ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

MSc THESIS

Fethiye YALÇIN

COMPARISON OF THE AUTOMOTIVE BUMPER PRODUCED WITH DIFFERENT COMPOSITE MATERIALS USING THE FINITE ELEMENTS METHOD

DEPARTMENT OF AUTOMOTIVE ENGINEERING

ADANA-2022

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We certify that the thesis titled above was reviewed and approved for the award of degree of the Master of Science by the board of jury on 19/10/2022

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This study supported by Çukurova University Scientific Research Projects Unit.
Project No: FYL-2021-13886

ABSTRACT

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Supervisor : Prof. Dr. Mustafa ÖZCANLI
Year: 2022, Page: 61
Jury : Prof. Dr. Mustafa ÖZCANLI
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In recent years with the developing technology, the automotive industry and composite material production have also developed. The vehicle lightening issue, which emerged with the aim of saving fuel in the automotive sector, has increased the competition. In parallel with the developments in the automotive sector, studies have increased in the production of composite materials used to lighten vehicles. Composite materials have become widespread in the production of automotive parts with the features they offer.

Composite materials are used in vehicle bumpers due to their strength and lightness. In this study, composite materials that can be used on the vehicle bumper were researched. Due to its low cost and easy processing, composite materials consisting of glass fiber and polyester are mostly used in vehicle bumpers. In the study, carbon fiber reinforcement and vinyl ester matrix, which can be an alternative to glass fiber reinforcement material and polyester matrix, were used. 6 different composite materials were created and used with 2 different reinforcement elements and 2 different matrix elements. The mechanical properties of 6 different composite materials were determined by the tensile test. The results were entered into the ANSYS program and the results of the static analysis on the buffer were compared.

Keywords: Composite, Vinyl ester, Automotive, Analysis

ÖZ

YÜKSEK LİSANS TEZİ

SONLU ELEMANLAR YÖNTEMİ KULLANILARAK FARKLI KOMPOZİT MALZEMELERLE ÜRETİLEN OTOMOTİV TAMPONUNUN KARŞILAŞTIRILMASI

Fethiye YALÇIN

ÇUKUROVA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ
OTOMOTİV MÜHENDİSLİĞİ ANABİLİM DALI

Danışman : Prof. Dr. Mustafa ÖZCANLI
Yıl:2022, Sayfa: 61
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Son yıllarda gelişen teknoloji ile otomotiv sektörü ve kompozit malzeme üretimi de gelişmiştir. Otomotiv sektöründe yakıt tasarrufu sağlama amacıyla ortaya çıkan araç hafifletme konusu rekabeti arttırmıştır. Otomotiv sektöründeki gelişmelere paralel olarak araç hafifletmek için kullanılan kompozit malzeme üretiminde de çalışmalar artmıştır. Kompozit malzemeler sunduğu özellikler ile otomotiv parça üretiminde kullanımı yaygınlaşmıştır.
Kompozit malzemeler mukavemetli ve hafif olması sebebiyle araç tamponunda kullanılmaktadır. Bu çalışmada araç tamponu üzerinde kullanılabilecek kompozit malzeme araştırması yapılmıştır. Araç tamponlarında düşük maliyet ve kolay işlenebilir olması sebebiyle çoğunlukla cam elyaf ve polyesterden oluşan kompozit malzeme kullanılmaktadır. Çalışmada cam elyaf takviye malzemesi ve polyester matrisine alternatif olabilecek karbon elyaf takviyesi ve vinyl ester matrisi kullanılmıştır. 2 farklı takviye elemanı ve 2 farklı matris elemanı ile 6 farklı kompozit malzeme kullanılmıştır. Oluşturulan 6 farklı kompozit malzemenin çekme testi ile mekanik özellikleri belirlenmiştir. Sonuçlar ANSYS programına girilip tampon üzerinde statik analiz sonuçları kıyaslanmıştır.

Anahtar Kelimeler: Kompozit, Vinyl ester, Otomotiv, Analiz

GENİŞLETİLMİŞ ÖZET

Enerji sorunu zaman geçtikçe büyüyor. Bir taraftan yeni kaynak arama çalışmaları devam ederken diğer taraftan şu anda kullanılan enerji miktarını azaltma çalışmaları devam etmekte. Otomotiv sektöründe akaryakıta çeşitlerinin artırılmasına yönelik çalışılmaktadır. Yakıt kullanımını azaltmaya yönelik çalışmalar bu konudaki en önemli en hızlı yapılabilecek çalışmalardır. Yakıt tasarrufunu sağlamak için öncelikle üzerinde durulması gereken çalışma araçları hafifletmeye yönelik olanıdır.

Gelişen teknoloji ile birlikte araç hafifletmeye yönelik çalışmalarla değişim hız kazanmaktadır. Daha iyi daha yeni olma konusunda yapılan çalışmalar ile birlikte rekabet artmaktadır. Artan rekabet ile sektörde çalışan araştırmacılar yeni malzeme arayışına girmektedir.

Kompozit malzemeler havacılık sektöründe düşük ağırlıklı ancak yüksek mukavemetli olması sebebiyle çelik ve alüminyum alaşımlarının yerine kullanılmak üzere geliştirilmiştir. Daha sonra havacılıkla beraber gemi, enerji, savunma sanayi ve otomotiv sektörü gibi alanlarda kullanılmaya başlanmıştır.

Uzun yıllardan beri araçlarda kullanılan demir, çelik gibi ağır metal parçaların yerine daha hafif olan kompozit malzemeler tercih edilmektedir. Kompozit malzemelerin otomotiv sektöründe kullanımı artmış olup araçların birçok yerinde kullanılmaktadır. Araçların far maskeleri, tamponları, çamurlukları, maskeleri, motor kapakları, bagaj kapakları, rüzgarlık gibi dış parçaları ile beraber gösterge paneli, fren pedali gibi iç parçaları da kompozit malzemelerden oluşmaktadır.

Kompozit malzeme iki ya da daha fazla malzemenin birbiri içerisinde çözülmeyecek şekilde birleşiminden oluşmaktadır. Kompozit malzeme kendini oluşturan malzemenin özelliklerini taşımaktadır ya da yeni bir özellik ile ortaya çıkmaktadır. Kompozit malzemenin alaşımdan farklı olarak kendini oluşturan malzemeler arasında fiziksel bağ oluşmaktadır. Malzemeler birbiri içerisinde tam olarak çözünmemektedir.

Kompozit malzemeyi oluşturan malzemeler takviye ve matris malzemelerdir. Matris malzemenin görevi yük altındaki takviye malzemelerini bir arada tutmaktır. Matris malzeme üretim aşamasında sıvı olup daha sonra katı hale gelmektedir. Matris malzeme kompozit malzemenin genel hacmini oluşturmaktadır. Takviye malzemesi kompozit malzemenin mukavemetini ve dayanıklılığını gibi mekanik özellikler sağlamaktadır. Matris elemanı ise deformasyonların parça tamamına yayılmasını önlemekte kompozit malzemenin kırılmasının ve kopmasının önüne geçmektedir. Matris malzeme kompozit malzeme üzerine uygulanan kuvvetin eşit bir şekilde parçanın tamamına dağılmasını sağlamaktadır. Kompozit malzemeyi oluşturan matris ve takviyenin ayrışması mümkün değildir. Kompozit malzemeler geri dönüşümü olmayan malzemelerdir.

Kompozit malzemenin özelliklerini onu oluşturan takviye ve matris elemanı belirlemektedir. İstenilen özellikte malzemeyi, uygun bileşenleri seçerek ortaya çıkarmak mümkündür. Kompozit malzemede olması istenen mekanik özelliklere göre takviye ve matris eleman seçilmektedir. Seçilen malzemelerin özellikleri kadar birbiriyle uyumu da kompozit malzemenin kalitesini belirlemektedir.

Otomotiv sektöründe genel olarak kullanılan kompozit malzemenin takviye malzemesi cam elyaf ve matris malzemesi polyesterdir. Cam elyaf takviyeli polyester (CTP) olarak da bilinen bu kompozit malzeme yaygın olarak kullanılmaktadır. Sadece otomotiv sektöründe değil farklı sektörlerde de kullanılmaktadır. Cam elyaf ve polyesterin kullanımı yaygın olduğu için ulaşılması kolay ve ucuz malzemelerdir. Üstelik alternatfileri de piyasada mevucttur.

Bu çalışmada parçayı hafifletme adına cam elyafla özelliklerini kıyaslamak adına karbon elyaf ikinci takviye eleman olarak kullanılmıştır. Üretilecek parçanın dayanımını artırmak ve kıyaslamak için vinyl ester ikinci matris malzeme olarak kullanılmıştır.

Cam ve karbon takviye elemanları ve polyester ve vinyl ester matris elemanları ile cam elyaf / polyester, cam elyaf / vinyl ester, karbon elyaf / polyester, karbon elyaf /vinyl ester, cam elyaf ve karbon elyaf hibrit /polyester, cam elyaf ve karbon elyaf hibrit / vinyl ester olmak üzere altı farklı kompozit malzeme oluşturulmuştur. Kompozit malzemelerden aynı ortamda eşit şartlar altında, aynı kalınlıkta Polüte Polyester şirketi bünyesinde El Yatırması Yöntemi ile plakalar üretilmiştir. El yatırması Yöntemi çok basit ve çok yönlü olduğu için tercih edilmiştir.

Üretilen plakalar için TS EN ISO 527-2 standardı tip 1B ölçülerine göre çekme testi numunesi boyutlarına göre kesim planı oluşturuldu. Plakalar kesim planına göre aşındırıcı su jet ile kesildi. Kompozit malzemelerin matris malzemeleri yanıcı malzemelerdir. Aşındırıcı su jeti ile kesme işlemi sırasında yanma, plastic deformasyon gibi hasarlar meydana gelmeyeceği için tercih edildi. Aşındırıcı su jetinden yanma olmadığı için kimyasal kirlilikte oluşmamıştır.

Her bir plakadan beşer adet kemik numuneler kesilmiştir. Kemik numuneler çekme testine tabii tutulup, beş numunenin ortalaması alınarak mekanik değerleri belirlenmiştir. Çekme testi sonuçlarına göre en iyi mekanik değerleri karbon elyaf ve vinil esterden oluşan kompozit malzeme vermiştir.

Mekanik değerler analiz programı olan ANSYS programına girilip malzemeler programa tanıtılmıştır. ANSYS programında gerçek ölçüler referans alınarak bir tampon tasarımı yapılmıştır. Tampon üzerinde meshleme işlemi tamamlanıp sınır şartları belirlenmiştir.

Aynı tampon tasarımı üzerinden her bir malzeme için ayrı ayrı analizler yapılmış ve sonuçları kıyaslanmıştır. Analiz sonuçlarına göre güvenlik faktörü değeri en iyi olan malzemenin karbon elyaf ve vinil esterden oluşan kompozit malzeme olduğu görülmüştür. Maksimum Von Misses değerinin en yüksek olduğu malzemenin ise cam elyaf ve karbon elyaf ile vinil esterden oluşan hibrit kompozit malzeme olduğu gözlemlenmiştir.

Bu çalışmada tampon hafifletmek için takviye seçimin, tamponun mekanik değerlerini iyileştirmek için matris seçiminin önemli olduğu sonucuna varılmıştır.

ACKNOWLEDGEMENTS

First of all, I would like to express my sincere gratitude to my supervisor, Prof. Dr. Mustafa ÖZCANLI, for his support and encouragement throughout the preparation of this thesis.

I sincerely thank Faruk ALTINBAŞ from Polütek Polyester Company and his team for sharing their knowledge, valuable time and technical support for this study.

I would like to thank Res. Assist. Berkay KARAÇOR and the Automotive Engineering Department academic personnel and also my dear colleague Melih Gazi KIRPIK for his valuable supports.

Last but not least, my parents and my sister. I wouldn't have succeeded my thesis without their support and encouragement.

