ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

M.Sc. THESIS

Muhammed Ali KARAT

VISCOSE SPUN YARN AND KNITTED FABRICS PROPERTIES PRODUCED BY USING DIFFERENT SPINNING TECHNOLOGIES

DEPARTMENT OF TIXTILE ENGINEERING

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We certify that the thesis titled above was reviewed and approved for the award of the degree of the Master of Science by the board of jury on 16/06/2020.

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Prof. Dr. Osman BABAARSLAN	Dr. Öğr. Üyesi Yılmaz ERBİL	Doç. Dr. Hatice Kübra KAYNAK
SUPERVISOR	MEMBER	MEMBER

This MSc thesis is written at the Department of Textile Engineering, Institute of Natural and Applied Sciences of Çukurova University.
Registration Number:

Prof. Dr. Mustafa GÖK
Director
Institute of Natural and Applied Sciences

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ABSTRACT

MSc. THESIS

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: Asst. Prof. Dr. Yılmaz ERBİL
: Assoc Prof. Dr. Hatice Kübra KAYNAK

In this thesis, using Ne 28/1 (21 tex) 100% viscose fiber, ring, compact, rotor, and vortex spinning systems are used to examine the yarns and some selected properties of knitted fabrics from these yarns. Yarns produced using different spinning technologies were knitted into a fabric with a plain structure produced in two different yarn stitch densities (ring and compact are the same, rotor and vortex are the same). Then, the pilling abrasion (with ICI box and Martindale) of knitted fabrics produced using yarns from different spinning technologies and burst strength performance are examined. As a result, the yarn produced with the compact system in terms of yarn gave the best results of general properties. Fabrics were examined in two groups, it was observed that the fabrics knitted with compact yarns had better pilling properties than the fabrics knitted with ring yarns. However, the pilling performance of knitted fabric made from yarns produced by vortex technology is better than knitted fabric from OE rotor yarns.

Key Words: Spinning Systems; Ring Comapct, OE Rotor, and Vortex, Yarn Properties, Knitted Fabric, Pilling, Bursting Strength

ÖZ

YÜKSEK LİSANS TEZİ

FARKLI EĞİRME TEKNOLOJİLERİ KULLANARAK ÜRETİLEN VİSKON İPLİK VE ÖRME KUMAŞ ÖZELLİKLERİ

Muhammed Ali KARAT

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: Dr. Öğr. Üyesi Yılmaz ERBİL
: Doç. Dr. Hatice Kübra KAYNAK

Bu tezde, Ne 28/1 (21 tex) numara % 100 viskon lifi kullanılarak ring, kompakt, rotor ve vorteks eğirme sistemleri ile eğrilmiş ipliklerin ve bu ipliklerden örülmüş kumaşların seçilmiş bazı özelliklerinin incelenmesi amaçlanmıştır. Farklı eğirme teknolojileri kullanılarak üretilen iplikler iki farklı iplik dikiş yoğunluğunda (ring ve kompakt aynı, rotor ve vorteks aynıdır) üretilen düz bir yapıya sahip örme kumaş haline getirilmiştir. Burada farklı eğirme teknolojilerinden elde edilen iplikler kullanılarak üretilen örme kumaşların boncuklanma davranışı (ICI kutusu ve Martindale ile) ve patlama mukavemeti performansı incelenmiştir. Sonuç olarak, iplik bakımından kompakt sistem ile üretilen iplikler genel özellikler bakımından en iyi sonuçları vermiştir. İki grup halinde incelenen kumaşlardan, kompakt iplikler ile örülmüş kumaşların ring iplikleri ile örülmüş kumaşlardan daha iyi boncuklanma özelliklerine sahip olduğu görülmüştür. Bununla birlikte, vorteks teknolojisi ile üretilen ipliklerle yapılan örme kumaşın boncuklanma performansı, OE rotor ipliklerle yapılan örme kumaştan daha iyi çıkmıştır.

Anahtar Kelimeler: Eğirme Sistemleri; Ring Kompakt, OE Rotor ve Vorteks, İplik Özellikleri, Örme Kumaş, Boncuklanma, Patlama Mukavemeti

EXPANDED ABSTRACT

The purpose of this work was to study the yarn properties (Um%, CVm%, Imperfection, Hairiness, etc.) of the ring, compact, rotor, and vortex, which have produced with Ne 28/1 (21 Tex) 100% viscose spun yarn and compare among them. We observed how yarn properties are changed with the change of technology. Then we studied the properties of knitted fabrics of yarns produced by the four production systems.

In the first stage, using 100% viscose fibers, the yarns were produced by the four spinning systems (compact, ring, open-end and vortex) with Ne 28/1 (21 tex) count, and then several experiments were made on the yarns (Um%, CVm%, imperfection, hairiness, strength, and elongation) in order to study their physical and mechanical properties and compare among them.

The result has shown that the yarn sample produced from ring spun yarn has the highest hairiness and the unevenness of compact yarn is the lowest compared with the others spun yarns. The vortex spun yarn has the largest number of thick places. The ring yarn has the largest number of neps (+280 %/km). The strength and elongation of compact spun yarn are the highest and rotor spun yarn has the least strength and elongation.

In the second stage, these yarns were knitted into a fabric with a plain 1/1 construction which was produced from each spinning system in two different yarn stitch densities (ring and compact have the same, rotor and vortex have the same). After that, we examined the influence of ring, compact, rotor, and vortex spun yarns on pilling abrasion (ICI box and Martindale) and bursting strength properties of knitted fabrics.

According to obtained results, knitted fabrics produced with compact yarns have less pilling tendency and also better bursting strength than the fabrics knitted from ring spun yarns. Rotor yarn knitted fabric has poor pilling resistance and

furthermore, bad bursting strength compared to the same stitch density of vortex yarn knitted fabrics.

In order to evaluate the obtained results, one of the general linear analysis methods (ANOVA) which is a statistical analysis method was used. The general linear model analysis was used to determine whether the contribution of the factors was statistically significant in explaining the total change on the dependent variable.

GENİŞLETİLMİŞ ÖZET

Bu çalışmanın amacı, Ne 28/1 (21 tex) %100 viskon ile üretilen ring, kompakt, rotor ve vorteks iplik özelliklerini (Um%, CVm%, İplik Hataları, Tüylülük vb.) incelemek birbirleriyle karşılaştırmaktır. İplik teknolojisinin değişmesi ile iplik özelliklerinin nasıl değiştiğini gözlemlenmiştir. Daha sonra dört üretim sistemi tarafından üretilen ipliklerin örme kumaşlarının özellikleri incelenmiştir.

İlk aşamada, % 100 viskon elyaf kullanılarak, iplikler Ne 28/1 (21 tex) sayısı ile dört eğirme sistemi (kompakt, ring, open-end ve vorteks) tarafından üretildi ve daha sonra birkaç deney yapıldı. fiziksel ve mekanik özelliklerini incelemek ve bunlar arasında karşılaştırma yapmak için iplikler (Um%, CVm%, iplik hataları, tüylülük, mukavemet ve uzama).

Sonuç, ring ipliklerinden üretilen iplik numunesinin en yüksek tüylülüğe sahip olduğunu ve kompakt ipliğin düzgünlüğünün diğer ipliklere kıyasla en düşük düzgünlüğe olduğunu göstermiştir. Vorteks bükülmüş iplik en fazla sayıda kalın yere sahiptir. Ring ipliği en fazla sayıda nipe sahiptir (% +280 / km). Kompakt eğrilmiş ipliğin mukavemeti ve uzaması en yüksek ve rotor ipliği en az mukavemet ve uzamaya sahiptir.

İkinci aşamada, bu iplikler her eğirme sisteminden iki farklı iplik doğrusal yoğunluğunda (ring ve kompakt aynı, rotor ve vorteks aynıdır) üretilen düz 1/1 yapıya sahip bir kumaşa örülmüştür. Bundan sonra, ring, kompakt, rotor ve vorteks ipliklerinin boncuklanma aşınması (ICI kutusu ve Martindale) ve örme kumaşların patlama mukavemeti özellikleri üzerindeki etkisini inceledik.

Elde edilen sonuçlara göre, kompakt ipliklerle üretilen örme kumaşlar, ring bükülmüş ipliklerden örme kumaşlardan daha az boncuklanma eğilimine ve daha iyi patlama mukavemetine sahiptir. Rotor ipliği örme kumaşı, vorteks ipliği örme kumaşlarının aynı doğrusal yoğunluğuna kıyasla zayıf boncuklanma direncine ve ayrıca kötü patlama mukavemetine sahiptir.

Elde edilen sonuçları değerlendirmek için istatistiksel analiz yöntemi olan genel doğrusal analiz yöntemlerinden (ANOVA) analiz yöntemi kullanılmıştır. Bağımlı değişkendeki toplam değişimin açıklanmasında faktörlerin katkısının istatistiksel olarak anlamlı olup olmadığını belirlemek için genel doğrusal model analizi kullanılmıştır.

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1. INTRODUCTION

The yarn industry is one of the first works that a human began in life. Neanderthals have noticed that nature contains many materials such as fibers and wool that some plants presented like cotton. Neanderthals also observed that if these fibers twisted around each other became consistent, making yarns from them that were used to connect things. Then, they began to make them interlock to form a surface that used in clothing, and in making tents to protect from natural factors, such as sunlight, rain, snow, and others. Then, these yarns have several classifications depending on the properties of the yarns. The spinning industry remained handicraft from the early ages until the beginning of the industrial revolution in Europe in the early last century, despite its development in the method of manual work and the tools used for the process of manual spinning (Al-Samsam and Fri, 2008).

All variations in yarn properties can be due to differences in their composition, which is the result of different processes of production. In textile short fiber spinning, four types of yarn production processes, i.e. ring, compact spinning, rotor, and vortex spinning, are commonly accepted today (Erdumlu and Fri, 2009).

The yarn manufacturing process, structure, properties, and performance have a direct relationship. Yarn production technology defines the term of the yarn forming process in this sequence of relationships in which ring spinning, rotor spinning, vortex spinning, friction spinning, etc. have different effects on the yarns produced (Eldessouki and Fri, 2014).

