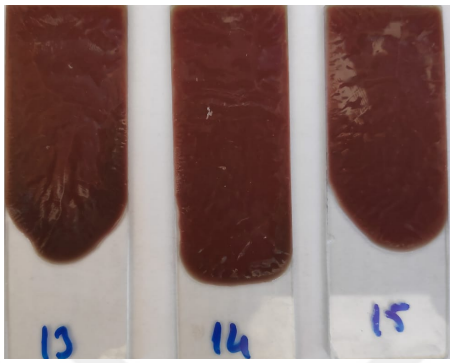
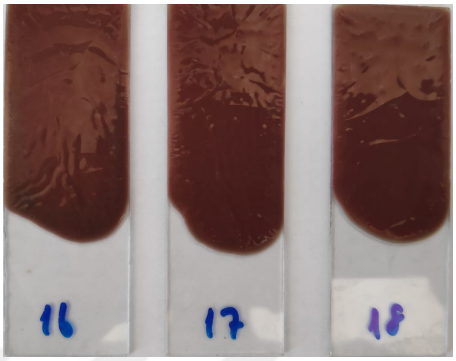
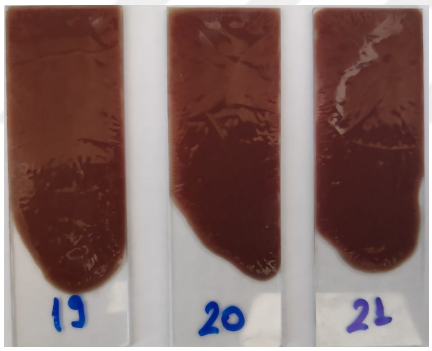
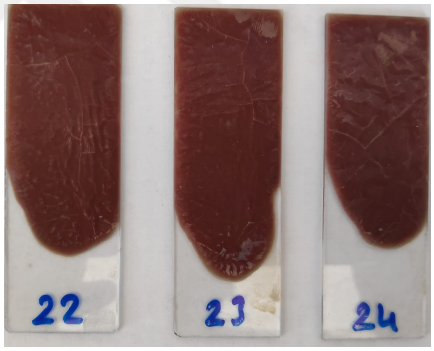
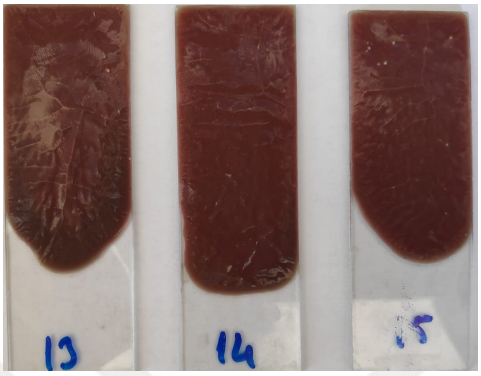
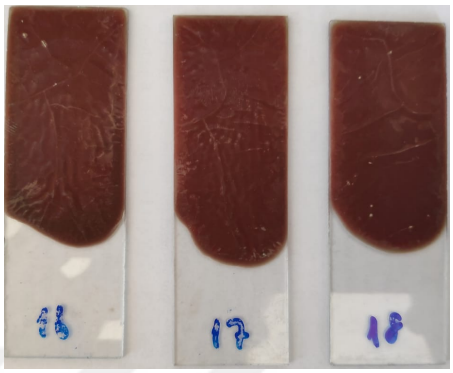
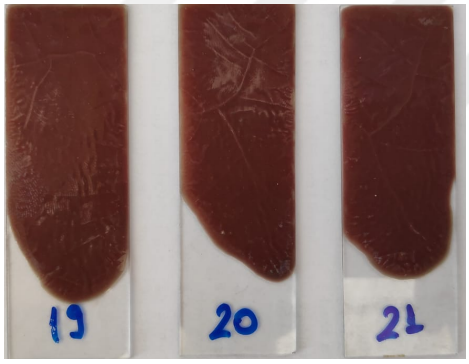
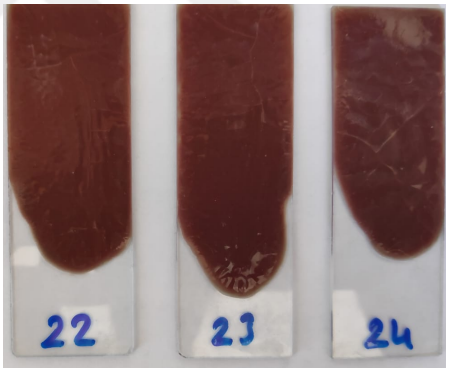
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.157 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing test of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint can be seen in Figure 3.62. The tests were made at 40 ºC. The results of the self-polishing tests one-way ANOVA analyses are given in Table 3.158. The highest self-polishing percentage was observed at 1000 RPM rotary rate for a 3-hour test period. Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500 and 750 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour time period did not show any statistical differences for 500 and 750 RPM rates ($p>0.05$). As it can be seen from Figure 3.63, the fiber reinforcement decreased the self-polishing percentage significantly. Table 3.159 depicts the results of the one-way ANOVA analyses for comparison of self-polishing percentage's means for the control and the fiber-reinforced paint. The photos of microscope slides used in the self-polishing tests which were covered by Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint can be seen from Table 3.160-Table 3.162.

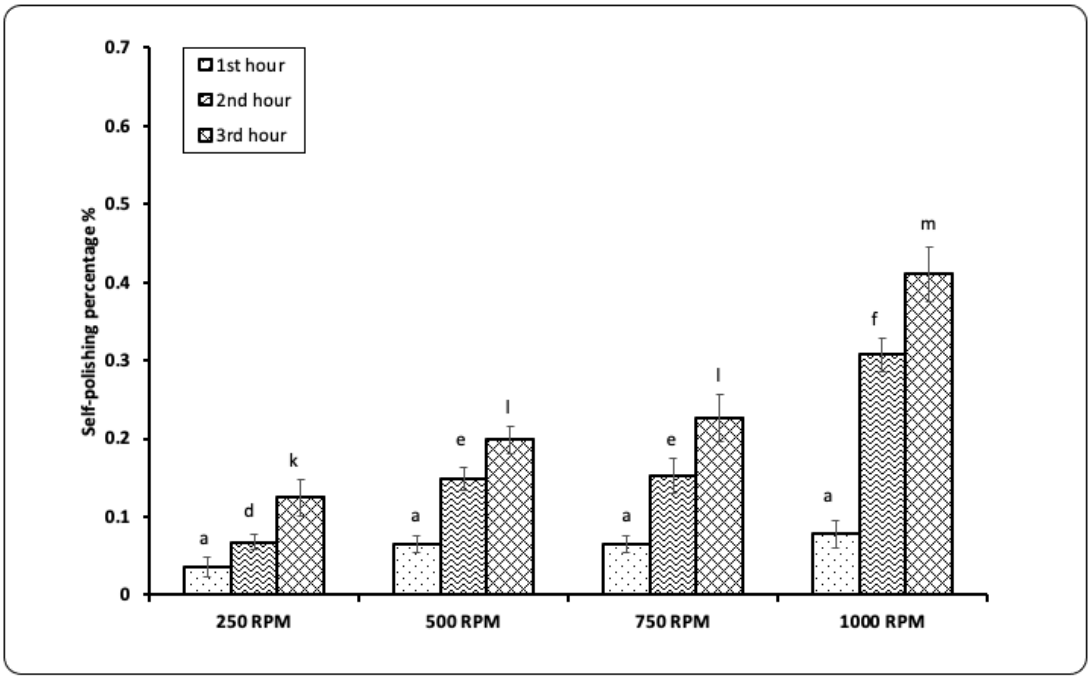


Figure 3.62 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 °C

Table 3.158 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.42263	11	0.03842	94.14	5.66646 e-17
Error	0.0098	24	0.00041		
Total	0.43243	35			

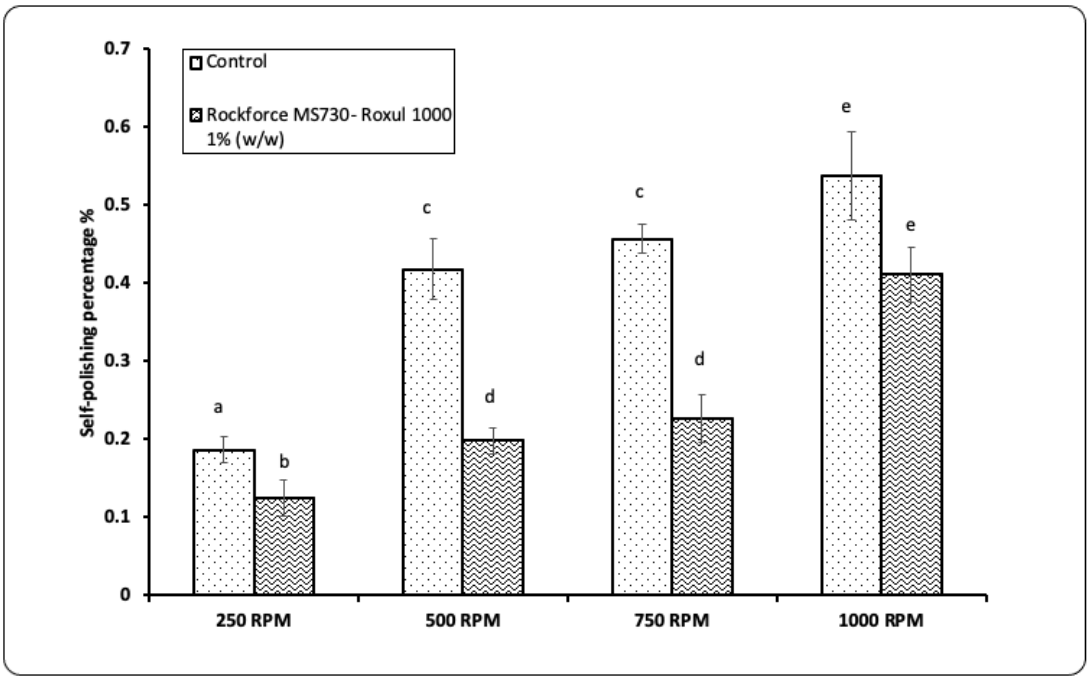


Figure 3.63 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC

Table 3.159 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.15266841	1	0.15266841	7.668431	0.01119034
Error	0.43799118	22	0.01990869		
Total	0.59065959	23			

Table 3.160 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour

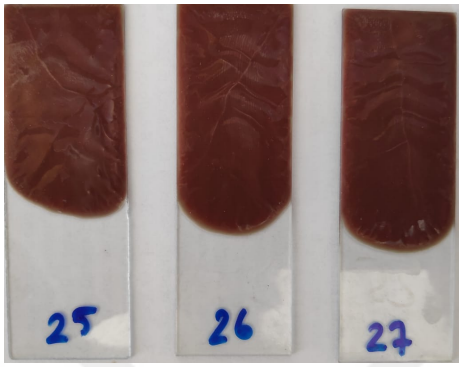
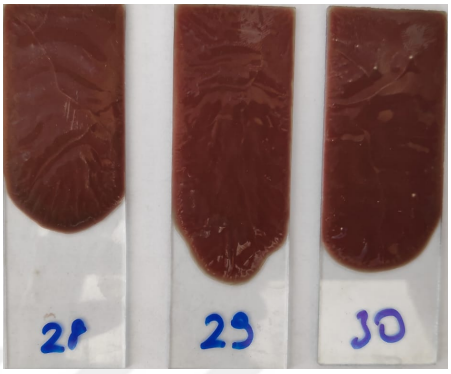
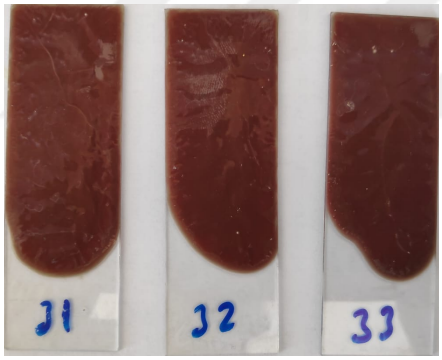
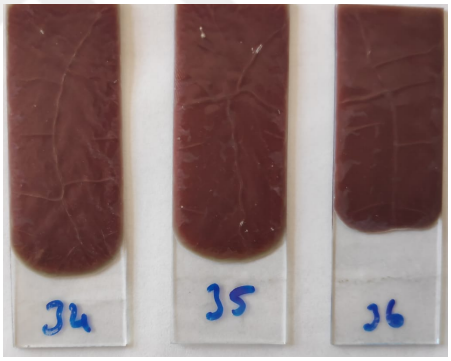
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.161 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours

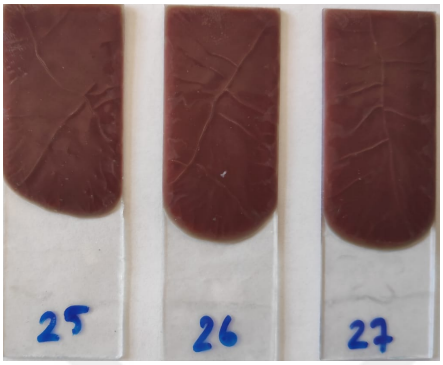
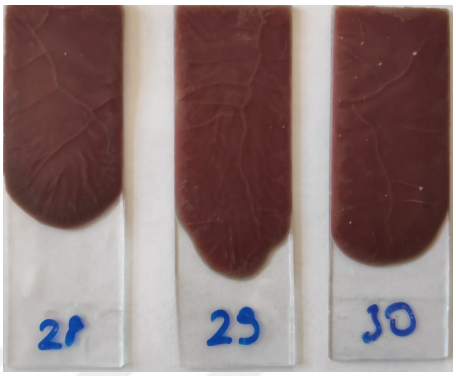
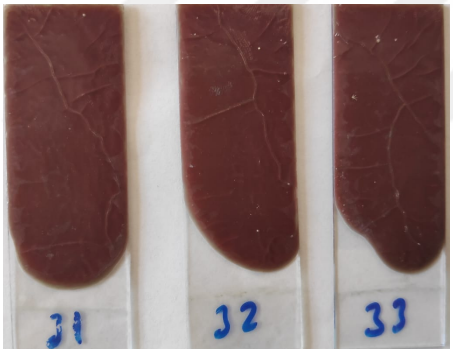
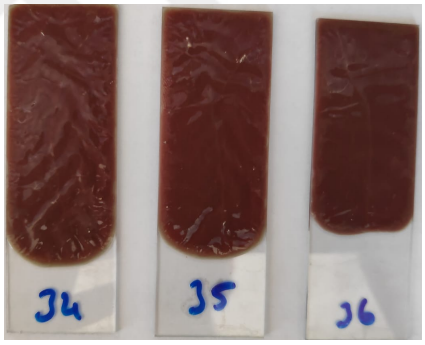
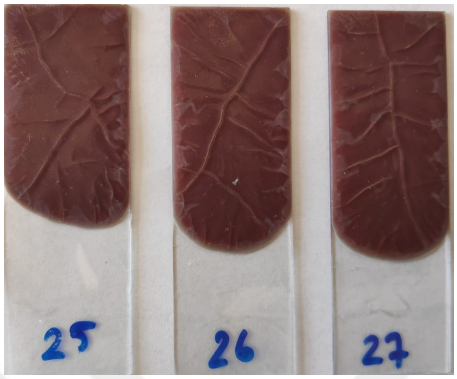
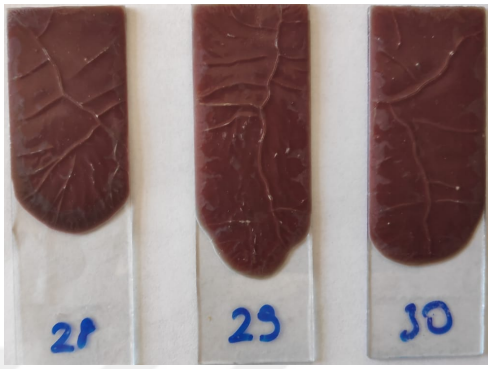
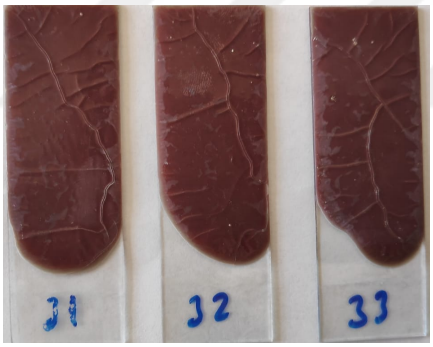
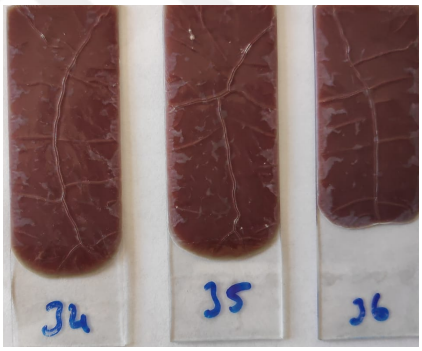
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.162 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The self-polishing test results of the Rockforce MS730-Roxul 1000 fiber 0.1% (w/w)-reinforced self-polishing antifouling paint are shown in Figure 3.64. The tests were done at 20 ^{o}C temperature. Self-polishing tests one-way ANOVA analyses results are given in Table 3.163. Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for 250-1000 RPM rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500-1000 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour time period did not show any statistical differences either for 500, 750 or 1000 RPM ($p>0.05$). From Figure 3.65 it can be seen that the decrease in the self-polishing percentage was not statistically meaningful. The results for the comparison of self-polishing percentage's means for the control and the fiber-reinforced paint are shown in Table 3.164. The photos of microscope slides used in the self-polishing test which was covered by Rockforce MS730-Roxul 1000 fiber 0.1% (w/w) reinforced self-polishing antifouling paint can be seen from Table 3.165-Table 3167.