INTRODUCTION

LIST OF TABLES **PAGE**

LIST OF FIGURES **PAGE**

LIST OF ABBREVIATIONS AND NOMENCLATURE

GP	:	Glass fiber and Polyester
GV	:	Glass fiber and Vinyl ester
CP	:	Carbon fiber and Polyester
CV	:	Carbon fiber and Vinyl ester
GCP	:	Glass fiber and Carbon fiber and Polyester
GCV	:	Glass fiber and Carbon fiber and Vinyl ester
FEA	:	Finite Element Analysis
FEM	:	Finite Element Method
CNC	:	Computer Numerical Control
AWJ	:	Abrasive Water Jet
PAN	:	Poly Acrylo Nitrile
MEK	:	Methyl Ethyl Ketone
3D	:	3 Dimensional
MPa	:	Mega Pascal
GPa	:	Giga Pascal
kg/m^3	:	Kilogramme per cubic metre

1. INTRODUCTION

Composite materials generally consist of two different materials called matrix and reinforcement. The matrix constitutes the overall volume of the material. The material which are used as reinforcement takes the stress on the composite material. The reinforcement element determines the toughness of the composite material, mechanical properties such as strength and resistance to impacts. The matrix element has the task of preventing the formation of deformation and the progression of deformation in the composite material. The matrix material prevents the composite material from rupture or breaking. The matrix material holds the reinforcing materials under load together and distributes the load homogeneously to the entire part. Although the matrix material is initially low in viscosity, it should be able to solidify easily. In order to achieve the desired success from the reinforcement element, the appropriate matrix material should be selected. The properties of the selected matrix and reinforcement element determine the properties of the composite material. (Beşergil, 2016; Türkmen and Köksal, 2013)

One of the most important advantages of composite materials is their low specific weight. Composite materials have high strength and their resistance to tensile and bending forces are higher than vast majority of the metals. Strength can be increased during lamination according to the desired direction. Thanks to its easy forming features, large and complex parts can be produced easily. It provides material and labor savings. If electrical properties are desired, composite products with electrical properties can be obtained by selecting the appropriate materials that are used to make up the composite material. The heat resistance properties of composites that are made out of materials which have low thermal conductivity coefficients are excellent. The heat resistance of the composite material can be increased with some special additives. Composite materials have vibration damping properties due to their ductility. In this way, the progression of cracks is prevented. Composite materials have high resistance to moisture, corrosion and chemical effects. Thanks to these features, it is used in the construction of chemical warehouses, marine vehicles, tanks and pipes. If the composite material is desired to be colored, the desired color can be given by adding color pigment to the resin. No additional expense or labor is required for the coloring process. (Türkmen and Köksal, 2013; Wang and Li, 2015)

Composite materials have many advantages over steel and aluminum. On the other hand, it has also some disadvantages. Raw materials are very expensive. The quality of the material depends on the quality of the production method. It doesn't have a standard quality. Composites are fragile materials and repairing damaged materials can create new problems. The formation of air bubbles during the production of composite materials adversely affects the fatigue properties of the material. It is not suitable for precision manufacturing as there may be separation in the fibers in processes such as cutting and drilling. The raw materials used in the production of composites have a shelf life.

Production of a composite material is a work that requires experience and research. There are many types of composite materials. There are many criteria for manufacturing composite materials. The matrix and reinforcement materials that make up the composite material are selected according to the technical specifications demanded from the composite material to be. The compatibility of the chosen reinforcement and the matrix with each other is also important. A composite material which has superior mechanical properties can be observed when matrix and reinforcement material are compatible with each other. The production method of the composite material also determines the quality of the composite material. (Saurabh, Ambhore, and Mache, 2017)

Composite materials have become widespread due to the above-mentioned advantages. It is used for different purposes in many different sectors such as defense, aviation, automotive, marine, sports vehicles, musical instruments, health sector and construction sector. According to a market researcher in India, the distribution of the composite material market in 2019 by sectors is shown in the Figure 1.1.

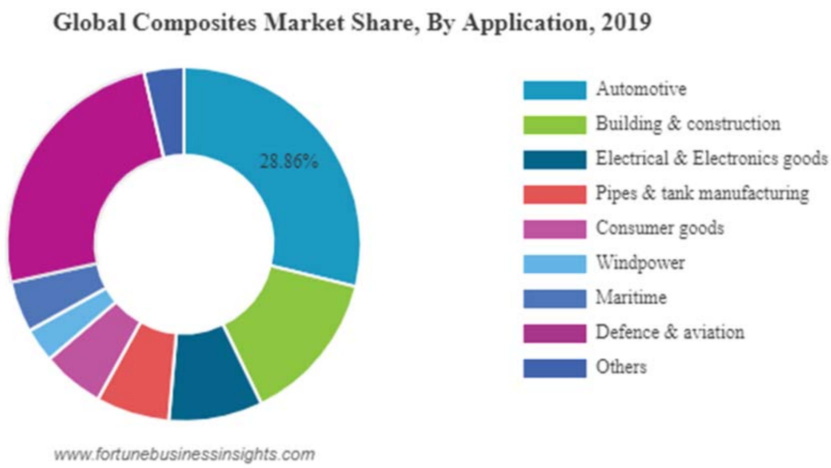

Figure 1.1. Distribution of the composite material market by sectors (%)

Composites have properties that the materials that compose them cannot have alone. The most typical example is “fiberglass” materials produced by reinforcing polyester-based resins with glass fiber. The beginning of modern composites dates back to the discovery of glass fiber in the 1930s.

The Stout 46 developed by Owens Corning and William Stout in 1945 is acknowledged as the world’s first composite prototype car. The body shell and air suspension of this car, shown in Figure 1.2, are produced with glass fiber.

Figure 1.2. The world's first composite prototype car

In today's automotive industry, efficiency comes to the fore in general. Improving lightness for a more efficient vehicle not only facilitates the acceleration of the vehicle, but also reduces the amount of energy required during deceleration. In this respect, the materials used in the automotive industry are important. The materials used for a lightweight vehicle increase energy efficiency. These materials are also expected to be in a structure that does not compromise passenger safety. This makes the use of light and high strength materials widespread in the automotive industry. Among these materials, composite materials are suitable for the specified properties and are currently used in many areas. Many parts of many vehicles produced today, such as fenders, front and rear bumpers, spoilers, headlight masks, front and rear masks, trunk lids, door panels, dashboard, are produced with composite materials. (Ahmad, Markina, Porotnikov, and Ahmad, 2020; Belingardi, Beyene, Koricho, and Martorana, 2015; Beyene, Koricho, Belingardi, and Martorana, 2014; Durgun et al., 2014; Jamrichová and Aková, 2013; Kumar.A, 2014; Ramachandra, 2017)

In Figure 1.3 an example that composite materials can be applied for a bus parts without sacrificing safety factor, and providing reduction in weight is shown.

Figure 1.3. Major parts that composite materials can be applied on a bus

The bumper, which is one of the automotive parts, is the first part that is exposed to the impact of the vehicle. In this study, the optimization of different composite materials has been studied instead of the composite material used in the rear bumper of the vehicle. 2 different reinforcement materials and 2 different matrix materials 6 different composite materials were produced using the traditional production method. Tensile tests were performed on 6 different composite materials produced under equal conditions and their mechanical values were compared. The mechanical values obtained as a result of the test were entered into the ANSYS analysis program. Force was applied to the designed rear bumper for 6 different materials.

2. LITERATURE REVIEW

Wonderly et al., (2005) used vinyl ester along with glass fiber and carbon fiber. The samples were produced by vacuum infusion method. Tension, compression, open hole tension, open hole compression, transverse tension, indentation and ballistic impact strengths were compared. The carbon fiber has proven to be mechanically superior under tensile loading. Fiber glass laminates proved stronger under pressure loading and ballistic impact conditions. (Wonderly, Grenestedt, Fernlund, and Cěpus, 2005)

Prabhakaran et al., (2012) designed and fabricated a glass fiber reinforced polymer composite to reduce the weight of the bumper. Composite bumper manufacturing was carried out by hand lay-up method using E-glass/epoxy double-sided laminates. Composite bumper was analyzed and Charpy impact tests were performed. Comparing with the steel bumper, it was found that the composite bumper has a 64% higher safety factor and 80% less cost. It was found that a weight reduction of 53.8 % was achieved by using composite material without sacrificing strength. (Prabhakaran, Chinnarasu, and Kumar, 2012)

Hu et al., (2015) conducted a study on the lightness and impact resistance of automotive bumpers. The carbon fiber reinforced plastic bumper beam is thought to replace the traditional high-strength steel one. Low-speed impact finite element simulations for two buffer beams were performed on LS-DYNA. The energy absorption capabilities and dynamic response characteristics of the carbon fiber reinforced plastic bumper beam were investigated and compared with the steel one. It was concluded that the carbon fiber reinforced plastic bumper beam has better energy absorption ability than the steel one. Weight is significantly reduced. (Hu, Liu, Zhang, Ding, and Wu, 2015)

John and Nidhi, (2014) modeled the bumper for the low passenger vehicle, the Ambassador, using CATIA V5R18 software. Static analysis of this model was done with ABAQUS 6.10. Modal analysis for the same model under dynamic loading was performed using ANSYS WORKBENCH 11.0. For these analyses, aluminum B390 alloy, chrome-plated mild steel and carbon composite were used. As a result of static analysis, the carbon composite gives the lowest deformation and the maximum von misses stress value. As a result of the impact analysis, the composite material shows the highest stress value, the lowest deformation and the lowest strain value. According to the analysis performed under dynamic loading, it shows that the composite has the maximum stress value and has the highest strength to weight ratio. From all these analyzes, it can be concluded that the composite is the best material to be used as a bumper material compared to the other materials used here. (John, 2014)

Şen, (2020), worked on the optimization of glass fiber, glass and carbon hybrid fiber, carbon fiber, glass and aramid hybrid fiber reinforced composite materials instead of the thermoplastic polypropylene material used in the front bumper of the vehicle. Fibers of different structures were produced by vacuum bagging method using epoxy resin under equal conditions. Impact and bending analyzes of the bumper made of polypropylene material were performed to determine the mechanical values. Fibers to be used in the optimization study were determined as glass fiber, glass and carbon hybrid fiber, carbon fiber, glass and aramid hybrid fiber reinforced composites to provide different properties suitable for use in the bumper. Tensile, bending and impact tests of composites were carried out at the same temperature and under equal conditions. Since the bumper is the structure that takes the first impact on the vehicle and acts as a damper, fibers with high strength values and epoxy resin are used as the matrix material in the construction of the composite plates. In this study, the mechanical values of polypropylene material used in vehicle bumpers and different fiber reinforced composite materials were compared. It is envisaged that the mechanical values obtained as a result of the experiments according to the desired properties of the bumper can be compared and material selection can be made according to the usage area. (Şen, 2020)

Gulmez (2018) gave information about the place and importance of polymer matrix composite materials in the automotive industry with various examples. Composite materials, whose use is increasing today, have started to be widely used in the automotive sector after the aviation, space and military fields, with the decrease in costs and the development of new methods, and have been the main subject of many studies. In particular, the use of fiber and polymer matrix composite materials in the automotive sector is increasing to a great extent. Although it is mostly used for weight reduction, visual improvement and increasing crash performance, it has started to be used in other automotive parts with the developing new materials and methods. (Gülmez, 2018)

Elanchezhian et al., (2014) investigated the composites they produced using glass fiber and carbon fiber and epoxy resin at different temperatures and shrinkage rates. As a result of the study, it was observed that the tensile strength value of carbon fiber reinforced composites is higher than glass fiber reinforced composites, and the elongation of glass fiber reinforced composites under tensile loads is higher than carbon fiber reinforced composites. It has been observed that the impact and bending strengths of carbon fiber reinforced composites are higher than glass fiber reinforced composites. In the examination made with SEM, it was seen that fiber directions were effective on mechanical values. (Elanchezhian, Ramnath, and Hemalatha, 2014)

Wang et al., (2015) investigated the mechanical properties of composites produced by using aramid and glass fiber reinforced woven fabrics and epoxy resin under tension, compression bending and shear conditions. In the experiments, it was seen that the shear strength of aramid fiber reinforced composites was insufficient. As a result of the non-linear tensile test, it was seen that aramid fiber reinforced composites showed distortions compared to glass fiber reinforced composites and had much lower strength in compression, bending and shear tests. (Wang and Li, 2015)

Cheon et al., (1995) found out that the best way to increase the fuel efficiency without sacrificing safety factor is using the fiber reinforced composite materials in some part of vehicles. Their study showed that it is possible to decrease the weight of the bumper with a ratio of seventy percent when it is used a bumper which made of glass fiber fabric epoxy instead of steel. (Cheon, Choi, and Lee, 1995)

Sujon et al., (2020) investigated that nowadays traditional metallic and alloy materials are replaced with the composite materials which are fiber based in engineering applications. The tensile and water absorption behavior of the produced composite samples were experimentally studied. To validate the experimental result of the tensile test, 3D model of the composite samples were imported to a Finite Element Analysis (ANSYS) software by applying the same conditions that tests were conducted. In conclusion, the results observed from the software application were similar with experimental results. (Sujon, Mehfuz, and Habib, 2020)

Özarslan (2016), produced and tested composite materials consisting of carbon fiber and epoxy. He designed the automobile chassis in 3D in Solidworks drawing program and used the test results. Aluminum material and composite material based chassis were examined and analyzed in the ANSYS program. Chassis development has been successfully completed. (Özarslan, 2016)

3. MATERIALS AND METHODS

3.1. Materials

3.1.1. Matrix Types and Properties

In composite structures, matrices are used to hold the fibers together, to distribute the load and to protect the composite against environmental factors. Although the matrix material has a low viscosity at the beginning, it should be able to become solid easily. An ideal matrix material should be able to hold the fibers together and strong. The mechanical properties of the matrices used together with fibers in composite materials are also very important. Matrix materials ensure that the load is evenly distributed among the fibers. It provides resistance to stresses under shear load. Matrix is weaker and more flexible than fiber. This feature is an issue that should be considered in the design of composite structures.

In order for the fiber to show the desired success, a suitable matrix must be selected. When choosing the matrix, the moisture and water absorption properties of the material are taken into consideration. The strength of the material, the amount of elongation, fatigue properties are also important. Viscosity is also important, as most matrices are in liquid form. Epoxy, polyester, vinyl ester and phenolic resins are matrix materials used in the production of composite materials.

Polyester and vinyl ester are used in this study.