1.1. Yarn Spinning Systems

The most important spinning systems used in the production of yarns:

1.1.1. Ring Spinning System

Ring spinning is a technique of yarn processing, using a small circular traveler for twist insertion. Through this procedure, twist insertion and winding of yarn on the ring bobbin occurs at the same time. In general, the ring yarn structure considered the fundamental formation of the spun yarn manufacturing. The ring spun yarns also have high strength, low imperfection, and ring yarn knitted fabric that has a smooth feel (Nakib-Ul-Hasan and Fri, 2014: Rameshkumar and Fri, 2008).

For example, the Ring spinning process provides high quality yarn and a wide range of styles of yarn. While ring spinning is the universal spinning system, the main drawback of this method is its restricted spindle speed, that the speed of the spindles amounts is 18,000 to 25,000 r/min for cotton (Ahmed and Fri, 2015: Basal, 2003).

Figure 1.1. Ring spinning system
http://msv.com.pl/en-machine-1827-856249739-rieter_g35.html

Figure 1.2. Ring machine (Rieter 35)
http://tekstilkutuphane.blogspot.com/2012/01/rieterden-g-35-ring iplikmakinesi.html

1.1.2. Compact Spinning System

Compact spinning is basically a spinning ring with advanced advantages in the condensing zone to remove or decrease yarn hairiness. It is done to enhance the consistency of the fiber and to raise yarn strength. The spinning triangle is decreased to condense the fibers in a narrow course, or removed. The closing and parallel system is positioned closely before the imparting of the twist. There are two main mechanisms, mechanical or airflow.

Compact spinning provides a near-perfect structure by applying air suction or magnetic device before twisting to condense the fibers, removing the spinning triangle. Compact spinning has been shown to greatly increase the tensile yarn properties and reduce the hairiness of the yarn. Both features are crucial for downstream manufacturing success.

Also, the compact spinning system gives an improvement in tensile properties, reduce hairiness as well as improved regularity of a yarn. On the other hand, compact yarns are considered to be stronger as well as less hairy for raise fiber connecting and have good yarn elongation, workability, and yarn unevenness compared to traditional ring yarns (Frey, 2001: Stalder, 2000: Saad and Fri, 2008).

Figure 1.3. Compact machine (Rieter k-46)
https://www.rieter.com/tr/sirket/haberler-ve-basari-hikayeleri/details/compact-spinning-machine-k46-successful-as-the-largest-compact-yarn-producer-in-turkey

1.1.3. Rotor Spinning System

The open-end spinning system is one of the recent developments in the spinning industry in recent years, with the aim of increasing production and raising the quality of yarns produced. In some industrialized countries open-end spinning production is above 35% and almost 22% globally, and soon will be used for any kind of yarns to become this most productive, reliable, and automated spinning technique.

Open-end spinning is a part of the technology, which is competent and capable of producing yarn without the usage of the spindle. However, the fibers in the core of the yarn are twisted during open-end rotor yarn forming and some surface fibers are wrapped around the core, this is which distinguishes this type of yarns (Klein, 1998).

Also, the production rates of rotor spinning are higher than that of ring spinning. High speed open-end spinning is discussed in relation to the properties of yarns spun in the speed range from 30,000 to 150,000 rev/min (Kyaw Soe and Fri, 2004).

Due to its high production and practical success, it has become of great importance in the cotton spinning industry, where began competition ring spinning machines, especially in the case of thick counts (Alshaban and Fri, 2007).

Rotor spinning, commonly referred to as open-end (OE) spinning, as there is a definite break (abruption or open end) in the fiber flowing prior to yarn forming, was commonly introduced in the late 1960s and is second only to the short-staple yarn processing of ring spinning. It has reached the point it is now known as 'conventional' spinning alongside ring spinning. It can manufacture yarn in the area of around 10 tex to 600 tex, most commonly 15 to 100 tex, with distribution speeds as high as 300 m / min and perhaps even higher, but at the finer end of the scale its efficiency is less suitable. Compared with ring spun yarns, the major negatives of rotor spun yarns are their weaker strength and the existence of wrapper fibers that negatively influence their handle. The spinning limitations are also lower, usually taken in the yarn cross-section between 100 and 120 fibers (Gordon and Fri, 2007).

In this case, rotor yarns are less uneven than ring spun yarn due to double duplication or back duplication of fibers in the rotor groove and the overall thickness of rotor spun yarn consists of several thin layers of fibers (Ghosh, 2006).

For rotor speeds varying from about 40,000 revs/min to 150,000 revs/min, being relative to the diameter of the rotor, the limit speed is approximately 180,000 revs/min (Egbers, 1999).

Figure 1.4. OE Rotor machine (Rieter R40)
http://www.im-tex.com/0035/12-Rieter-R40/en

1.1.4. Vortex Spinning System

Vortex spinning is one of the recent developments in the spinning industry during recent years, to increase production and raise the level of quality of yarns produced. There have been many attempts to invent a new method for spinning yarns to overcome the difficulties which faced increasing production. Therefore, the Japanese company Murata invented a new method for spinning through air jetting, which is considered the natural development of the mechanism is a type of modern spinning and is considered development Murata vortex spinning (MVS) yarn. Vortex spinning method characterized by a high production rate, more economic and high-speed spinning.

The structure and characteristics of vortex spinning yarns varied from other processes, considering the processing speed of vortex yarns that are 15 to 30 times higher than the ring spun yarns, the yarn delivery speed of vortex spinning can be basically as high as 500 m / min (Pei and Fri, 2017: Basal and Fri, 2003).

On the other hand, the vortex spinning system was found to be beneficial in terms of energy costs compared with both ring and open-end rotor spinning systems, given the high-pressure air consumption in vortex spinning and by making high whirl airflow twisting open-end trailing fibers into yarn, great success has now been reached in the textile industry (Zou and Fri, 2008: Ortlek and Fri, 2004).

Figure 1.5. Vortex machine (MVS Ⅲ 870)
https://hangyue-tex.com/product/12-sets-murata-vortex-870-iii-year-2013/

1.2. Textile Structures

The textile industry has developed rapidly, as well as its entry into many industrial fields in addition to its uses in the household foundations and the garment industry, which required innovation and development of advanced technology, and therefore the need to diversify in the manufacture of machinery and devices attached to it.

Fabrics can be divided into the process they are produced into three main sections (Sultan, 1998):

1.2.1. Woven Fabrics

It is the shape that most fabrics take, and it consists of using two types of yarns that overlap at vertical angles according to the required design.

1.2.2. Knitted Fabrics

This type of fabric does not need more than one yarn to make it as this yarn overlaps with each other in the form of loops without the need for two types of yarn to interlock with each other.

1.2.3. Non-Woven Fabrics

This type of fabric differs in its manufacture from the previous two types, as it does not depend on the use of yarn spinning, which meaning without a textile process. An example of this type is felt compressed, which is made by pressure, heat, and moisture.

1.3. Knitted Fabrics

The requirements of the times and the new fashion constantly changing, and newly produced fabrics have become a challenge to the expertise, skills, and capabilities of the designer who designs clothes. Therefore, there must be a link between fabrics, clothes, or furnishings, and our needs for a great deal of variation and diversity in fashion. On this basis, there has been a major development in knitted fabrics and is still compatible with the needs of the times and requirements of the future (Nanah and Fri, 2008).

Knitting fabric production technology is one of the technological methods of fabric production in the textile industry. Owing to their easy manufacturing methods, low price, high rates of clothing comfort, and large product selection, those last few years have observed an increasing interest in knitted fabrics. It possesses properties very different from those produced by other technological methods such as woven and non-woven fabric.

Knitting is a fabric forming process involving interloping of the yarn through needles in a sequence of linked loops. Knitted fabrics are known for producing exceptional characteristics for comfortable. Not only do they enable flexibility and ease of movement, but they also have good handle properties and promote the fast transfer of body water vapor. These characteristics make knitted fabrics the common choice for sports clothing, casual clothes, and underwear (Chidambaram and Fri, 2011).

Some Advantages of knitted fabrics compared to woven fabrics that the production rate of the knitting machine is relatively high (about four times as many square meters per hour for the weaving machine since the width of the machine is not related to the speed of performance). This speed can be considered as a positive economic factor in favoring the knitting process as a production method over the weaving process, but this saving in the cost of industry is less than the high cost with the required yarn. Technological developments with the sewing machine have helped to expand the end-use of woven fabrics. There are other advantages of knitted fabrics such as comfort and appearance after stretching. Giving a feeling of comfort is based on the ability to adapt to the movements of the body. The huge structure of knitted fabrics confines many air cells within it, which acts as a good insulator for the outside air. Preventing cold air from penetration. On a warm or humid day, knitted fabrics can be very warm because they tend to rest the body and insulation well and there are some types of special fabrics for the summer which are Pique fabrics containing large voids that allow air to circulate and ventilate the body to reduce the effect of sweat on the body. The quality of knitted fabrics is evaluated in almost the same way as woven fabrics. Producers focus on checking defects and estimating how the fabrics will behave when used. The reliable qualities for determining the high quality of woven fabrics include the weight of the fabric and its component fibers and the behavior at end-use (Labanieh and Fri, 2007).

1.4. Rayon (Viscose Rayon)

Cotton is the perfect fiber for clothing purposes, particularly in a tropical area where comfort is of prime importance. The cotton's major manufacturers are the developing nations. However, the burgeoning community has produced a scarcity of required farmland in this area. Thus, meeting enhanced cotton requests is also difficult. It has influenced the course of research in discovering the possibility of manmade fibers. The choice of a replacement should also not be considered in terms of amount but also quality.

Synthetic origin-based products (Nylon Polyester, etc.) are not capable to give comparable comfort to organic cellulosic cotton, although they have undergone changes through different processing (texturizing / short staple spinning). This has led scientists to improve man-made yarn that is derived from natural regenerated cellulose viscose solution. Initially and later, it was nomenclature as regenerated cellulose as viscose rayon. Unlike other manmade fabrics, rayon is also not synthetic, since it is made of natural, cellulose-based raw material made from wood pulp. Viscose rayon is classified, therefore, not as a synthetic base polymer but as a natural base polymer. The characteristics of viscose rayon do seem to be more similar to those of natural cellulose fibers, such as cotton or linen, than those of synthetic fibers based on petroleum, such as nylon or polyester (Ava, 2008: Goswami and Fri, 1977).