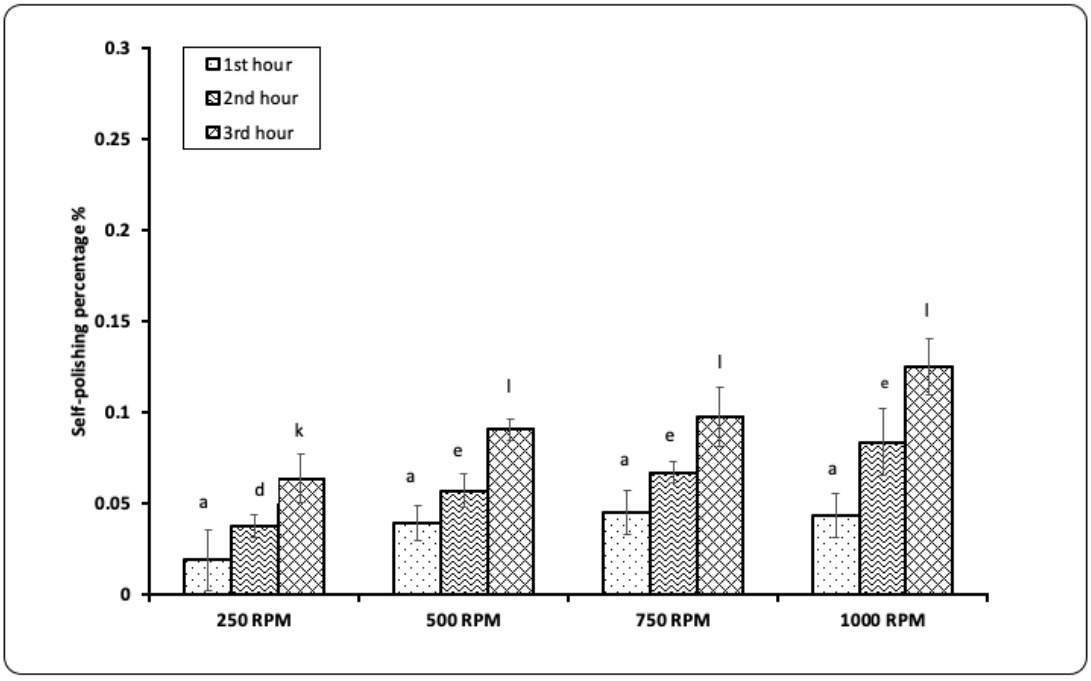


Figure 3.64 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 20 °C

Table 3.163 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.04161	11	0.00378	29.55	2.84197 e-11
Error	0.00307	24	0.00013		
Total	0.04468	35			

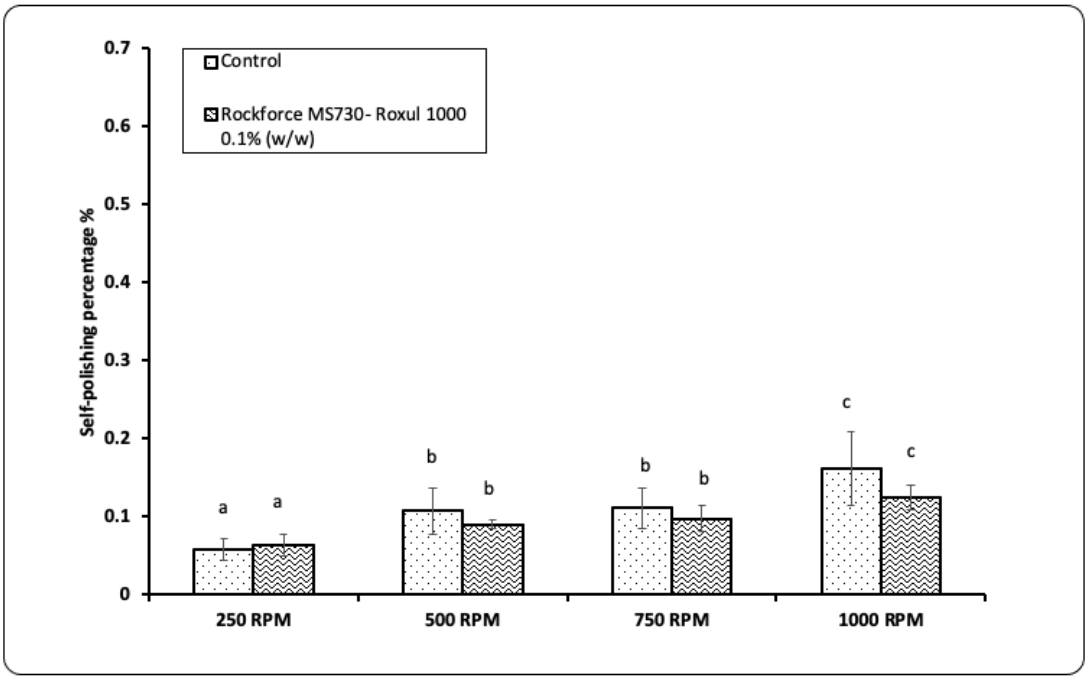


Figure 3.65 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC

Table 3.164 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.00144976	1	0.00144976	1.03145747	0.32085646
Error	0.03092192	22	0.00140554		
Total	0.03237168	23			

Table 3.165 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour

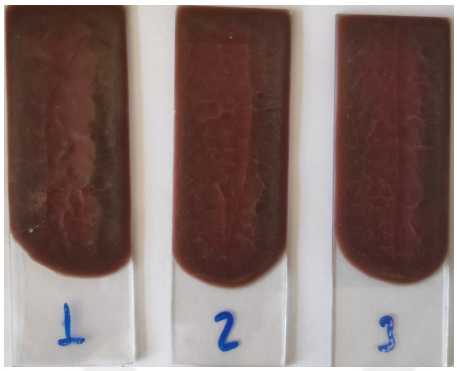
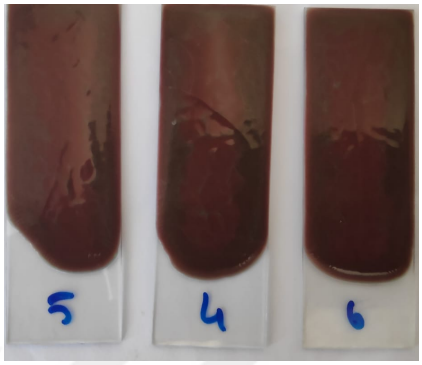
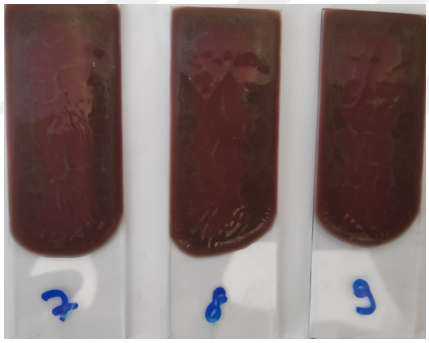
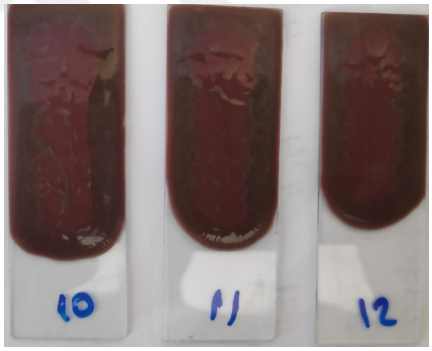
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.166 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours

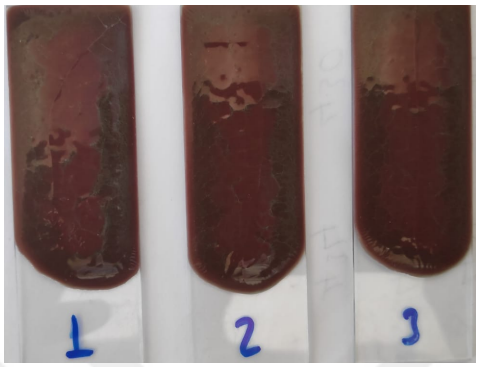
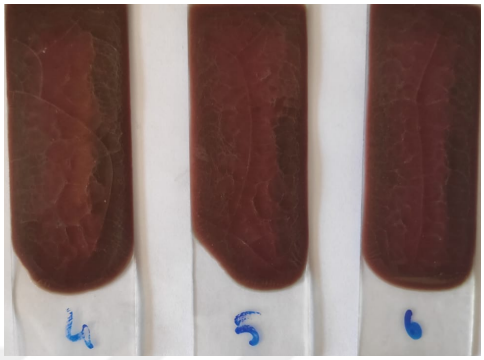
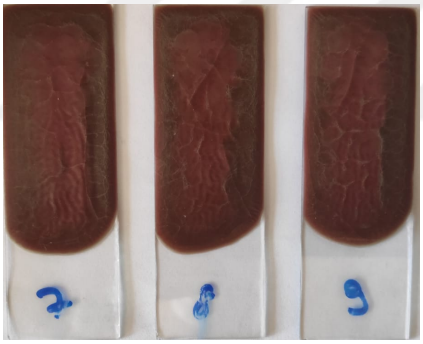
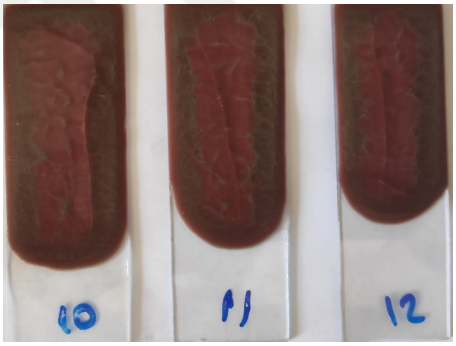
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.167 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours

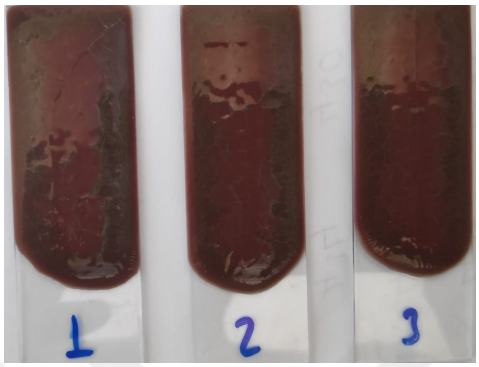
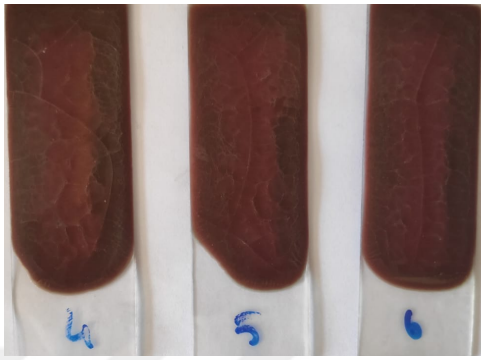
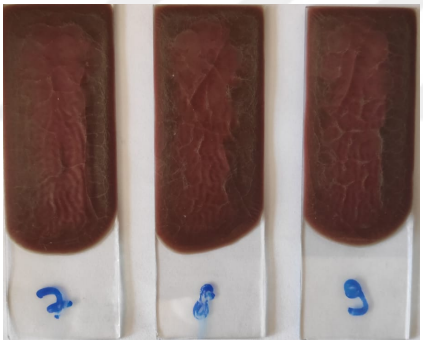
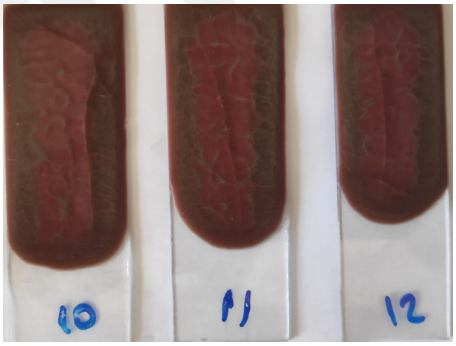
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Figure 3.66 depicts self-polishing test results of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint. The tests were done at 30 ^{o}C. The self-polishing test's one-way ANOVA analyses results are given in Table 3.168. Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for 500-1000 RPM rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500-1000 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour time period did not show any statistical differences either for 500, 750 or 1000 RPM ($p>0.05$). When Figure 3.67 is examined, a decrease in self-polishing percentage after the Rockforce MS730-Roxul 1000 fiber 0.1% (w/w) reinforcement is observed. No significant difference was observed between the control and the fiber-reinforced paints self-polishing percentages which are depicted in Table3.169. The photos of microscope slides used in the self-polishing tests which were covered by Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint can be seen from Table 3.170-Table 3.172.

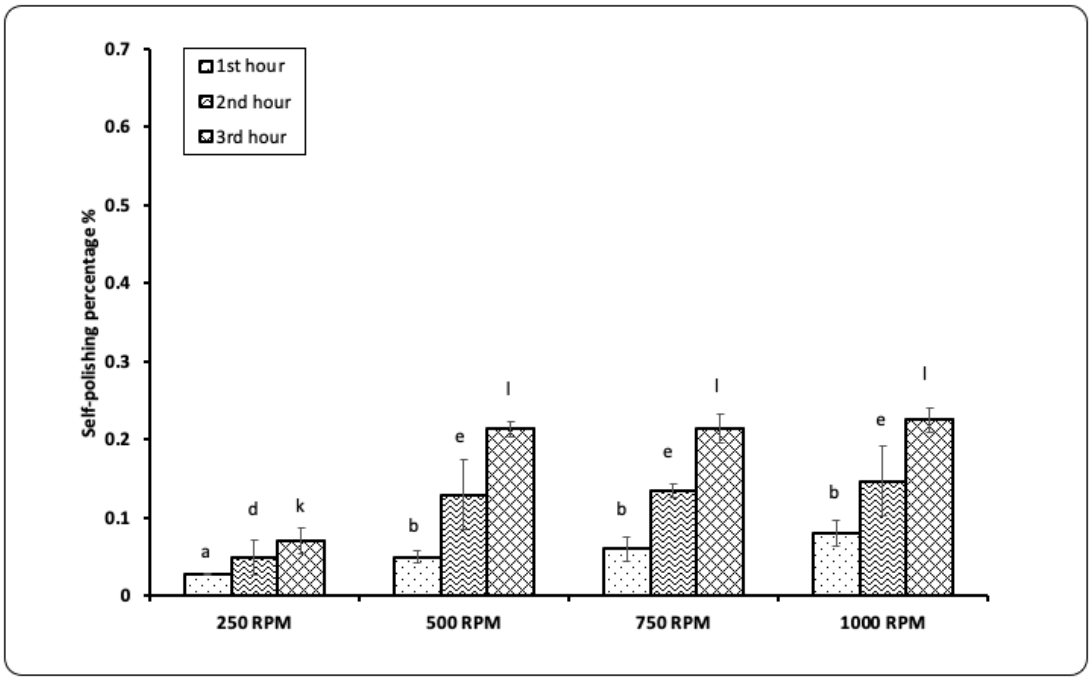


Figure 3.66 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 30 °C

Table 3.168 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.1667	11	0.01515	29.89	2.50613 e-11
Error	0.01217	24	0.00051		
Total	0.17887	35			

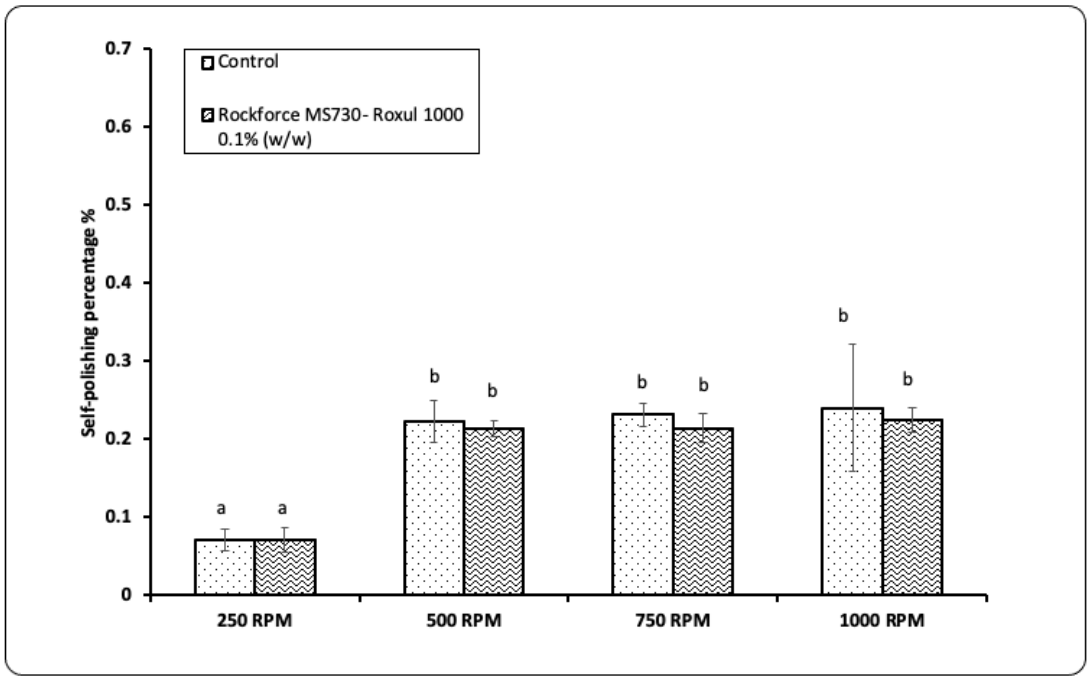


Figure 3.67 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC

Table 3.169 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.00070209	1	0.00070209	0.12918873	0.72270168
Error	0.11956172	22	0.00543462		
Total	0.12026381	23			

Table 3.170 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour

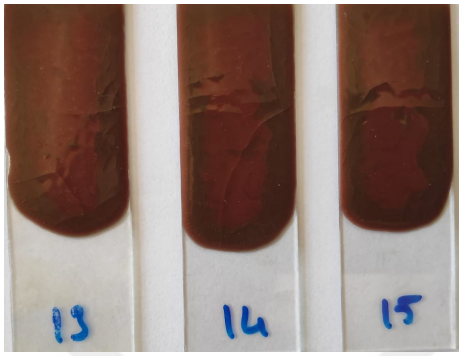
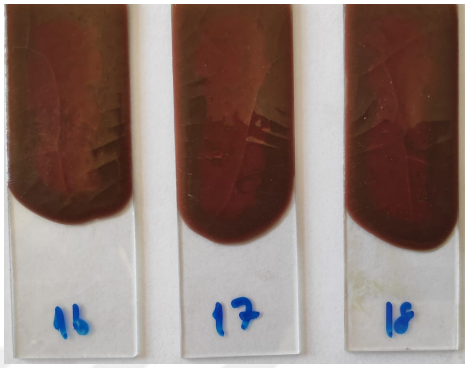
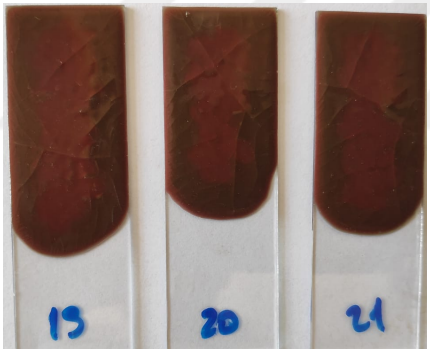
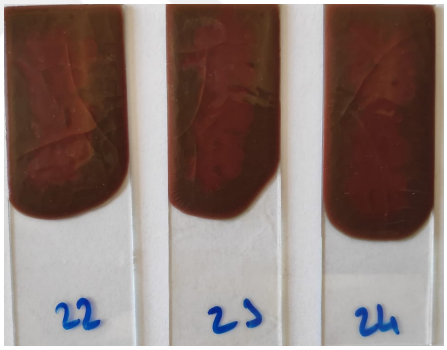
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.171 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours

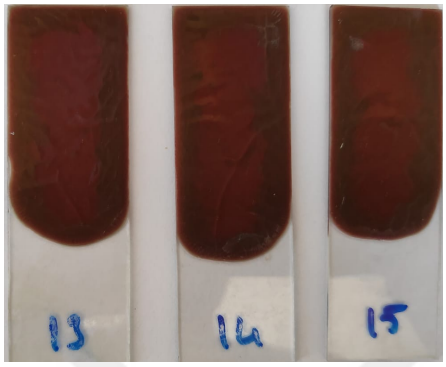
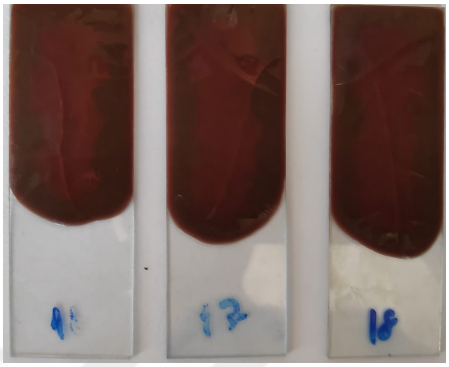
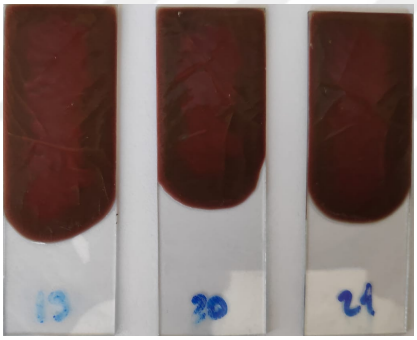
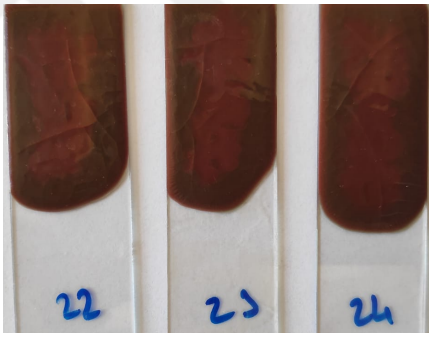
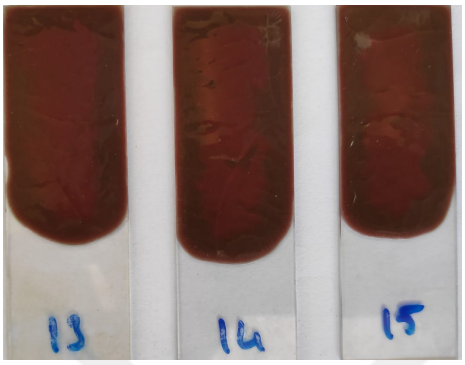
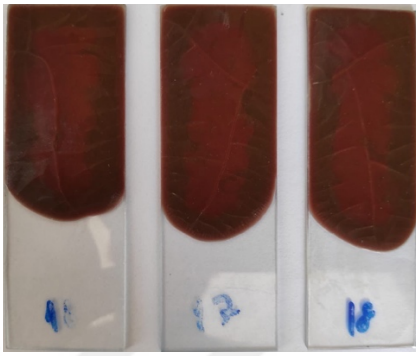
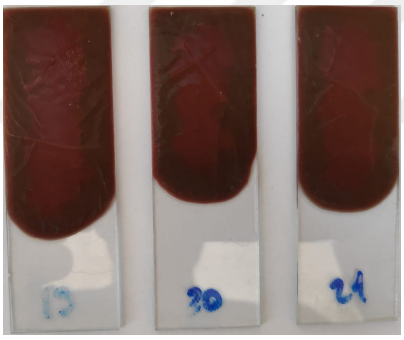
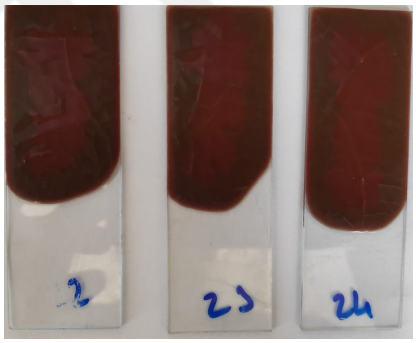
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.172 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing test of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint are shown in Figure 3.68. The tests were done at 40 °C. The self-polishing test's one-way ANOVA analyses can be seen in Table 3.173. Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500 and 750 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour time period did not show any statistical differences either for 500 or 750 RPM ($p>0.05$). It can be seen from Figure 3.69 that the fiber reinforcement decreased paints self-polishing percentage and this decrease was statistically meaningful ($p<0.05$). Table 3.174 depicts one-way ANOVA results for comparison of self-polishing percentage's means for the control and the fiber-reinforced paint. The photos of microscope slides used in the self-polishing test which was covered by Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint can be seen from Table 3.175-Table 3.177.