3.1.1.1. Polyester

Polyester is the simplest and most economical resins. Polyester resins have been accepted as the least toxic thermoset for personnel. Most polyesters are air pressed and do not cure in contact with air. Therefore, before the polyester is applied, a paraffin, such as wax, which has the effect of covering the surface, is applied. Wax film on the surface causes problems in secondary bonding, it must be removed. The curing of polyester without the addition of heat is accomplished by adding an accelerator along with a catalyst. Gelling times can be controlled with formulations prepared by paying attention to laminate thickness and ambient temperature. (Eric Greene Associates., 1999)

Cobalt can be given as an example of accelerators added to shorten the gelling time of polyester. A catalyst such as MEK (Methyl ethyl ketone) peroxide is added to initiate the reaction of the polyester to solidify. Since the polyester used in this study contains cobalt, no accelerator was added. However, a certain amount of MEK peroxide was added.

Polyester resins are the most used resins in the composite industry. Polyester is easily processed with various variants, has a low viscosity, and has high environmental resistance. It is easy to evacuate moisture. The disadvantage of polyester resin is that it has a brittle structure and low chemical resistance. Due to the exothermic reaction, bond formation remains weak.

In table 3.1 the properties of polyester which is used in this study to produce composite material is shown.

Table 3.1. Mechanical properties of BOYTEK 452 Polyester (Boytek, 2018a)

MATERIAL / PROPERTIES	TENSILE STRENGTH (MPa)	BENDING STRENGTH (MPa)
POLYESTER BOYTEK 452	72	130

3.1.1.2. Vinyl ester

The usage properties of vinyl esters are similar to polyester and their performance properties to epoxy. Vinyl ester is more durable and flexible than polyester. Vinyl ester provides excellent corrosion resistance. When vinyl ester is used as a matrix, quality bonds are established with the fiber. The chemical resistance of vinyl ester is high. Although vinyl esters have superior physical properties like epoxy resins, they do not require complex processes or special handling skills like epoxy resins. (Eric Greene Associates., 1999; Genç, 2006; Şen, 2020; Türkmen and Durmuş, 2013)

Although vinyl ester is expensive compared to polyester, it provides the properties of epoxy resin, which is more expensive. The catalyst used for polyester in this study was also used for vinyl ester. Since cobalt is also in the vinyl ester, it was not added again.

In table 3.2 the properties of vinyl ester which is used in this study to produce composite material is shown.

Table 3.2. Mechanical properties of BOYTEK BE 780 Vinyl ester (Boytek, 2018b)

MATERIAL / PROPERTIES	TENSILE STRENGTH (MPa)	BENDING STRENGTH (MPa)
VINYL ESTER BOYTEK BVE 780	85	145

3.1.2. Fiber Types and Properties

The basic element of the composite structure is the fibers, which are the reinforcement elements used together with the matrix material. Corrosion resistance, hardness, low density, high modulus of elasticity and high strength are the superior mechanical properties of reinforcement materials. The placement of the fibers in the matrix directly affects the strength of the composite materials. Fibers should be placed in the matrix in both directions to provide strength in both directions. The strength and properties of the fibers used are very important for the strength of the composite material. (Şen, 2020)

In addition to their low densities, fibers with high modulus of elasticity and hardness are also resistant to chemical corrosion. Glass fibers are the oldest fiber types used. Boron, carbon, silicon carbide and aramid fibers, which have been developed in recent years, are the fibers used in advanced composite structures. The small grain size of the fibers and their small-scale production provide superior microstructural properties. As the length/diameter ratio increases, the amount of load transmitted by the matrix material to the fibers increases.

3.1.2.1. Glass Fiber

In glass fiber production, various stones combine in liquid form at approximately 1600 C to form glass. This liquid passes through very thin buckets and forms glass fiber threads with a diameter of 9 to 25 microns. These threads are tightly joined to form fibers or loosely rovings. These are then coated with various chemicals to create the adhesion properties of the threads and increase their resistance to abrasion. Glass fiber has good chemical resistance and is easy to process. Their tensile strength is excellent. However, they can deteriorate if they are under load for a long time. Different types of glass fiber can be formed according to the types of stone used during production. (Genç, 2006)

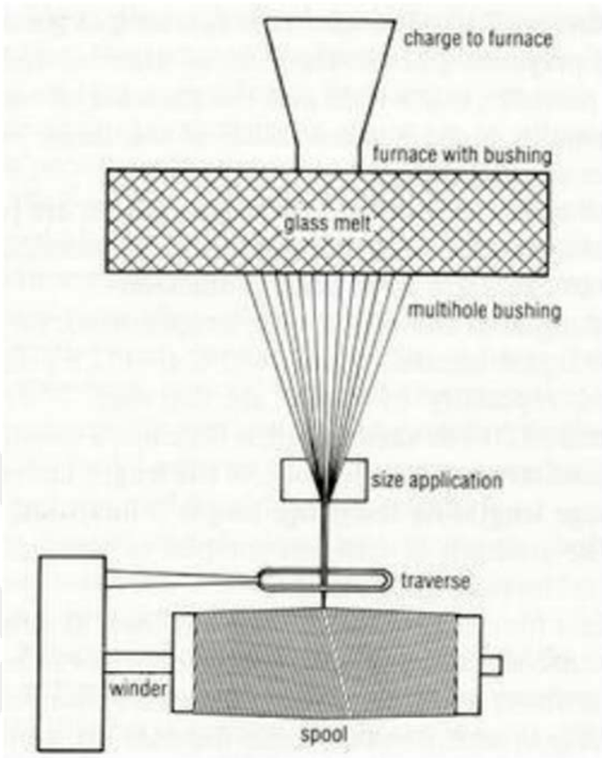

Figure 3.1. Glass fiber production

Properties of Glass Fiber;

- Glass fibers have high tensile strength. Its strength per unit weight is higher than that of steel.
- Glass fiber has low thermal resistance, they do not burn at high temperatures, and they only soften.
- They are resistant to chemical materials.
- They do not have moisture absorbing properties, but this property can be achieved with special fiber coating processes.
- They cannot conduct electricity. Glass fiber composites can be used where electrical insulation is required. (Şen, 2020)

Figure 3.2. Woven glass fiber (500 gr/m²)

It is the most common fiber used in glass polymer composites. The most commonly used glass fibers are E-glass, S-glass, R-glass, C-glass and D-glass. The E in E-glass stands for electricity as it is designed for electrical applications. E-glass fiber is a high quality glass fiber used as a standard reinforcement for all resin systems and well suited to mechanical property requirements. The S in S-glass stands for higher silica content. It maintains its strength at high temperature and has higher fatigue strength. S-glass is mainly used in aerospace applications. The C in C-glass represents corrosion. C in C-glass represents corrosion. It is designed to provide better surface quality. It is often available in the form of surface textures for reinforcing abrasive barriers in chemical plants. The D in D-glass refers to the dielectric used for applications that require low electrical constants. (Prabhakaran et al., 2012)

The main glass type used in the automotive sector is E-glass. In this study, it was found appropriate to use E-glass.

3.1.2.2. Carbon Fiber

Carbon is a crystalline material with a density of 2.268gr/m3. Carbon fibers are a group of fibers that developed later than glass fibers and are very widely used. In terms of carbon fiber production, it is produced on a short and continuous basis. Although it is more durable than glass fiber, the production cost is more. The most important properties of carbon fibers are low density value, high strength and toughness. Carbon fibers are not affected by moisture and their friction resistance is very high. Their wear and fatigue strength is quite good. The durability and hardness properties of carbon fibers increase compared to the resin used together. (Şen, 2020; Türkmen and Durmuş, 2013)

Carbon fibers are commercially available in two forms. Continuous fibers are woven, braided, resinized fibers. They can be used with all resin types. Cropped fibers are obtained by trimming continuous fibers. It is less durable than continuous fibers.

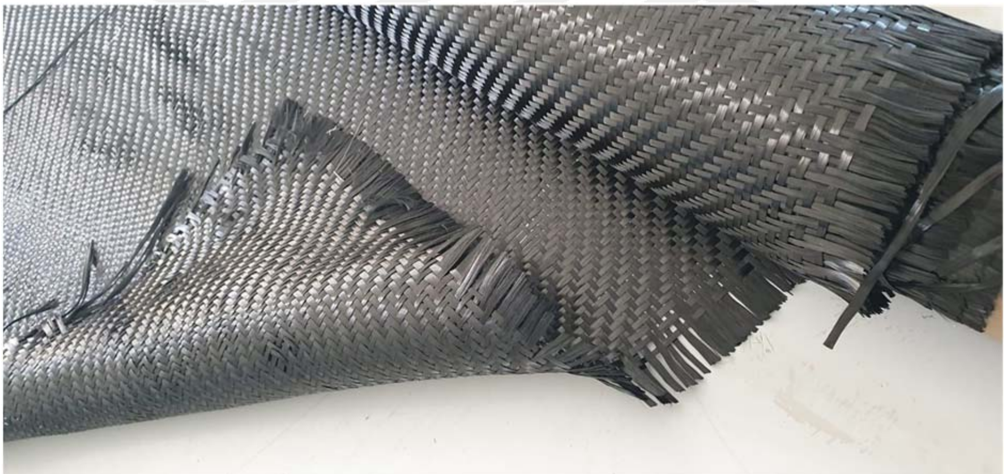

Figure 3.3. Woven Carbon fiber (250 gr/m²)

Carbon fibers have very good corrosion resistance as well as a strong and rigid structure. They are produced from two materials: PAN (poly acrylo nitrile) and pitch. Composite materials produced using PAN-based carbon are subjected to four stages: oxidation, carbonization, surface improvement and coating to make them more durable and lighter. Pitch-based carbon fibers are rarely used. Its mechanical properties are low compared to PAN-based composites. Graphite processing is carried out using carbon fiber production methods, oxidation and organic precursor. (Şen, 2020)

In this study, pan-based woven fiber was used.

Table 3.3. Properties of fibers

FABRIC	WEAVE	WEIGHT (gr/m²)
Glass fiber	Twill	500
Carbon fiber	Twill	250

3.2. Methods

3.2.1. Hand Layup

Hand layup method is the most traditional method known. Before starting the application in the hand layup method, it is necessary to make a few preparations. First of all, it is necessary to clean the mold. After the mold is cleaned, wax is applied to the mold. Wax prevents the manufactured part from sticking to the mold. Production begins with the application of resin to the mold. Then fiber is laid on the resin. The resin is impregnated with the reinforcement material with the help of a roller. Equal distribution of the resin in the mold is ensured. Reinforcement layers are applied until the desired thickness is reached. Reinforcement layers are added and applied as much as they can absorb. The product is left to cure at room temperature. The product is left to cure at room temperature, after solidification it is removed from the mold.

Since all operations are performed manually, it is called the Hand Layup Method. The ratio of resin and reinforcement material to be used in production depends on the experience and knowledge of the manufacturer. The quality of the material produced depends on the manufacturer's capabilities. That is why it is a very flexible process that allows the product to be optimized. It requires little capital, it is labor intensive.

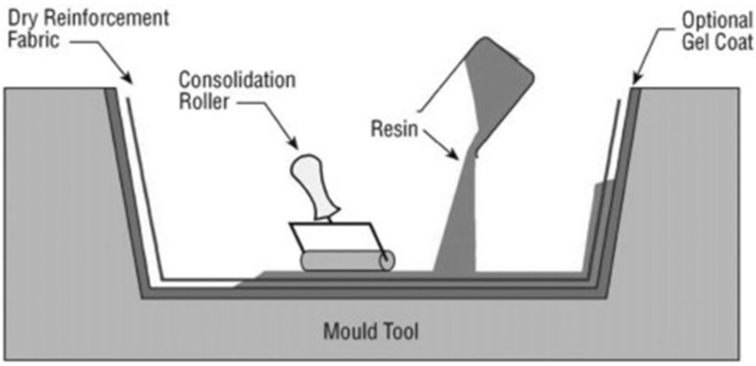

Figure 3.4. Hand layup process (Prabhakaran et al., 2012)

The mold design in the hand layup method is low-cost and simple compared to other methods. Low pressure and room temperature are sufficient for curing the manufactured parts. The method is very simple and versatile. The choice of reinforcement material and resin to be used in production can be easily changed. By changing the laying direction of the reinforcement material, the strength and resistance direction of the part to be produced can be determined. Different orientations can be created with the same materials. Since simple molds can be used, the cost of producing prototype parts is very low. The raw materials used and raw material preparation processes are cheaper than other methods. Human labor is intensive in the processes of the hand layup method. That is why the quality of each manufactured part is different from the other. Since the production is done by human hands, large parts can be produced even if they are not as easy as small parts. It is an ideal method for production in low quantities. (Prabhakaran et al., 2012)

The production of all plates were carried out at room temperature. The surface on which the production made was cleared of foreign materials such as dust and dirt. The surface must be clean, smooth and flat to have clean cut plates. In order to provide a smooth surface on the produced plates, the processes were performed on the glass surface.

Wax was applied to the surface and allowed to dry. The surface was cleaned with a clean cloth. After drying, another coat of wax was applied. This process was repeated three times in total. Wax is applied to the surface to easily separate the produced plate from the glass surface. The process of applying wax to the surface is shown in Figure 3.5.

Figure 3.5. Applying wax to the surface

Fiber fabrics were cut in A3 sizes. Since the resins are cobalt-containing products, cobalt was not mixed again. 0.7% MEK was mixed into the resin. The prepared resin mixture was applied with a brush on the dry clean surface. The resin application process is shown in Figure 3.6.