Cloth obtained from this yarn has shown good emulation with a natural cotton fiber cloth, especially in the properties consistent with comfort. Viscose rayon yarn lags in-service properties and technological properties behind cotton. Its physical-mechanical properties should be a high standard in order to meet the rigorous business requirements and satisfy customers' expectations for desirable goods. So, the production process has encountered several improvements in terms of technology, material, etc. to get the most desired cotton substitute.

Viscose rayon products have a silk-like look with excellent drape and feel and maintain its beautiful colors. The cellulosic basis contains several similar features to cotton or other natural cellulosic fibers. Rayon is absorbent in moisture (more than cotton), breathable, flexible, and quickly colored in bright colors. If the fabric is made of short, low-twist yarns, it does not build up static electricity nor does it pill.

Rayon is convenient, smooth to the skin, and has mild resistance to dryness and abrasion. It is not really flexible like other cellulosic fabrics, which also indicates it can wrinkle. Rayon with ironing stands temperatures a little lower than cotton ones. Silverfish and termites can attack it but it usually resists insect harm. It may be supposed to mildew, which is usually not a concern. One of the strengths of the rayon is its flexibility and ability to easily combine with other fibers occasionally minimize price, certain times for luster, softness, or absorbency and resulting comfort. Rayon has reasonable resistance to acids and alkalis, and bleaches do not necessarily affect the fiber itself; however, dyes can occur changes in the color of the fabric. Rayon can burn as a cellulosic fiber, however, flame retardant finishes can be added, so the properties of the rayon are more similar to those of natural cellulosic fibers (www.swicofil.com/viscose.html: Salome and Fri, 2013).

Rayon is used to producing blouses, skirts, suiting, sport shirts, work clothes, slacks, and accessories for a variety of garments as either 100 percent rayon or blended. Also, interior goods are commonly combined and involve mainly upholstery, draperies, slipcovers, bed covers and tablecloths. High-wet modulus rayon prefers to be used in lingerie and knitwear. Nonwoven rayon uses are also comprehensive because of its high absorption. Which include balls made from cosmetic "cotton," industrial wipes, reusable cleaning cloths, disposable diapers, and sanitary products, and medical-surgical material. High tenacity rayon can be used for tire cords and other industrial products (Collier and Fri, 2000).

While viscose rayon has several advantageous qualities, during its processing it has some limitations. Medium dry strength, resistance to pill, and resistance to abrasion along with low wet strength affect its processability. While the rayon fiber construction is smooth, inelastic filaments such as glass rods make it slippery in nature, difficult to manage until sized or strongly twisted during production. Beyond this, entangling with a shuttle eye or needle is extremely coherent. Everything together adds to the difficulties with its manufacturing (Ivanova and Fri, 1971: Mogilevskii and Fri, 1974).

There are many experiments to solve these constraints earlier. The best-used method for the same is cutting staple spinning of continuous filament yarns by ring spinning method as either 100 percent viscose yarn or in a combine. While these yarns overcome the above-mentioned constraints, they will pursue a longer manufacturing path. Longer manufacturing cycles not only lead to time delay but also to product costs (Klein, 1994).

2. PREVIOUS STUDIES

Moučková, Mertová, Jirásková, Krupincová and Křemenáková (2015), "Properties of viscose vortex yarns depending on technological parameters of spinning" in this work, two kinds of yarns were used, the first one vortex spinning system and the second one open-end spinning system with 100% CV, were yarns properties are compared between the previous two spinning systems. Tested showed that higher hairiness, lower tenacity and decreased elongation of rotor yarn spun, lower mass irregularities and the number of imperfections, higher resistance to abrasion, and lower bending rigidity in contrast with measured vortex spun yarn was observed in rotor spun yarns. This means that the vortex yarns were more efficient than the rotor yarns.

Ahmed, Syduzzaman, Mahmud, Ashique and Rahman (2015), "comparative study on ring, rotor, and air-jet spun yarn" in this work, yarns are produced with 20's Ne, 100% cotton from the ring, rotor, and air-jet systems. Then, they comparison the yarn properties (Um%, CVm%, Imperfection, Hairiness, etc) between the above systems. The results show that air jet yarn evenness is the highest, whereas the spun rotor yarn is higher than the spun yarn of the ring. The rotor spun yarn imperfection is significantly lower than the ring spun yarn, but rotor spun yarn has more thin places. The hairiness of a rotor spun yarn is less than that of ring spun yarn, while yarn with air jet clearly shows the least hairiness. Ring spun yarn strength is higher than rotor spun yarn while air jet yarn strength exists among ring and rotor yarn.

Çelik, Bedez Üte and Kadoğlu (2012), "Comparative analysis of the physical properties of the fabrics knitted with sirospun and ring spun yarns produced by short and long staple fibers" in this work, in both long and short staple, separate siro spun and ring spun yarns were spun from 100% wool, 100% PAN, 100% cotton and 100% viscose. Next, the knitted fabrics of single jerseys were made from these yarns. The physical features of yarns and knitted fabrics were checked, and the results appear that siro spun yarns obviously had better yarn features compared to ring spun yarns, particularly siro spun yarn hairiness values were significantly lower than ring spun yarns. The bursting strength, air permeability, surface friction characteristics of the fabrics knitted from siro spun yarns were also found to be better than those knitted from ring spun yarns.

Kaynak, Babaarslan, Avcı and Doğan (2017), "Effects of spinning technology on denim fabric performance" in this work, five separate 100% Cotton Ne 16/1 yarn samples were generated using five separate spinning technologies; combed ring, compact, sirospun, Open-End (OE) rotor, and vortex. Then, denim fabric pieces were woven using certain product yarns only in the direction of weft. Breaking strength, tear strength, abrasion resistance, rigidity and stretch properties of denim fabric products were evaluated to examine the influence of yarn spinning technology on denim fabric performance. The results show that ring and compact spinning systems have better strength properties for breaking and tearing as well as strong tenacity for yarn. The fabric sample made from ring yarn has the worst resistance to abrasion, and the ring yarn fabric also has the lowest stretch property of all samples. The compact yarn sample seems to be beneficial. Samples of fabric made from compact, vortex, and OE rotor yarns suffer from high stiffness while samples of siro and ring fabric are preferable for a better handle.

Busiliene, Lekeckas and Urbelis (2012), "Pilling resistance of knitted fabrics" in this work, fabrics were knitted in different proportions of viscose and cotton fibers, with various elastane amounts, notable for high viscosity and elasticity. The different industrial softeners that change the behavior of knitted fabrics from 12 percent to 20 percent of the active substance, e.g. fatty acid condensate (Tubingal 5051) or silicone microemulsion (Tubingal SMF), during technological processes imitating operating conditions. After that, several experiments were conducted to establish the effect of fibrous composition and chemical softeners on the tendency to fuzzing and pilling to knitted fabrics with plain and plated jersey designs. The result appears that knitted fabrics examined from viscose and recycled bamboo fibers get the lowest pilling resistance. Knitted fabrics from reclaimed bamboo fiber, differentiated just after 1000 revolutions by the fastest pilling operation, were evaluated using grade 3 pilling. As the improvement in the thickness of the knitted fabric increases to 9.7%, the resistance to pilling decreases to 64%. It established a stronger linear dependency between the amount of elastane in investigated knitted fabrics and the change in thickness confirms that pilling is affected by the quantity of the above-mentioned fiber. The washing and softening technique increased the pilling resistance of investigated knitted fabrics from 33% to 67%. The fabrics that have been softened with fatty acid concentrations are resistant to pilling from 25 to 50 percent compared to fabrics that have been softened with a silicone microemulsion softener. Substantial differences were not specified for other investigated fabrics.

Rameshkumar, Anandkumar, Senthilnathan, Jeevitha and Anbumani (2008), "Comparative studies on ring rotor and vortex yarn knitted fabrics" in this work ring, rotor and air vortex spinning systems were used to produce yarns with 30's Ne, 100% cotton. The yarns were made from the above-mentioned systems and knitted in a single jersey device. The result shows the rotor spun yarns that were found during knitting with repeated breakage. The ring and air vortex yarns have shown comparatively strong knitting performance results. The yarns were studied in tensile, evenness, and hairiness and bursting strength, abrasion resistance, pilling, drapability, and color matching of the knitted fabrics. The spun ring yarns have high strength, low imperfection, and strong bursting force. Rotor and vortex yarns made of fabrics with abrasion resistance were found to be higher than the ring spun yarns. Ring yarn knitted fabric seems to have high bursting strength, air vortex yarn knitted fabric has low drape due to stiffer yarn structure, and pilling resistance of the MVS yarn fabric has low. Rotor, MVS yarns made from fabrics have excellent resistance to abrasions. Drapability of knitted fabrics from vortex yarn was lower than fabrics knitted from ring and rotor yarn.

Chetan and Shah (2015), “Comparing the properties of ring and rotor spun after doubling” for this study, the ring and rotor yarn properties were measured after doubling by taking the three separate counts (10's, 16's and 20's with 100% cotton). For yarn tenacity, the results show that the yarn strength enhancement after doubling is comparable to the ring spun yarn. On the other side, the increase in rotor yarn tenacity after doubling is even higher than double ring yarn. The result shows that rotor spun yarn is better for yarn elongation than ring spun yarn in case of break elongation (%). In addition, elongation at break of rotor spun yarn is higher than that of comparable ring spun yarn in both single and double yarn, and significantly increases after doubling elongation of ring and rotor yarn. For yarn hairiness, the result shows that rotor spun yarn has significantly lower hairiness than comparable ring spun yarn. It shows progress in both ring and rotor yarn after doubling and decreases hairiness after doubling. It also indicates an improvement in the imperfection after doubling of both types of yarn.

3. MATERIAL AND METHOD

3.1. Yarns

100% viscose fibers (fineness 1.2 denier with 38 mm length) were spun to produce yarns from four different systems ring, compact, rotor, and vortex spun yarns. For the vortex spun yarns, after the carding process, to enhance the fiber orientation and sliver evenness, sliver was drawn using three consecutive drawing passages (Figure 3.1). The drawn sliver was spun using the Murata vortex machine to produce yarns with count Ne 28/1 (21 tex). The same raw material was used for the open-end spun rotor yarn but two draw frame passages were used instead of three. The open-end rotor spinning machine Rieter was used to manufacture yarns of the same count. Yarn samples were conditioned prior to testing under standard conditions 20±2 °C and 65±4 % relative humidity according to ISO 139 before the tests (ISO 139:2005).