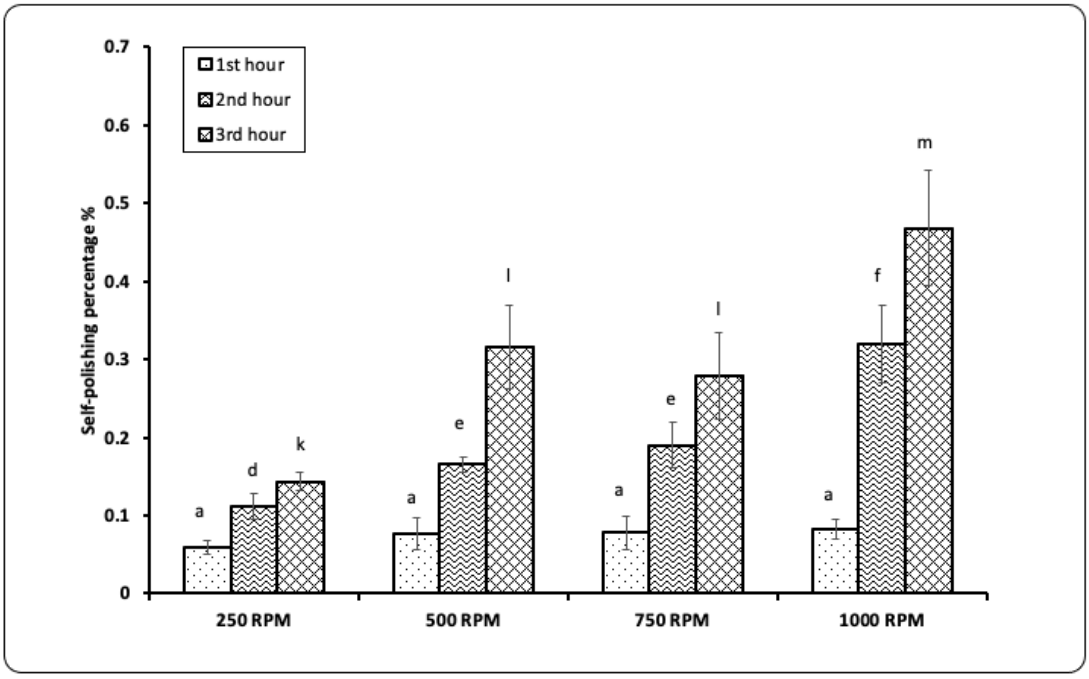


Figure 3.68 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 40 °C

Table 3.173 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.5422	11	0.04929	36.11	3.13759 e-12
Error	0.03276	24	0.00137		
Total	0.57496	35			

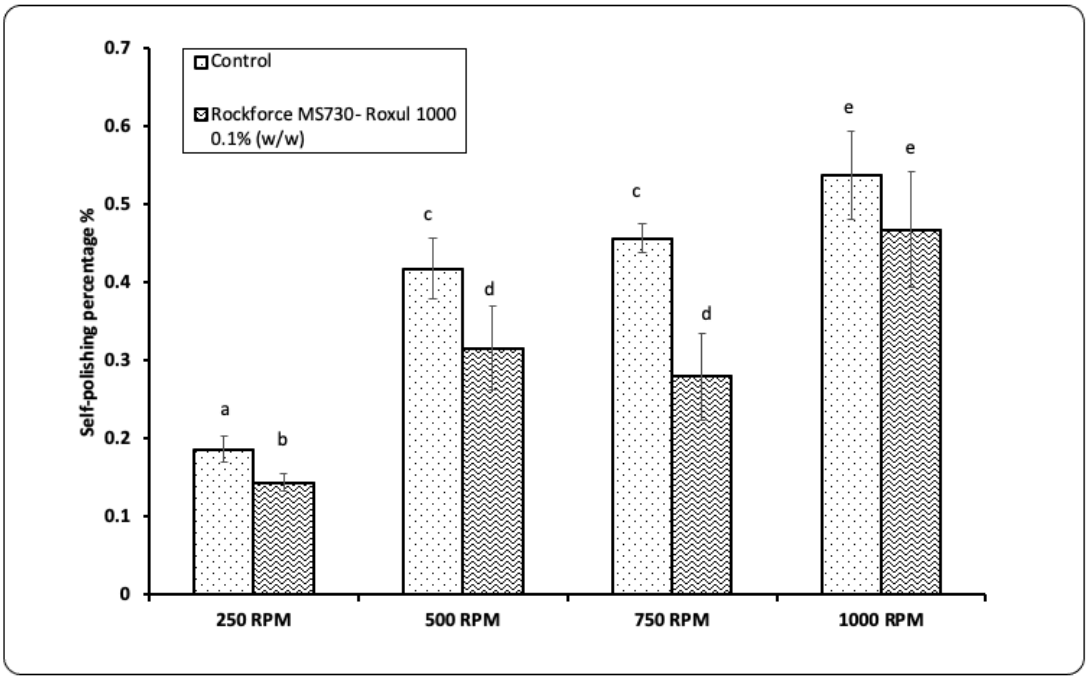


Figure 3.69 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC

Table 3.174 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.05737384	1	0.05737384	2.61958123	0.11980085
Error	0.48184205	22	0.02190191		
Total	0.53921589	23			

Table 3.175 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour

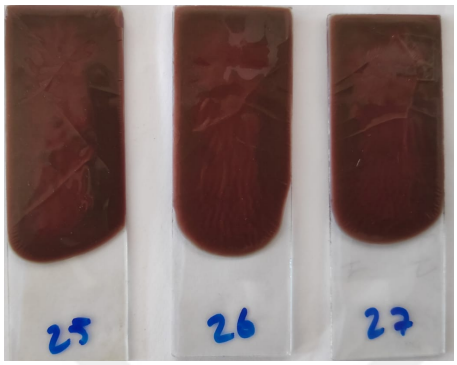
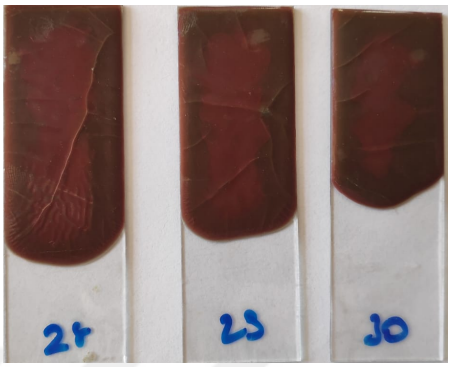
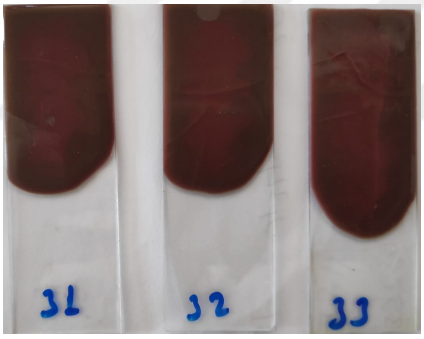
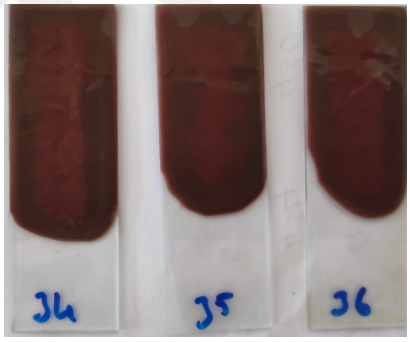
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.176 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours

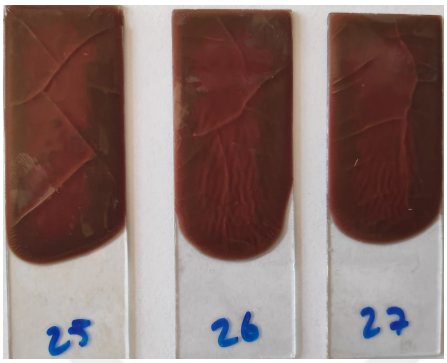
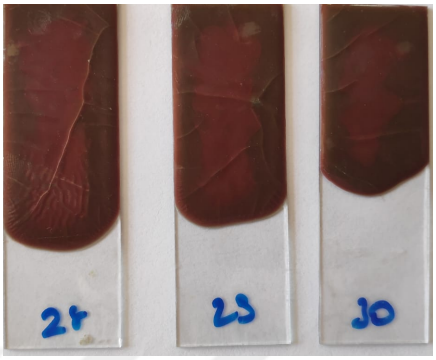
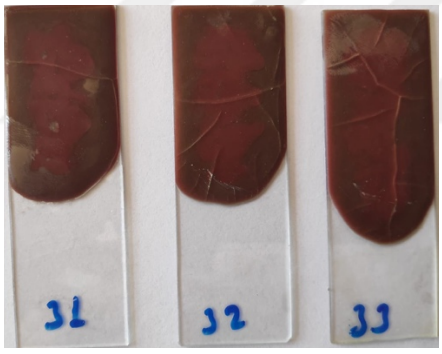
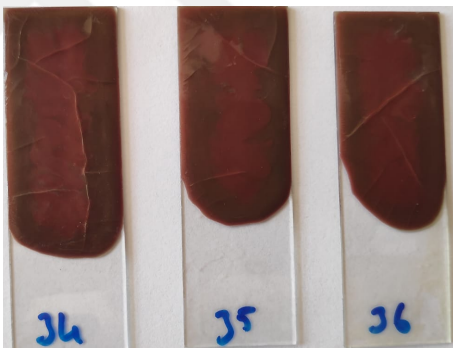
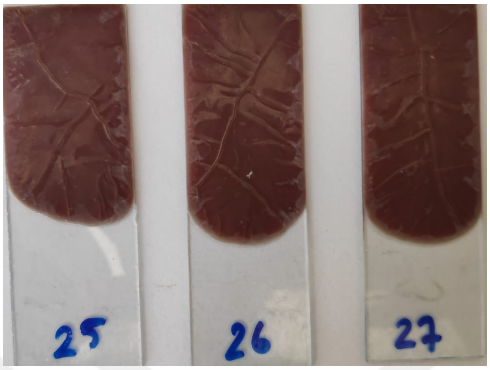
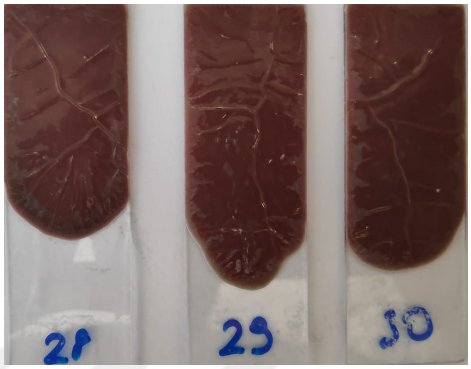
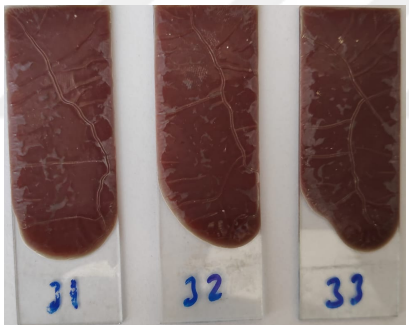
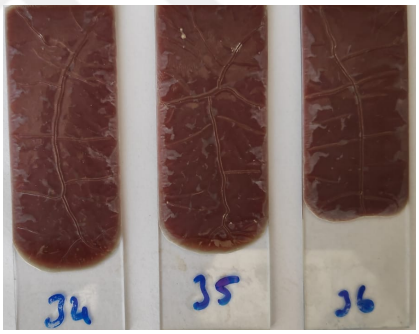
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.177 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Self-polishing test results of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint are shown in Figure 3.70. The tests were made at 20 °C. One-way ANOVA analyses related to self-polishing tests can be seen in Table 3.178. The highest self-polishing percentage was observed at 1000 RPM rotary rate for a 3-hour test period. Self-polishing percentages of tests that were done for a 1-hour period were not significantly different for 500-1000 RPM rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 250-1000 RPM rotary rates ($p>0.05$). The data obtained from tests that were done for a 3-hour time period did not show any statistical differences for 500 and 750 RPM rates ($p<0.05$). A significant decrease in the self-polishing percentage after fiber reinforcement was not observed for all rotary rates and it can be seen from Figure 3.71. One-way ANOVA analyses of self-polishing percentage's mean comparison for the control and the fiber-reinforced paint can be seen in Table 3.179. The photos of microscope slides used in the self-polishing tests which were covered Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint can be seen from Table 3.180-Table 3.182.

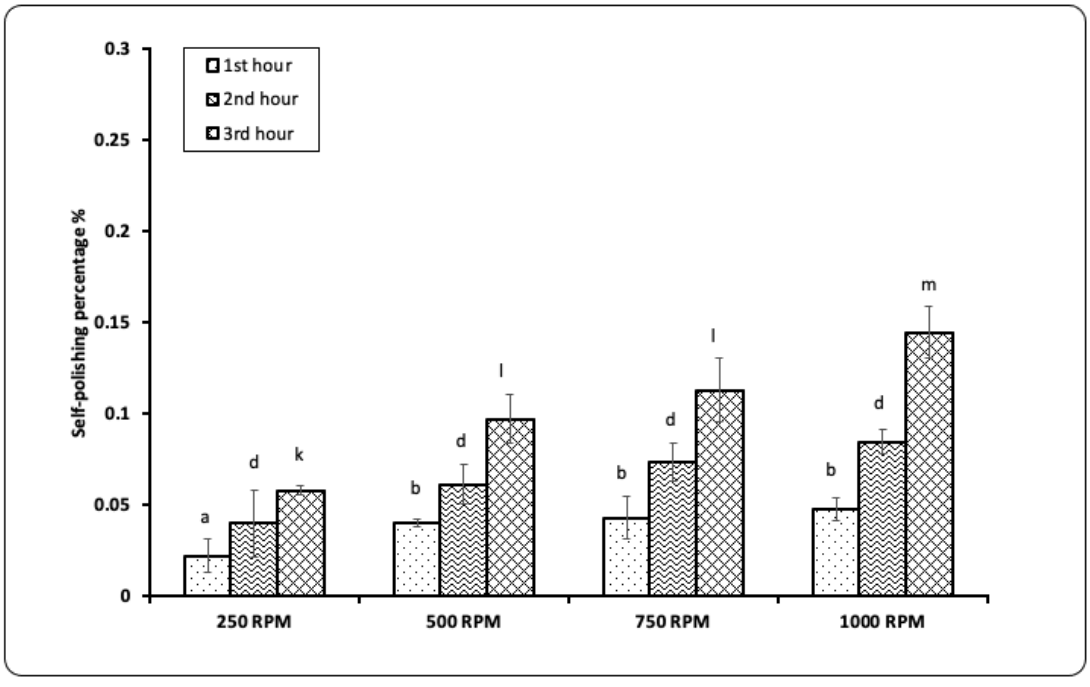


Figure 3.70 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 20 °C

Table 3.178 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing paint at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.04161	11	0.00378	29.55	2.84197 e-11
Error	0.00307	24	0.00013		
Total	0.04468	35			

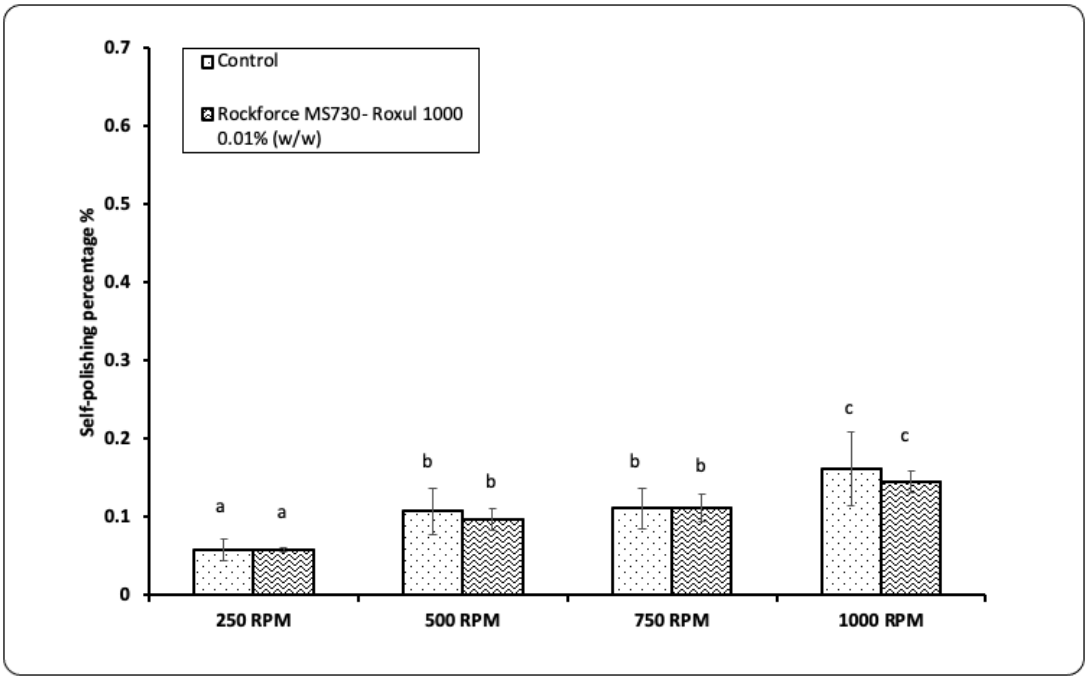


Figure 3.71 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 20 ºC

Table 3.179 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 20 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.00026372	1	0.00026372	0.15787542	0.69494889
Error	0.03675014	22	0.00167046		
Total	0.03701386	23			

Table 3.180 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 1 hour

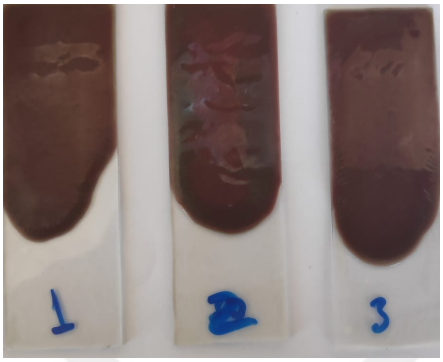
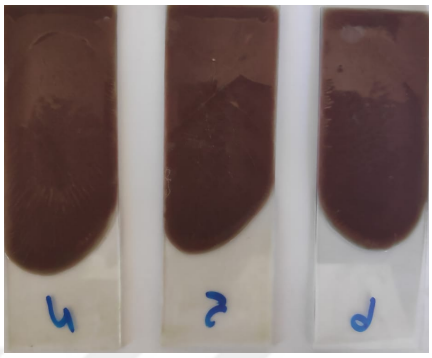
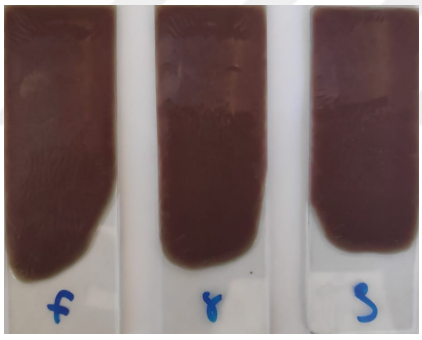
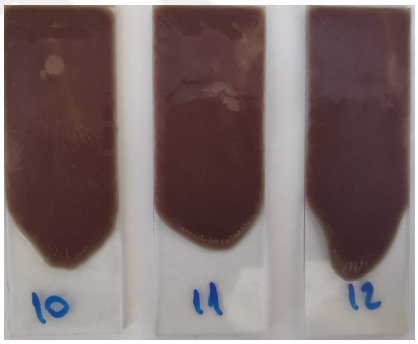
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.181 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 2 hours