Figure 3.6. Applying the resin

The first layer of fiber was placed on the resin and the resin on the surface was absorbed into the fiber with the help of a brush. The fibers were placed in layers. The fibers were layered and the resin was applied with a brush between the fiber layers. The resin application between the fiber layers is shown in Figure 3.7.

Figure 3.7. Applying resin between fiber layers

Roller was used to have homogen plates and to have equally distributed resin beside of removing over applied resin. With the help of roller, trapped air between the layers of plates was removed and this provided more homogen structure for production and for specimens to be tested. The over-applied resin was removed from the system with the help of a roller. Absorption of resin by fiber was increased with decreased trapped air thanks to roller shown in Figure 3.8

Figure 3.8. Removal of excess resin with a roller

In order to have identical plates, it was ensured that each plate had 4 mm thickness. A glass plate was placed on the upper surface to make it smooth and to have equal pressure distribution on plate. So that both surfaces of each plate were smooth and have equal thickness. After the drying process was completed, the plates were separated from the glass plates and post-cured. The post curing process was carried out at 90ºC for 2 hours.

A total of 6 plates were produced, which were composed of fiberglass/polyester, fiberglass/vinyl ester, carbon fiber/polyester, carbon fiber/vinyl ester, glass fiber and carbon fiber hybrid/polyester and glass fiber and carbon fiber hybrid vinyl ester. The production of these 6 plates was carried out under the same conditions.

3.2.2. Abrasive Water Jet

In the cutting process with AWJ, the water pressure is increased to approximately 4000 bar with the help of a pump mechanism and the high pressure water is conveyed to the cutting head. In the cutting head the high pressure water flow is focused through an orifice into the mixing chamber. In this chamber, a certain amount of pre-dosed abrasive particles are added to the focused water stream. When leaving the mixing chamber, the mixture, which is passed through a sapphire tip between 0.8-1.2 mm, focuses on the workpiece and as a result, the desired operation is performed.

Since the AWJ method is carried out without burning, there is no heat-affected zone in the material and there is no change in the mechanical and chemical properties of the material in the cutting zones of the cut material. Cutting speed is high. The cutting surface is smooth and burr-free. The cutting force applied during the process is very low. (Akkurt, 2004; Armağan and Arici, 2017)

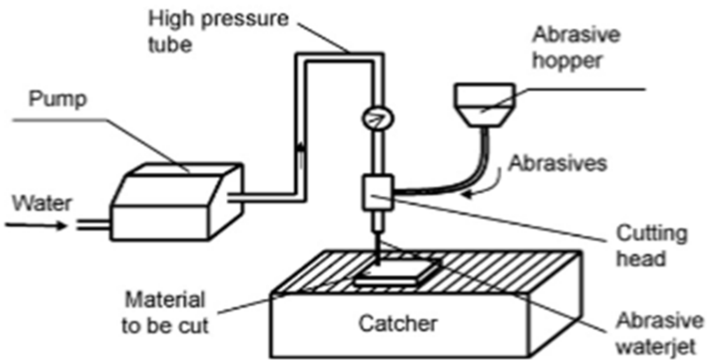

Figure 3.9. Schematic of an abrasive water jet cutting system (Shanmugam and Masood, 2009)

The produced plates are composite materials. Since there is a fibrous structure in it, incorrect cutting action leads to result in incorrect values in the mechanical test results. Moreover, since the resins are flammable materials, even if the post curing process is completed, it may burn by cutting it in a machine such as a CNC Laser cutting machine. For all these reasons, the abrasive water jet method was preferred. A cutting plan was created according to TS EN ISO 527-2 standard type 1B tensile test specimen dimensions. Five of specimens from each plate was cut with abrasive water jet. To be able to distinguish the specimens from each other different dye colors were used. Each color represented one material that the specimen made out of. Specimen dimensions are shown in Figure 3.10. The specimens cut according to the standard are shown in Figure 3.11.

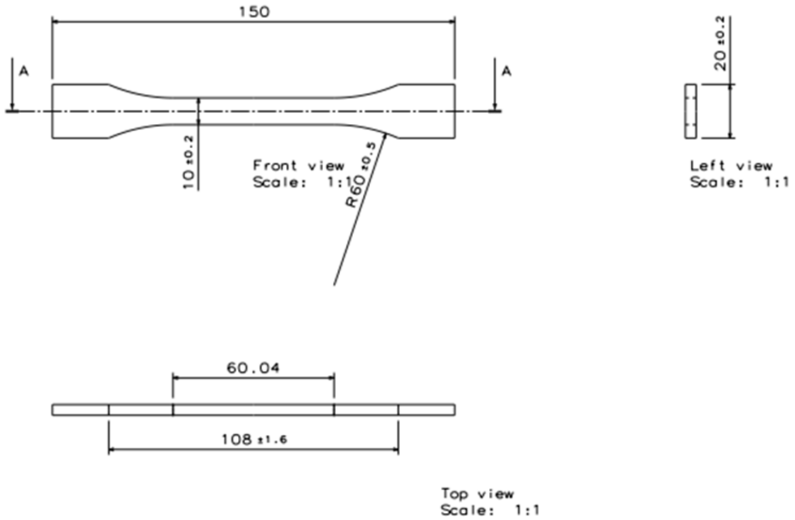

Figure 3.10. ISO 527-2 Type 1B tensile test specimen dimensions (mm) (British Standards Institution., 2010)

Figure 3.11. Tensile test specimens

3.2.3. Tensile Test

The tensile test is popular because different components can be designed with the properties obtained. The tensile test measures the resistance of a material to a static or slowly applied force. The sample with a standard diameter and length is placed in the testing machine. A force f called load is applied. A universal testing machine is used where tensile and compression tests can be performed frequently. A strain gauge or extensometer is used to measure the amount the specimen stretches between the gage marks when force is applied. So that the variation in the length of the sample is measured relative to the original length. Information on the strength, young's modulus and ductility of a material can be obtained from such a tensile test. Tensile testing is usually done on metals, alloys and plastics. (Askeland, Fulay, and Wright, 2010)

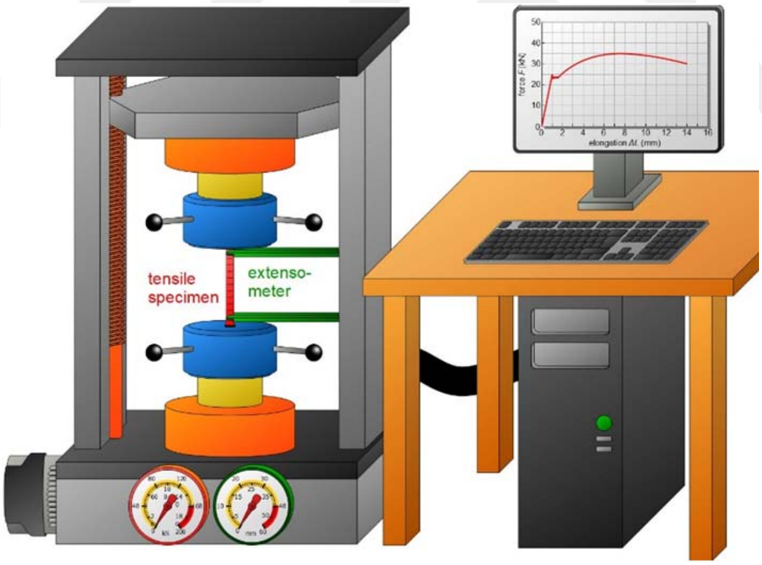

Figure 3.12. Setup for tensile testing

The poison's ratio attributes the longitudinal elastic deformation produced by simple stretching or compression to the lateral deformation occurring simultaneously.

The surface of the specimens painted to distinguish them from each other and prevent the reflection of the light from the surface as extansiometer is a device that is sensitive to the light, which may cause inaccurate measurement. Therefore, the surfaces of the specimens were painted with matte black spray paint. The applied paints were allowed to dry to perform the tensile test. The specimens with painted surfaces are shown in Figure 3.13. The tensile test was performed with the SCHIMADZU Tensile Test Machine with a capacity of 100 kN, shown in Figure 3.14. The data acquisition rate was 6000 data/minute in the test device. The screen of the tensile tester is shown in Figure 3.15. An extensometer was used to determine the percent elongation in gauge length and percent reduction at width of the test specimen. A photo which was taken during the test is shown in Figure 3.16.

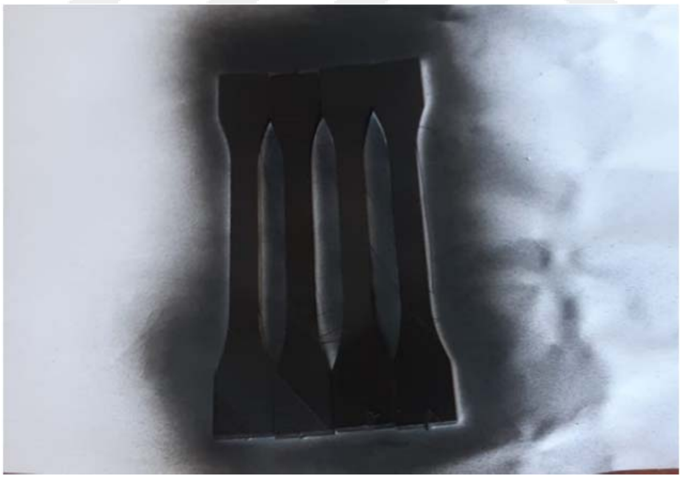

Figure 3.13. Specimens with painted surfaces

Figure 3.14. Tensile Test Machine

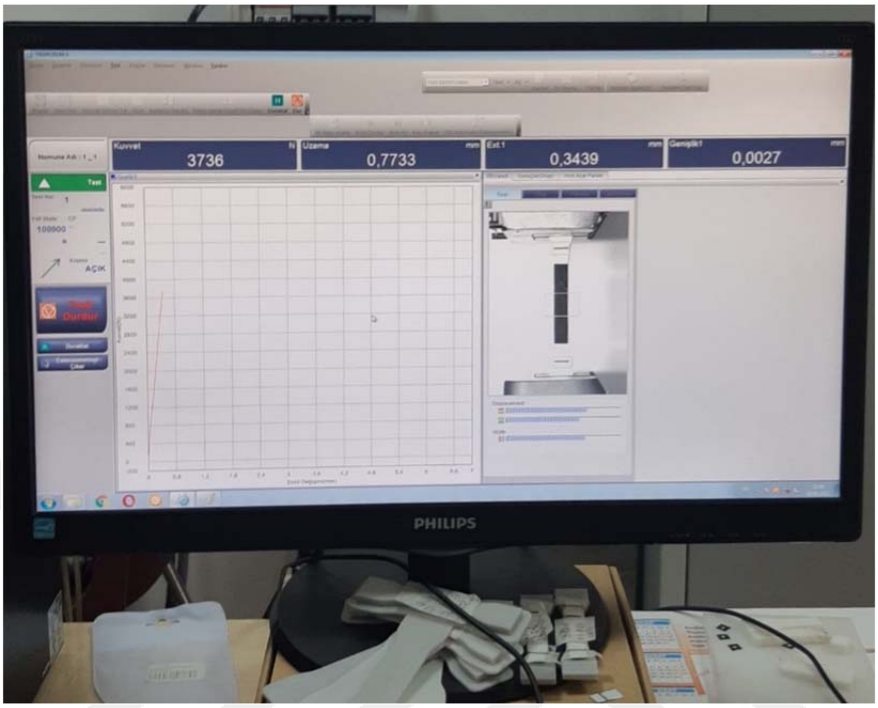

Figure 3.15. Screen of Tensile Testing Machine

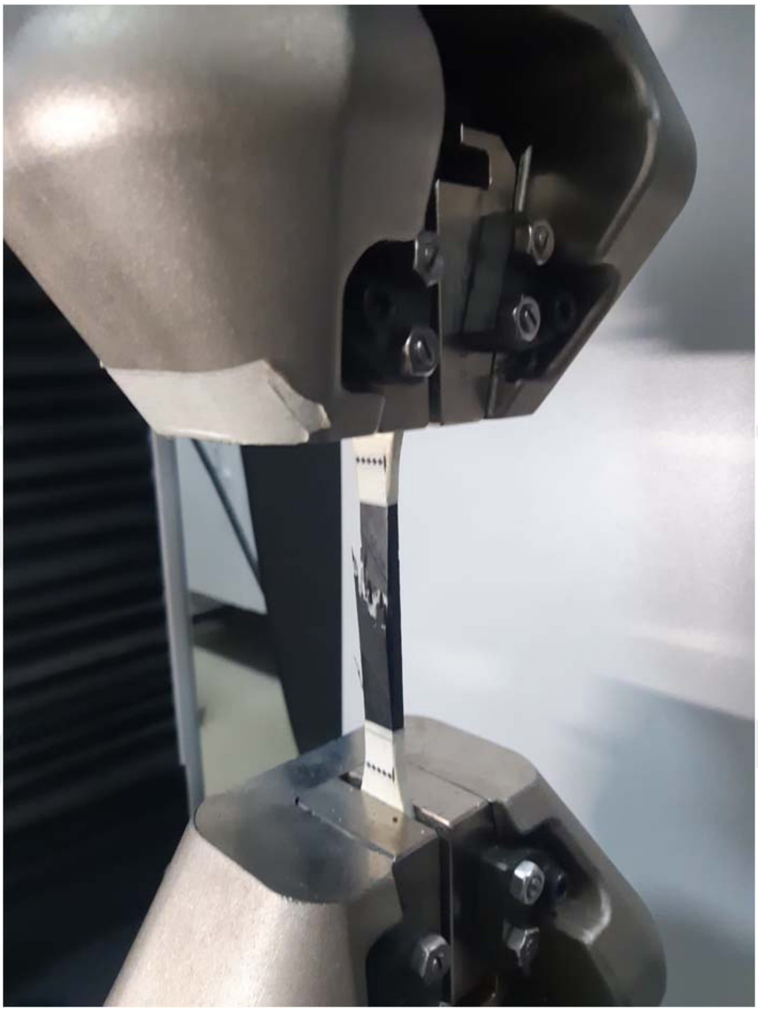

Figure 3.16. Moment of application in Tensile Testing Machine

All of the specimens were subjected to the tensile test under the same conditions. The state of the specimen at the end of the tensile test is given in Figure 3.17.