1. Yarn Linear Density Test (Ne)
    - Test standard; TS 244 EN ISO 2060, 13.04.1999 Textiles-Yarn from packages-Determination of linear density (mass per unit length) by the skein method.
    - Device Used; Yarn Wrap Reel Machine (Uster Zweigle Yarn Reel & Auto Sorter 4).
    - 100 yards (91.44 meters) x 10 bobbins were measured.
2. Twist Test (Turns / inch)
    - Test standard; TS 247 EN ISO 2061: 1999 "Textiles - Determination of twist in yarns - Direct counting method".
    - Device Used; Yarn twisting Device (Uster Zweigle Twist Tester 5).
    - 500 mm x 10 bobin were measured per coil.
3. Yarn Unevenness Test
    - Test standard; TS 628 July 1970 Yarn Unevenness Determination Methods.

• Device Used; Unevenness Device (Uster Tester 4).

• 400 m x 10 bobin were measured.

4. Yarn Strength Test

• Test Standard; TS 245 April 1988 Breaking Strength of Single Yarn and Determination of Breaking Elongation.

• Device Used; Strength Device (Uster Tensorapid 4).

• 50 cm x 10 Measurement x 10 bobin were measured.

We observed the different yarn properties in our project work such as U%, CV%, Imperfection Index (thick/km, thin/km, neps/km), hairiness, and strength (CSP) of the ring, compact, rotor, and vortex spun yarns. The spinning systems used in this work is seen in Figure 3.2. Parameters for the production of sample yarns are given in Table 3.1.

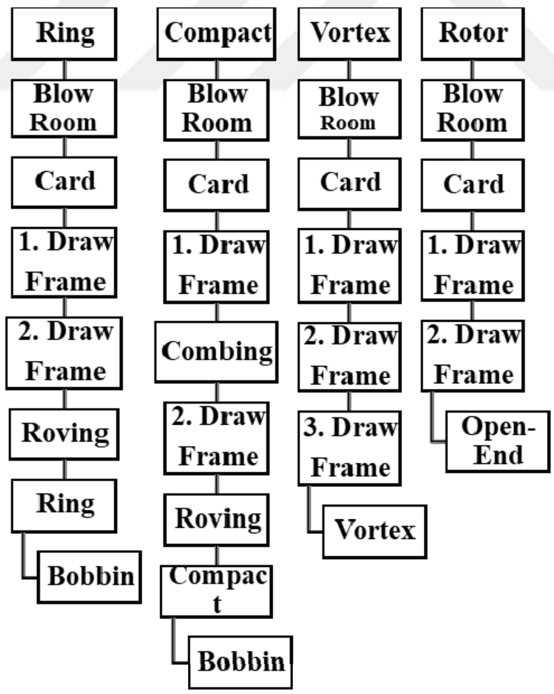
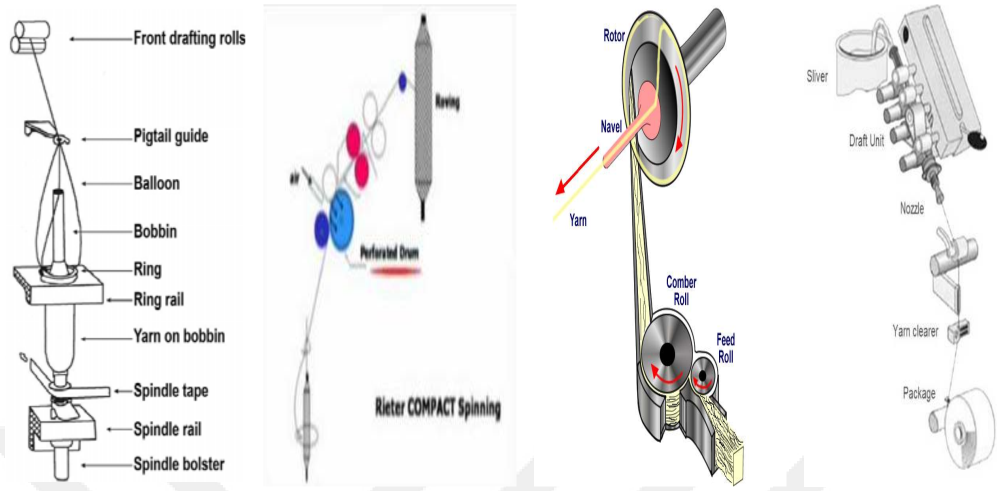


Figure 3.1. Process steps up to spinning for different systems



a b c d

Figure 3.2. Spinning technologies used in the work (a) ring, (b) compact, (c) OE rotor and (d) vortex (https://www.nptel.ac.in/courses/116102038/44: RIETER AG 2018).

Table 3.1. Production parameters of sample yarns

	Ring (Rieter 35)	Compact (Rieter k-46)	OE Rotor (Rieter R40)	Vortex (MVS III 870)
Raw materials	**CV100%**	**CV100%**	**CV100%**	**CV100%**
Origin	**Taiwan**	**Taiwan**	**Taiwan**	**Taiwan**
Number of passages	**2**	**2**	**2**	**3**
Card sliver count, Ne	**0.110**	**0.110**	**0.110**	**0.140**
Roving count, Ne	**0.90**	**0.90**	**-**	**-**
Yarn Count, Ne	**28/1**	**28/1**	**28/1**	**28/1**
Delivery speed, m/min	**19.62**	**24.27**	**158.5**	**450**
Ring diameter, mm	**38**	**38**	**-**	**-**
Spindle speed, rev/min	**15500**	**17800**	**-**	**-**
Yarn twist, turns/m	**790**	**790**	**705**	**-**
Rotor speed, rev/min	**-**	**-**	**111760**	**-**
Rotor diameter of, mm	**-**	**-**	**40**	**-**
Spindle air pressure, MPa	**-**	**-**	**-**	**0.49**
Spindle holder	**-**	**-**	**-**	**Orient M1**
Spindle, mm	**-**	**-**	**-**	**1.08**

3.2. Knitted Fabrics

In this work, it is aimed to investigate the influence of spinning technology on the properties of knitted fabrics performance namely, fabric pilling performance and fabric bursting resistance.

Four different yarn samples with Ne 28/1 (21 tex) were produced from 100% viscose (fibers fineness 1.2 denier with 38 mm length) raw material via different spinning, that viscose fiber provides fabrics with superior clothing comfort and appearance characteristics. Four different fabric samples were knitted with the same structure 1/1 plain. All fabrics types were knitted with 100% viscose yarn with a count of Ne 28/1 (21 tex) were used as a pattern yarn. All fabrics samples were conditioned according to TS EN ISO 139, before the tests and the tests were performed in the standard atmosphere of 20±2 °C and 65±4 % relative humidity.

In order to investigate the effects of spinning technology on the fabric pilling resistance (Nu-Martindale Figure 3.4, ICI pilling box Figure 3.5) and the burst strength (Figure 3.6), fabric samples were tested according to the standards of EN ISO 12945-1, EN ISO 12945-2 and EN ISO 13938-2 respectively. These tests were performed on dry relaxed fabrics, structural features of knitted fabric samples namely, fabric wight, fabric thickness and numbers of wales and courses were determined according to TS EN 12127, TS 7128 EN ISO 5084 and TS EN 14971 standards, respectively. Structural features of knitted fabric samples are given in Table 3.2.

To understand the statistical significance of spinning technology on knitted burst strength fabric efficiency, ANOVA was performed in one-way. Tukey HSD multiple comparison tests were applied to determine which classes, belong to the substantial differences obtained. To this purpose, the experimental data were interpreted using the statistical software program SPSS 22.0. All test results were evaluated at a confidence interval of 95%.

Table 3.2. Structural features of sample knitted fabrics

	Ring	**Compact**	**Rotor**	**Vortex**
Dry weight, g/m2	**1.219**	**1.261**	**1.383**	**1.339**
Thickness, mm	**0.42**	**0.42**	**0.47**	**0.47**
Wales, number/10 cm	**140**	**140**	**170**	**170**
Courses, number/10 cm	**120**	**120**	**120**	**120**

Figure 3.3. Knitting machine Mayer & Cie MV 4 32"
https://www.wotol.com/product/2-mayer-cie-mv-4-32-28gg/1849447

Figure 3.4. Nu-Martindale abrasion and pilling tester

Figure 3.5. The ICI pilling box tester

Figure 3.6. The bursting strength tester

4. RESULTS AND DISCUSSION

4.1. Yarns

The tenacity parameters of the sample yarns were tested with the USTER TENSORAPID test device. The physical and mechanical properties results of the used yarns are presented in Table 4.1 (all the results in Table 4.1 are the average obtained from the tested samples) and all detailed results of the samples are available in the section ADDS. Also, in this work, all test results were evaluated using one-way ANOVA to detect the significant difference between the means of the properties of yarns spun on the four spinning systems.

Table 4.1. Values of yarn physical and tensile properties measured

Properties		Ring Spun Yarn	Compact Spun Yarn	Rotor Spun Yarn	Vortex Spun Yarn
Mass variation	U %	9.12	8.35	10.89	10.2
	CVm %	11.57	10.53	13.7	12.88
Imperfection	Thin (-50%/Km)	0.8	0	15.5	5.5
	Thick (+50%/Km)	8	3.5	23.5	26
	Neps (+200%/Km)	12.3	7.3	12.5	10
	Neps (+280 %/Km)	5.8	1.8	0.3	1.5
Hairiness	H	4.39	4.15	4.02	3.79
	Sh	0.95	0.90	1.05	0.88
Strength N		3.71	4.14	2.87	3.21
Elongation %		10.93	11.95	9.44	9.72
Tenacity CN/tex		17.59	19.62	13.59	15.2
Breaking strength s		0.66	0.72	0.57	0.58

4.1.1. Comparison Of Mass Variation

Observing the results of yarn irregularity is shown in Figure 4.1. Generally, the test results show that the compact yarn had the best irregularity, whereas rotor yarn had the worst irregularity results. However, ring spun yarn shows higher evenness than vortex spun yarn. Also, it can be seen in Figure 4.1, it is clear that ring yarn shows the total average 9.12% improvement in the U% whereas the rotor yarn shows the total average 10.89%. Then, the yarn irregularity deteriorates as the number of fibers in the yarn cross section decreases. On the other hand, the average difference between the four spinning systems is found to be statistically significant.