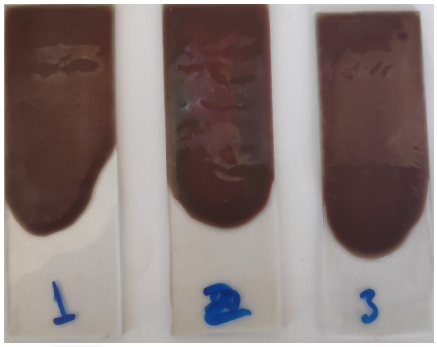
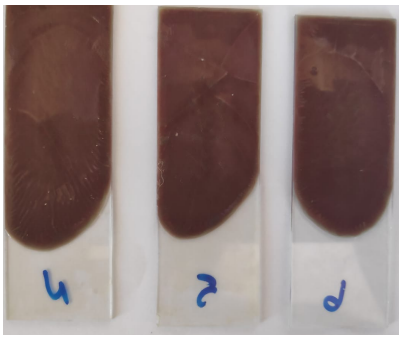
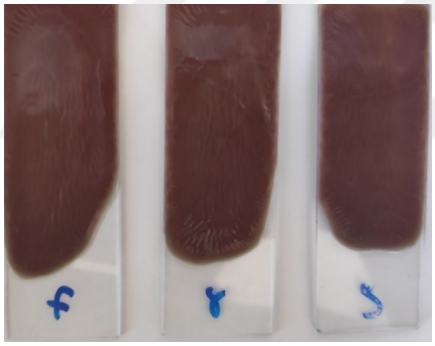
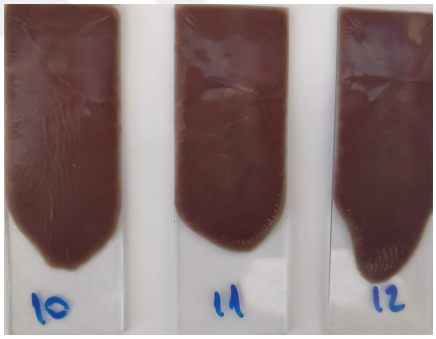
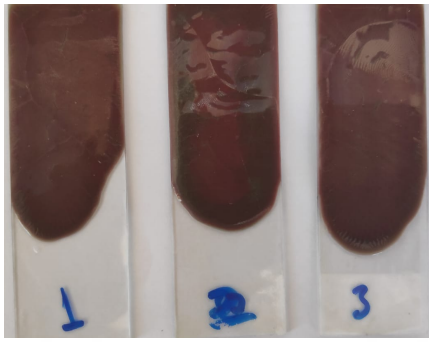
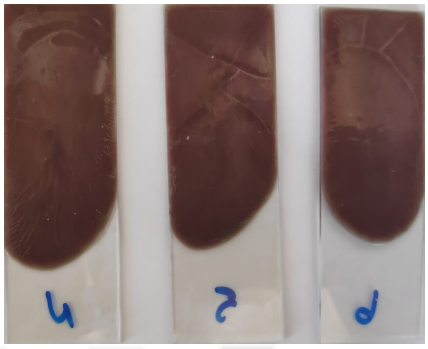
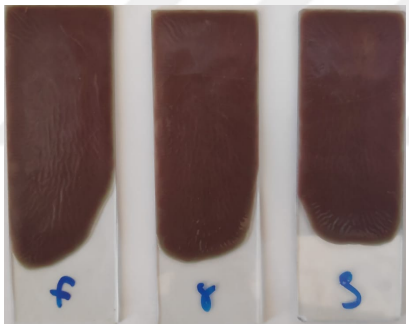
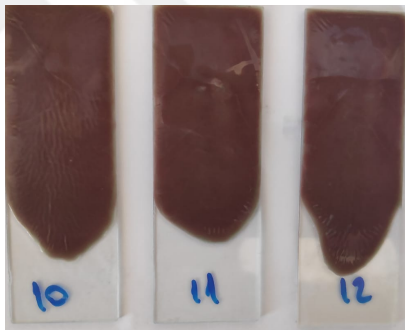
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.182 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 20 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing tests for the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint are shown in Figure 3.72. The tests were made at 30 ºC temperature. One-way ANOVA analyses results of self-polishing tests are depicted in Table 3.183. The highest self-polishing percentage was observed at 1000 RPM rotary rate for a 3-hour test period as expected. Self-polishing percentages of tests that were held for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500-1000 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour time period did not show any statistical differences either for 500, 750 or 1000 RPM ($p>0.05$). The fiber reinforcement did not affect polishing percentage significantly ($p>0.05$) after fiber reinforcement and it can be seen in Figure 3.73. One-way ANOVA analyses results are given in Table 3.184 related to the comparison of self-polishing percentage's means for the control and the fiber-reinforced paint. The photos of microscope slides used in the self-polishing tests which were covered by Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint can be seen from Table 3.185-Table 3.187.

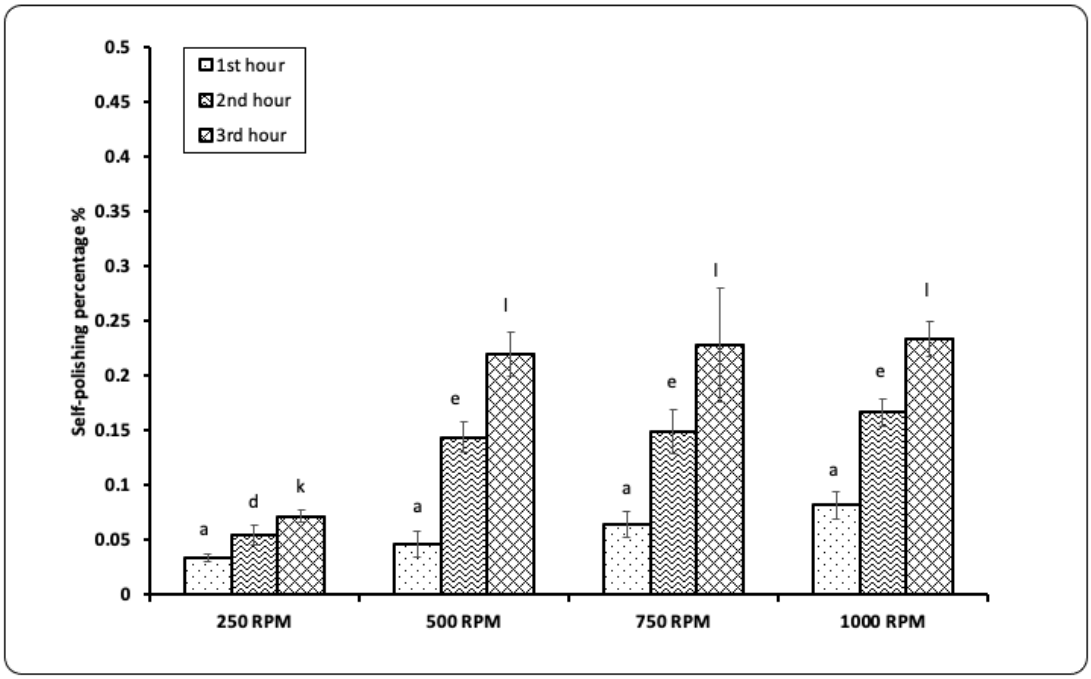


Figure 3.72 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 °C

Table 3.183 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.18661	11	0.01696	43.18	4.26484 e-13
Error	0.00943	24	0.00039		
Total	0.19604	35			

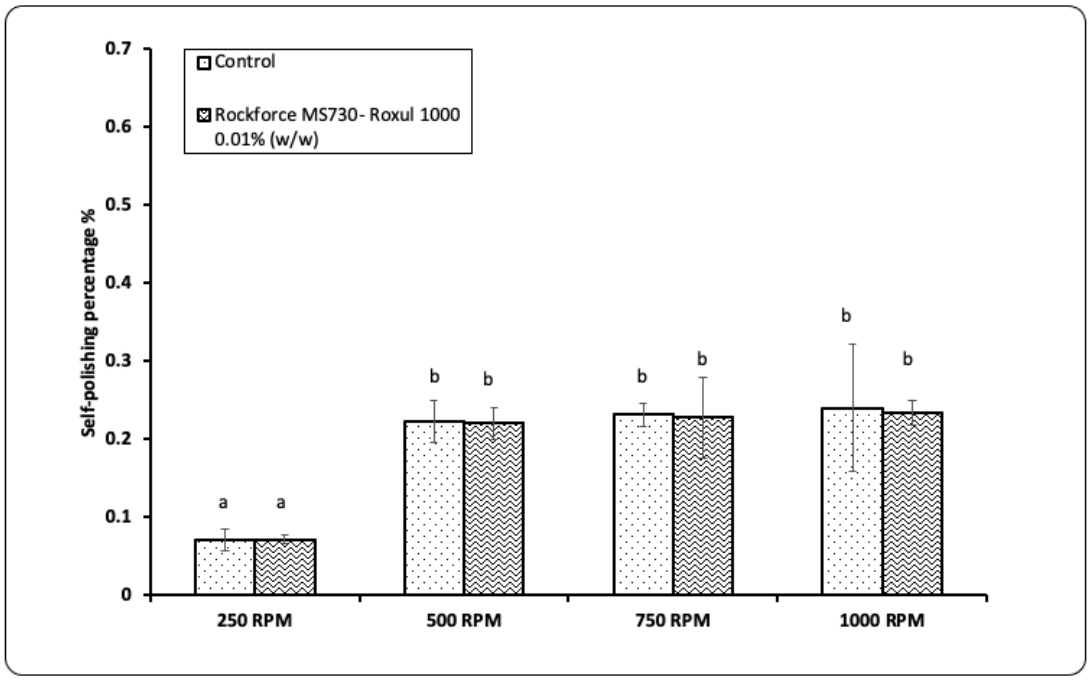


Figure 3.73 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 30 ºC

Table 3.184 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 30 ºC

Source	SS	df	MS	F	Prob>F
Columns	5.24E-05	1	5.24E-05	0.00883058	0.92598265
Error	0.13043576	22	0.0059289		
Total	0.13048812	23			

Table 3.185 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 1 hour

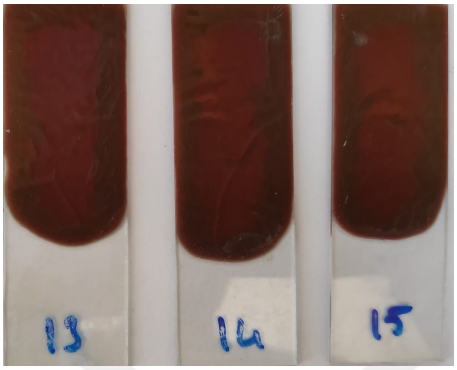
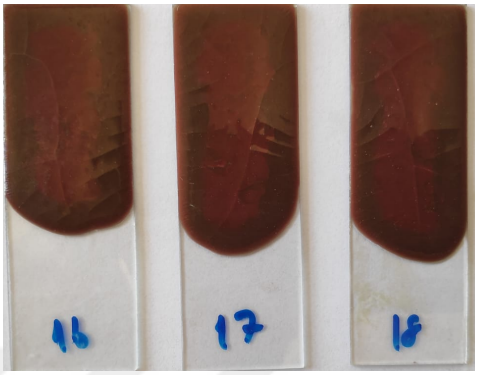
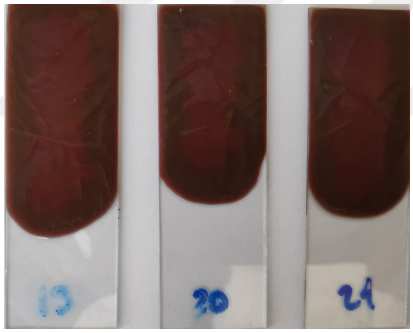
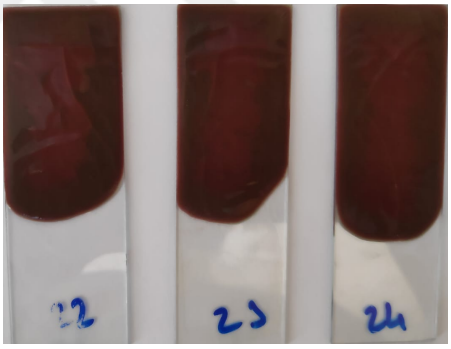
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.186 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 2 hours

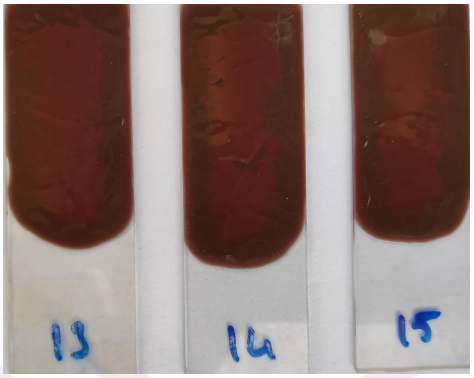
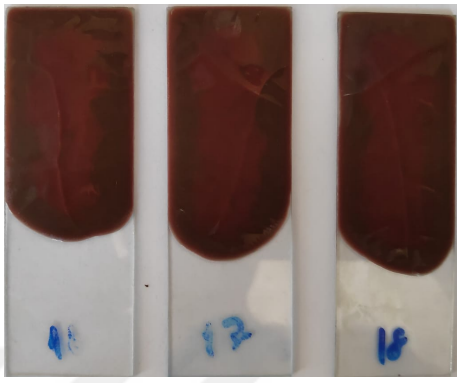
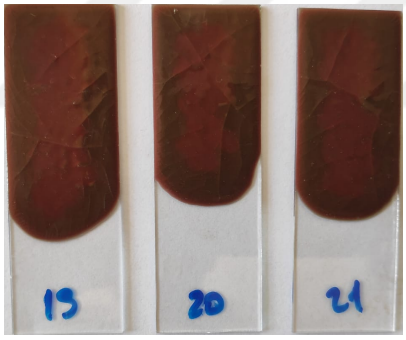
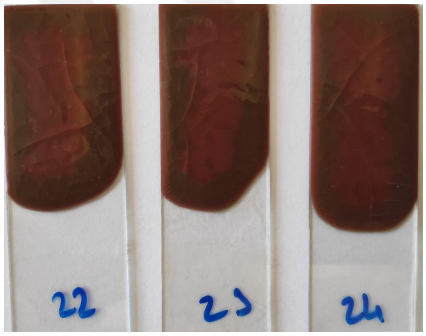
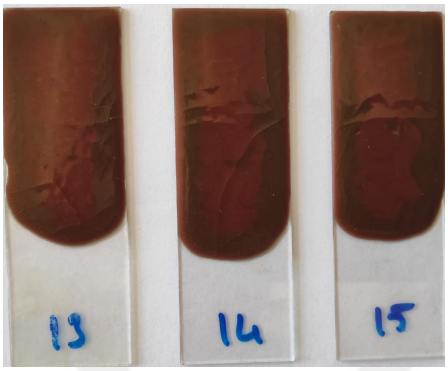
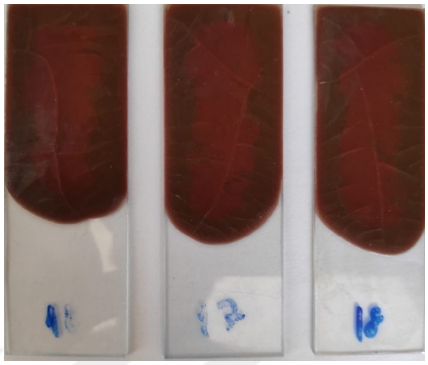
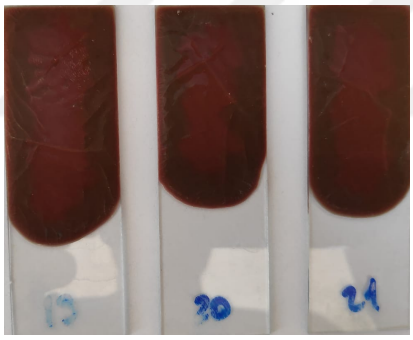
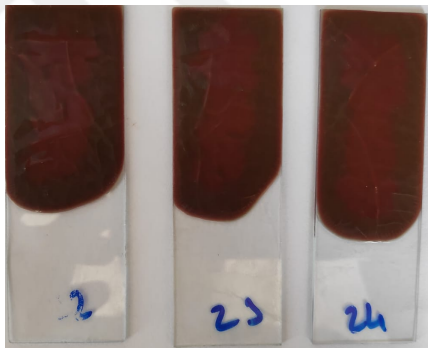
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.187 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 30 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

The results of the self-polishing test of the Rockforce MS730-Roxul 1000 fiber 0.01% (w/w) reinforced self-polishing antifouling paint are shown in Figure 3.74. The tests were made at 40 °C. One-way ANOVA analyses results of self-polishing tests can be seen in Table 3.188. The highest self-polishing percentage was observed when the test was done at 1000 RPM rotary rate for a 3-hour period. Self-polishing percentages of tests that were made for a 1-hour period were not significantly different for all rotary rates ($p>0.05$). The results of the test that were done for 2 hours did not show any significant differences between 500 and 750 RPM rotary rates ($p>0.05$). Data obtained from tests that were done for a 3-hour time period did not show any statistical differences for 500, 750 or 1000 RPM ($p>0.05$). No significant decrease was observed after the fiber reinforcement, and it can be seen from Figure 3.75. One-way ANOVA analyses for self-polishing percentages mean comparison between the control and the fiber-reinforced paint can be seen in Table 3.189. The photos of microscope slides used in the self-polishing tests which were covered by Rockforce MS730-Roxul 1000 fiber 0.01% (w/w) reinforced self-polishing antifouling paint can be seen from Table 3.190-Table 3.192.

