

EFFECT OF FIBER TYPE AND POLYETHYLENE FILM ON MECHANICAL PROPERTIES OF ULTRASONICALLY BONDED MULTI LAYER NONWOVEN FABRICS

LİF TİPİNİN VE POLİETİLEN FİLMİN ULTRASONİK YÖNTEMLE BİRLEŞTİRİLMİŞ ÇOK KATMANLI NONWOVEN KUMAŞLARIN MEKANİK ÖZELLİKLERİ ÜZERİNE ETKİSİ

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ABSTRACT

In this study mechanical properties of the ultrasonically bonded nonwoven fabrics were investigated. For this purpose polypropylene, polyester and polyester-viscose nonwoven fabrics which have three different fabric area densities were obtained. Then nonwoven fabrics were bonded to each other by using ultrasonic sewing machine and two layered structures were produced. Also polyethylene film was placed between two nonwoven fabrics and these three surfaces were bonded by using ultrasonic sewing machine and three layers fabrics were obtained. Tensile strength and elongation at break properties of the 2 and 3 layers structures were investigated and effect of the polyethylene film on the mechanical properties of the 3 layers structures was studied. And higher mechanical properties were obtained from the 3 layers polypropylene-polyethylene film-polypropylene structures.

Key Words: Nonwoven fabric, Ultrasonic sewing, Mechanical properties, Polyethylene film.

ÖZET

Bu çalışmada ultrasonik yöntemle birleştirilmiş nonwoven kumaşların mekanik özellikleri incelenmiştir. Bu amaçla 3 farklı gramajda polipropilen, poliester ve poliester – viskon nonwoven kumaş kullanılmıştır. Ardından nonwoven kumaşlar birbirleriyle ultrasonik dikiş makinesiyle birleştirilmiş ve 2 katmanlı yapılar üretilmiştir. Ayrıca iki nonwoven kumaş arasına polietilen film yerleştirilerek bu 3 yüzey ultrasonik dikiş makinesiyle birleştirilmiş ve 3 katmanlı yapılar üretilmiştir. 2 ve 3 katlı yapıların kopma dayanımı ve kopma anındaki uzama özellikleri araştırılmıştır ve polietilen filmin 3 katmanlı yapıların mekanik özelliklerine etkisi incelenmiştir. En yüksek mekanik özellikler 3 katmanlı polipropilen – polietilen film – polipropilen yapısında elde edilmiştir.

Anahtar Kelimeler: Nonwoven kumaş, Ultrasonik dikiş, Mekanik özellikler, Polietilen film

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1. INTRODUCTION

Technology is rapidly developing nowadays. Textile and readymade garment industries are trying to exploit from these developments. One of those areas is the use of ultrasonic energy in ready-made garment industry. Therefore, ultrasonic energy takes its part in textile and readymade garment industries and is being used in many applications (1,2).

Ultrasound is simply sound that is above the frequency range of human hearing (3). The normal range of human hearing is between 16 Hz and 16 kHz, while ultrasonic frequencies are generally considered to lie between 20 kHz and 500 MHz (4). The chemical effect of the power of

ultrasonic energy is emerged by cavitations. Ultrasonic energy is conveyed by waves. These waves create compression and relaxation in molecular structures of the environment which they pass (5). In other words, when a disturbance occurs at a portion in an elastic medium, it propagates through the medium in a finite time as a mechanical sound wave by the vibrations of molecules; atoms or any particles present (3). The field of ultrasonic is still making strides towards perfection, but many applications of ultrasonic waves have already been found in science and technology. Ultrasonic energy has been widely used on research for engineering (20–50 kHz) and in medical science (1–10 MHz) for many years. The ultrasonic energy in these fields is used for; cleaning, sterilization,

plastic welding, homogenization and filtration. Some examples of ultrasonic energy are military and non-military exploration of sea floor and sonar systems, non-destructive testing in material engineering, medical therapy and diagnosis. Ultrasonic energy is also widely used for cleaning and degreasing of parts and assemblies in automotive and other industries (4).

Ultrasonic energy is also used in textiles to accelerate and develop the textile processes. It was reported by several workers that ultrasonic energy has been successfully applied to the surface modification processes of textiles and improved properties have been gained from the final textile products (6-10). Ultrasonic energy is also applied to the textile dyeing processes (11-14). In the same way, some studies were conducted on the use of ultrasonic energy on bleaching, cleaning and washing processes of textiles (15-19).