ANOVA results for the mass variation property of samples are given in Table 4.2. The effect of yarn spinning technology on mass variations is considered statistically significant ($p=0.000<0.05$) at a 95% confidence interval. According to Tukey HSD multiple comparison test results yarns produced from the ring, compact, rotor, and vortex have statistically similar CVm% values among each other.

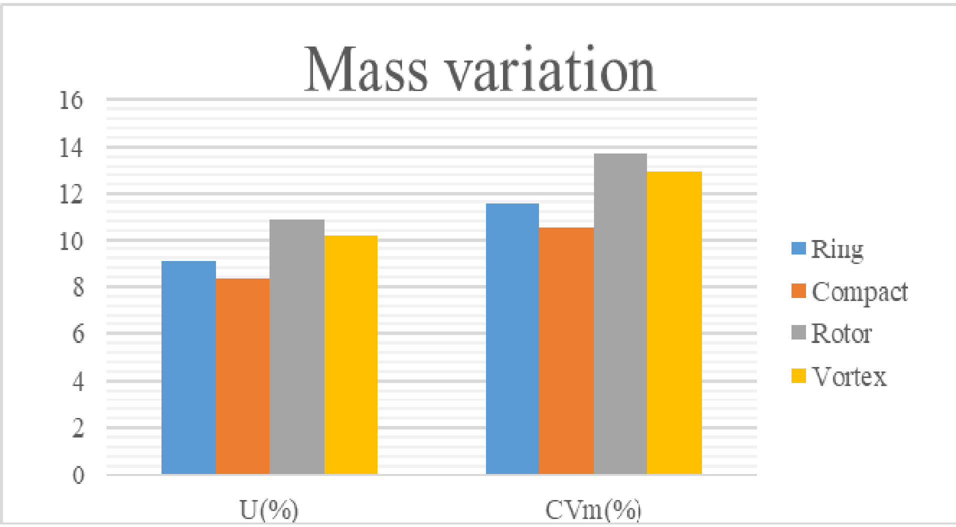


Figure 4.1. Comparison of mass variation among ring, compact, rotor and vortex yarn

4.1.2. Comparison Of Imperfection

The effect of spinning system types on the spun yarn imperfection index is shown in Figure 4.2. According to Figure 4.2 it is clear that compact yarn appears to have given the best values for the thin place, whereas rotor yarn gave the worst values around 15. On the other hand, the numbers of thin places in vortex yarn reached around 5, while it was slightly under 1 for ring spun yarn. However, these thin places probably appear in the form of yarns caused by an irregular (uncontrolled) process which happened in draft zones of the draft machine.

Figure 4.2 shows the number of thick places in the four spinning systems yarns. It is clearly evident that thick places values (Figure 4.2) similar to the thin places value results. Overall, thick places values have increased for all spinning systems. The largest numbers of thick places were found on vortex yarn, that reaching 26, whereas it was the least in compact yarn at just under 4. On the other hand, the number of thick places in the rotor was higher than that of ring yarn (about 23.5 and 8 respectively). Also, there had been an increase in the number of thick places in each of the ring and compact yarn. However, no statistically significant difference was found between rotor and vortex yarn test results.

Also, Figure 4.2 provides information on the number of neps in the yarns. According to Figures 4.2, it is obvious that both ring and rotor yarns having approximately the same and largest values of neps(+200%)/km nearly 13. On the other hand, the number of neps (+200%)/km was in compact yarn with around 7 which is lower than vortex yarn with 10. Due to the processing of fibers (cleaning, carding, and drawing) tends to produce neps through a stress buildup/sudden release mechanism, which induces buckling along the fiber length.

Looking more closely at Figure 4.2, there was a decrease in the number of neps (+280%)/km for all the yarns. General, the number of neps (+280%)/km decreased in ring yarn, reaching closely 6, while rotor yarn recorded the lowest values with slightly below 1, also compact and vortex yarns decreased too, showing around 2 for neps (+280%)/km.

ANOVA results for the number of thin places property of samples are given in Table 4.2. The effect of yarn spinning technology on the number of thin places is considered to be statistically significant (p=0.000<0.05) at a 95% confidence interval. According to Tukey HSD multiple comparison test results yarns produced from rotor and vortex have a statistically different number of thin places values among each other, besides ring and compact samples have a statistically similar number of thin places results.

ANOVA results for the number of thick places property of samples are given in Table 4.2. The effect of yarn spinning technology on the number of thick places is found to be statistically significant (p=0.000<0.05) at a 95% confidence interval. According to Tukey HSD multiple comparison test results yarns produced from the ring, compact, rotor, and vortex have a statistically similar number of thick places results. ANOVA results for numbers neps (+200%/km) property of samples are given in Table 4.2. The effect of yarn spinning technology on numbers neps is found to be insignificant (p=0.305>0.05) at a 95% confidence interval.

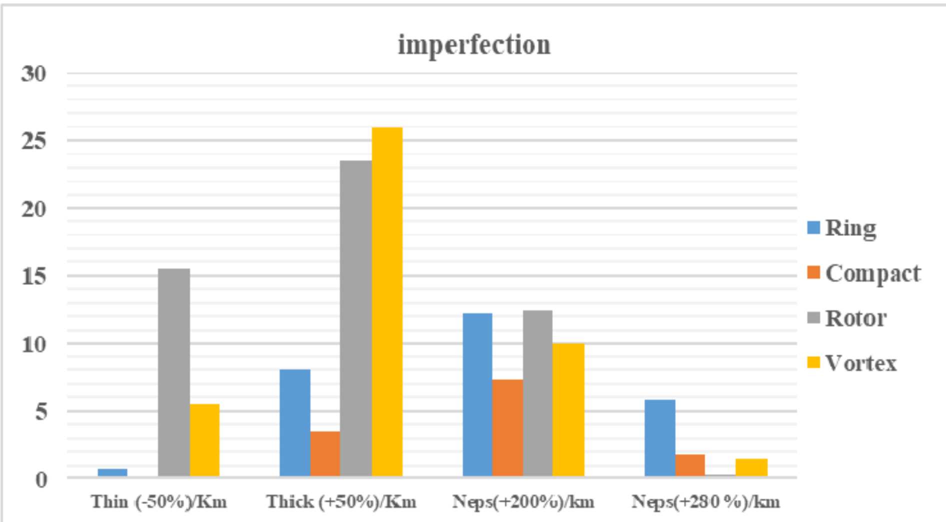


Figure 4.2. Comparison of IPI among ring, compact, rotor and vortex yarn

Table 4.2. ANOVA results of the yarn properties

ANOVA Results							
		Sum of squares	**df**	**Mean square**	**F**	**Sig.**	**Tukey HSD**
Mass variation (CVm %)	**Between groups**	**58.687**	**3**	**19.563**	**134.901**	**0.000**	**(ring, compact, rotor, vortex)***
	Within groups	**5.220**	**36**	**0.145**	**-**	**-**	
	Total	**63.907**	**39**	**-**	**-**	**-**	
Imperfection Thin (-50%/km)	**Between groups**	**1527.969**	**3**	**509.323**	**44.926**	**0.000**	**(ring, compact)**
	Within groups	**408.125**	**36**	**11.337**	**-**	**-**	
	Total	**1936.094**	**39**	**-**	**-**	**-**	
Imperfection Thick (+50%/Km)	**Between groups**	**3742.500**	**3**	**1247.500**	**23.120**	**0.000**	**(ring, compact, rotor, vortex)***
	Within groups	**1942.500**	**36**	**53.958**	**-**	**-**	
	Total	**5685**	**39**	**-**	**-**	**-**	
Imperfection Neps(+200%/km)	**Between groups**	**178.750**	**3**	**59.583**	**1.253**	**0.305**	**-**
	Within groups	**1711.250**	**36**	**47.535**	**-**	**-**	
	Total	**1890.000**	**39**	**-**	**-**	**-**	
Hairiness (H)	**Between groups**	**1.885**	**3**	**0.628**	**40.913**	**0.000**	**(compact, rotor)***
	Within groups	**0.553**	**36**	**0.15**	**-**	**-**	
	Total	**2.438**	**39**	**-**	**-**	**-**	

*This means difference is significant at the 0.05 level.

4.1.3. Comparison Of Hairiness

The Uster hairiness (H) result is given in Figure 4.3. It is clearly evident from Figure 4.3, that vortex yarn shows the least hairiness with just under 4, whereas compact spun yarn is less hairy than ring spun yarn. Also, as shown in Figure 4.3, the vortex yarn has lower hairiness than other system yarns, which is due to a uniform layer of wrapper fibers in yarn sheath that decreases hairiness along yarn lengths. However, the increased hairiness of ring spun yarn is attributable to the unregulated passage of edge fibers in roller drafting and friction occurring in the balloon control ring. ANOVA results for hairiness property of samples are given in Table 4.2. The effect of yarn spinning technology on hairiness is found to be statistically significant ($p=0.000<0.05$) at a 95% confidence interval. According to Tukey HSD, multiple comparison test results yarns produced from ring and vortex have statistically different hairiness values among each other. Besides, rotor and compact samples have statistically similar hairiness results, which is clear in Figure 4.4.