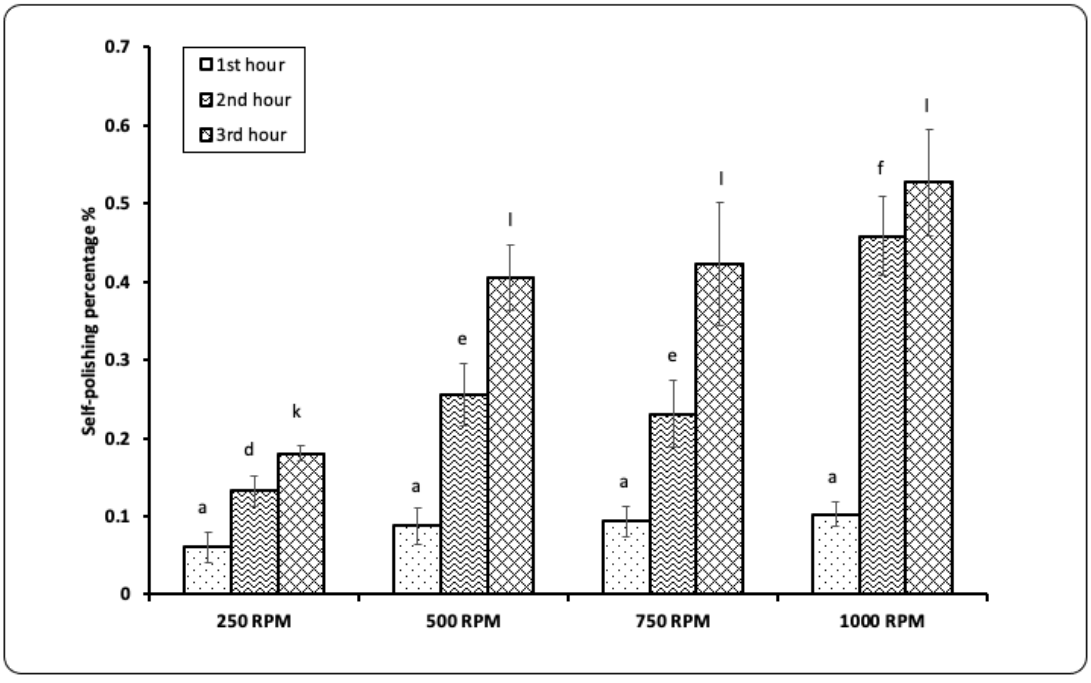


Figure 3.74 The effect of rotary rate and time on the self-polishing percentage of Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 °C

Table 3.188 One-way ANOVA results related to the effects of rotary time and rate on the self-polishing percentages of Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.9041	11	0.08219	47.99	1.30049 e-13
Error	0.04111	24	0.00171		
Total	0.94521	35			

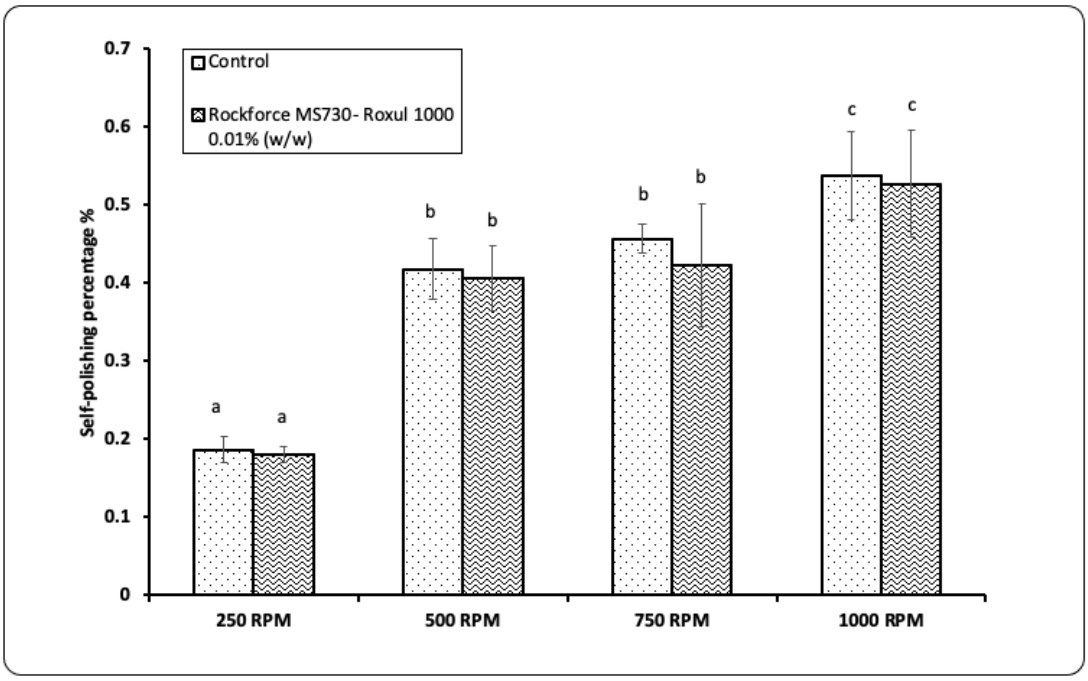


Figure 3.75 The comparison of self-polishing percentages between control and Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint for 3-hour test period at 40 ºC

Table 3.189 One-way ANOVA results related to mean comparison of control and Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paints self-polishing percentages for 3-hour test period at 40 ºC

Source	SS	df	MS	F	Prob>F
Columns	0.00149214	1	0.00149214	0.0636385	0.80317678
Error	0.51583693	22	0.02344713		
Total	0.51732907	23			

Table 3.190 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 1 hour

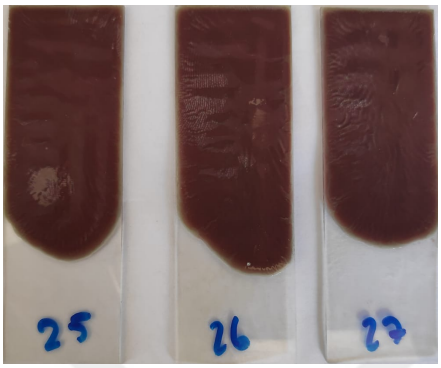
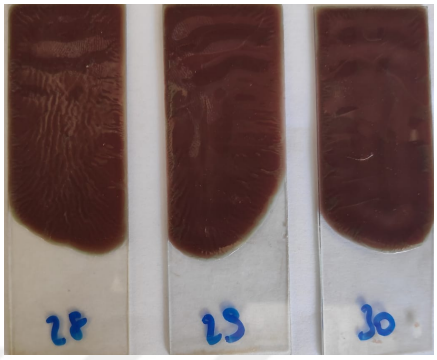
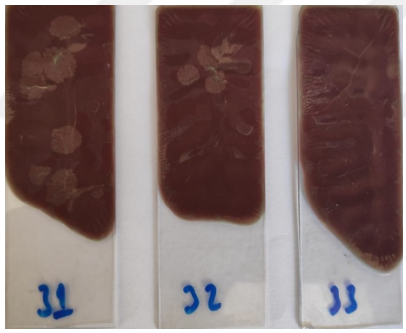
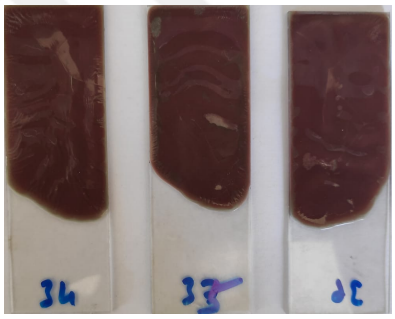
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.191 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 2 hours

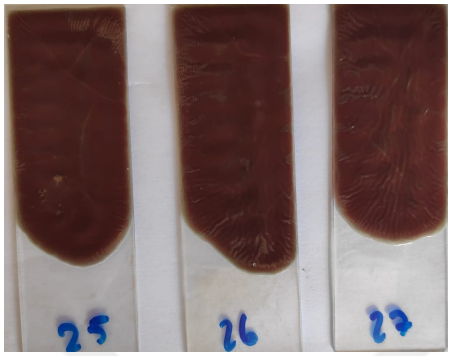
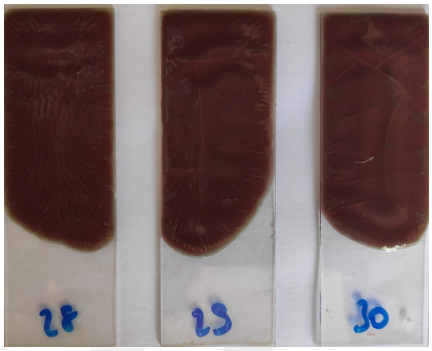
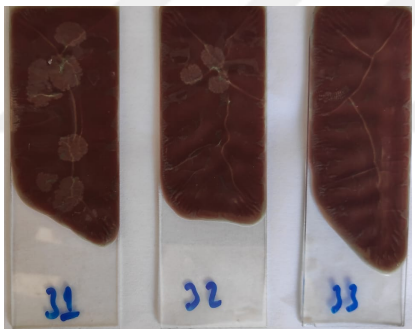
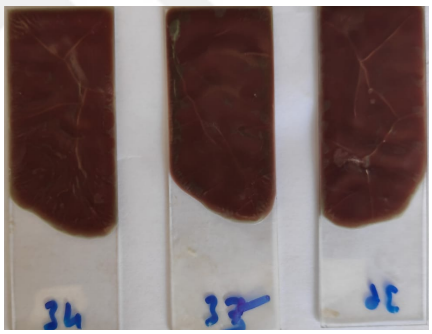
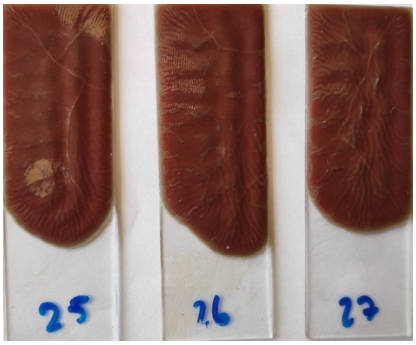
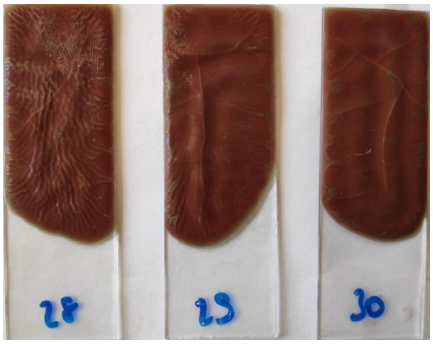
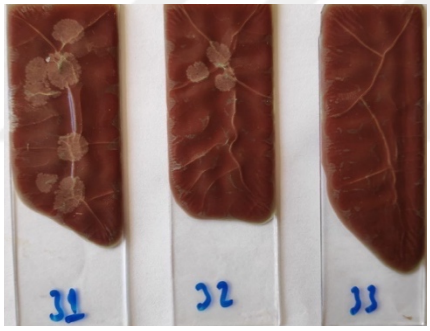
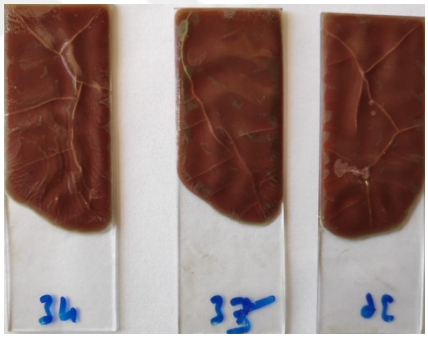
 250 RPM	 500 RPM
 750 RPM	 1000 RPM

Table 3.192 The photos of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) self-polishing antifouling paint covered microscope slides at 40 ºC for 3 hours

 250 RPM	 500 RPM
 750 RPM	 1000 RPM

3.2 Results of the Eco-toxicity Test Using *Artemia salina*

Ecotoxicity tests were made to gain information about toxicity levels of biocide econea (tralopyril) used in self-polishing antifouling paints formulation. Figure 3.76 shows the results of the toxicity tests. DMSO and seawater solutions were used as a control to compare the effect of the biocide solution. When the data obtained as the result of the experiment were examined, it was determined that econea solution was lethal for *Artemia salina* larvae at all experimental concentrations ranged from 0.625-20 ppm. A correlation was observed between increasing econea concentrations and *A.salina* mortality rate. The increase in concentration caused *A.salina* larvae to die faster. It was observed that the exposure to econea solution resulted in 90% mortality for all *A.salina* larvae at 20 - 2.5 ppm concentration range at 30 min period. LC_{50} value for econea was found to be 2.72 ppm. The 240 min of 0.625 ppm econea solution exposure resulted in mortality for all living *A.salina* larvae. When the data obtained as the result of the experiment were examined, it was determined that the econea solution was lethal to the model organism even at a low concentration such as 0.625 ppm.

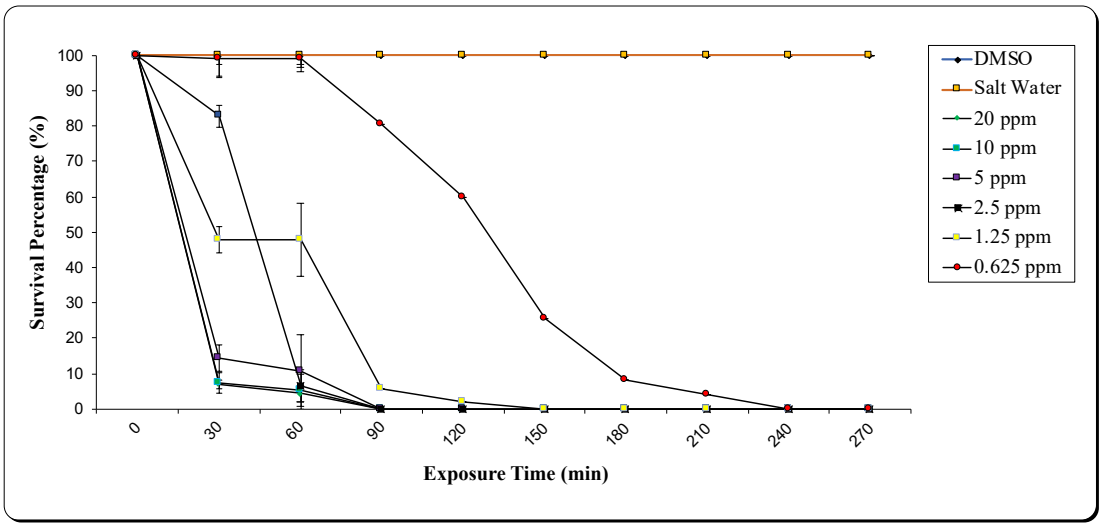


Figure 3.76 Results of the econea toxicity tests using model organism *Artemia salina*

3.3 Econea Analysis Using RP-HPLC

RP-HPLC analysis was performed to examine purity of econea. For this purpose, a 5 ppm econea solution was prepared using ACN. When the HPLC chromatogram of the prepared econea solution shown in Figure 3.77 is examined, it is seen that there is no impurity in the econea solution. The prepared econea solution was then heated to a high temperature of 88 °C. After the econea solution was heated, samples were taken at 30, 60, 90, 120 and 150 minutes and HPLC analysis was performed. The formation of impurities was investigated by injecting 20 µl of econea solution into HPLC at each analysis time. HPLC chromatograms of the samples taken with a time interval of thirty minutes are shown in Figure 3.78. Color codes for samples taken from different time interval are as follow: Sampled at Black: 30 min; Red: 60 min; Blue: 90 min; Pink: 120 min; Turquoise: 150 min. When the chromatogram shown in Figure 3.78 was examined, it was determined that there was no degradation product. A detailed HPLC chromatogram can be seen in Figure 3.79.

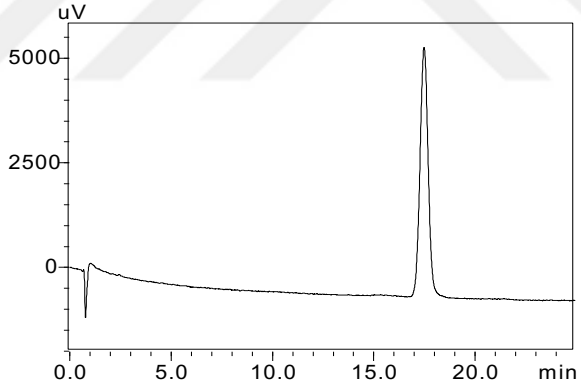


Figure 3.77 HPLC chromatogram of 5 ppm econea

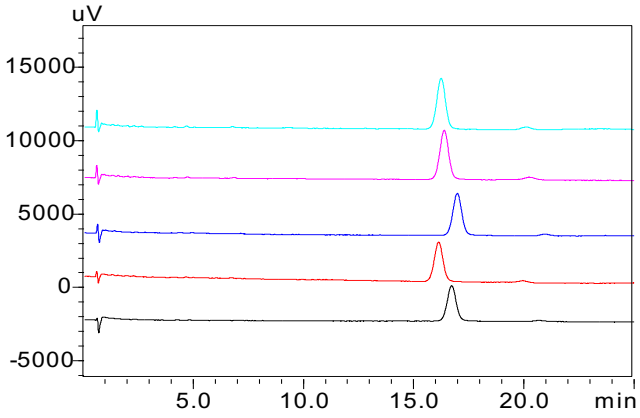


Figure 3.78 Time-dependent comparison HPLC chromatogram of 5 ppm econea at 88°C water

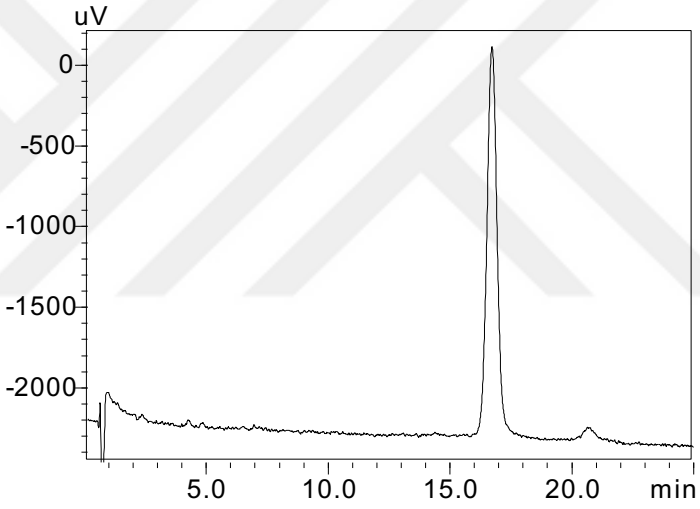


Figure 3.79 Detailed HPLC chromatogram of econea at 88°C

3.4 Results of Direct Impact and Cross Cut Tests

The mechanical behaviors of fiber-reinforced and fiber-free antifouling paints were investigated by direct impact and crosscut tests. The paints prepared for this purpose were applied to the metal plates and waited for them to dry for 5 days. Tests were carried out on the surface of the plate after it was completely dry. Control paint-covered metallic plate is depicted in Table 3.193 at plate number one. The surface of the plate has been deformed after direct impact and crosscut test. The number two metal plate shown in Table 3.193 shows the plate coated with the linen fiber reinforced 1% (w/w) antifouling paint. When the plate surface was examined, it was observed that there was a paint removal on the surface after the direct impact test. Looking at the results of the crosscut tests, it was seen that the fiber reinforcement increased the mechanical behavior of the paint. In Table 3.193, the number three plate shows the direct impact and crosscut tests result of the plate coated with the linen fiber reinforced 0.1% (w/w) paint. When the plate surface is analyzed, it can be seen that there is no major deformation on the paint surface. The number four plate shown in Table 3.193 shows the mechanical test results of the metal plate covered with the linen fiber reinforced 0.01% (w/w)paint. When the plate surface is examined, it is seen that there are breaks in the paint structure. Looking at the crosscut test results, it is seen that the paint surface is deformed. Plate five, shown in Table 3.193, is coated with the jute fiber reinforced 1% (w/w) paint. When the direct impact and crosscut test results of this plate are compared with the control plate, it can be seen that the surface is less deformed. The plate surface shown in Table 3.193 at number six was coated with the paint reinforced with 0.1% (w/w) jute fiber. When the mechanical behavior of this paint is compared with the control plate, it is seen that there is an increase in the mechanical behavior of the paint. The surface of the number seven plate shown in Table 3.193 is covered with the paint reinforced by 0.01% (w/w) jute fiber. When the mechanical behavior of this paint as the result of direct impact and crosscut tests was examined, it was observed that the paint surface ruptures in small amounts. The surface of the plate in Table 3.193, shown with the number eight, is coated with the Rockforce MS730-Roxul 1000 fiber reinforced 1% (w/w) paint. It is seen that there is an increase in the mechanical behavior of this paint compared to the control group. The plate,

which surface is coated with paint reinforced with the 0.1% (w/w) Rockforce MS730-Roxul 1000, is shown in Table 3.193 with number nine, it is seen that the surface is not deformed much compared to the control plate as the result of direct impact and crosscut tests. The surface of the plate with number ten in Table 3.193 is covered with the paint reinforced by Rockforce MS730-Roxul 1000 fiber 0.01% (w/w). It has been observed that there is an increase in the mechanical behavior of this paint compared to the control paint. The surface of the plate with number eleven in Table 3.193 is covered with the paint reinforced with Rockforce MS675-Roxul 1000 fiber 1% (w/w). The increase in the mechanical behavior of the paint is seen via the non-deformation of the paint surface. The plate surface, which is a twelve numbered plate and shown in Table 3.193, is coated with the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) antifouling paint. Fiber reinforcement caused an increase in the mechanical behavior of the paint. When the mechanical behavior of the Rockforce MS730-Roxul 1000 fiber reinforced 0.01% (w/w) paint on the surface of the thirteen numbered plate in Table 3.193 is examined, it is seen that this paint has better mechanical behavior compared to the control paint.