Figure 3.17. Specimens after Tensile Test

3.2.4. FEM (The Finite Element Method)

The Finite Element Method (FEM) is a numerical calculation method used to see the problems that occur in a structure under applied forces. Finite Element Analysis (FEA) is a practical application of The Finite Element Method (FEM). It is used by engineers to solve very complex structural and multi physics problem numerically. ANSYS is a multi-purpose Finite Element Analysis (FEA) program. ANSYS includes the ability to solve static and dynamic structural analysis, transient heat transfer problems, static or time varying magnetic analysis, and various steps of field and coupled-field applications. (Akhil, Shaa G, and Kumar, 2016; Özarslan, 2016; Prabhakaran et al., 2012)

Various analyzes such as static analysis are required to determine the best material for the bumper. Static analysis is used to find the deformation and stress distribution on the structure. In this project, ANSYS 17.0 was used as a tool to achieve the project target.

In this chapter, firstly the materials used in preparing the catalysts and their properties were identified. Then, the stages of the catalyst production process were explained in detail. In the next section, technical information was given about the devices used to prepare the catalyst and analyze the chemical and structural properties of the catalyst. Finally, information was given about the emission performance test system in which the catalyst was tested under real conditions, the technical specifications of the equipment in the system, and the programs used.

There are a lot of materials which are defined in ANSYS Engineering Data Sources. However, the materials that were produced can be defined to the Engineering Data Sources. Each material has unique material properties especially if they are composite materials as Mechanical properties of composites depend on a lot of factors such as production method, environment that plates were produced and so on. In this study, the mechanical properties of the produced composite materials don’t exist in Engineering Data Sources. Results of the composite materials that were tested shown in Table 3.1. This results have to be added to do engineering data to be able to do static analyses in ANSYS. Some of the mechanical properties to do static analysis in ANSYS are density, Poisson’s ratio, yield strength, ultimate tensile strength and Young’s modulus. In Figure 3.18 the materials are shown after they were added to the Engineering Data Sources.

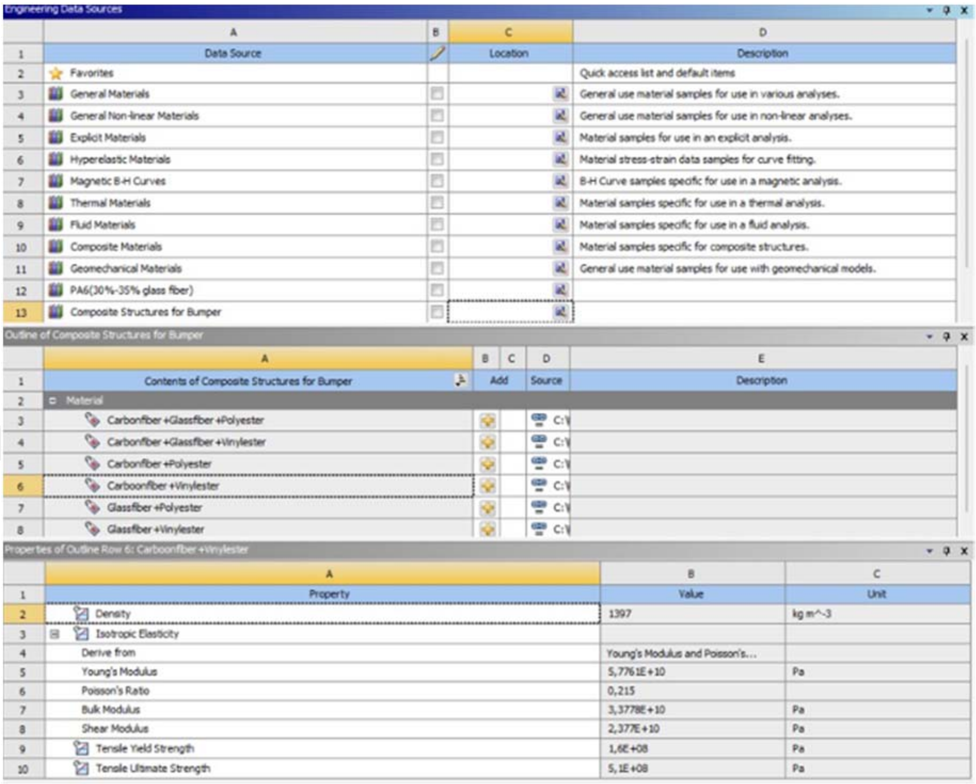

Figure 3.18. Representation of Engineering Data Sources after composite materials were defined

In Figure 3.19 the bumper which was designed by taking the referance of commercial bus dimensions is shown. The dimensions of the bumper shown in Figure 14 the tickness of the bumper was chosen as 3 mm.

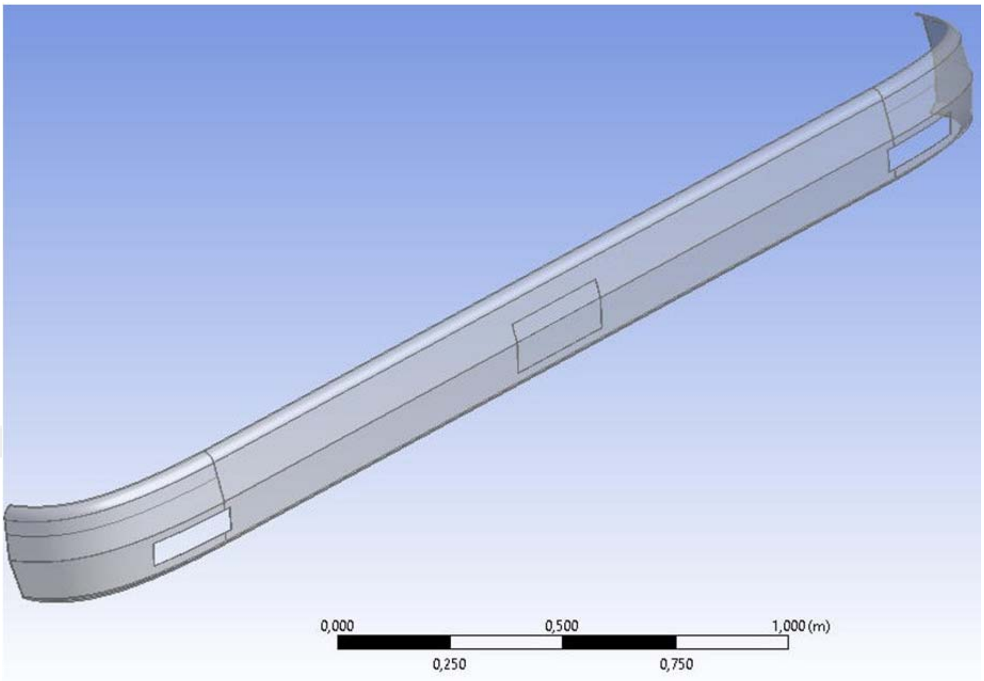

Figure 3.19. Modal bumper

To be able to implement the composite materials that were produced in this study, the bumper model designed which is shown in Figure 3.20.

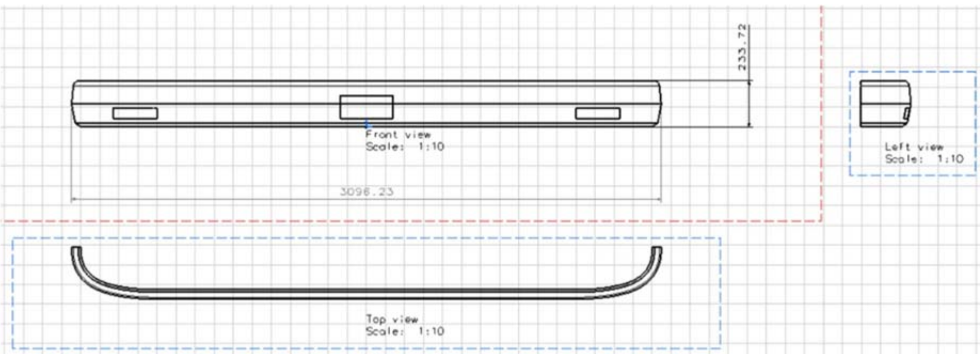

Figure 3.20. The dimensions of bumper

After the modeling process was completed, the meshing process was performed. The mesh model has 245935 elements and 476505 nodes. The completed meshing of the bumper model is shown in Figure 3.21.

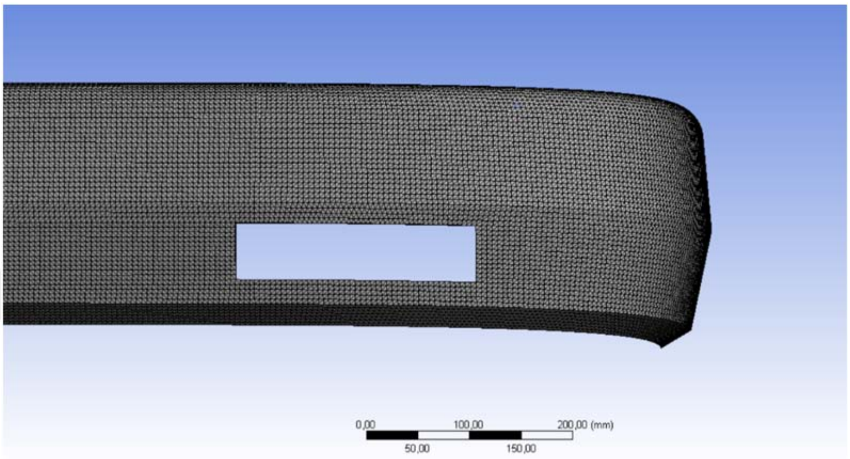

Figure 3.21. Meshed model of bumper

The bumper model, whose meshing process was completed, was fixed on both sides. Fixed support faces are shown in Figure 3.22.

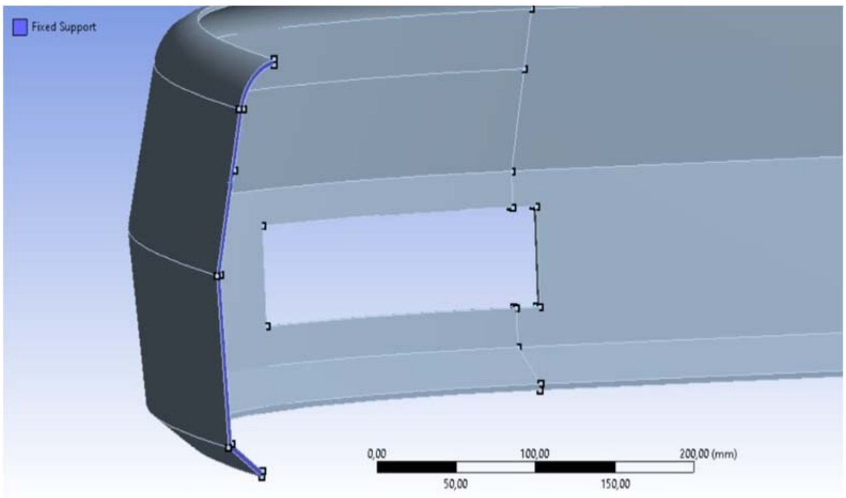

Figure 3.22. Fixed support regions

To be able to compare the Von Misses stresses and safety factors of the materials a 400 N force was applied on bumper. It was clearly seen that some of the materials couldn't handle with that force so that the safety factors were lower than 1. The surface on which the force is applied on the bumper model and the force direction are given in Figure 3.23.

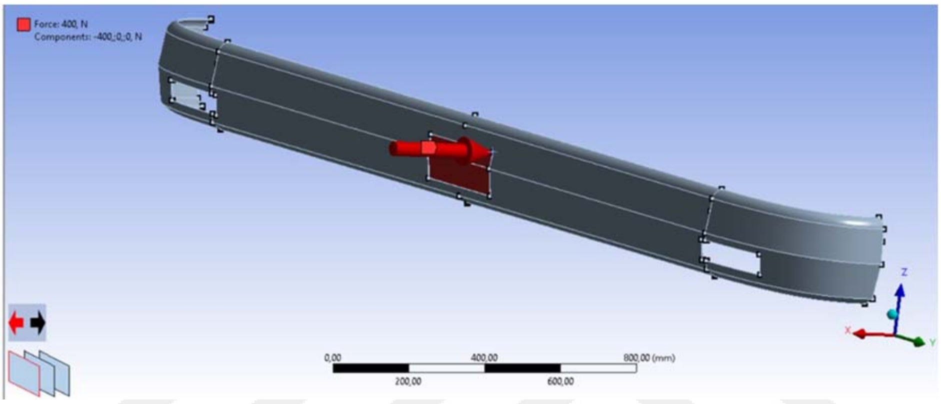

Figure 3.23. The surface on which the force is applied

4. RESULTS AND DISCUSSION

The values seen in Table 4.2 found by taking the average of five specimens for each set that represents a composite structure such as GP. With respect to the results of tensile tests mechanical properties of composite structures had been shown in Table 4.2.

