Süleyman Demirel Üniversitesi
Fen Bilimleri Enstitüsü Dergisi
Cilt 28, Sayı 2, 148-153, 2024

Süleyman Demirel University
Journal of Natural and Applied Sciences
Volume 28, Issue 2, 148-153, 2024

DOI: 10.19113/sdufenbed.1381685

The Effects of Weaving Process on the Damage Formation of the E- Glass Yarn

Mehmet Korkmaz *[1], **Melih Korkmaz**[2,3]

[1]Dokuz Eylül Üniversitesi, Mühendislik Fakültesi, Tekstil Mühendisliği Bölümü, 35397, İzmir, Türkiye

[2]Dokuz Eylül Üniversitesi, Fen Bilimleri Enstitüsü, Mekanik Anabilim Dalı, 35397, İzmir, Türkiye

[3]Fibrosan A.Ş, İzmir, Türkiye

(Alınış / Received: 26.10.2023, Kabul / Accepted: 11.05.2024, Online Yayınlanma / Published Online: 23.08.2024)

Keywords
E- glass fiber,
Weaving technology,
Degradation,
Friction,
Strength

Abstract: The woven fabric production can be executed in the weaving machine by the using of different mechanisms, which are working simultaneously. Because of the weaving mechanisms, the yarn has under tension and changed between the determined range within the repetitive cycles. The mechanisms and unsteady tension cause to damage on the yarns in the woven fabric production process. The breakable fibers like carbon or glass are more sensitive to degrade in the weaving machine because of their low friction resistance in comparison with the traditional fibers. The several of studies had been carried out to determine the tension of yarns and their damage mechanisms in the weaving process. However, they focused on the damage evolutions of warp yarns in the weaving process. In addition to the warp yarns, the damage evolution of weft yarns was investigated for industrial production in this study. The prevalent weft tensioning systems were evaluated, and the spring yarn tensioning system shown the best performance. Moreover, the yarn- to-machinery part type of friction was determined as the main reason to degrade warp yarns in the industrial production of glass woven fabric.

Dokuma İşleminin E- Cam İplikler Üzerinde Hasar Oluşumuna Etkilerinin İncelenmesi

Anahtar Kelimeler
E- cam lifi,
Dokuma teknolojisi,
Aşınma,
Sürtünme,
Mukavemet

Özet: Dokuma makinesinde kumaş oluşumu farklı mekanizmaların eş zamanlı çalışması ile sağlanmaktadır. Dokuma mekanizmalarından dolayı iplik belirli bir gerginlik altındadır ve bu durum bir çevrim halinde devam etmektedir. Kullanılan mekanizmalar ve sabit olmayan gerginlik dokuma işlemi sırasında ipliğe zarar verebilmektedir. Düşük aşınma dayanımı gösteren cam ya da karbon gibi kırılgan lifler geleneksel liflere göre hasar oluşumuna karşı daha yatkındırlar. Dokuma işleminde iplik gerginliğinin ve hasar mekanizmalarının belirlenmesi üzerine birçok çalışma yapılmıştır. Bu duruma karşın çalışmalarda genellikle çözgü iplikleri üzerinde oluşan hasar incelenmiştir. Yapılan bu çalışmada endüstriyel üretim sırasında çözgü ipliklerinin yanı sıra atkı iplikleri üzerinde oluşan hasar araştırılmıştır. Endüstride yaygın olarak kullanılan atkı gerginlik sistemleri incelenmiş, yaylı iplik gerdirici sistem en iyi performansı göstermiştir. Elde edilen bu sonucun yanı sıra endüstriyel cam dokuma kumaş üretiminde iplik- makine aksamı arasında oluşan sürtünmenin çözgü iplikleri üzerinde hasara yol açan başlıca neden olduğu belirlenmiştir.

1. Introduction

The shedding, picking, and beating are constituted the three essential processes to obtain woven fabric. In addition, the let- off warp yarn and the take- up of fabric are other significant processes to provide continuity in the weaving.

Due to the different mechanisms of weaving machine, the yarn tension is changed in the weaving process. Accordingly, the yarn tension is a substantial point in the weaving because it should be kept within the determined range. If the type of raw material, the structural properties of yarn and woven fabric, the setting of weaving machine are not well optimized, the damages on the yarn and finally break off can be

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*Corresponding author: mehmet.korkmaz@deu.edu.tr occurred. The studies [1 - 3] had been executed about the yarn tension in the weaving process.