Use of ultrasonic energy as sewing process in readymade garment production is also developing. Sewing process can be defined as assembling of cut fabrics by using proper machines to obtain a cloth (20). Conventional sewing process is performed by discontinuous assembly and perforated stitch. For the continuous assembly and without perforated stitch, other sewing methods should be used. Ultrasonic, laser and heat assembly methods are performed by melting and cooling of the joined thermoplastic surface (21). Ultrasonic sewing is an effective method to assemble the thermoplastic materials in industry. Ultrasonic assembly technology uses high frequency vibration to join two or more thermoplastic and thermoplastic blended materials. Neither needle nor yarn is required for the ultrasonic sewing process. Assembly process is performed by the melting and bonding of the material (2, 22).

The first main fiber and fabric assembly application of this technology was performed in 1970s. Invention of Branson ultrasonic sewing machine was revolutionary in 1970s for the sewing of the fabrics without needle and yarn. Kuttruff investigated the mechanism of the ultrasonic welding in 1991. A similar research was repeated by Abramov in 1994. Material properties and material content of the ultrasonic sewing applications and ultrasonic sewing mechanism were investigated by Kuttruff in 1994. Finally, factors which effect the ultrasonic welding strength and placement of the optic fibers into the fabrics by using ultrasonic welding were investigated by Shi and Little in 2000 (21).

Besides, sewing processes of the nonwoven and woven fabrics by using ultrasonic sewing method have been studied in recent years. Erdogan compared the ultrasonic sewing and double pressure sewing of the nonwoven and woven fabrics (23). In another study it was reported that better bonding was achieved by using polypropylene-polypropylene and polyester-polyester fabrics. (21). Kayar, investigated the effect of the fiber type on the seam strength properties of the ultrasonic sewing (22). Mistik, compared the seam strength properties of the ultrasonic, lock and chain sewing methods (20).

Readymade garment industry uses the ultrasonic energy in different processes. Nowadays ultrasonic energy is an important process to sew, cut and form the woven, knitted, nonwoven fabrics and films according to the requirements of the industry and the final consumer. Ultrasonic sewing finds application in automotive industry, medical and hygienic

products, sports, work and protective wears, covering and packaging, underwear, filter and technical textiles (23).

Multi layered or double face structures (composites) can be used in industrial applications such as, protective clothes, filtration, automotive applications and clothing industry. Two or more functions are combined by producing multi layered structures. Thus, multi functions are joined in one structure.

In this study, polypropylene (PP), polyester (PES) and polyester/viscose (PES/CV) nonwoven fabrics were sewn together by using ultrasonic sewing machine. By sewing these 3 types fabrics together 2 layered structures were obtained. Then, film was placed between these nonwoven fabrics and ultrasonic sewing process before sewing process polyethylene was performed. Finally tenacity and elongation at break properties of the single nonwoven fabrics, 2 layered structures and 3 layered structures (PE film placed) were investigated.

The reason of the chosen of PES and PP fibers, they are widely used fibers in nonwoven industry and there are several studies on Polypropylene and Polyester nonwoven fabrics and ultrasonic sewing applications on Polypropylene and Polyester woven and nonwoven fabrics. (2, 22-27). And also these fibers have enough tenacity values for production of nonwoven fabrics. In addition, non-thermoplastic fibers decrease the ultrasonic seam tensile strength of the fabrics because thermoplastic fibers are used for ultrasonic sewing. In this study, PES/CV nonwoven fabric was chosen to investigate the effect of non-thermoplastic fibers on ultrasonic seam tensile strength. PE film has lower melting point than other fibers used. That's why PE film was chosen the combine the nonwoven fabrics.

2. MATERIAL AND METHOD

In the experimental process; 100% polypropylene (PP), 100% polyester (PES) and 60% polyester (PES) - 40% viscose (CV) nonwoven fabrics were used. 100% PP, 100% PES and 60% PES – 40% CV nonwoven fabrics have 3 different fabric area densities (45, 65 and 80 g/m²). Nonwoven fabrics were supplied from Telasis Co, Turkey. Also polyethylene (PE) film was used for the bonding of the nonwoven fabrics.

Three different fibers were used for the production of the nonwoven fabrics and Polyethylene film was used for the joining of the nonwoven fabrics. The properties of these fibers and Polyethylene film are shown in Table 1.

Table 1. Properties of the fibers and the polyethylene film

Fibers	Fibre count (dtex)	Density (g/cm ³)	Melting Point (°C)
Polyester (PES)	1.7	1.41	250-280
Viscose (CV)	1.6	1.52	-
Polypropylene (PP)	2.2	0.90	160-175
Polyethylene film	-	0.92	135

The properties of nonwoven fabrics and the polyethylene film are given in Table 2. Tenacity and elongation properties of the nonwoven fabrics and the polyethylene film were performed according to TS EN ISO 13934-1 standard. 10 specimens were tested for each sample (28).