The abbreviations of the specimens are shown in Figure 4.1.

Table 4.1. The abbreviations of the specimens

SPECIMENS	ABBREVIATIONS
Glass fiber and Polyester	GP
Glass fiber and Vinyl ester	GV
Carbon fiber and Polyester	CP
Carbon fiber and Vinyl ester	CV
Glass Fiber and Carbon fiber and Polyester	GCP
Glass Fiber and Carbon fiber and Vinyl ester	GCV

Table 4.2. Mechanical properties of specimens

SPECIMEN	DENSITY (Kg /m³)	POISSON'S RATIO	YIELD STRESS (MPa)	ULTIMATE TENSILE STRESS (MPa)	YOUNG'S MODULUS (GPa)
GP	1879	0.400	90	274	18.0
GV	1759	0.266	94	341	20.5
CP	1373	0.251	151	378	41.8
CV	1397	0.215	160	510	57.8
GCP	1662	0.340	129	380	38.4
GCV	1457	0.100	110	370	31.1

The results of 6 different materials were compared with respect to their safety factor and von misses stresses which were taken from ANSYS.

Results show that maximum von Misses stress of the GP bumper model is 99,218 MPa. Figure 4.1 shows the von Misses stress distribution of GP composite during static analysis.

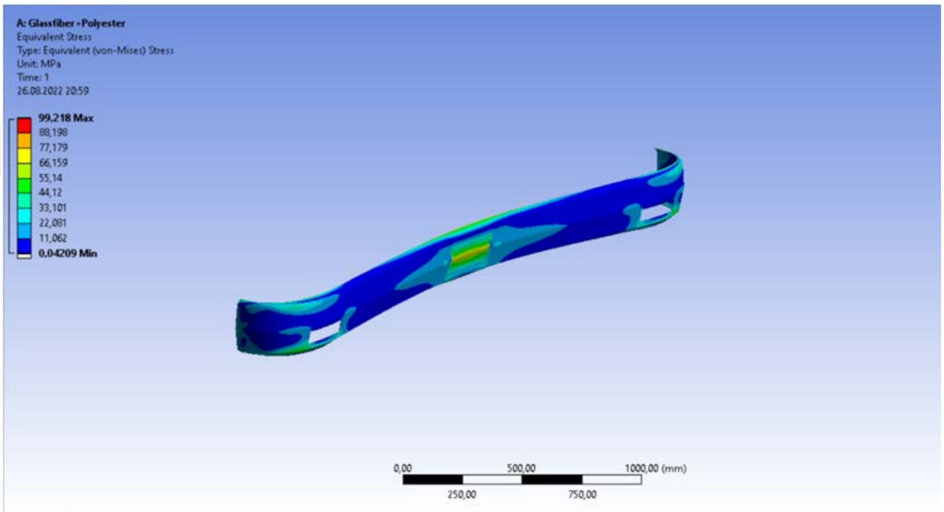

Figure 4.1. Von Misses stress distribution of GP composite during static analysis

As a result of the static analysis, the minimum safety factor value of the GP composite was found to be 0.9071. Figure 4.2 shows the safety factor obtained for GP composite during static analysis.

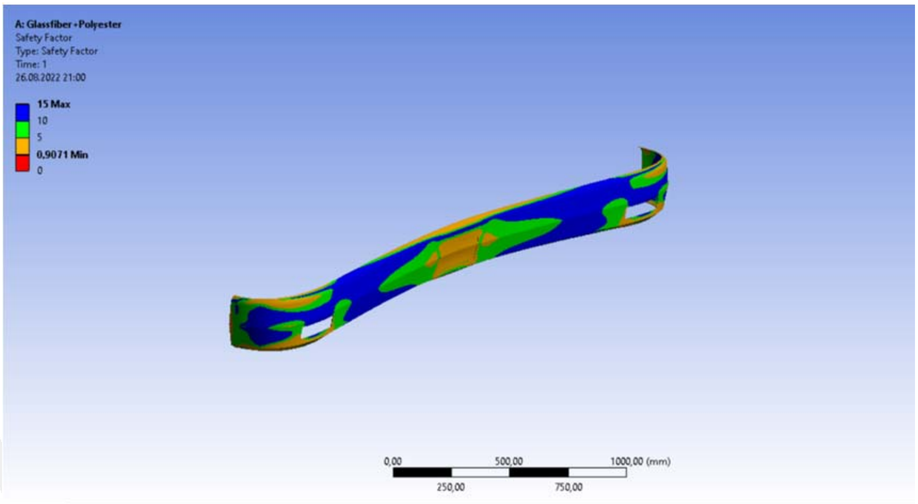

Figure 4.2. The safety factor obtained for GP composite during static analysis

Figure 4.3 shows Von Misses stress distribution of GV composite during static analysis. In the static analysis, the maximum Von Misses stress value for the GV composite material was found to be 110.670 MPa.

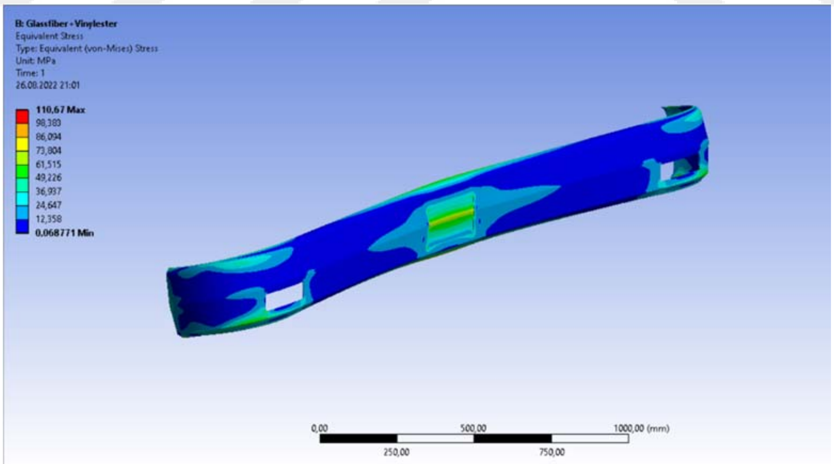

Figure 4.3. Von Misses stress distribution of GV composite during static analysis

Figure 4.4 shows the safety factor obtained for GV composite during static analysis. As a result of the static analysis, the minimum safety factor value of the GV composite was found to be 0.84936.

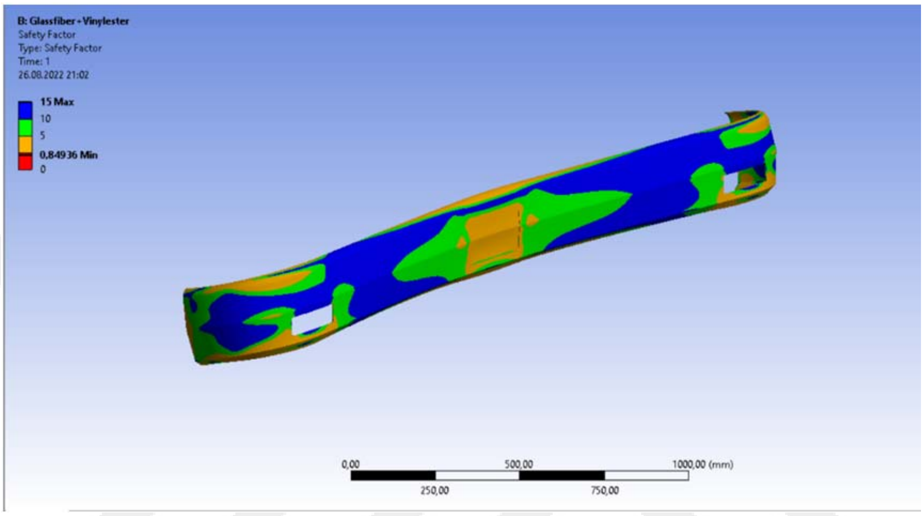

Figure 4.4. The safety factor obtained for GV composite during static analysis

Figure 4.5 represent the maximum Von Misses stress obtained CP composite during static analysis. The maximum Von Misses stress value for the CP composite material was found to be 111.85 MPa.

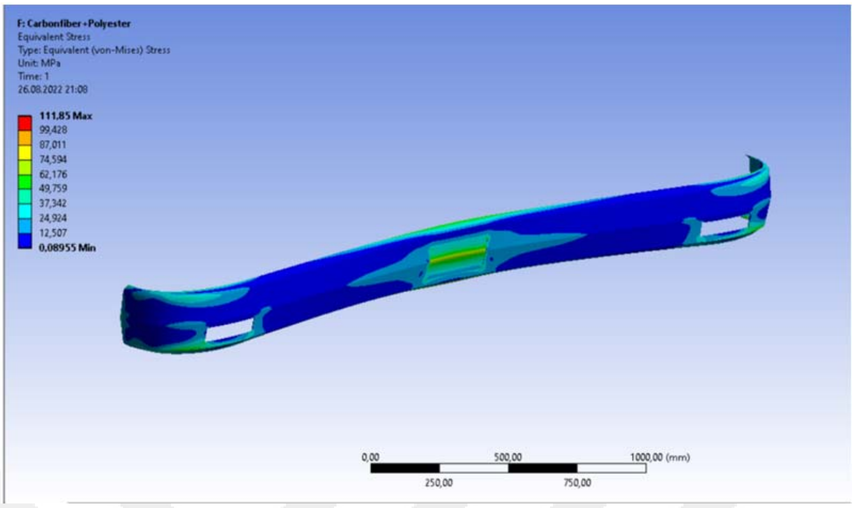

Figure 4.5. The maximum Von Misses stress obtained CP composite during static analysis

As a result of the static analysis, the minimum safety factor value of the CP composite was found to be 1.3501. Figure 4.6 shows the safety factor obtained for CP composite during static analysis.

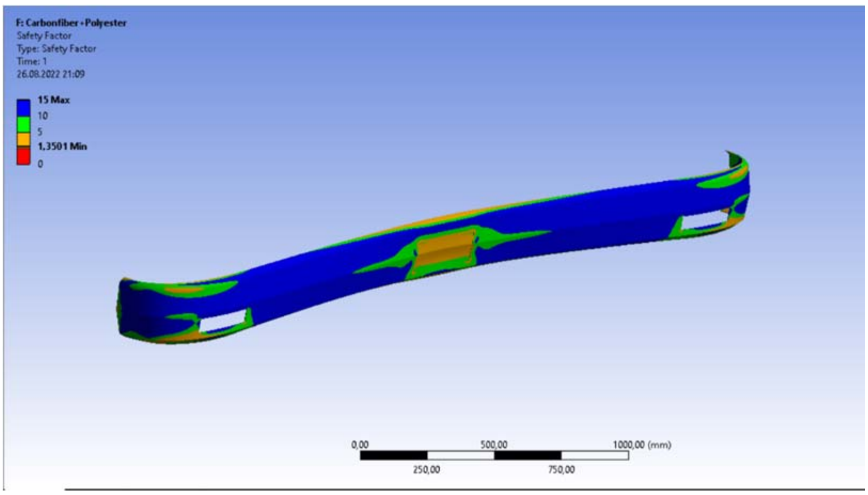

Figure 4.6. The safety factor obtained for CP composite during static analysis

Figure 4.7 represent the maximum Von Misses stress obtained for CV composite during static analysis. The maximum Von Misses stress value for the CV composite material was found to be 114.37 MPa.

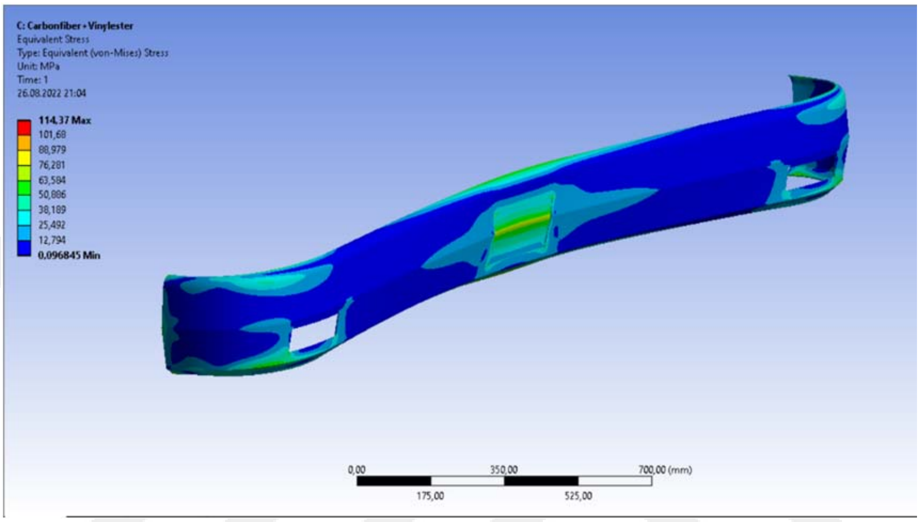

Figure 4.7. The maximum Von Misses stress obtained for CV composite during static analysis

Figure 4.8 shows the safety factor obtained for CV composite during static analysis. As a result of the static analysis, the minimum safety factor value of the CV composite was found to be 1.3989.