Table 3.193 Results of the direct impact and crosscut test

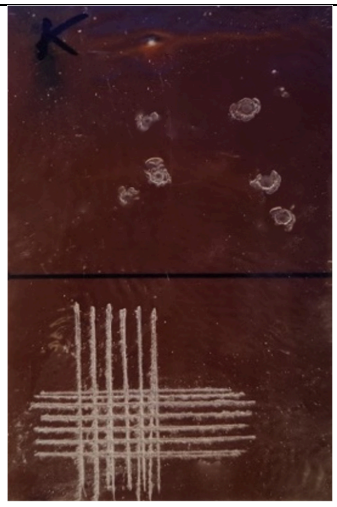
No	Before	After
1		

Table 3.193 Continuous

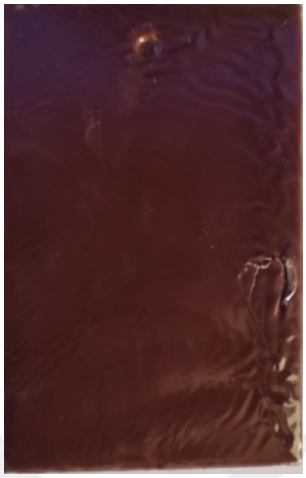
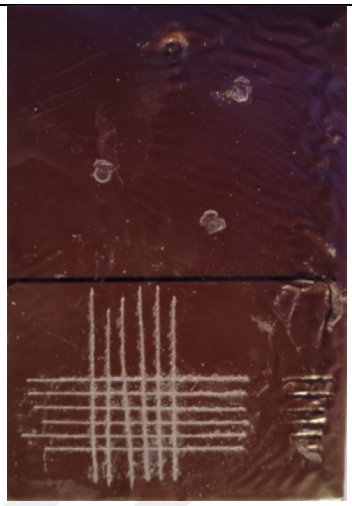
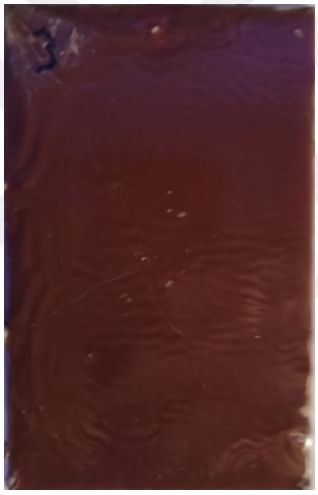
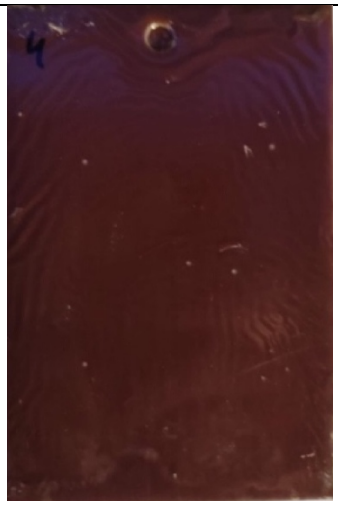
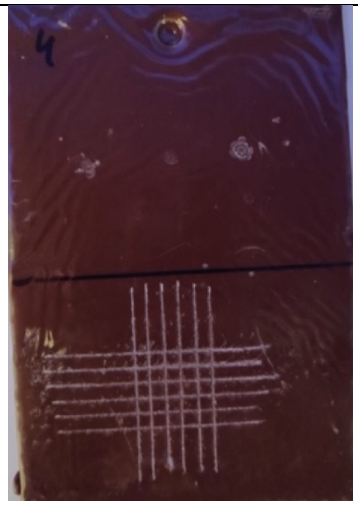
No	Before	After
2		
3		
4		

Table 3.193 Continuous

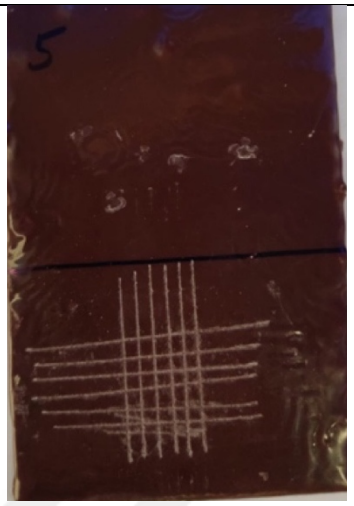
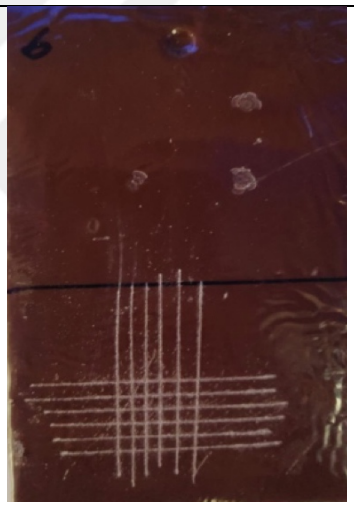
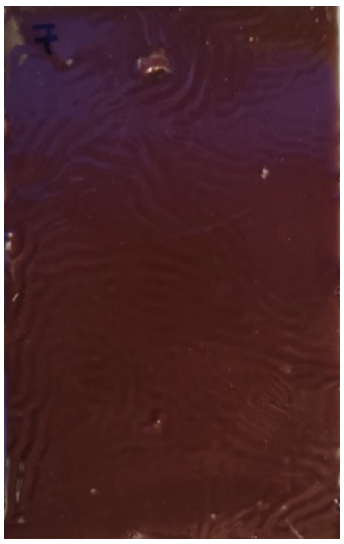
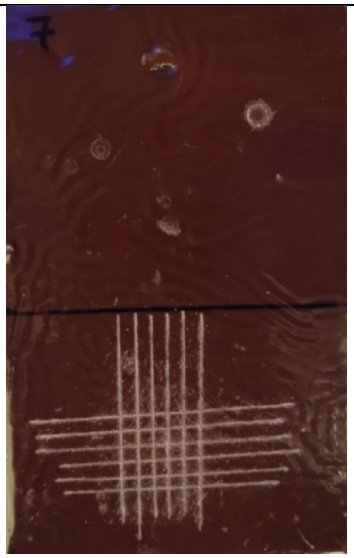
No	Before	After
5		
6		
7		

Table 3.193 Continuous

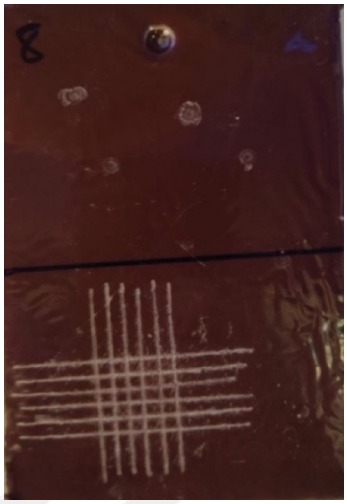
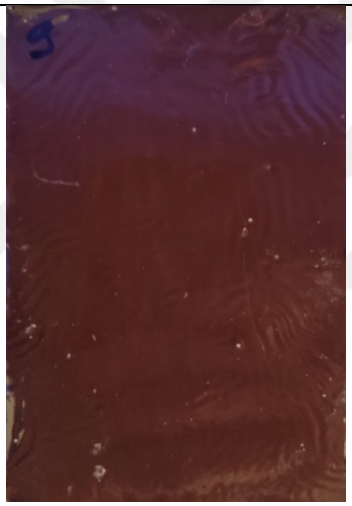
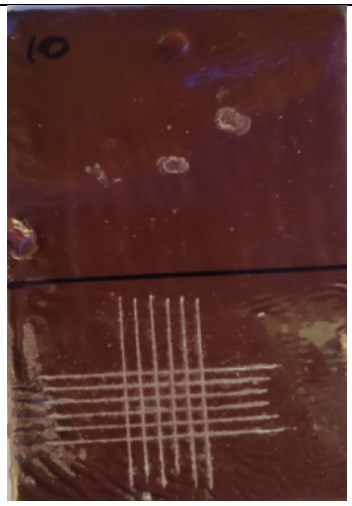
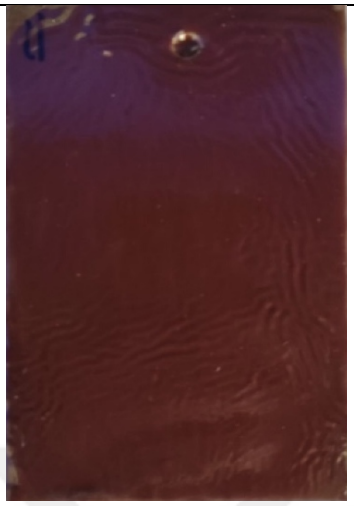
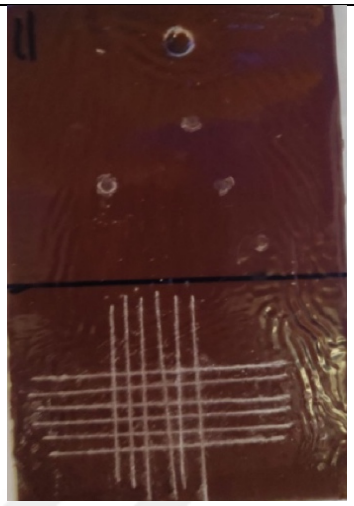
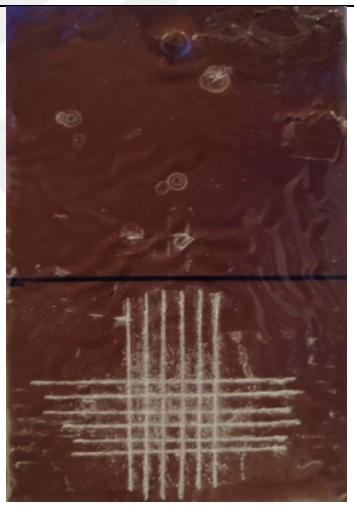
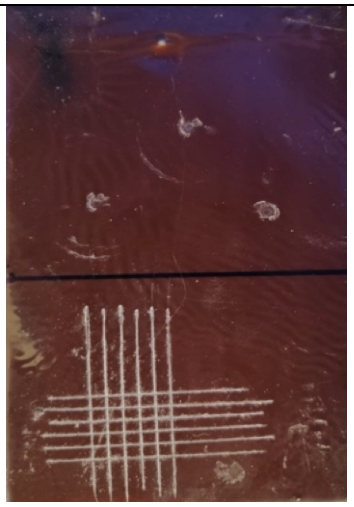
No	Before	After
8		
9		
10		

Table 3.193 Continuous

No	Before	After
11		
12		
13		

3.5 The Field Test Results

The field trial was conducted to examine the antifouling performances of fiber-reinforced self-polishing antifouling paints. For this purpose, the antifouling performances of the prepared paints were evaluated by preparing paints reinforced by linen, jute, Rockforce MS675-Roxul 1000 and Rockforce MS730-Roxul 1000 fibers at 1%, 0.1% and 0.01% ratios. Antifouling paints that do not contain any fiber reinforcement and antifouling paints that do not contain econea were also prepared for control purposes. The prepared paints were applied to the plates and their antifouling effect was examined over one month. In addition, the performance of the antifouling was evaluated by preparing a plate containing only anticorrosive primer and not any antifouling paint. Table 3.194 represents photos of the metallic plate that is only covered by anticorrosive primer. As can be seen from the table surface of the metallic plate was heavily fouled by *Hydroides elegans*. Macroalgae *Ulva lactuca* also can be found on the surface. When we consider fouling criteria, this surface can be scored as level 5. In Table 3.195, a metallic plate coated with anticorrosive primer and antifouling paint, which does not contain fiber and booster biocide econea in formulation, is shown. When the plate was examined, it was observed that no macrofouling was found on the surface. The surface is only covered with a microfilm layer. This surface appears to be in the level 3 fouling category. Table 3.196 shows the field test result of the plate covered with antifouling paint reinforced with any fiber. When surface the of this plate was examined, it was seen that the surface was not covered by any macrofouling organisms. It can be said that surfaces fouling score is 2. Table 3.197 depicts the results of the field test for the plate that was coated by the 1% (w/w) linen fiber reinforced antifouling paint. As can be seen from the plate surface, some of the paint has been peeled off from the plate surface. No macrofouling organisms were found on the surface of the plate. The score of the plate based on fouling criteria is 2. When Table 3.198 was examined, that the metallic plates coated by 0.1% (w/w) linen fiber reinforced antifouling paint before and after field trials can be seen. The surface of the plate was protected from biofouling. Only a microfilm layer occurred on the surface of the plate. The score of the plate shown in Table 3.198 is level 2. The field test result of metallic plate coated by 0.01% (w/w) linen fiber-

reinforced antifouling paint can be seen from Table 3.199. When the surface of the plate was analyzed, no hard fouling was found on the surface. The surface only has a microfilm layer on it. By considering fouling criteria we can say that score of this plate is 2. Table 3.200 shows the results of field tests for the plate that was coated by the jute fiber reinforced 1% (w/w) antifouling paint. The surface was protected from biofouling thanks to antifouling paint. When the surface of the plate was examined, it was seen that there were cracks on the surface. If we evaluate this plate according to the fouling criteria, score 2 fouling is seen on the surface. Field trial photos of the metallic plate coated with the antifouling paint reinforced with 0.1 (w/w) jute fiber are shown in Table 3.201. When the surface of this plate was examined, it was seen that the surface was protected against biofouling. Score of the plate is level 2 based on the fouling criteria. Table 3.202 depicts field test results of the plate covered with the antifouling paint reinforced 0.01% (w/w) jute in its structure. When the surface of this plate was analyzed, it can observe that only a microfilm layer is formed on the surface. In the light of these data, it can be said score off the biofouling is level 2. The results of the field trials for metallic plate coated by the antifouling paint which was reinforced by Rockforce MS730-Roxul 1000 fiber 1% (w/w) can be seen from Table 3.203. As can be seen from photos of the metallic plate, no macrofouling organisms attached to the surface. The scoring of the fouling for the metallic plate is level 2. Table 3.204 represents the field test result of the metallic plate that was coated by the Rockforce MS730-Roxul 1000 fiber reinforced 0.1% (w/w) antifouling paint. No hard fouling was observed on the surface of the plate. By considering the scoring of fouling criteria scoring of this palate is 2. The surface of the metallic plate which was coated by 0.01% (w/w) Rockforce MS730-Roxul 1000 reinforced antifouling paint examined which is shown in Table 3.205 we can see the microfilm layer and formation of macro fouling on the surface of the plate. The score of this plate is level 2. Table 3.206 depicts the field test results of the plate that was coated by Rockforce MS675-Roxul 1000 fiber reinforced 1% (w/w) antifouling paint. As can be seen from photos of the metallic plates the prepared antifouling paint protected the surface from biofouling. The score of this plate is 2. From Table 3.207 the results of the field test for metallic plate coated by Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) reinforced antifouling paint can be seen. No significant biofouling can be seen from photos of the metallic plate. The

score of this plate based on fouling criteria is 2. Table 3.208 shows photos of the plate that was coated by the 0.01 % (w/w) Rockforce MS675-Roxul 1000 fiber-reinforced antifouling paint before and after field trials. No macrofouling was observed on the surface of the plate. The surface has a microfilm layer on it. The score of the plate is 2. Evaluation of fouling levels of the metallic plates used in the field test can be seen in Table 3.209.

Table 3.194 The metallic plate covered by only anticorrosive primer before and after immersion to sea

Before front	After front
Before back	After back

Table 3.195 The metallic plate covered by booster biocide (econea) and fiber free antifouling paint before and after immersion to sea

Before front	After front
Before back	After back

Table 3.196 The metallic plate covered by fiber free antifouling paint before and after immersion to sea

Before Front	After front
Before back	After back

Table 3.197 The metallic plate covered by antifouling paint containing linen fiber 1% (w/w) before and after immersion to sea

Before Front	After front
Before back	After back

Table 3.198 The metallic plate covered by antifouling paint containing linen fiber 0.1% (w/w) before and after immersion to sea

Before front	After front
Before back	After back

Table 3.199 The metallic plate covered by antifouling paint containing linen fiber 0.01% (w/w) before and after immersion to sea

Before front	After front
Before back	After back

Table 3.200 The metallic plate covered by antifouling paint containing jute fiber 1% (w/w) before and after immersion to sea

Before front	After front
Before back	After back

Table 3.201 The metallic plate covered by antifouling paint containing jute fiber 0.1% (w/w) before and after immersion to sea

Before front	After front
Before back	After back

Table 3.202 The metallic plate covered by antifouling paint containing jute fiber 0.01% (w/w) before and after immersion to sea

Before front	After front
Before back	After back

Table 3.203 The metallic plate covered by antifouling paint containing Rockforce MS730-Roxul 1000 fiber 1% (w/w) before and after immersion to sea

Before front	After front
Before back	After back

Table 3.204 The metallic plate covered by antifouling paint containing Rockforce MS730-Roxul 1000 fiber 0.1% (w/w) before and after immersion to sea

Before front	After front
Before back	After back

Table 3.205 The metallic plate covered by antifouling paint containing Rockforce MS730-Roxul 1000 fiber 0.01% (w/w) before and after immersion to sea

Before front	After front
Before back	After back

Table 3.206 The metallic plate covered by antifouling paint containing Rockforce MS675-Roxul 1000 fiber 1% (w/w) before and after immersion to sea

Before front	After front
Before back	After back

Table 3.207 The metallic plate covered by antifouling paint containing Rockforce MS675-Roxul 1000 fiber 0.1% (w/w) before and after immersion to sea

Before front	After front
Before back	After back

Table 3.208 The metallic plate covered by antifouling paint containing Rockforce MS675-Roxul 1000 fiber 0.01% (w/w) before and after immersion to sea

Before front	After front
Before back	After back

Table 3.209 Evaluation of fouling level of the metallic plates used in field test

Plate name	Fouling Level
The metallic plates covered by only anticorrosive primer	V
The metallic plates covered by booster biocide and fiber free antifouling paint	III
The metallic plates covered by fiber free antifouling paint	II
The metallic plates covered by antifouling paint containing 1% (w/w) linen fiber	II
The metallic plates covered by antifouling paint containing 0.1% (w/w) linen fiber	II
The metallic plates covered by antifouling paint containing 0.01% (w/w) linen fiber	II
The metallic plate covered by antifouling paint containing 1% (w/w) jute fiber	II
The metallic plate covered by antifouling paint containing 0.1% (w/w) jute fiber	II
The metallic plate covered by antifouling paint containing 0.01% (w/w) jute fiber	II
The metallic plate covered by antifouling paint containing Rockforce MS730-Roxul 1000 fiber 1% (w/w)	II
The metallic plate covered by antifouling paint containing Rockforce MS730-Roxul 1000 fiber 0.1% (w/w)	II
The metallic plate covered by antifouling paint containing Rockforce MS730-Roxul 1000 fiber 0.01% (w/w)	II
The metallic plate covered by antifouling paint containing Rockforce MS675-Roxul 1000 fiber 1% (w/w)	II
The metallic plate covered by antifouling paint containing Rockforce MS675-Roxul 1000 fiber 0.1% (w/w)	II
The metallic plate covered by antifouling paint containing Rockforce MS675-Roxul 1000 fiber 0.01% (w/w)	II

CHAPTER FOUR
DISCUSSION

The self-polishing percentage is one of the most important parameters that affect the antifouling performance of the paint. If the prepared paints are applied to a static surface such as petrol platforms, it is expected that the self-polishing percentage of this paint will be high so that the active chemicals in its matrix are released from the paint surface before it's too late, to protect the surface from biofouling. The paints used on non-static surfaces such as ship hulls should have a low self-polishing percentage. If the self-polishing percentage of the paint used on the non-static surface is high, the paint surface erodes in a short time and the active chemicals in its matrix are quickly released from the structure. This prevents the long-term protection of the surface. For this reason, the self-polishing percentage of the paints must be carefully adjusted. In this thesis, self-polishing percentages of fiber-free and fiber-reinforced antifouling paints were studied.

When the results of the self-polishing test performed at 20 ºC and 30 °C of the paint with linen fiber 1% (w/w) reinforcement were examined, it was seen that the self-polishing percentage of this paint was decreased in the range of 500-1000 RPM compared to the control group. The reductions at 20°C were 23.7%, 5.5% and 17.3% for 500, 750 and 1000 RPM rotary rates, respectively. The reduction in self-polishing percentages at 30 ºC were 43.7%, 29.4% and 19.4% for 500, 750 and 1000 RPM rotary rates, respectively. Although reductions in the self-polishing percentages were observed, these reductions were not statistically meaningful. Contrary to expectations, an increase was observed in the self-polishing percentages of the antifouling paint which were reinforced with 0.1% (w/w) linen fiber, when compared to the control group. These increases were observed at temperatures ranging between 20-40 °C. When the self-polishing test results of the antifouling paint with the linen fiber 0.01% (w/w) reinforcement are reviewed, it is seen that the polishing percentages of the paint at 500, 750 and 1000 RPM rotary rate at 30 °C were decreased by 0.49%, 2.7% and 3.3%, respectively, compared to the control group. These decreases were seen as 1.4%, 6.07% and 3.01% for 250, 500 and 750 RPM rotary rates at 40°C, respectively.