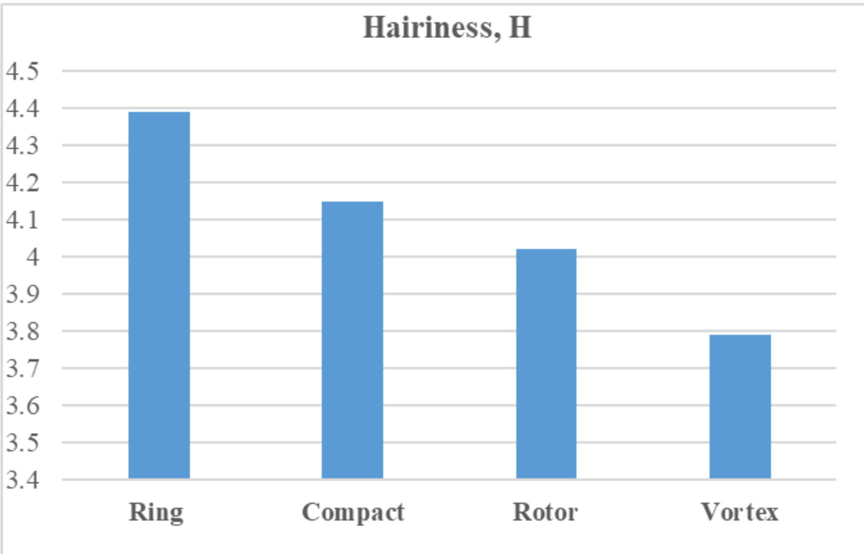


Figure 4.3. Comparison of hairiness among ring, compact, rotor and vortex yarn

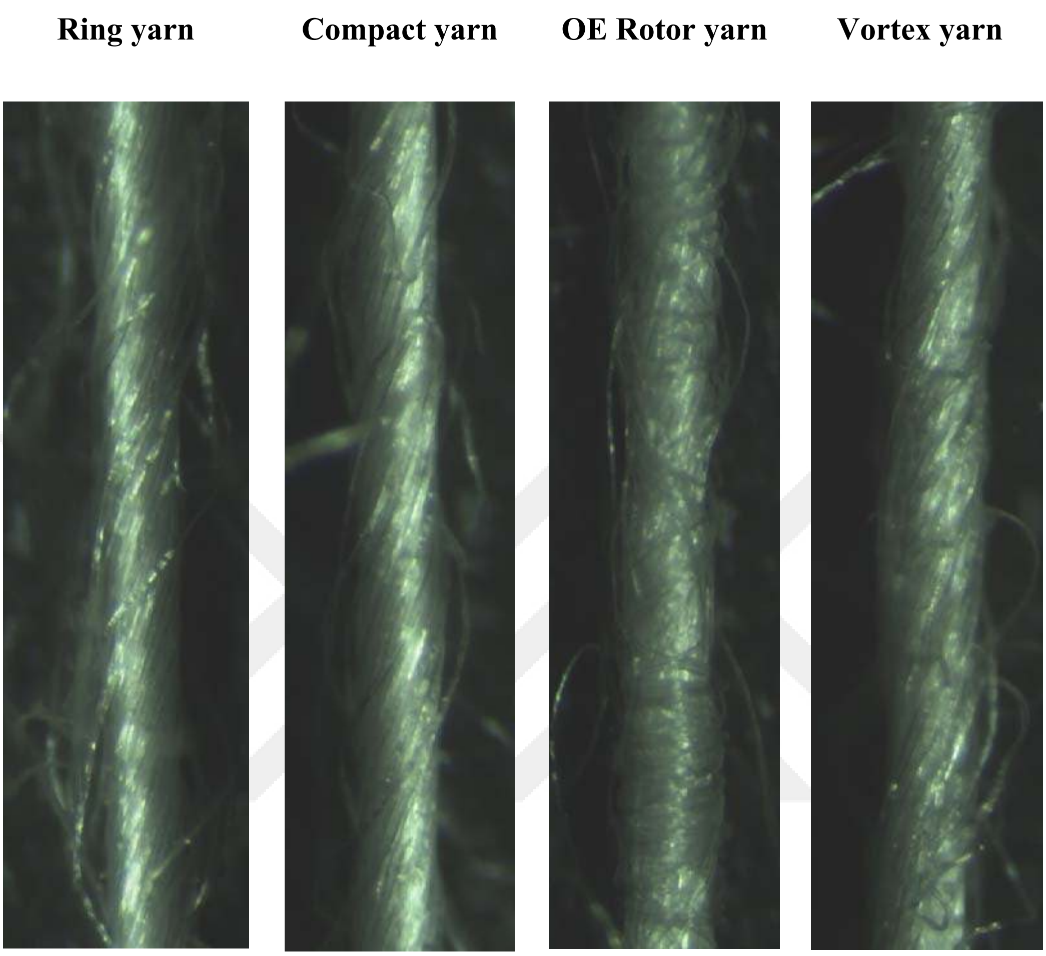


Figure 4.4. Shots of yarn surfaces spun with different spinning processes (65x)

4.1.4. Comparison Of Strength

The strength test results are shown in Figure 4.5. According to the Figure 4.5, it is clear that strength of compact spun yarn (4.14 N) is higher than the rotor (2.87 N) and ring (3.71 N) spun yarn, whereas the strength of vortex (3.21) lies between ring and rotor yarn, so we can say that compact yarn has the best strength compared with the other four systems. However, it is also apparent that the number of twists of ring spun yarns is greater than the number of twists of rotor spun yarns due to the various methods used for twist delivery to the yarn. All parameters (number of twist, uster uniformity, and number of irregularities) influence the yarn tensile properties shown in Figure 4.5, this means that parameters have an effect on the tensile property of the yarns, either over or decrease. Overall, in the case of rotor and vortex yarn, the increase in tenacity due to the greater number of fibers in the yarn cross section and the higher number of fibers contributes to the yarn and load bearing composition.

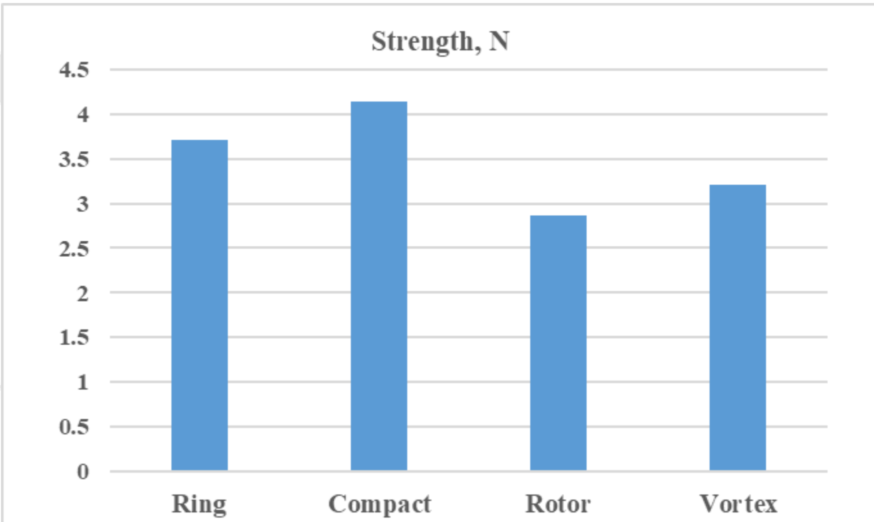


Figure 4.5. Comparison of Strength among ring, compact, rotor and vortex yarn

4.1.5. Comparison Of Elongation

Figure 4.6 provides information on the elongation of the four systems yarns. From Figure 4.6, it is clearly evident that compact in case of breakage elongation (%), spun yarn is better than ring spun yarn, whereas elongation at break of vortex spun yarn lies between ring and rotor spun yarn. It is apparent that the trend in yarn elongation is nearly identical to its related trend in tenacity. However, the rotor yarn has the lowest breaking elongation compared to other systems yarns due to irregular wrapping effect in rotor yarns, which raises premature failure incidence.

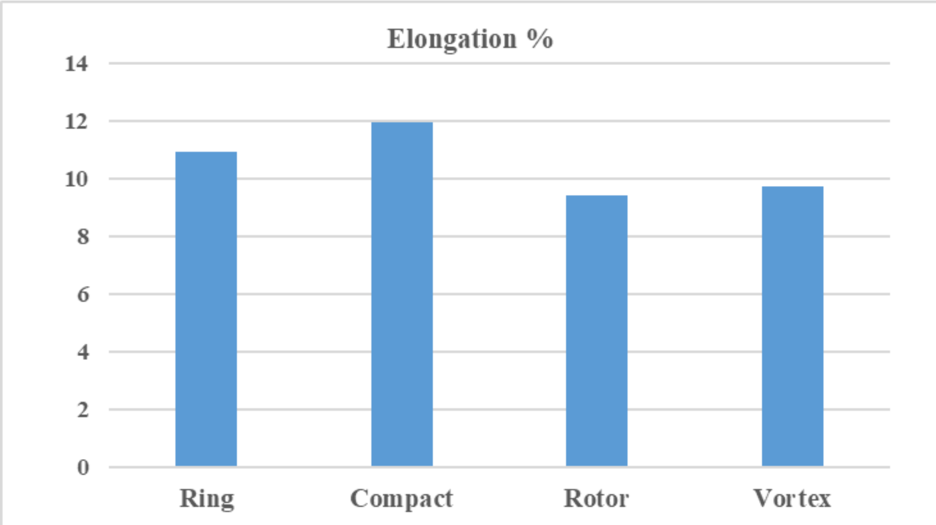


Figure 4.6. Comparison of elongation among ring, compact, rotor and vortex yarn

4.2. Knitted Fabrics

In this work, the pilling performance and bursting strength of plain knitted fabrics produced from the ring, compact, open-end, and vortex yarns with 100% viscose fibers and Ne 28/1 (21 tex) count yarn were evaluated. Each two fabrics type was produced at the same stitch density, open-end and vortex fabrics have the same stitch density, where ring and compact have the same one.

4.2.1. Pilling

The pilling tendency of the test samples and their resistance to abrasion is evaluated with the Martindale and the ICI pilling box abrasion tester, respectively.

4.2.1.1 Nu-Martindale Abrasion and Pilling Tester

Martindale Tester was used to find out the pill form of the fabrics. Fabrics were mounted the Nu-Martindale tester according to EN ISO 12945-2 standard and the face of the same fabric for a specific number of movements. For all the samples standard 500, 1000, 2000, 5000, and 7000 revolutions were given, and the fabrics were graded for grades there. The fabrics then compared to the standard pilling photographs for calculating pilling grades and values were given in Table 4.3. According to standard pilling rating standards are 1- Severe formation of pills, 2-Obvious pilling, 3-Moderate pilling, 4-weak pilling, 5-No, or very weak pilling.