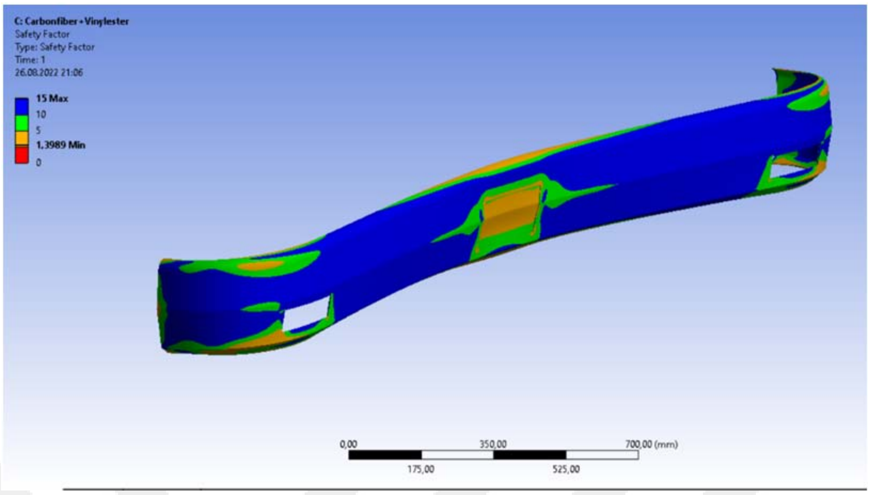

Figure 4.8. The safety factor obtained for CV composite during static analysis

Figure 4.9 shows maximum Von Misses stress distribution of GCP composite during static analysis. In the static analysis, the maximum Von Misses stress value for the GCP composite material was found to be 103.56 MPa.

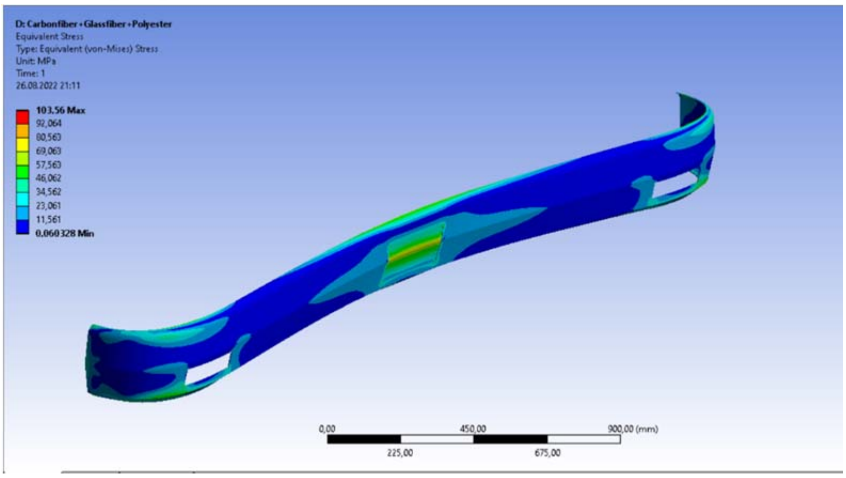

Figure 4.9. Maximum Von Misses stress distribution of GCP composite during static analysis

Figure 4.10 shows the safety factor obtained for GCP composite during static analysis. As a result of the static analysis, the minimum safety factor value of the GCP composite was found to be 1.2456.

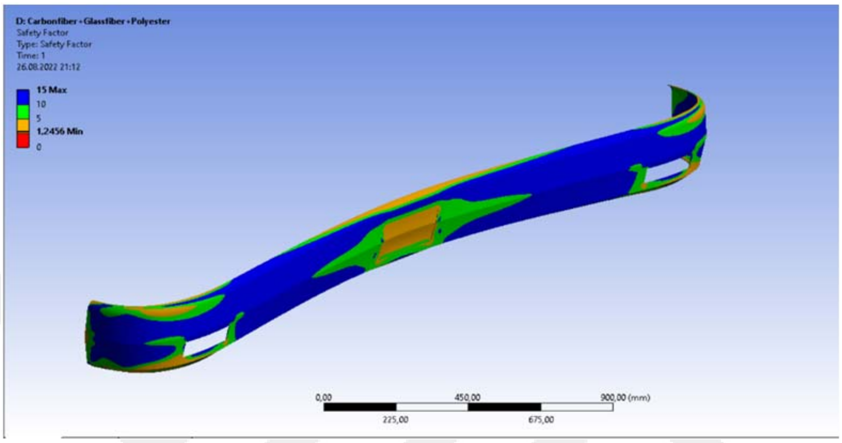

Figure 4.10. The safety factor obtained for GCP composite during static analysis

Figure 4.11 shows maximum Von Misses stress distribution of GCV composite during static analysis. In the static analysis, the maximum Von Misses stress value for the GCV composite material was found to be 120.23 MPa.

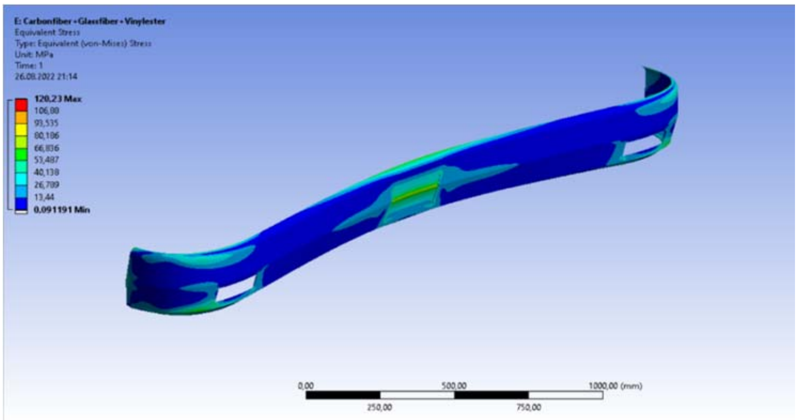

Figure 4.11. Maximum Von Misses stress distribution of GCV composite during static analysis

Figure 4.12 shows the safety factor obtained for GCV composite during static analysis. As a result of the static analysis, the minimum safety factor value of the GCV composite was found to be 0.91489.

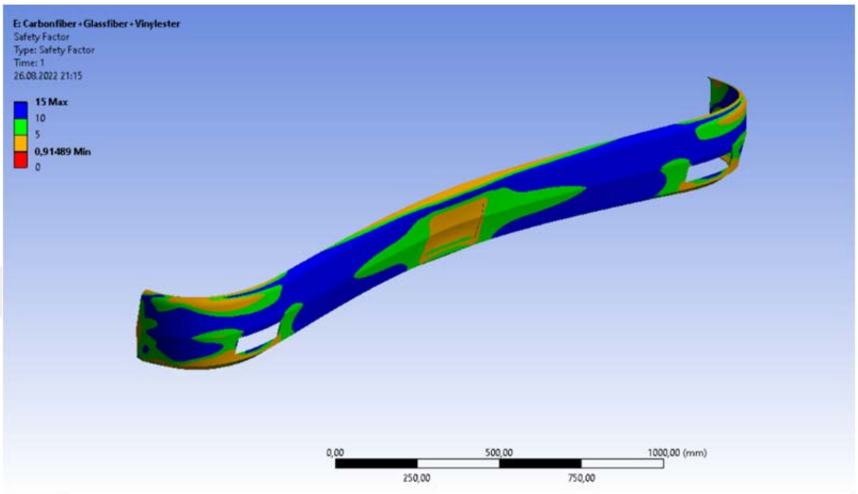

Figure 4.12. The safety factor obtained for GCV composite during static analysis

Results show that Total Deformation of the GP bumper model is 83,028 mm. Figure 4.13 shows the Total Deformation of GP composite during static analysis.

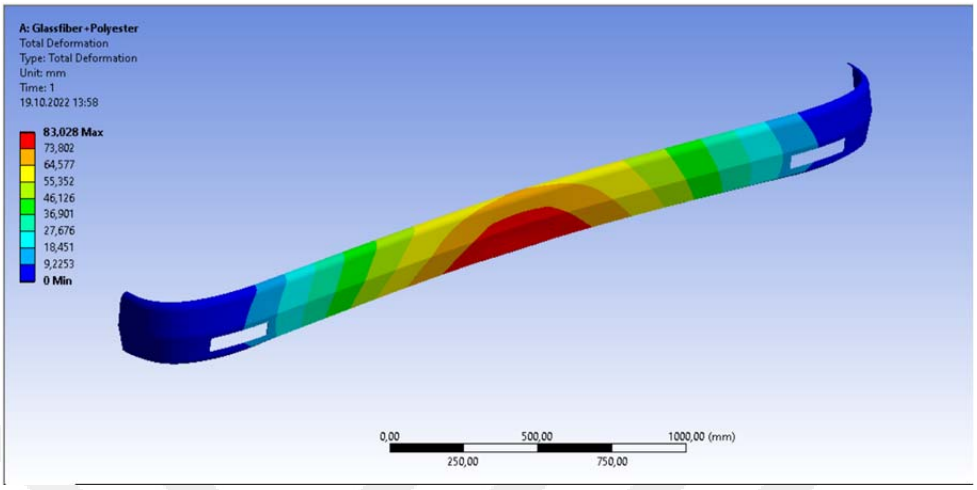

Figure 4.13. The Total Deformation of GP composite during static analysis

Figure 4.14 shows Total Deformation of GV composite during static analysis. In the static analysis, the Total Deformation value for the GV composite material was found to be 72,698 mm.

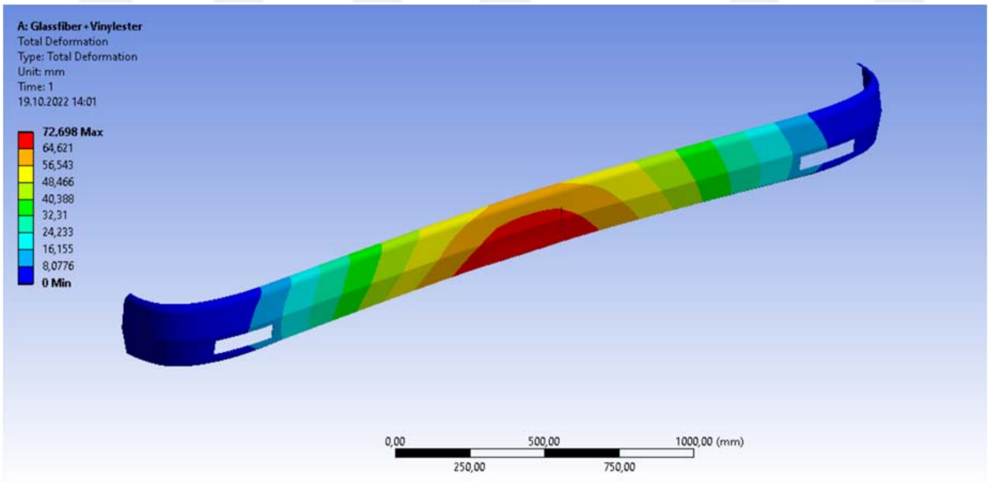

Figure 4.14. The Total Deformation of GV composite during static analysis

Figure 4.15 represent Total Deformation CP composite during static analysis. The Total Deformation value for the CP composite material was found to be 35,518 mm.

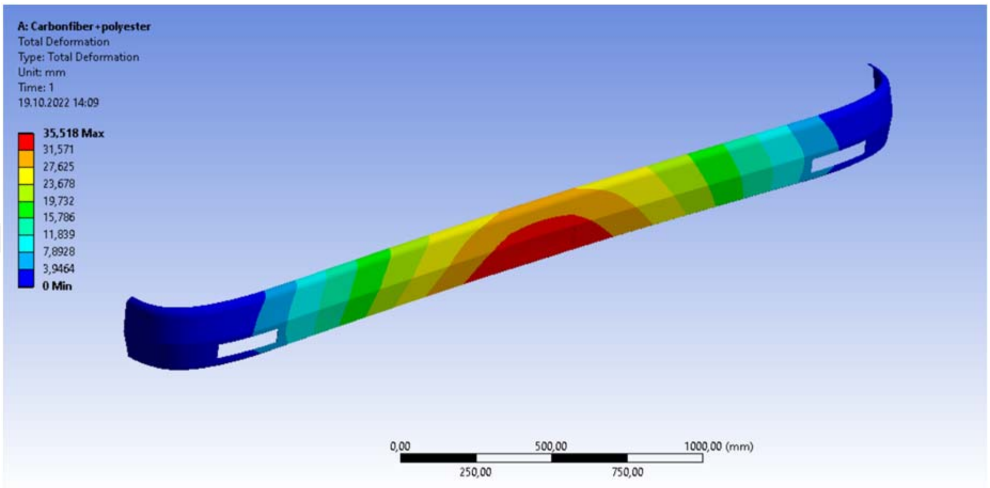

Figure 4.15. The Total Deformation obtained CP composite during static analysis

Figure 4.16 represent the Total Deformation obtained for CV composite during static analysis. The Total Deformation value for the CV composite material was found to be 25,659 mm.