Table 2. Properties of the nonwoven fabrics and the polyethylene film

Surface	Origin	Production method	Fabric area density (g/m ²)	Tenacity (Kgf)	Elongation at break (%)
Nonwoven	Polyester (PES) 100%	Thermal Bonding	45	6.4	35.5
			65	9.0	37.7
			80	13.6	18.8
Nonwoven	Polyester / Viscose (PES / CV) (60% - 40%)	Wet Bonding	45	5.8	13.8
			65	7.9	13.4
			80	8.8	12.3
Nonwoven	Polypropylene (PP) 100 %	Thermal Bonding	45	11.2	68.2
			65	11.2	49.9
			80	14.9	46.8
Film	Polyethylene 100%	Film Extrusion	8.2	0.55	164

According to the *Table 2*, PP nonwoven fabric has the highest tenacity; PES/CV nonwoven fabric has the lowest tenacity. Tenacity properties of the nonwoven fabrics increased with the increase in the fabric area density. Fiber counts are given in *Table 1*, as seen from the table fiber count of the PP fiber is higher than the other fibers. The reason of the high tenacity of PP fabric is higher fiber count and low density of the PP fiber and PP fiber has low density so fiber content of the PP nonwoven fabric in unit area is higher than other nonwoven fabrics. Same as the tenacity properties, highest elongation properties were obtained from PP nonwoven fabrics and PES/CV nonwoven fabric has the lowest elongation properties. Elongation properties of the PP and PES/CV nonwoven fabrics decreased with the increase in the fabric area density. Adversely, elongation properties of the PES nonwoven fabric increased by the increase in the fabric area density.

2 nonwoven fabrics were sewn together and 2 layered structures were obtained. Also 2 nonwoven fabrics and polyethylene film sewn together and 3 layered structures were obtained, polyethylene film was placed between 2 nonwoven fabrics (*Table 3*).

Table 3. Fabric placement of the 2 and 3 layered structures

2 layered structures	3 layered structures
PES + PES	PES + PE film + PES
PES / CV + PES / CV	PES / CV + PE film + PES / CV
PP + PP	PP + PE film + PP
PES + PP	
PP + PES / CV	
PES + PES / CV	

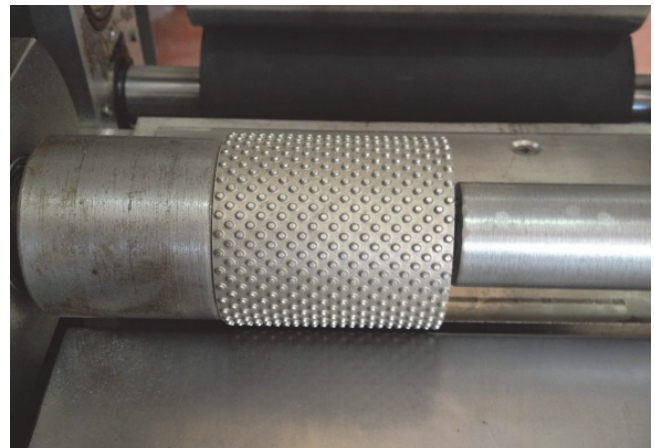
2.1. Ultrasonic sewing process

The nonwoven fabrics were sewn by using Sonimak ultrasonic sewing machine model of US-52. Mechanical vibration of the machine at the contacted surface is 25-30 microns. Machine vibrates 20.000 times in a second. Pressure of the roller is 2.2 kg/cm². Speed of the machine is 2 m/min (May reach to 35-40 m/min). Ultrasonic sewing process of a sample is shown in *Figure 1*.

Ultrasonic sewing process was performed by using a roller which is shown in *Figure 2*.

Connection surfaces of the roller are circular and diameter of the connection surface is 1.1 mm which was measured

on Projectina projection microscope. Sewing surface area was occupied by the roller used was measured as 0.19625 cm² / cm² (*Figure 3*).

**Figure 1.** Sonimak ultrasonic sewing machine**Figure 2.** Roller of the ultrasonic sewing machine

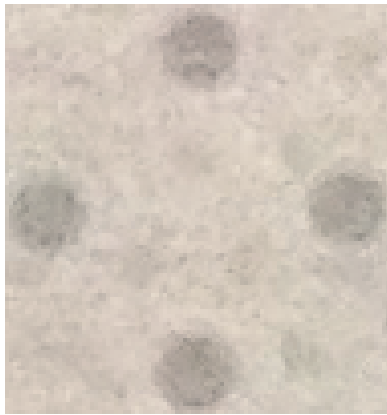


Figure 3. Connection surfaces of the nonwoven fabric after ultrasonic sewing process

When *Figure 3* investigated, sewing area was calculated as 0.35 cm² for 1 cm length. There were 16 points in that area, so 4 points (0.037994 cm²) were placed in 0.1936 cm² and 19.625% of these points were formed the sewing connection surface.