The weaving of breakable fibers like carbon or glass are more complicated than traditional fibers. Although they have high strength and stiffness values in their main axis, they show low friction resistance because of their breakable structure. Therefore, the weaving processes of breakable yarns should be specialized according to their friction sensitive nature. Otherwise, the weaving processes can seriously degrade them.

Because of the degradation, the fibrillation is begun on the yarn then it is broken if the yarn is exposed a greater number of weaving cycles at the same conditions. The breakage of warp yarn directly reduces the productivity of weaving process and increase the number of defects on the fabric. Moreover, the yarn’s all strength cannot be transferred to the fabric or its composite due to the degradation.

Rudov- Clark et al. [4] carried out a study to investigate the degree of degradation on the breakable fibers owing to the weaving process. E- glass yarn was used as raw material, and the tensile strengths of yarn groups (binding warp, stuffer warp and weft) were measured at different stages of weaving. The weaving process severely damaged the warp yarns, the stuffer and binding warp yarns lost 30% and 50% of their strength in the weaving process, respectively. Lee et al. [5] examined the degradation on the carbon yarn in the weaving process. In addition, single yarn composites were produced and the effect of yarn degradation on the composite mechanics was analyzed in the study. The friction, which is between yarn and machinery part, was determined as main factor for yarn degradation. The carbon yarn lost 12% of its strength due to the weaving process. The wear-resistance material was recommended to cover machinery parts to reduce the yarn degradation. Moreover, only severely damaged yarns caused the loss of composite tensile strength. Abu Obaid et al. [6] indicated the fiber breakage as one of main factors to cause degradation on the yarn in the weaving process as well as the friction. The E- glass yarn was used as the binding warp yarn, and it was the most damaged among all yarn groups. Owing to the bending and tension variations, the yarn lost %29- 35 of its strength. The hybridization of yarn groups was suggested as a solution to minimize the degradation of binding warp yarn.

The yarn damage varied in the different stages of weaving process. Nauman et al. [7] studied on the shedding mechanism and concluded that it is main operation to degrade the yarn. The carbon yarn lost %42 of its tensile strength in the weaving process. Boussu et al. [8] investigated the kinematics of weaving process to clarify damage mechanism of yarn. Different weaving steps were monitored globally and locally with high-speed camera and in-situ sensors, which were made from e-glass yarn. The shed opening and reed beat-up mechanisms were confirmed to give the maximum damage on the yarn in weaving process. Decrette et al. [9] focused on the shed opening step in the weaving process to evaluate the damage, which was occur on the yarn. The close shed profile and yarn shedding speed were determined as significant parameters to reduce the degradation on the yarn in the weaving process. Leng et al. [10] developed kinematical model for heald frame to analyze the effects of shedding process on the yarn damage. It was determined that the friction between the yarn and heddle eye not only related with the size parameters of shedding mechanism but also related with the acceleration. Afterward, the acceleration was optimized to determine the derived curve trajectory of heald frames. Therefore, the lower number of fiber breakage could be obtained. Besette et al. [11] examined the contact forces, which were between warp yarns, were investigated in the weaving process as well as the tension variation on the yarn. The contact forces had peak values in shed opening, reed beat-up and back movement of reed steps same as the yarn tension. Moreover, it was found that the contact forces were deeply affected by the number of warp yarns unlike the yarn tension.

At the same time, the research studies have been carried out to predict the fiber damage or breakage thanks to the experimental methods and developed mathematical models. Li et al. [12] measured the hairiness of carbon yarn with the tribometer. The tribometer can determine the normal force and the frictional force values. It was found that the normal force is the main factor to raise frictional force and cause the hairiness on the carbon yarn. Wu et al. [13] investigated the tow- on- tool friction to simulate the beating- up process in the carbon weaving. The filaments reveal multiple fracture damage pattern, when they are exposed by the stretching, shearing, and compressing forces during the weaving process. Guo et al. [14] developed a weaving load simulation tester device to predict warp tension and optimize the weaving parameters. Azevedo et al. [15] estimated the warp and weft yarn breakages in the weaving process thanks to the machine learning approach. Xu et al. [16] established a yarn hanging model based on the catenary theory to estimate the applied minimum initial warp tension, which ensure the clear shedding in the weaving process.

Furthermore, several studies were carried out to clarify the effects of fabric architecture on the yarn degradation in the weaving process [17 - 21].