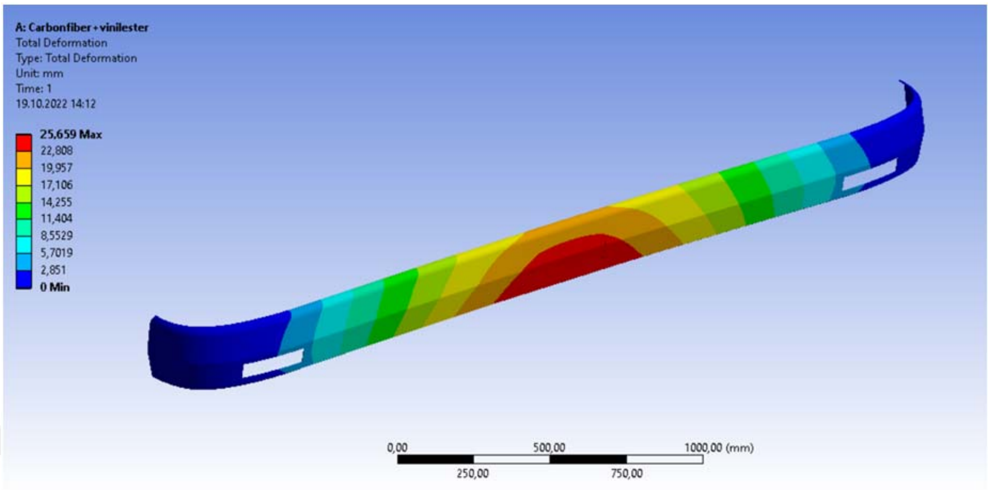

Figure 4.16. The Total Deformation obtained for CV composite during static analysis

Figure 4.17 shows Total Deformation distribution of GCV composite during static analysis. In the static analysis, the Total Deformation value for the GCV composite material was found to be 47,224 mm.

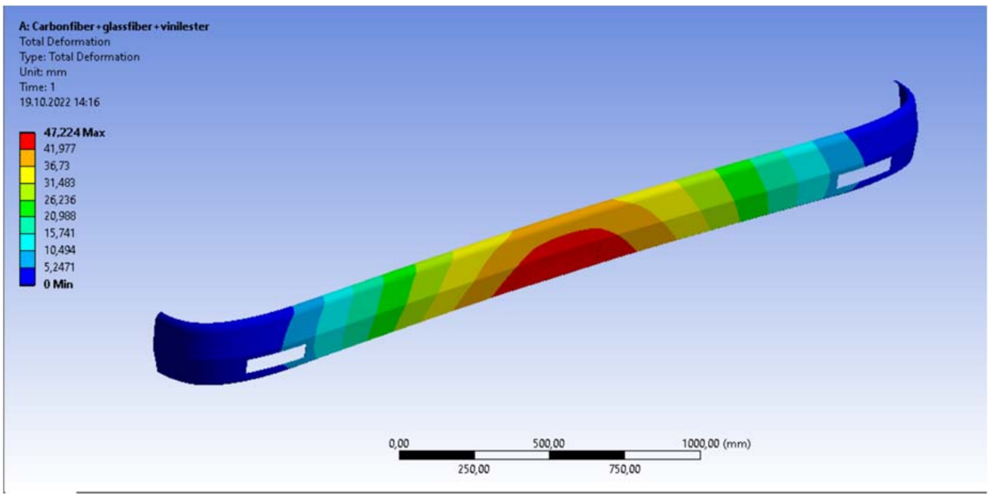

Figure 4.17. The Total Deformation distribution of GCV composite during static analysis

Figure 4.18 shows Total Deformation distribution of GCP composite during static analysis. In the static analysis, the Total Deformation value for the GCP composite material was found to be 38,867 mm.

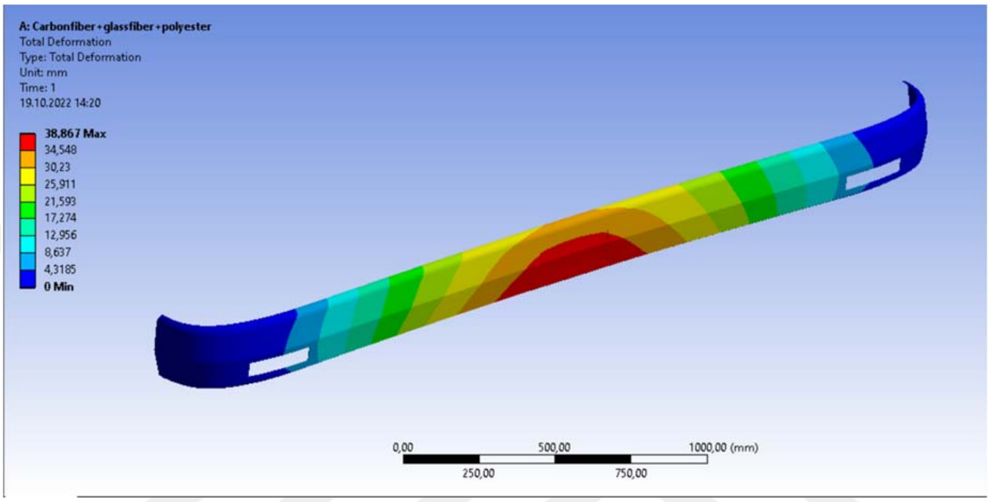

Figure 4.18. The Total Deformation distribution of GCP composite during static analysis

In Table 4.3 the results of Von Misses Stresses, Safety Factor and Total Deformation of tested materials by using ANSYS software are shown.

Table 4.3. Comparison of mechanical properties of materials

Materials / Properties	Safety Factor	Von Misses Stresses (MPa)	Total Deformation (mm)
GP	0.9071	99.218	83.028
GV	0.8490	110.670	72.698
CP	1.3500	111.850	35.518
CV	1.3990	114.370	25.659
GCP	1.2450	103.560	38.867
GCV	0.9150	120.230	47.224

The total deformation results of the composite samples are shown in Table 4.3**.** When the total deformation results are examined, it is seen that the material with the best value is the material consisting of carbon and vinyl ester. It has been observed that the deformation value of the material consisting of glass fiber and polyester is very high compared to other materials. When the whole table is examined, it is seen that the deformation value depends on the type of fiber.

Von Misses stress is commonly used by designers to check whether their designs will withstand certain load conditions. In this study, the strength of the composite bumper against static forces was investigated. In this analysis, maximum Von Misses stress and safety factor values on the bumper of 6 different composite materials were compared. The mechanical values of the composite materials produced under equal conditions were compared as a result of the tensile tests.

As a result of the tensile tests of the samples taken from the composite material produced with glass fiber and polyester (GP), yield stress was found to be 90 MPa, Ultimate tensile stress 274 MPa, Young's Modulus 18 GPa. As a result of the static analysis made in ANSYS, the maximum Von Misses stress was found to be 99.218 MPa and the safety factor was 0.9071.

According to the tensile tests of the samples taken from the composite material produced with glass fiber and vinyl ester (GV), yield stress was 94 MPa, ultimate tensile stress 341 MPa, Young's Modulus 20.5 GPa. As a result of the static analysis made in ANSYS, the maximum Von Misses stress was found to be 110.67 MPa and the safety factor was 0.84936.

As a result of the tensile tests of the samples taken from the composite material produced with carbon fiber and polyester (CP), yield stress was found to be 151 MPa, ultimate tensile stress 378 MPa, Young's Modulus 41.8 GPa. As a result of the static analysis made in ANSYS, the maximum Von Misses stress was found to be 111.85 MPa and the safety factor was 1.3501.

With the tensile tests of the samples taken from the composite material produced with carbon fiber and vinyl ester (CV), yield stress was found to be 160

MPa, ultimate tensile stress 510 MPa, Young's Modulus 57.8 GPa. As a result of the static analysis made in ANSYS, the maximum Von Misses stress was found to be 114.37 MPa and the safety factor was 1.3989.

According to the tensile tests of the samples taken from the composite material produced with glass fiber, carbon fiber and polyester (GCP), yield stress was 129 MPa, ultimate tensile stress 380 MPa, Young's Modulus 38.4 GPa. As a result of the static analysis made in ANSYS, the maximum Von Misses stress was found to be 103.56 MPa and the safety factor was 1.2456.

As a result of the tensile tests of the samples taken from the composite material produced with glass fiber, carbon fiber and vinyl ester (GCV), yield stress was found to be 110 MPa, ultimate tensile stress 370 MPa, Young's Modulus 31.1 GPa. As a result of the static analysis made in ANSYS, the maximum Von Misses stress was found to be 120.23 MPa and the safety factor was 0.91489.

As a result of the study, it was seen that the density of CP and CV composite materials produced with carbon fiber was less than the other 4 materials.

In the tensile test results of the composite material produced with carbon fiber and vinyl ester, it has been calculated that the yield stress value is 77.78% and the ultimate tensile stress value is 86.13% better than the composite material produced with glass fiber and polyester.

When young's modulus values are compared, the values of GP and GV composite materials are close to each other and the lowest. The Young's modulus value of the GP composite material was approximately twice that of the GP and GV composite materials.

According to the tensile test results of GCP and GCV materials, which are hybrid composite materials, it has been observed that the mechanical values are average values compared to the other 4 materials.

Neelima et al., (2016) are centered on the selection of bumper beam under varying parameters such as shape and material. They used steel, aluminum, carbon fiber epoxy and S2 glass epoxy in their study. Young's Modulus, Poisson's ratio and density values of these materials were compared. Carbon fiber epoxy values obtained from the study of Neelima et al. were compared with the 6 materials used in this study. The compared values are given in Table 4.4. When the mechanical values of carbon fiber epoxy are compared with the materials used in this study, it is seen that the density value is close to the material consisting of glass fiber, carbon fiber and polyester. However, the Young's Modulus value of carbon fiber epoxy material is much higher than other materials. (Neelima, Bala, Rao, Viswatej, and Tech, 2016)

Table 4.4. Mechanical properties of specimens and carbon fiber epoxy (Neelima et al., 2016)

SPECIMEN	**DENSITY (kg /m³)**	**POISSON'S RATIO**	**YOUNG'S MODULUS (GPa)**
GP	1879	0.400	18.0
GV	1759	0.266	20.5
CP	1373	0.251	41.8
CV	1397	0.215	57.8
GCP	1662	0.340	38.4
GCV	1457	0.100	31.1
Carbon fiber epoxy	1600	0.150	85.0

The cost analyzes of the produced specimens were evaluated and given in Table 4.5. Fibers and resins prices were taken while calculating the cost of the specimens. Molding costs and some additional materials (wax, MEK, so on) are not taken into account. Glass fiber and carbon fiber unit prices were supplied as 4 Euros and 50 Euros, respectively. Resins, on the other hand, were purchased at unit prices of polyester and vinyl ester at $4.5 and $8.5, respectively. The entire table is calculated with the exchange rates taken on the same date and is shown in Turkish Lira in the table.

Looking at table 4.5, it is seen that the specimens using glass fiber are much cheaper than the ones using carbon fiber. The cost of specimens consisting of hybrid fibers is average. The cost of vinyl ester used specimens is higher than polyester used specimens.

Table 4.5. The cost of specimens

SPECIMENS	**COST (TL)**
glass fiber / polyester	130.00
glass fiber / vinyl ester	151.00
carbon fiber / polyester	1178.00
carbon fiber / vinyl ester	1217.00
glass fiber / carbon fiber / polyester	655.00
glass fiber / carbon fiber / vinyl ester	672.00

5. CONCLUSION

The aim of this study is to find out a composite material for the production of a light weight bumper with better mechanical properties. First of all, 6 different composite materials were determined and produced. Secondly, the tensile tests of the produced composite materials were performed and the mechanical data of the materials were compared. Thirdly, a bumper model was designed in ANSYS and the mechanical values of 6 different composite materials were defined into ANSYS. Finally, by applying the same force in the same area with the same direction static analysis results of materials taken from ANSYS were compared to each other.

As a result of the study, 6 different composite materials produced were compared. It was observed that the material with the lowest density among the 6 different composite materials was the composite material consisting of carbon fiber and polyester. According to the tensile test results, it has been observed that the material which has superior mechanical properties in terms of yield strength, ultimate tensile strength and Young's modulus values is the composite material consisting of carbon fiber and vinyl ester. Considering the static analysis results made in ANSYS, the material with the highest maximum Von Misses value is the GCV hybrid composite material. It has been seen that the material with the best safety factor value is the composite material consisting of carbon fiber and vinyl ester. Considering the Safety Factor, Von Misses Stress, Total Deformation and cost parameters, it has been clearly seen that the material with the most optimum values is the GCV hybrid composite material.

In this study, it was observed that the choice of fiber to lighten the bumper and the choice of resin to improve the mechanical values of the bumper are important. As a result of the research, it is appropriate to carry out an optimization study by considering the mechanical values obtained from the composite materials according to the cost criterion, usage area and desired mechanical properties.

Carbon fiber and vinyl ester composite is superior to others so that an optimization that can be done to the bumper which was produced by using carbon fiber and vinyl ester can be improved further for lightweight and safe design.

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