Ultrasonic sewing machine was adjusted to 20 kHz frequency during the ultrasonic sewing process.

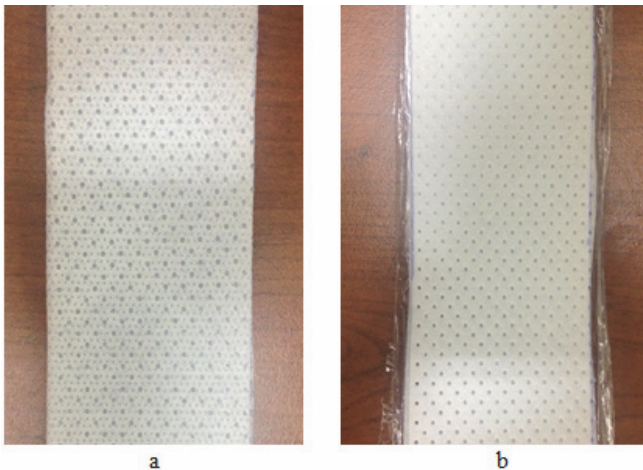


Figure 4. Photos of the sewn structures before tenacity test a) 2 layered structure b) 3 layered structure

2.2. Tenacity test

Seam strength test of the 2 and 3 layered structures were performed according to the TS EN ISO 13934-1 standard (24). Fabrics were cut to 300x50mm, then fabrics were

sewn by the ultrasonic sewing machine and 2 and 3 layered structures were produced. Test of the 2 and 3 layered structures were performed by using Instron 4411 testing instrument. Speed of the instrument was set to 100 mm/min. 10 samples were tested for each structures.

3. RESULTS AND DISCUSSIONS

Seam strength and elongation at break properties of the sewn 2 and 3 layered structures are given below. Seam strength and elongation at break properties of the polyester, polypropylene and Polyester / CV nonwoven fabric based 2 and 3 layered structures are given in Figure 5-10.

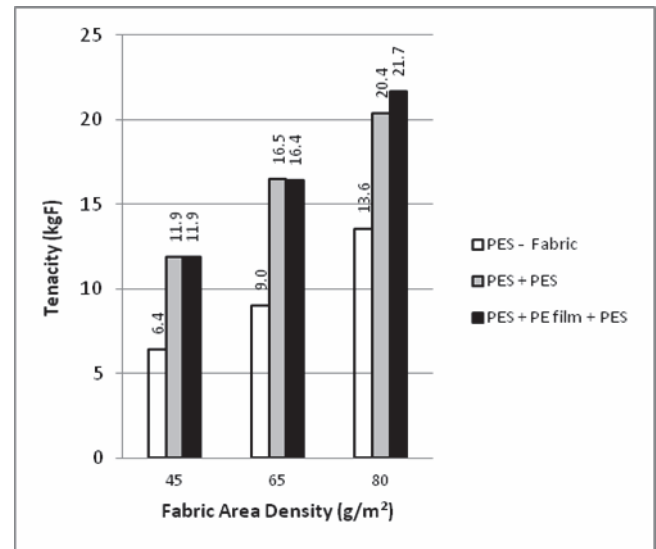


Figure 5. Tenacity properties of the polyester nonwoven fabric based 2 and 3 layered structures

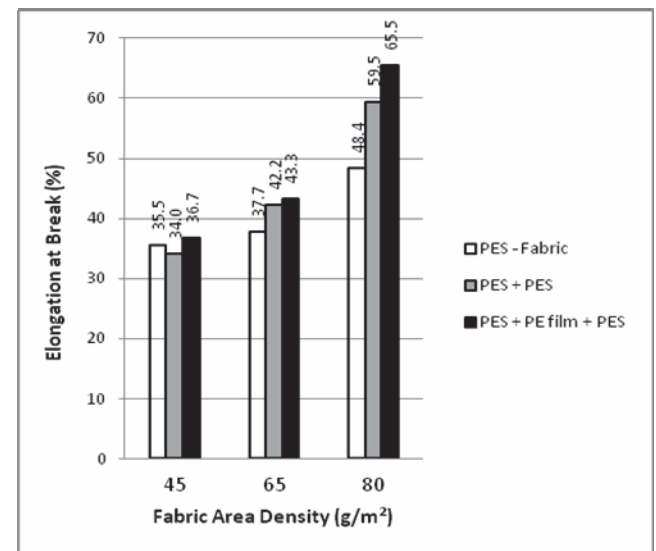


Figure 6. Elongation at break properties of the polyester nonwoven fabric based 2 and 3 layered structures

According to the *Figure 5* tenacity properties of the 2 and 3 layered structures are higher than single PES fabric due to increased fabric area density. Tenacity properties of the single, 2 and 3 layered PES fabrics were increased with the increase in the fabric area density.