Within the scope of this study, the yarn degradation was investigated from bobbin to the e- glass woven fabric production, which was carried out by the industrial weaving loom. The previous research studies focused to measure or predict the damage formation on the warp yarns during the weaving process. However, the damage on the weft yarns have significance to achieve higher production rates and obtain high quality e-glass woven fabrics. Therefore, the damage formation on the weft yarns had been investigated as well as the warp yarns in this study. Moreover, the various weft tensioning systems had been examined and the best system was determined.

2. Material and Method

2.1. Tested material

The production stage of e- glass woven fabric was investigated in the study. The structural properties of e- glass woven fabric is presented in Table 1. The 600 Tex e- glass yarn, which is belong to the Jushi company, were used for warp and weft yarns in the production of fabric.

Table 1. The structural properties of produced e- glass woven fabric

Weave Pattern	Yarn Density (yarn/cm)		Yarn Types		Areal Density (g/m^2)
	Warp	Weft	Warp	Weft	
Plain	2.4	2.5	E- glass (600 Tex)	E- glass (600 Tex)	300

2.2. Method of measurement

2.2.1. Measurement of warp yarn damage

The woven fabric production divided three sections to follow the evolution of yarn mechanical properties. Therefore, the yarn mechanical properties could be examined from bobbin to the weaving zone of machine. The specified sections,

a. The yarn from bobbin,
b. The section between the creel and back reed of weaving machine,
c. The section between the back reed and frames of weaving machine,
d. The section between the frames and reed of weaving machine.

The yarn specimens were collected from the specified sections and tested under the tensile load. Thus, their maximum breaking load, elastic module and maximum elongation values were determined. In every stage of measurement, ten specimens were tested according to NF EN 2062 test standard. The Instron 4411 tensile test machine with 10 kN load cell was used, the machine is shown in Figure 1.

Figure 1. Instron 4411 tensile test machine

2.2.2. Measurement of weft yarn damage

In addition to the warp direction, the damage in the weft yarns were evaluated in the study according to the different weft tensioning systems. As the glass yarns are sensitive for the friction, the glass woven production can be carried out with or without automatic weft tension control systems. In the study, two types of brushes, which are belong to the automatic yarn tension system, were used to observe their effects on the damage of weft yarns. The brushes were diversified according to their rigidities. The white brush (W.A.T) has more rigidity than brown brush (B.A.T), which are presented in Figure 2.

(a) (b)

Figure 2. The automatic weft tension control systems with different brushes, (a) system with the white brush, (b) system with the brown brush

At the same time, the glass woven fabric production was carried out with the manual tensioning systems. The triple metal weft frame (M.T) and spring yarn tensioner systems were used to investigate their effects on the damage of e- glass yarn. Moreover, both systems were diversified to two subgroups. The liquid ceramic was applied to the metals of triple weft frame system (C.M.T). In addition, the metal (M.S.T) and ceramic types (C.S.T) of spring yarn tensioning systems were used to evaluate their effects on the glass yarn damage. All manual tensioning systems are presented in Figure 3. As the damage of weft yarn can be determined, the broken and then accumulated glass filaments were weighted. For accumulation of broken filaments, the weaving machine, which is Dornier P2, had been running for 15 minutes at 170 rpm. The process was repeated three times to obtain average and standard deviation values.

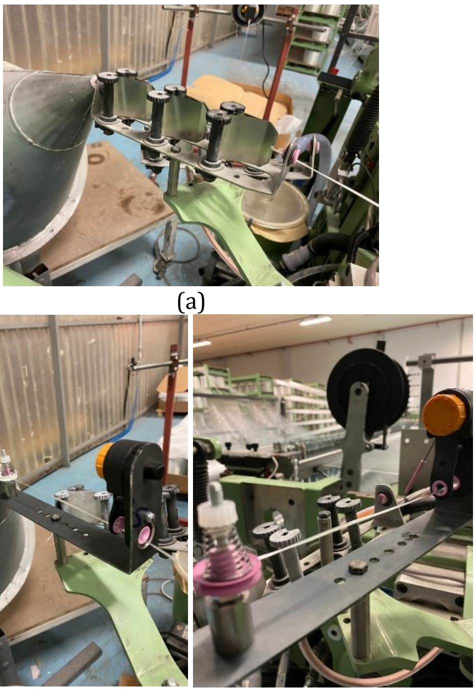

(a)
(b) (c)

Figure 3. The manual weft tensioning systems, (a) triple metal weft frame, (b) metal spring yarn tensioning system, (c) ceramic spring yarn tensioning system

3. Results and Discussion

3.1. The damage measurement in the warp yarns

3.1.1. The mechanical properties of yarn from bobbin

As the evolution of yarn properties could be examined, the e-glass yarn was tested from bobbin to the different sections of fabric production. The determined load (N)- strain (%) graphs and mechanical properties of e-glass yarn, which were taken from the bobbin, were presented in Figure 4 and Table 2, respectively.