Although reductions in the self-polishing percentages were observed these reductions were not statistically meaningful. The effect of the jute fiber reinforcement made to the paint structure on the self-polishing percentage was investigated. Compared to the control group, increases were observed in the self-polishing percentages of the paint with jute fiber 1% (w/w) reinforcement. In addition, the cracks and the loss of color were observed on the surfaces of these paints. One reason for this can be explained by the fact that the sizes of the fibers used in the paint's structures were larger than necessary. The large fiber size may affect the structural properties of the matrix material rosin. When the self-polishing percentages of the jute fiber reinforced 0.1% (w/w) paint were compared with the control paint, the decrease in the self-polishing percentages at 20 ºC were 8.4%, 11.9%, 4.1% and 4.7 % for 250, 500, 750 and 1000 RPM rotary rates, respectively; In the tests that were done at 30 ºC, reductions in the self-polishing percentages were 14.7%, 5.8%, 5.4% and 3.5% for 250, 500, 750 and 1000 RPM rotary rates, respectively; for the tests that were done at 40°C, reductions in the self-polishing percentages were 22.2%, 18.1%, 14.4%, and 10.1% for 250, 500, 750 and 1000 RPM rotary rates, respectively. Although reductions in the self-polishing percentages were observed, these reductions were not statistically meaningful. The jute fiber 0.01% (w/w) reinforcement to the paint structure decreased the self-polishing percentages at some RPM rotary rates, but these reductions were not statistically significant. The Rockforce MS675-Roxul 1000 fiber 1% (w/w) reinforcement to the paint structure increased the self-polishing percentage of the paint at 20 ºC and 30 ºC temperatures, contrary to expectations. This effect can be the due size of the binder and pigment materials in the paint’s structure. Lack of basket mill and paint stirrers can lead to this kind of drawbacks. The discoloration of the paint at high temperatures such as 40 ºC was observed. It was determined that the 0.1% (w/w) Rockforce MS675-Roxul 1000 fiber reinforcement to the paint structure decreased the self-polishing percentage of the paint compared to the control group by 14.2%, 9.38%, 11.53% and 10.31%, respectively, for 250-1000 RPM rotary rates at 40 °C. The use of the 0.01% (w/w) Rockforce MS675- Roxul 1000 fiber in the paint formulation also reduced the self-polishing percentages of the paint compared to the control group at all temperatures. It was observed that there were decreases in the self-polishing percentages of the 1% (w/w) Rockforce MS730- Roxul 1000 fiber-reinforced paint at

all experimental temperatures compared to the control group. 0.1% (w/w) and 0.1% (w/w) Rockforce MS730- Roxul 1000 fiber reinforcement also caused a significant decrease in the self-polishing percentages of the paint. Although there are publications examining the self-polishing percentages of antifouling paints in the literature, there is no publication examining the self-polishing percentage of the natural fiber reinforced self-polishing antifouling paint.

Karabay (2011) examined the self-polishing performance of a lanolin-based material in his thesis. In the thesis study, the lanolin-based material was reinforced by using MS730-Roxul 1000 and MS675- Roxul 1000 fibers. When the results obtained were examined, it was observed that the MS730-Roxul 1000 and MS675- Roxul 1000 fibers used in the structure of the lanolin-based material decreased the self-polishing percentage of the substance.

Patent by Codolar et al. (2000a) introduces copolymer binder based antifouling paint formulation. The paint formulation in this patent also uses fiber to increase its mechanical behavior. In the patent, fiber-reinforced and fiber-free model paints were prepared. The prepared model paints were subjected to blister box and rotary tests, and the effects of paint reinforcement on the formulation were investigated. The changes in the surfaces of the samples are examined every 1, 3, 5 and 8 weeks while the tests are being carried out. When the results in the patent are examined, it is seen that the fiber reinforcement prevents paint deformations such as cracks and flakes that may occur.

When the patent of Codolar et al. (2000b) is examined, it is seen that silicon-based copolymer is used as the binder material. Thanks to the use of fiber in the paint structure, it has been observed that there are improvements in the mechanical behavior of the paint. It is stated in the patent that model paints containing and not containing fiber in their structure, as well as commercial paints containing and without fiber in their structure, are prepared. Rotary and blister box tests were carried out to understand the mechanical behavior of the prepared model paints. It is stated in the patent that the test periods are 2, 4, 6, 8, 10 and 12 months. As can be seen from patent mechanical test outcomes fiber reinforcement increased mechanical properties of applied paint.

Paper written by Kiil et al. (2002) describes the mathematical model that can be used for the development of self-polishing antifouling paints. Researchers performed simulations and suggested that parameters such as solubility and seawater diffusivity can drastically influence self-polishing performance of the paint. The paper also indicates that pigment size only had a minor influence on paint seawater interaction. Simulations conducted by the team indicated that compounds that show anti biofouling activity at very low concentration can be used as active antifouling paint ingredients. This model can be used for the research of antifouling paint and the development of new coating systems.

Paper written by Yebra et al. (2005) proposed a mathematical model for determining the behavior of rosin based marine antifouling paint. Reaction rate and reaction mechanism of rosin compound with seawater was investigated. The team obtained model kinetic expression and this model can be used as input for the development of new rosin based antifouling paints. An experimental method developed was used to measure the influence of NaCl, seawater temperature, pH on reaction rate. The kinetic expression which can be used for calculation of steady-state Zn release rate was proposed.

Patent issued by Olsen et al. (2014) describes an antifouling paint composition based on silyl acrylate copolymer. In this patent, rosin and other components are encapsulated into the paint matrix. In this way, it is aimed to reduce the use of Zn and Cu compounds in the paint structure. When we look at the prepared paint formulation, it is seen that the paint binder structure contains rosin in addition to silyl acrylate. It is also stated in the patent that fiber is used in the paint structure to reduce the self-polishing percentage.

Although the fibers used in patents are increasing mechanical characteristics of the paint it still possesses environmental concerns. When the paint surface polishes this type of inorganic particles will spread to marine ecosystem. For this reason, the natural fibers can be used as a replacement material for inorganic fibers. The natural fibers are used to increase the mechanical behavior of composite and polymer-based materials and it can be seen in many scientific research. Therefore, the natural fibers can be also used in paint formulations to increase the mechanical properties of paints.

The paper written by Bledzki et al. (2007) describes the use of abaca fiber as a reinforcement for polypropylene composite material. Writers also prepared linen and jute fiber-reinforced composite material. Properties such as mechanical, structural and odor emission were investigated by researchers. Fiber reinforcement up to 40% increased tensile, charpy impact and flexural strength of composite material. In the paper, writers compared mechanical behaviors of abaca fiber-reinforced composite material with jute and flax fiber-containing composite material. From the results of the paper, jute fiber-reinforced composite had the best tensile strength property.

The paper written by Ramnath et al. (2013) describes the preparation of natural fiber composite and reinforcement of this material with natural fibers. The natural composite material was reinforced by jute and abaca fibers. The team evaluated newly prepared hybrid composite material's impact, shear, tensile and flexural strength. To gain homogeneous strength property fibers were arranged in vertical and diagonal directions within the composite material. Research outcomes indicate that tensile and shear properties of abaca-jute reinforced natural composite materials were higher than a composite that was only reinforced by abaca fiber.

The study conducted by Boopalan et al. (2013) investigates the effect of natural fiber reinforcement on thermal and mechanical properties of epoxy-based hybrid composite materials. Hybrid composite materials were reinforced by jute and banana fibers. Hybridization of jute fiber with banana fiber was done to achieve improved mechanical characteristics. Different ratios of jute-banana fibers by weight were incorporated into epoxy material. The team tested flexural, tensile, impact, water absorption and thermal characteristic of hybrid composite material. The writers stated that banana fiber reinforcement to jute fiber-reinforced composite material increased the material's thermal and mechanical properties.

In this thesis, purity check of econea was also investigated using HPLC. For this, the econea solution was prepared and heated to a temperature of 88 °C. When the data obtained as the result of the experiment were examined, it was observed that there were no impurities even at high temperatures. When looking at the detailed HPLC chromatogram obtained after the experiment, it is seen that there are traces of impurities. It was determined that this impurity may related to the econea solution as

the result of contamination. According to the SDS form of the econea, it is stated that econea's decomposition temperature is higher than 400 ^{o}C (ECONEA®, Janssen PMP - ChemPoint, n.d.). The data obtained as the result of the experiment show correlation with the data of the SDS form.

Ecotoxicity tests of the booster biocide econea used in the paint formulation were performed using the model organism *Artemia salina*. The use of *Artemia salina* in these tests allowed the tests to be done in a short time. *Artemia salina* individuals were transferred to the test mediums after a short hatching period of 1 day and exposed to different concentrations of econea solutions. After adding the econea solutions to the medium, the *Artemia salina* individual counts were made at half-hour intervals. The effect of the biocide was examined by counting the mobile and immobile *Artemia salina* individuals. When the data obtained as the result of the experiment were examined, it was seen that the econea solutions were lethal against the *Artemia salina* individuals at all experimental concentration ranges (0.625 - 20ppm). The fact that the econea solution is effective even in small doses such as 0.625 ppm allows this substance to be used in small amounts in the paint structure. There is only one patent studying the toxicity of tralopyril on *Artemia salina* by Kempen (2007). This patent mostly focused on finding Minimum inhibitory Concentration (MIC) of tralopyril on *Artemia salina* after 24 hours of exposure. In this patent combinations of different biocides with tralopyril in different ratios were done to find synergetic effect and MIC value. According to their results, the MIC value for tralopyril with no combination was found to be 0.14 ppm after 24 hours of exposure. Several papers are studying the toxic effects of econea using algae, fish, and other marine organisms as model organisms. *Artemia salina* is also used in many papers for assessing the toxic effect of booster biocides.

Oliveira et al. (2017) investigated the toxic effects of tralopyril, capsaicin and triphenylborane. For this purpose, the researchers used three different model organisms. Algae *Chlamydomonas reinhardtii*, crustacean species *Daphnia magna* and fish species *Danio rerio* were used for this study and the toxic effects of biocides were investigated. Among the booster biocides that the researchers tested, the strongest inhibitory effect was determined by tralopyril against the growth of *Chlamydomonas*

reinhardtii. Researchers have also examined changes in protein levels. Tralopyril has been found to affect the upregulation of 6 proteins involved in energy metabolism, cytoskeleton, mRNA splicing, and cell division. Finally, the researchers determined that capsaicin has no toxic effects against marine organisms, whereas tralopyril have toxic effects against freshwater organisms.

Bioconcentrations of econea, which is used as an environmental biocide in antifouling paint, against *Mytilus galloprovincialis* mussel found in the Mediterranean region were investigated by Oliveira et al. (2016). The presence of tralopyril (econea) in the gill proteome were investigated using acute and long-term experiments. Tralopyril concentration was chosen as 1 µg/L and the effects of DMSO solution on *Mytilus galloprovincialis* were investigated as a control experiment. The researchers have also studied the effects of tralopyril by performing proteomic analyzes using mass spectrometry. The researchers have stated that tralopyril accumulates in the tissues of the model organism at concentrations up to 362 ng/g. It was also stated that 80% of the accumulated tralopyril concentration was eliminated after the 10-day cleaning period of the organism. The researchers also noted that there was upregulation of 46 proteins of *Mytilus galloprovincialis* when exposed to tralopyril under different conditions. It has also been observed that DMSO modulates gill proteins. The researchers have observed that both structures adversely affect oxidative stress, active efflux, immune system and bioenergetic pathways, which are important for the survival of *Mytilus galloprovincialis.*

Lavtizar et al. (2019) investigated the toxic effects of tralopyril and its degradation products. For this purpose, the researchers used three different sea urchin species. *Clypeaster japonicus*, *Pseudocentrotus depressus* and *Hemicentrotus pulcherrimus* were used as model organisms in experiments. The researchers observed that tralopyril degrades to two degradation products in the test medium, and noted that the degradation process is slower at 17°C than at 20°C. They determined that the two degradation products of tralopyril were not toxic at 100 mg/L, but that tralopyril had toxic effects towards all model organisms.

In another study, Chen et al. (2020) investigated the toxic effects of tralopyril using zebra fish *Danio rerio* embryos. For this purpose, researchers carried out thyroid

hormone levels, gene expressions and metabolomic studies, which are the development indicators of *Danio rerio*. Considering the findings obtained because of the research, it was determined that the heartbeat and body size of zebra fish decreased at a concentration of 4.20 μg/L and above. In addition, it has been determined in the research that tralopyril causes various deformations such as pericardial hemorrhage, spinal deformation, pericardial edema, tail malformation and uninflated gas bladder in model organism. As a result of the researchers' metabolomic studies, it was concluded that tralopyril affects the amino acid, energy and lipid metabolism of the model organism.

Artemia salina also used in many papers for assessing toxic effect of booster biocides because of its short hatching period, commercial availability and resistance to broad spectrum of chemicals.

Jung et al. (2017) investigates the toxic effects of antifouling biocides used in marine industries. Biocides like Irgarol 1051, Diuron, Chlorothalonil, Dichlofluanid, Sea-nine 211, Copper pyrithione, Zinc pyrithione, Ziram, and Zineb was used. Toxic effects were evaluated against *Nitzschia pungens* and *Artemia salina*. *Artemia salina* was used to obtain data for LC_{50} values for 48 hours test time. Sea nine 211 and Copper pyrithione expressed the lowest LC_{50} value.

In search of new sustainable alternatives to reduce the use of metallic antifouling pigments in marine paints, three n-alkyl 2-furoates were synthesized by safe procedures framed within the green chemistry concepts by Escobar et al. (2019). These compounds were characterized by current organic analysis, and their antifouling properties were first evaluated on *Artemia salina* nauplii in the laboratory. Then, antifouling paints formulated with these compounds were assayed in a marine environment.

In study conducted by Darya et al. (2020), antifouling and antibacterial properties of polar, semi-polar and non-polar bioactive compounds derived from the sea cucumber *Holothuria leucospilota* were investigated. A series of extracts from four different organs of sea cucumber (body wall, gonad, digestive tract and respiratory tree) were investigated for their antibacterial and antifouling activity against two

species *Amphibalanus amphitrite* and *Artemia salina*. Among the twelve extracts, the ethyl acetate extracts of the body wall showed the maximum antibacterial and antifouling activities. The bioactive compounds of the ethyl acetate extract of the sea cucumber body wall were determined using gas chromatography coupled with mass spectrometry. Writers indicates that fatty acids and terpenes were the major compounds, which may be responsible for the antibacterial and antifouling activity of the ethyl acetate extract of the body wall of the sea cucumber *Holothuria leucospilota*.

Paper which was written by Gutner-Hoch et al. (2019) focuses on the assessment of toxic effects of commercially available booster biocides. Engineered micro/ nanomaterials (EMNMs) were used as a carrier of booster biocides and the release rate was controlled. Zinc pyrithione (ZnPt) and copper pyrithione were chosen as the main biocides. Three unloaded engineered micro/nanomaterials layered double hydroxides, silica nano capsules, polyurea microcapsules, and six novel EMNMs were used to gain information about toxicity levels. Toxicity was assessed by using *Artemia salina* and *Paracentrotus lividus*. The discharged silica nanoparticles showed slight toxic effect on the *Artemia salina* and *Paracentrotus lividus* embryos. The highest toxicity levels were observed when ZnPT was used.

The effects of the reinforcement materials to the paint structure on the mechanical properties of the paint were investigated by direct impact and cross-cut tests. The prepared paints were applied to the surfaces of the metal plates which were previously coated with the anticorrosive primer and left to dry for 5 days. After the drying period, the upper parts of the plate's surfaces were used for the direct impact tests and the lower parts were used for the cross-cut tests. After the fiber reinforcements were made to the paint structures, improvements were observed in the mechanical properties of the paints. It was observed that the reinforcement of 1% (w/w) and 0.1% (w/w) linen and jute fibers to the paint structure positively affects the direct impact and cross-cut test results of the paint. When the effects of Rockforce MS730-Roxul 1000 and Rockforce MS675-Roxul 1000 inorganic fibers reinforcements to the paint structure on the mechanical properties were examined, it was observed that these fibers resulted in improvements in the mechanical behavior of the paint at both 1% (w/w) and 0.1%

(w/w) percentage. Research using direct impact tests for mechanical property evaluation can be found in the literature.

In the patent stated that inorganic fiber reinforcement is applied to rosin-based self-polishing antifouling paints composition (Codolar et al.,2001). Inorganic fiber reinforcement caused an improvement in the mechanical behavior of the paint. In the mechanical tests carried out within the scope of the patent, it was determined that fiber reinforced paints had better performance in direct impact, mandrel and elongation tests compared to paints without fiber reinforcement.

Dustebek et al. (2016) investigated mechanical properties of antifouling paint reinforced by carbon nanotubes. For this reason, paints containing carbon nanotubes in different ratios were prepared. Mechanical characteristics of prepared paints were evaluated by direct impact test. Carbon nano tube reinforcement to the paint structure increased mechanical performances of paints.

The field trial was conducted over a one-month period to obtain information about the antifouling performances of the prepared paints. The prepared paints were applied to the surfaces of the metallic plates previously coated with an anti-corrosive coating and left to dry for five days. It is necessary to apply an anticorrosive primer to the plate surface beforehand. If the plates were immersed in the marine environment without applying an anticorrosive primer, the surfaces of these plates would be corroded and become useless by the effect of the seawater. To compare the antifouling performances, the fiber-free paint and both the fiber and the econea-free paint were prepared and applied to the plate surfaces. The metallic plate, which was not covered by any antifouling paint, but only anticorrosive primer was also prepared. The surface of the plate which was only covered by anticorrosive primer was heavily fouled. When the field test result of the paint, which was not reinforced by any fiber, was examined, it was seen that the cracks occurred on the paint surface. Although the deformations occur on the plate surface, it was seen that the prepared paint protected the metal surface from biofouling. When the field trial result of the antifouling paint which does not contain any biocide and was not reinforced by any fiber was examined, it was determined that the paint protected the metal surface from biofouling. This effect can be explained by the Cu_2O used in the paint structure and the natural self-polishing

property of rosin. When the result of the field trial of the paint, which's structure was reinforced with 1% (w/w) linen fiber, it was seen that some parts of the paint have been peeled away from the surface of the metal plate. Even if there were peelings on the paint surface, the prepared paint protected the metal plate from biofouling. The paints reinforced by linen fiber 0.1% and 1% (w/w) were also successful at protecting metal surfaces from biofouling. When the 1% (w/w) and jute fiber reinforced 0.1% (w/w) paint was reviewed as the result of the field trial, it was observed that the plates were protected from biofouling, although the crack formations were observed on the surface. The cracks on the paint surface can be explained by the large fiber size. Considering the field trial results of jute fiber reinforced 0.1% (w/w) paint, it was seen that there was no deterioration on the paint surface and the surface was protected from biofouling. When the field trial results of paints reinforced by 1% (w/w), 0.1% (w/w) and 0.01% (w/w) MS730-Roxul 1000 fiber were examined, it was seen that the cracks were formed on the paint surface, but the surfaces were protected against biofouling. The cracks on paint surfaces can be explained by the paint particles being larger than desired. When the field trial results of the metal plates covered with paints reinforced with MS675-Roxul 1000 fiber at 1% (w/w), 0.1% (w/w) and 0.01% (w/w) ratios were examined, it was seen that the plates were protected from the biofouling. In addition, the cracks did not occur on the paint surface at any fiber reinforcement ratios. The fibers produced by Lapinus company are protected by patents to be used in antifouling paint compositions. It is seen from market reports that very successful fiber reinforced antifouling paints are produced.