Table 4.3, below gives information about the results of fabric resistance to the pilling by the Nu-Martindale device. In Table 4.3, it is clear by comparing the compact and the ring fabrics (which have the same stitch density), that the best pilling resistance of fabrics was a compact system. However, ring spun yarn knitted fabrics have shown higher pilling than the fabrics produced with compact yarns at the same number of revolutions (2000). Ring also reported 4, 3-4 and 3 grades for the number of revolutions 1000, 2000 and 5000 respectively, whereas compact reported 4, 4 and 3-4 grades for the number of revolutions 1000, 2000 and 5000 respectively, due to the ring spun yarns are hairier than compact spun yarns (see Table 4.1), which can require quick exposure to abrading forces from the raised fiber ends. Also, no change in the grades of both ring and compact after the 5000 revolutions.

Table 4.3. Pilling resistance of Nu-Martindale

Revolutions	**Ring**	**Compact**	**Rotor**	**Vortex**
500	**4-5**	**4-5**	**4-5**	**5**
1000	**4**	**4**	**4**	**4-5**
2000	**3-4**	**4**	**4**	**4**
5000	**3**	**3-4**	**3-4**	**3-4**
7000	**3**	**3-4**	**3**	**3-4**

On the other hand, the results show in Table 4.3, that as expected, the fabrics made from vortex yarns have better pilling resistance performance compared with the one which knitted from open-end yarns (which have the same stitch density). The grades of the vortex are around 5 and 3-4, while it is around 4-5 and 3 for the rotor. However, the fabrics which knitted from open-end yarns have a tendency to pill a much higher degree than the vortex fabric, this is attributed to the low hairiness value of the vortex yarn compared to the rotor yarn (see Table 4.1.). In other words, the more hairy the surface of the yarn, the more pill formation on the surface of the fabric is.

4.2.1.2 ICI Pilling Box

Fabrics were mounted the ICI pilling box by using James Heal Orbitor® test device, according to EN ISO 12945-2 standard. For measuring pilling grades, the same pilling standard photographs of Nu-Martindale tester were used with the same number of revolutions. Pilling values of the fabrics are classified from worse to best as 1-3, 2-3, 3-4, and 4-5.

Table 4.4, below illustrate the pilling test results of the samples were given by using the ICI pilling box device. The results in Table 4.4 (see Figure 4.7) show as expected for the same stitch density knitted fabrics (ring and compact) that the pilling resistance of compact fabric was higher compared to ring fabric as like as Nu-Martindale test, due to compact yarns have less hairiness than ring yarns. It can be said that yarn hairiness is effective in fabric pilling performances. Also, the obtained results in Table 4.4, showed that the pilling resistance of vortex fabric is better than the rotor fabric.

Moreover, for the same number of test revolutions (e.g., 7,000) and the same fabric, the degree of damage in ICI pilling box fabrics was more than the Nu-Martindale test, this may be because of the different experimental conditions between the two tests. Furthermore, the samples of the ICI pilling box test were exposed to greater stress than the Nu-Martindale test which helps for greater and faster weariness with less resistance to pilling.

In this case, the vortex and rotor fabrics have a good pilling performance compared to the compact and ring fabrics, this is most probably due not only to hairiness but also to stitches density of these fabrics.

Test results for the pilling tendency are explained visually in the photographs below (Figure 4.7).

Table 4.4. Pilling resistance of ICI pilling box

Revolutions	Ring	Compact	Rotor	Vortex
500	4-5	5	5	5
1000	4-5	4-5	4-5	4-5
2000	3-4	4	3-4	4
5000	2-3	3	3	3-4
7000	2	2-3	3	3-4

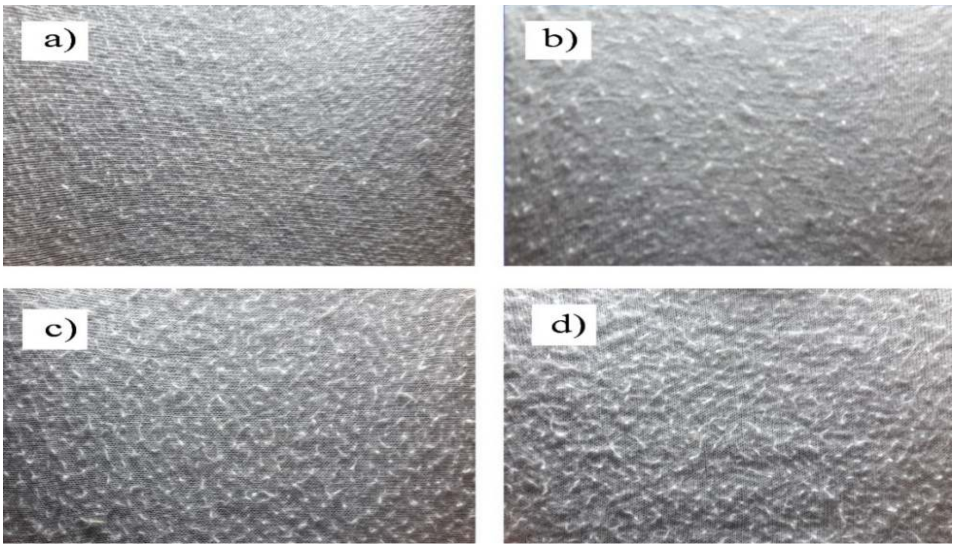


Figure 4.7. Photos of fabrics after pilling; a) vortex, b) rotor, c) compact, d) ring.

When the values of the images in Figures 4.7 are evaluated, it is found that the pilling tendencies of fabrics knitted from vortex yarns are lower than those of fabrics knitted from rotor yarns. This situation may be the result of lower hairiness of vortex yarns compared to the rotor yarns which are given in Table 4.1. Besides, it can be seen that compact knitted fabrics have a better appearance than ring knitted fabrics.

4.2.2. Bursting Strength

The bursting strength of the fabrics was measured in accordance with the EN ISO 13938-2 standard with James Heal Truburst® bursting strength measurement device. In the case of knitted fabric with the same stitch densities (ring and compact).

According to Figure 4.8, the bursting strength of the sample knitted fabrics changes between approximately 300 to 365 kPa. (all the results in Figure 4.8 are the average obtained from the tested samples) and all detailed results of the samples are available in the section ADDS.

The results of the measurements of bursting strength (see Figure 4.8) show that with high imperfection and lower tenacity, the ring knitted fabric shows low bursting strength than the compact knitted fabric.

The results also show that as expected, rotor fabrics have weaker bursting strength performance compared with vortex fabrics due to the higher tenacity of the vortex yarn compared with the rotor yarn. In this process, as the tenacity values of the yarn increases, the bursting strength increases too.

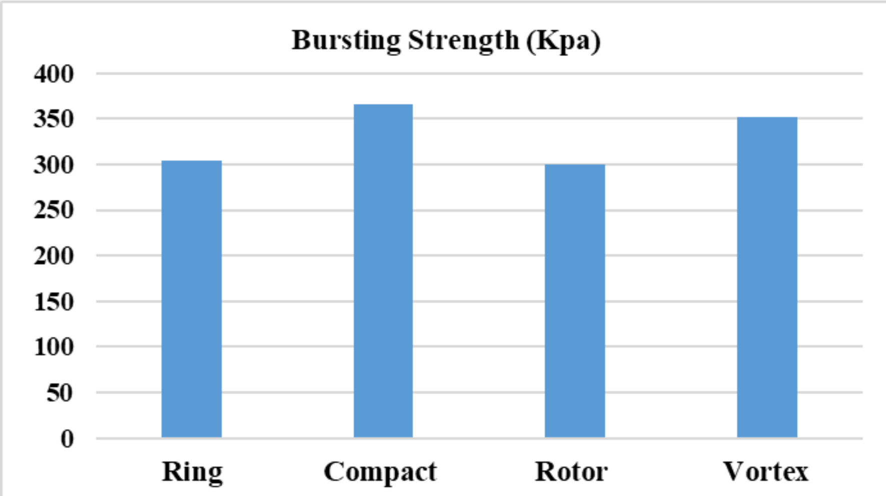


Figure 4.8 Bursting strength values (kPa) of the fabrics

ANOVA results are given in Table 4.5 for the bursting strength properties of the samples. The effect on bursting strength of knitted fabric spinning technology is found to be statistically significant (p=0.011<0.05) at a confidence interval of 95 %. Knitted fabrics produced from the ring, compact, rotor, and vortex knitted fabrics have statistically similar bursting strength results, according to Tukey HSD multiple comparison tests.

Table 4.5. ANOVA results of the bursting strength

ANOVA for bursting strength							
		Sun of squares	**df**	**Mean square**	**F.**	**Sig**	**Tukey HSD**
Bursting strength	**Between groups**	**118080.850**	**3**	**3936.283**	**5.152**	**0.011**	**(ring, compact, rotor, vortex)***
	Within groups	**12225.320**	**16**	**764.082**	**-**	**-**	
	Total	**24034.170**	**19**	**-**	**-**	**-**	

*This mean difference is not significant at the 0.05 level.

5. CONCLUSION

5.1. Yarns

Spun yarns were produced from 100%viscose fibers at Ne 28/1 (21 Tex) count with four different spinning technologies namely ring, compact, rotor and vortex. Regard to the results of the performance test and ANOVA, spinning technology has a major effect on the properties of mass variation, imperfection, hairiness, strength, and elongation. It is seen from the research experimental results that ring and compact spinning systems have a better evenness, strength and elongation properties and fewer imperfection properties to the yarns. However, yarns spun using the rotor technique has more irregularity than other systems yarns. The imperfection of compact spun yarn is very much lower than rotor spun yarn, but rotor spun yarn contains fewer neps (+280%)/km. IPI of ring yarn lies between compact and rotor yarn. The vortex spun yarn has the largest number of thick places compared with the others spun yarns. As for the spinning systems, the variation in neps is very small but the variation is very noticeable for the thick and thin places.

According to Tukey HSD multiple comparison tests, there are two groups of yarns that exhibit similar to the number of thin places results, the first group consists of ring and compact with fewer thin places and the second group consists of rotor and vortex with more number of thin places. In a 95% confidence interval, the difference between these groups is found to be statistically significant. The yarn sample produced from ring spun yarns is hairier than that of vortex yarns, with less thin and thick places, but with more neps of 1000 m of yarn. The compact yarn showed better yarn evenness due to the lower U%, the hairiness of compact yarn are also lower than other systems yarns.