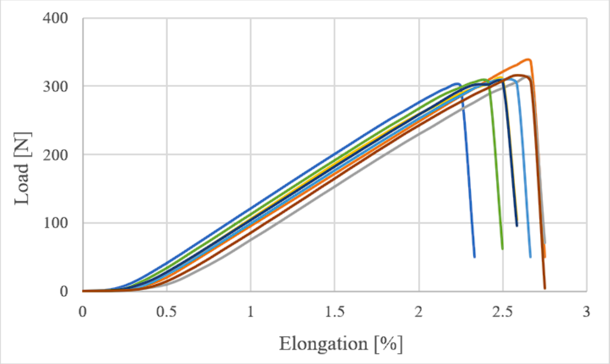


Figure 4. The load- elongation graphs of e-glass yarns from bobbin

Table 2. The properties of e- glass yarn from bobbin

Grade	Yield	Tensile Strength	Tensile Modulus	Elongation
	Tex	N	N	%
Jushi 386 H	600	311.5 (∓10.93)	157.32 (∓2.19)	2.49 (∓0.14)

3.1.2. The evolution of yarn mechanical properties within the weaving machine

The maximum load values of yarns from the different sections are presented in Figure 5. Although the e-glass yarns could keep their strength till the back reed of weaving machine, they were seriously damaged tensioning section and the weaving zone of machine. It was already proven that the yarn- to- machinery parts and yarn- to -yarn frictions are constituted the main reasons to damage on the yarns [4]. The obtained results are showed that the damage on the yarns originated from the yarn- to- machinery parts friction. The tensioning section of weaving machine is constituted by the cylinders, which are placed along the width of machine. If these cylinders are covered or renewed by the softer surface materials, the severity of warp yarn damage could be seriously reduced. In addition, the special designed heddles eye systems could help to decrease the damage on the warp yarns in the weaving zone. Moreover, the speed of weaving machine could be optimized to obtain less damage in the warp yarns.

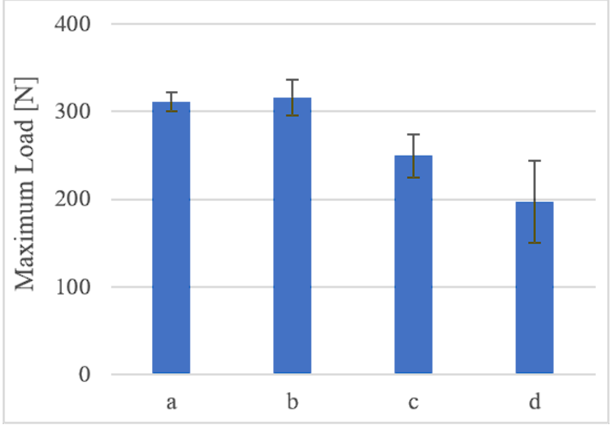
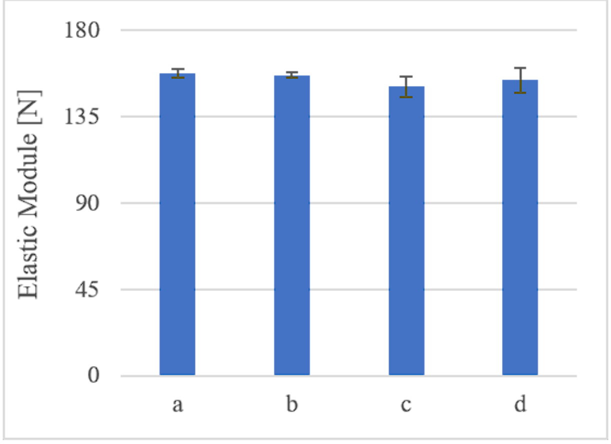
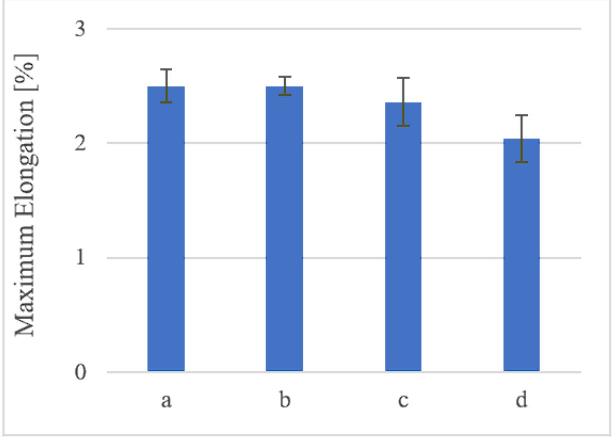