CHAPTER FIVE
CONCLUSION

When surfaces are used in an aquatic environment such as a marine ecosystem, they must be coated with the protective coatings known as antifouling paints. The reason for this is that organisms living in the marine ecosystem attach to these surfaces. If these surfaces are of commercial importance, such as a ship hulls, this event can have negative consequences in various ways. If the antifouling paints are not used in the ship's hulls, biofouling reduces the speed and maneuverability of the ship as the load of the ship increases as the result of the attachment of the living organisms. This causes the speed of the ship to decrease and the prices of the goods it carries increase by this event. Even though the most effective antifouling paints used so far are those based on TBT, after the banning of TBT, it became necessary to produce more environmentally friendly paints. The damage caused by heavy metal-containing compounds used in paint formulations to the environment has been stated in a series of publications. Therefore, it is necessary to develop environmentally friendly antifouling paints with low heavy metal content. In this thesis, rosin-based self-polishing antifouling paint was prepared. Due to its organic binder structure, rosin was chosen as the main matrix material of the paint. The rosin's natural self-polishing property has enabled the use of this substance. Although the use of rosin in paint structure has given good results, the mechanical behavior of the paint can be increased by implementing a number of reinforcements. The use of the natural and the inorganic fibers increases the mechanical properties of paints. Although it shows good reinforcement support to the paint structure, the spread of the inorganic fibers into the marine ecosystem as the result of the erosion of the paint structure is an undesirable result. For this purpose, using the natural fibers can be a good alternative. Even if the natural fibers are released from the paint structure, they are subject to biodegradation. Therefore, the use of the natural fibers as a reinforcing material in the paint structure can be used to increase the mechanical behavior of the paint and decrease the damage caused by inorganic fibers

to the marine ecosystem. The use of linen and jute fibers in some ratios decreased the self-polishing percentages of self-polishing antifouling paints, but it was found that these decreases were not statistically significant. When the natural fibers are used in the paint structure, the fibers should be cut as small as possible. In this way, the fibers can be dispersed homogeneously in the paint structure. The use of the fibers used in later studies after acidic or alkaline treatments may show better performance as the result of an increase in the fiber surface area. The use of environmentally friendly biocides such as econea instead of heavy metal-containing biocides in the paint structure gives good results without reducing the performance of the paint. When the eco-toxicity test results of the booster biocide econea used in the paint formulation were evaluated, it was observed that the econea was effective against the model organism *Artemia salina* even at low concentrations such as 0.625 ppm. This indicates that the use of econea in small amounts in paint formulations will be effective in the protection of the surfaces against biofouling. The results of the field tests are in coloration with this outcome. When the result of the econea purity analyze using HPLC was examined, it was observed that there were no impurities in econea solution even at a high temperature such as 88 °C. 88 ºC was the highest temperature that water bath could get so this temperature was chosen experimental temperature. The stability of the econea allows econea to be used at different sea temperatures in different regions. Reliable protection can be achieved by using the econea in areas where seawater is at high temperatures. It was seen that the use of fibers in the paint formulation caused an increase in the mechanical behavior of the paint as the result of the direct-impact and crosscut tests. It was observed that the fibers used in the paint formulations caused fewer cracks on the surfaces in the direct-impact test and less paint removal on the paint surfaces in the cross-cut tests. When the results of the field trials in which the paint's antifouling performances were evaluated, were examined, it was observed that the prepared paints were effective in protecting the metal plates against biofouling. Although the use of jute and linen fibers in the paint formulations caused some paint cracks on metal plate surfaces, the number of the cracks can be reduced by further reducing the fiber size in further studies.

In conclusion, the use of the jute and the linen fibers in some ratios as a reinforcement material in the paint formulation decreased the self-polishing

percentage of the paint. However, these decreases were not statistically significant. From the results of mechanical tests, it can be said that jute and linen fiber reinforcement causes an increase in the mechanical behavior of the paint. In the light of these data, it is seen that the natural fibers such as jute and linen fibers can be used as the reinforcement material in the paint formulations by bringing them to certain sizes. In this way, the natural fibers can be used in paint formulation instead of commercial fibers.

REFERENCES

Almeida, E., Diamantino, T.C. & de Sousa, O. (2007). Marine paints: the particular case of antifouling paints. *Progress in Organic Coatings*, *59*(1), 2-20.

Alyuruk, H. (2012). *Antifouling performances of eco-friendly secondary metabolite cocktails from marine plants*. Master Thesis, Dokuz Eylül University, İzmir.

Amara, I., Miled, W., Slama, R. B., & Ladhari, N. (2018). Antifouling processes and toxicity effects of antifouling paints on marine environment. A review. *Environmental Toxicology and Pharmacology*, *57*, 115-130.

Andersons, J., & Joffe, R. (2011). Estimation of the tensile strength of an oriented flax fiber-reinforced polymer composite. *Composites Part A: Applied Science and Manufacturing*, *42*(9), 1229-1235.

Arbelaiz, A., Fernández, B., Cantero, G., Llano-Ponte, R., Valea, A., & Mondragon, I. (2005). Mechanical properties of flax fibre/polypropylene composites. Influence of fibre/matrix modification and glass fibre hybridization. *Composites Part A: Applied Science and Manufacturing*, *36*(12), 1637-1644.

Arimura, H., Hiyoshi, S., Nakamura, N. & Tsuboi, M (2004). (Poly)oxyalkylene block silyl ester copolymer, antifouling coating composition, antifouling coating formed from antifouling coating composition, antifouling method using antifouling coating composition and hull or underwater structure covered with antifouling coating. *U.S. Patent and Trademark Office*, *US 6,828,030 B2*

Assarar, M., Scida, D., El Mahi, A., Poilâne, C., & Ayad, R. (2011). Influence of water ageing on mechanical properties and damage events of two reinforced composite materials: Flax–fibres and glass–fibres. *Materials & Design*, *32*(2), 788-795.

Bao, V. W., Leung, K. M., Qiu, J. W., & Lam, M. H. (2011). Acute toxicities of five commonly used antifouling booster biocides to selected subtropical and cosmopolitan marine species. *Marine Pollution Bulletin*, *62*(5), 1147-1151.

Barkoula, N. M., Garkhail, S. K., & Peijs, T. (2010). Biodegradable composites based on flax/polyhydroxybutyrate and its copolymer with hydroxyvalerate. *Industrial Crops and Products*, *31*(1), 34-42.

Bixler, G.D., Bhushan, B. (2012). Biofouling: lessons from nature. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *370*(1967), 2381-2417.

Bledzki, A. K., Mamun, A. A., & Faruk, O. (2007). Abaca fibre reinforced PP composites and comparison with jute and flax fibre PP composites. *eXPRESS Polymer Letters*, *1*(11), 755-762.

Boopalan, M., Niranjanaa, M., & Umapathy, M. J. (2013). Study on the mechanical properties and thermal properties of jute and banana fiber reinforced epoxy hybrid composites. *Composites Part B: Engineering*, 51, 54-57.

Chambers, L. D., Stokes, K. R., Walsh, F. C., & Wood, R. J. (2006). Modern approaches to marine antifouling coatings. *Surface and Coatings Technology*, *201*(6), 3642-3652.

Chandramohan, D., & Marimuthu, K. (2011). A review on natural fibers. *International Journal of Research and Reviews in Applied Sciences*, *8*(2), 194-206.

Chen, X., Teng, M., Zhang, J., Qian, L., Duan, M., Cheng, Y., Zhao, Feng., Zheng, J., & Wang, C. (2020). Tralopyril induces developmental toxicity in zebrafish embryo (Danio rerio) by disrupting the thyroid system and metabolism. *Science of The Total Environment*, *746*, 141860.

Clemons, C. M., & Caulfield, D. F. (2005). Natural fibers. In *Functional fillers for plastics* (195-206). Weinheim: Wiley-VCH.

Codolar, S. A., & Elbro, H. S. (2001). Antifouling paint. *U.S. Patent and Trademark Office, U.S 6,248,806 B1*.

Codolar, S. A., Elbro, H.S., Pedersen, M.S., Gladwin, T.S. & Buchwald, F. (2000). Self-polishing marine antifouling paint composition containing block acid functional co-polymers and fibers. *World Intellectual Property Organization, WO 00/77103 A1.*

Codolar, S. A., Elbro, H.S., Pedersen, M.S., Gladwin, T.S. & Buchwald, F. (2000). Self-polishing marine antifouling paint composition containing silicon containing co-polymers and fibers. *World Intellectual Property Organization WO 00/77102 A1*.

Cresswell, T., Richards, J. P., Glegg, G. A., & Readman, J. W. (2006). The impact of legislation on the usage and environmental concentrations of Irgarol 1051 in UK coastal waters. *Marine Pollution Bulletin*, *52*(10), 1169-1175.

da Costa, M.B., Zamprogno, G.C., Otegui, M.B.P., de Morais, L., Pedruzzi, F.C., Dalbem, G.B. & Resende, A.C. B. (2017). A temporal and spatial monitoring of organotin pollution in a harborside region of Brazil by imposex and ecological quality ratio using Leucozonia *nassa*. *Environmental Monitoring and Assessment*, *189*(12), 650 .

Dafforn, K. A., Lewis, J. A., & Johnston, E. L. (2011). Antifouling strategies: history and regulation, ecological impacts and mitigation. *Marine Pollution Bulletin, 62*(3), 453-465.

Darya, M., Sajjadi, M. M., Yousefzadi, M., Sourinejad, I., & Zarei, M. (2020). Antifouling and antibacterial activities of bioactive extracts from different organs of the sea cucumber *Holothuria leucospilota*. *Helgoland Marine Research*, *74*(1), 4.

Davidson, I. C., Brown, C. W., Sytsma, M. D., & Ruiz, G. M. (2009). The role of containerships as transfer mechanisms of marine biofouling species. *Biofouling*, *25*(7), 645-655.

Dustebek, J., Kandemir-Cavas, C., Nitodas, S. F., & Cavas, L. (2016). Effects of carbon nanotubes on the mechanical strength of self-polishing antifouling paints. *Progress in Organic Coatings*, 98, 18-27.

ECONEA®, Janssen PMP - ChemPoint. (n.d.). https://www.chempoint.com. Retrieved September 1, 2021, from https://www.chempoint.com/products/janssen-pmp/janssen-pmp-microbial-control/econea.

Escobar, A., Pérez, M., Sathicq, Á., García, M., Paola, A., Romanelli, G., & Blustein, G. (2019). Alkyl 2-furoates obtained by green chemistry procedures as suitable new antifoulants for marine protective coatings. *Journal of Coatings Technology and Research*, *16*(1), 159-166.

Faruk, O., Bledzki, A. K., Fink, H. P., & Sain, M. (2012). Biocomposites reinforced with natural fibers: 2000–2010. *Progress in Polymer Science*, *37*(11), 1552-1596.

Gutner-Hoch, E., Martins, R., Maia, F., Oliveira, T., Shpigel, M., Weis, M., ... & Benayahu, Y. (2019). Toxicity of engineered micro-and nanomaterials with antifouling properties to the brine shrimp *Artemia salina* and embryonic stages of the sea urchin *Paracentrotus lividus*. *Environmental Pollution*, *251*, 530-537.

Holbery, J., & Houston, D. (2006). Natural-fiber-reinforced polymer composites in automotive applications. *Jom*, *58*(11), 80-86.

Hossain, M. K., Dewan, M. W., Hosur, M., & Jeelani, S. (2011). Mechanical performances of surface modified jute fiber reinforced biopol nanophased green composites. *Composites Part B: Engineering*, *42*(6), 1701-1707.

John, M. J., & Anandjiwala, R. D. (2009). Chemical modification of flax reinforced polypropylene composites. *Composites Part A: Applied Science and Manufacturing*, *40*(4), 442-448.

Jones, G. (2009). The battle against marine biofouling: a historical review. *Advances in marine antifouling coatings and technologies* (19-45). Sawston, Cambridge, UK: Woodhead Publishing.

Jung, S. M., Bae, J. S., Kang, S. G., Son, J. S., Jeon, J. H., Lee, H. J., ... & Shin, H. W. (2017). Acute toxicity of organic antifouling biocides to phytoplankton *Nitzschia pungens* and zooplankton *Artemia* larvae. *Marine Pollution Bulletin*, *124*(2), 811-818.

Karabay, Z. (2011). *Antifouling performances of some eco-friendly biocides*. Master Thesis, Dokuz Eylül University, İzmir.

Kempen, T. M. J. (2007). Combination of 4-bromo-2-(4-chlorophenyl)-5-(trifluoromethyl)-1//-pyrrole-3-carbonitrile and metal compounds. *World Intellectual Property Organization, WO 2007/088172 A2.*

Kiil S., Weinell C. E., Pedersen M. S. & Dam-Johansen K. (2002). Mathematical Modelling of a Self-Polishing Antifouling Paint Exposed to Seawater: A Parameter Study. *Chemical Engineering Research and Design*, *80*, 45-52.

Kristensen, J. B., Meyer, R. L., Laursen, B. S., Shipovskov, S., Besenbacher, F., & Poulsen, C. H. (2008). Antifouling enzymes and the biochemistry of marine settlement. *Biotechnology Advances, 26*(5), 471–481.

Kwon, S.H., Lee, I., Park, H. & Lee, S.G. (2020). Decomposition mechanisms of self-polishing copolymers for antifouling coating materials through first-principles approach. *Progress in Organic Coatings*, *138*, 105406.

Lejars, M., Margaillan, A., & Bressy, C. (2012). Fouling release coatings: a nontoxic alternative to biocidal antifouling coatings. *Chemical reviews*, *112*(8), 4347-4390.

Lapinus | Part of the ROCKWOOL Group. (n.d.). Lapinus. Retrieved August 20, 2021, from https://www.lapinus.com.

Lavtizar, V., & Okamura, H. (2019). Early developmental responses of three sea urchin species to tralopyril and its two degradation products. *Chemosphere*, *229*, 256-261.

Liang, S., Gning, P. B., & Guillaumat, L. (2012). A comparative study of fatigue behaviour of flax/epoxy and glass/epoxy composites. *Composites Science and Technology*, *72*(5), 535-543.

Lilholt, H., & Lawther, J. M. (2000). Natural organic fibers. In *Comprehensive Composite Materials* (vol 1) (303-325). Amsterdam: Elsevier press.

Liu, L., Yu, J., Cheng, L., & Qu, W. (2009). Mechanical properties of poly (butylene succinate) (PBS) biocomposites reinforced with surface modified jute fibre. *Composites Part A: Applied Science and Manufacturing*, *40*(5), 669-674.

Liu, Q., & Hughes, M. (2008). The fracture behavior and toughness of woven flax fibre reinforced epoxy composites. *Composites Part A: Applied Science and Manufacturing*, *39*(10), 1644-1652.

Lodha, P., & Netravali, A. N. (2005). Characterization of Phytagel® modified soy protein isolate resin and unidirectional flax yarn reinforced "green" composites. *Polymer Composites*, *26*(5), 647-659.

Maciel, D.C., Castro, Í.B., de Souza, J.R.B., Yogui, G.T., Fillmann, G. & Zanardi-Lamardo, E. (2018). Assessment of organotins and imposex in two estuaries of the northeastern Brazilian coast. *Marine Pollution Bulletin*, *126*, 473-478.

Martinez, K., & Barceló, D. (2001). Determination of antifouling pesticides and their degradation products in marine sediments by means of ultrasonic extraction and HPLC–APCI–MS. *Fresenius' Journal of Analytical Chemistry*, *370*(7), 940-945.

Mert, N., Topcam, G. & Cavas, L. (2014). RP-HPLC optimization of econea by using artificial neural networks and its antifouling performance on the Turkish coastline. *Progress in Organic Coatings*, *77*(3), 627-635**.**

Miao, M., & Shan, M. (2011). Highly aligned flax/polypropylene nonwoven preforms for thermoplastic composites. *Composites Science and Technology*, *71*(15), 1713-1718.

Mitchell, E. J., Burgess, J. E., & Stuetz, R. M. (2002). Developments in ecotoxicity testing. *Reviews in Environmental Science and Biotechnology, 1*(2), 169-198.

Modniks, J., & Andersons, J. (2010). Modeling elastic properties of short flax fiber-reinforced composites by orientation averaging. *Computational Materials Science*, *50*(2), 595-599.

Murdan, S., Kerai, L., & Hossin, B. (2015). To what extent do in vitro tests correctly predict the in vivo residence of nail lacquers on the nail plate?. *Journal of Drug Delivery Science and Technology, 25*, 23-28.

Oliveira, I. B., Groh, K. J., Schönenberger, R., Barroso, C., Thomas, K. V., & Suter, M. J. F. (2017). Toxicity of emerging antifouling biocides to non-target freshwater organisms from three trophic levels. *Aquatic Toxicology*, *191*, 164-174.

Oliveira, I. B., Groh, K. J., Stadnicka-Michalak, J., Schönenberger, R., Beiras, R., Barroso, C. M., ... & Suter, M. J. F. (2016). Tralopyril bioconcentration and effects on the gill proteome of the Mediterranean mussel *Mytilus galloprovincialis*. *Aquatic Toxicology*, *177*, 198-210.

Olsen, S. M., Yebra, D. M. & Schandel, T. (2014). Self-Polishing antifouling paint composition comprising solid particles of entrapped or encapsulated rosin constituents. *United States Patent Application Publication, US 2014/0242403 A1*.

Qian, P. Y., Chen, L., & Xu, Y. (2013). Mini review: Molecular mechanisms of antifouling compounds. *Biofouling*, *29*(4), 381-400.

Qian, P.Y. & Xu, Y., Fusetani, N. (2009). Natural products as antifouling compounds: recent progress and future perspectives. *Biofouling*, *26*(2), 223-234.

Ramnath, B. V., Kokan, S. J., Raja, R. N., Sathyanarayanan, R., Elanchezhian, C., Prasad, A. R., & Manickavasagam, V. M. (2013). Evaluation of mechanical properties of abaca–jute–glass fibre reinforced epoxy composite. *Materials & Design*, *51*, 357-366.

Readman, J. W. (2006). Development, occurrence and regulationof antifouling paint biocides: historical review and future trends. In *Antifouling paint biocides* (1-15). Berlin, Heidelberg: Springer.

Rodríguez, Á. S., Ferrera, Z. S., & Rodríguez, J. J. S. (2011). A preliminary assessment of levels of antifouling booster biocides in harbours and marinas of the island of Gran Canaria, using SPE-HPLC. *Environmental Chemistry Letters*, *9*(2), 203-208.

Sanjay, M. R., Arpitha, G. R., Naik, L. L., Gopalakrishna, K., & Yogesha, B. (2016). Applications of natural fibers and its composites: An overview. *Natural Resources*, *7*(3), 108-114.

Satheesh, S., Ba-Akdah, M. A., & Al-Sofyani, A. A. (2016). Natural antifouling compound production by microbes associated with marine macroorganisms—A review. *Electronic Journal of Biotechnology*, *21*, 26-35.

Sathicq, Á., Paola, A., Pérez, M., Dallesandro, O., García, M., Roldán, J. P., ... & Blustein, G. (2019). Furylchalcones as new potential marine antifoulants. *International Biodeterioration & Biodegradation, 143,* 104730.

Schultz, M.P. (2007). Effects of coating roughness and biofouling on ship resistance and powering. *Biofouling*, *23*(5), 331-341.

Thomas, K. V. (1999). Determination of the antifouling agent zinc pyrithione in water samples by copper chelate formation and high-performance liquid chromatography–atmospheric pressure chemical ionisation mass spectrometry. *Journal of Chromatography A*, *833*(1), 105-109.

Tsang, V. W. H., Lei, N. Y., & Lam, M. H. W. (2009). Determination of Irgarol-1051 and its related s-triazine species in coastal sediments and mussel tissues by HPLC–ESI-MS/MS. *Marine Pollution Bulletin*, *58*(10), 1462-1471.

Urban, C., Elbro, H.S., Codolar, S.A. & Schultz A.C. (2003). Antifouling paint composition. *European Patent Office, EP 0 952 194 B1.*

Van de Weyenberg, I., Truong, T. C., Vangrimde, B., & Verpoest, I. (2006). Improving the properties of UD flax fibre reinforced composites by applying an alkaline fibre treatment. *Composites Part A: Applied Science and Manufacturing*, *37*(9), 1368-1376.

Wang, H., Memon, H., AM Hassan, E., Miah, M., & Ali, M. (2019). Effect of jute fiber modification on mechanical properties of jute fiber composite. *Materials*, *12*(8), 1226.

Yan, L., Chouw, N., & Jayaraman, K. (2014). Flax fibre and its composites–A review. *Composites Part B: Engineering*, *56*, 296-317.

Yebra, D. M., & Weinell, C. E. (2009). Key issues in the formulation of marine antifouling paints. In *Advances in Marine Antifouling Coatings and Technologies* (308-333). Sawston, Cambridge: UK Woodhead Publishing.

Yebra, D.M., Kiil, S. & Dam-Johansen, K. (2004). Antifouling technology – past, present and future steps towards efficient and environmentally friendly antifouling Coatings. *Progress in Organic Coatings 50*, 75–104.

Yebra, D.M., Kiil, S., Weinell, C. & Dam-Johansen, K. (2005). Reaction rate estimation of controlled-release antifouling paint binders: rosin-based systems. *Progress in Organic Coatings 53*, 256–275.

Yebra, D.M., Kiil, S., Weinell, C.E. & Dam-Johansen, K. (2006). Presence and effects of marine microbial biofilms on biocide-based antifouling paints. *Biofouling 22*(1), 33–41.