Compared to the rotor yarn, the strength of the yarn is significantly lower relative to the other systems produced, and this is attributed to the variation in the structure of the yarns produced by the different spinning techniques. Consequently, compact yarn can be adjudged to have better quality characteristics than the other yarn spinning technology.

5.2. Knitted Fabrics

In this thesis, we intended to investigate the effect of plain knitted fabrics made from 100% viscose ring, compact, rotor, and vortex spun yarns with Ne 28/1 (21 tex) count on the pilling performance and bursting strength properties. The results of investigation for pilling performance show that fabrics knitted with compact yarns were found to have better pilling properties than fabrics knitted with ring yarns. However, the pilling performance of knitted fabric made from vortex spun yarns have a higher value compared with rotor knitted fabric. The hairiness of the yarn is the most important property that affects the performance of the knitted fabrics towards the pilling. In this case, an increase in yarn hairiness property reduces knitted fabric abrasion resistance and pilling performance.

On the other side, fabrics knitted with compact yarns had higher bursting strength than knitted fabrics produced with ring yarns. Furthermore, the rotor knitted fabrics have less bursting strength compared with vortex knitted fabrics. Mainly, the difference between bursting strength results of the knitted fabrics produced depends on the tenacity of yarns.

It can be concluded that to be able to produce knit fabrics whose bursting strength and pilling performance are high, vortex and compact yarns should be used.

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AUTOBIOGRAPHY

Muhammed Ali KARAT was born in Syria, in 1993. He completed the High School at Aleppo, Syria in 2010. In 2015, he graduated from the Department of Textile Engineering, Aleppo University, Aleppo, Syria. He came to Turkey in 2016. He started the MSc program at the Department of Textile Engineering, Çukurova University, Adana, in 2017 under the supervision of Prof. Dr. Osman Babaarslan. He completed the MSc program at the Department of Textile Engineering in 2020.

ADDS

Total tests for ring yarn

Nr	U% %	CVm %	Thin -50% /km	Thick +50% /km	Neps +200% /km	Neps +280% /km	H	sh
1	9.47	12.89	7.5	12.5	30.0	20.0	4.35	0.94
2	9.08	11.43	0	0	2.5	0.0	4.23	0.90
3	9.32	11.77	0	12.5	15.0	2.5	4.18	0.94
4	8.85	11.09	0	2.5	5.0	0.0	4.42	0.92
5	8.90	11.14	0	5.0	10.0	7.5	4.46	0.94
6	8.98	11.30	0	2.5	2.5	2.5	4.40	0.92
7	8.92	11.22	0	0.0	7.5	0.0	4.79	1.10
8	9.29	11.74	0	17.5	17.5	10.0	4.33	0.93
9	9.57	12.10	0	25.0	32.5	15.0	4.23	0.94
10	8.77	11.07	0	2.5	0.0	0.0	4.53	0.96
Ortalama	9.12	11.57	0.8	8.0	12.3	5.8	4.39	0.95
CV	3.0	5.0	316.2	106.0	93.5	124.8	4.0	5.8
s	0.28	0.57	2.4	8.5	11.5	7.2	0.18	0.06
Q95	0.20	0.41	1.7	6.1	8.2	5.1	0.13	0.04
USP™13	-	38	12	31	10	-	51	41

No	Strength N	Elongation %	Tenacity CN/tex	Breaking strength s
Ortalama	3.71	10.93	17.59	0.66
CV	14.51	15.64	14.51	15.63
Min	2.66	6.81	12.59	0.41
Max	4.8	13.36	22.74	0.80
USP™13	16	> 95	16	-

Total tests for compact yarn

Nr	U% %	CVm %	Thin -50% /km	Thick +50% /km	Neps +200% /km	Neps +280% /km	H	sh
1	8.30	10.49	0.0	10.0	12.5	0.0	4.44	0.97
2	8.27	10.44	0.0	0.0	7.5	0.0	3.97	0.88
3	8.23	10.37	0.0	2.5	10.0	0.0	4.08	0.87
4	8.24	10.40	0.0	5.0	10.0	5.0	3.91	0.86
5	8.25	10.40	0.0	5.0	7.5	2.5	4.10	0.86
6	8.20	10.39	0.0	5.0	2.5	0.0	4.24	0.93
7	8.83	11.10	0.0	2.5	5.0	2.5	4.08	0.89
8	9.10	11.49	0.0	0.0	5.0	2.5	4.29	0.94
9	7.93	10.0	0.0	2.5	7.5	2.5	4.16	0.92
10	8.13	10.25	0.0	2.5	5.0	2.5	4.20	0.92
Ortalama	8.35	10.53	0.0	3.5	7.3	1.8	4.15	0.90
CV	4.2	4.1		83.8	41.3	96.4	3.7	4.0
s	0.35	0.43	0	2.9	3.0	1.7	0.15	0.04
Q95	0.25	0.31		2.1	2.1	1.2	0.11	0.03
USP™13	-	9	< 5	9	< 5	-	39	28

No	Strength N	Elongation %	Tenacity CN/tex	Breaking strength s
Ortalama	4.14	11.95	19.62	0.72
CV	8.20	8.01	8.20	8.01
Min	3.40	9.96	16.12	0.60
Max	4.57	13.14	21.69	0.79
USP™13	< 5	78	< 5	-

Total tests for rotor yarn

Nr	U% %	CVm %	Thin -50% /km	Thick +50% /km	Neps +200% /km	Neps +280% /km	H	sh
1	10.73	13.49	17.5	27.5	15.0	2.5	4.03	1.05
2	10.82	13.64	17.5	35.0	12.5	0.0	4.04	1.05
3	10.84	13.65	12.5	20.0	17.5	0.0	4.05	1.06
4	11.27	14.18	10.0	37.5	10.0	0.0	4.03	1.05
5	10.78	13.57	17.5	22.5	22.5	0.0.	4.02	1.06
6	11.04	13.85	10.0	15.0	10.0	0.0	4.03	1.06
7	11.03	13.80	17.5	17.5	12.5	0.0	4.02	1.05
8	10.84	13.68	15.0	15.0	2.5	0.0	4.01	1.04
9	10.76	13.54	10.0	25.0	15.0	0.0	4.02	1.06
10	10.80	13.59	27.5	20.0	7.5	0.0	4.01	1.06
Ortalama	10.89	13.70	15.5	23.5	12.5	0.3	4.02	1.05
CV	1.6	1.5	34.7	33.3	44.2	316.2	0.3	0.6
s	0.17	0.20	5.4	7.8	5.5	0.8	0.01	0.01
Q95	0.12	0.15	3.8	5.6	4.0	0.6	0.01	0.0
USP™13	-	27	65	6	< 5	< 5	38	40

No	Strength N	Elongation %	Tenacity CN/tex	Breaking strength s
Ortalama	2.87	9.44	13.59	0.57
CV	8.20	10.49	8.20	10.47
Min	2.59	8.44	12.26	0.51
Max	3.38	11.25	16.01	0.68
USP™13	17	> 95	17	-

Total tests for vortex yarn

Nr	U% %	CVm %	Thin -50% /km	Thick +50% /km	Neps +200% /km	Neps +280% /km	H	sh
1	10.08	12.71	2.5	17.5	7.5	0	3.99	0.87
2	10.21	12.83	10.0	12.5	5.0	0	3.81	0.85
3	10.07	12.71	5.0	15.0	7.5	0	3.78	0.86
4	10.12	12.79	2.5	32.5	5.0	0	3.76	0.86
5	10.12	12.83	2.5	37.5	12.5	0	3.77	0.88
6	10.25	12.98	5.0	30.0	10.0	5.0	3.78	0.89
7	10.40	13.12	5.0	35.0	10.0	0	3.74	0.88
8	10.24	12.96	5.0	25.0	12.5	0	3.78	0.90
9	10.12	12.77	12.5	25.0	10.0	5.0	3.76	0.90
10	10.34	13.05	5.0	30.0	20.0	5.0	3.73	0.88
Ortalama	10.20	12.88	5.5	26.0	10.0	1.5	3.79	0.88
CV	1.1	1.1	59.8	33.1	44.1	161.0	2.0	1.8
s	0.11	0.14	3.3	8.6	4.4	2.4	0.07	0.02
Q95	0.08	0.10	2.4	6.1	3.2	1.7	0.05	0.01
USP™13	-	-	-	-	-	-	-	-

No	Strength N	Elongation %	Tenacity CN/tex	Breaking strength s
Ortalama	3.21	9.72	15.20	0.58
CV	5.98	7.88	5.98	7.88
Min	2.95	8.69	14.00	0.52
Max	3.58	11.12	16.98	0.67
USP™13	-	-	-	-

Bursting strength test results for ring knitted fabrics

N	kpa	mm	s
1	315.9	12.9	19
2	283.3	11.8	17
3	299.8	11.4	18
4	337.0	11.2	19
5	286.6	13.0	17
Mean	304.5	12.1	18

Max	337.0
Min	283.3
Range	53.7
S.D.	22.24
CV%	7.30
Q95%	27.58

Bursting strength test results for compact knitted fabrics

N	kpa	mm	s
1	374.2	13.3	20
2	346.8	11.6	19
3	352.9	11.8	19
4	370.0	13.1	20
5	382.8	13.5	20
Mean	365.3	12.7	19..6

Max	382.8
Min	346.8
Range	36.0
S.D.	15.04
CV%	4.12
Q95%	18.65

Bursting strength test results for rotor knitted fabrics

N	kpa	mm	s
1	319.0	12.5	18
2	267.1	10.4	16
3	301.0	11.8	18
4	326.6	12.2	19
5	287.2	12.2	17
Mean	300.2	11.8	17.6

Max	326.6
Min	267.1
Range	59.5
S.D.	24.06
CV%	8.01
Q95%	29.83

Bursting strength test results for vortex knitted fabrics

N	kpa	mm	s
1	372.4	12.7	20
2	349.5	13.1	19
3	373.3	13.5	20
4	334.6	12.7	19
5	330.9	12.4	18
Mean	352.1	12.9	19.2

Max	373.3
Min	330.9
Range	42.4
S.D.	20.17
CV%	5.73
Q95%	25.0