Figure 5. The breaking load values of yarns from different sections

In addition to the maximum load values, the elastic module and maximum elongation values of yarns were determined in the study. The values are presented in Figure 6. Although the friction reduced the strength of yarns, it did not change the elastic module values. Moreover, a statistically meaningful difference was occurred in the maximum elongation values between the section a, b and section d. This difference could be explained with the breaking of filaments within the e-glass yarn. As the number of filaments was decreased in the yarn, it was broken at lower elongation value. This result support the maximum load values of e-glass yarns. In addition, the obtained results proven that first the fibrillation is begun in the damaged e-glass yarn. If the problem is not solved, the severity of damage is increased and the accumulated fibrillation cause to break e- glass yarn.



(a)



(b)

Figure 6. The mechanical properties of yarns from different sections, (a) the elastic module values, (b) maximum elongation values

3.2. The damage measurement in the weft direction

The weights of broken e- glass yarn filaments are presented in Figure 7. The automatic weft tensioning system, which have standard brush, gave the highest damage to the e- glass yarn. The softer brown brush significantly reduced to damage the yarns. Moreover, the application of liquid ceramic improved the surface quality of metals and decreased the damage on the yarns. Both spring yarn tensioning systems have similar values and showed the best performance according to the damage on the yarns. The results proven that even automatically weft tensioning system with softer brush give serious damage on the e-glass weft yarns. The damage could be minimized with the spring tensioning systems. Although liquid ceramic metals seriously reduced the damage on the weft yarns, the implementation the liquid ceramic on the metals cause to spend time and cost. The spring tensioning system adapted automatically weft insertion systems can be developed in further research studies to obtain high quality e-glass woven fabrics.

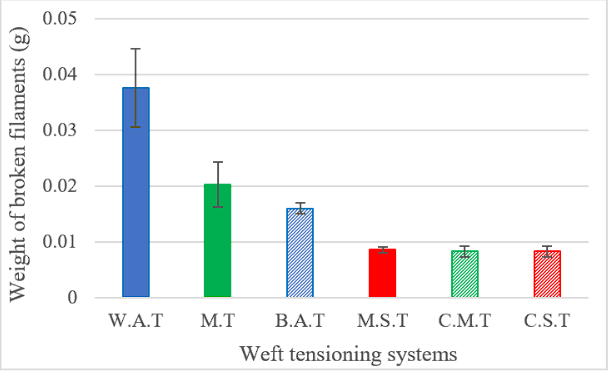


Figure 7. The weights of broken weft yarns filaments according to the different tensioning systems

4. Conclusion

In the study, the damage evolutions of warp and weft yarns were investigated in the industrial production of e- glass woven fabric. While the damage of warp yarns was measured thanks to the loss of tensile strength, the broken filaments were weighted to evaluate the damages in the weft yarns.

The e- glass warp yarns were seriously damaged in the tensioning section of weaving machine. The severity of degradation was raised in the weaving zone. The yarn-to- machinery part type of friction was determined as the main factor to degrade the warp yarns in the industrial e- glass woven fabric production. The automatic and manual weft tensioning systems were examined to specify their degradation on the e-glass weft yarns. The improvement can be obtained in the automatic weft tensioning system with the using of soft brush. In addition, the liquid ceramic application reduced the friction between the yarn and metal plate in the triple metal tensioning system. As results, the spring yarn tensioning system shown the best performance.

Acknowledgement

The authors would like to thanks to the Fibrosan Corporation and Production Manager Rahmi KORKMAZ for their support to carry out the study.

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