Tenacity properties of the 2 and 3 layered structures were 1.75 times higher than the tenacity properties of the single PES fabric for each fabric area density.

The differences of the tenacity properties of the 2 and 3 layered structures were eligible. It can be said that PE film has not improved the tenacity properties of the PES based 3 layered structure.

According to the Figure 6 elongation at break properties of the single PES fabric, 2 and 3 layered structures were increased with the increase in the fabric area density. 80 g/m² 3 layered structure has the highest elongation at break properties.

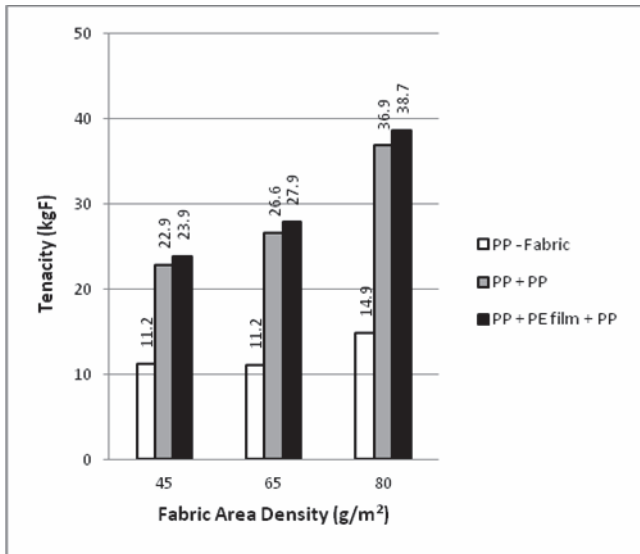


Figure 7. Tenacity properties of the polypropylene nonwoven fabric based 2 and 3 layered structures

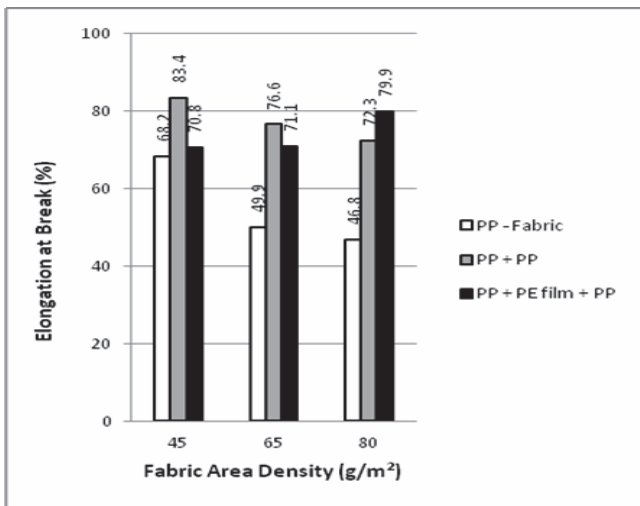


Figure 8. Elongation at break properties of the polypropylene nonwoven fabric based 2 and 3 layered structures

When Figure 7 investigated, tenacity of 2 and 3 layered PP structures has higher tenacity properties than the single PP fabric has due to their higher area densities. Tenacity properties of the single PP fabric, 2 and 3 layered PP structures were increased with the increase in the fabric area density. Highest tenacity properties were obtained from 80 g/m² fabric area density.

Tenacity properties of the 2 and 3 layered structures were 2.33 times higher than the tenacity properties of the single PES fabric for each fabric area density. The differences of the tenacity properties of the 2 and 3 layered structures were eligible. It can be said that PE film has not improved the tenacity properties of the PP based 3 layered structures.

When Figure 8 investigated, 2 and 3 layered PP based structures have higher elongation at break values than the single PP fabric. Elongation at break properties of the single PP fabric and 2 layered PP structure was decreased with the decreasing of the fabric area density, but adversely elongation at break properties of the 3 layered structures was increased with the increase in the fabric area density due to the elastic properties of the PE film.

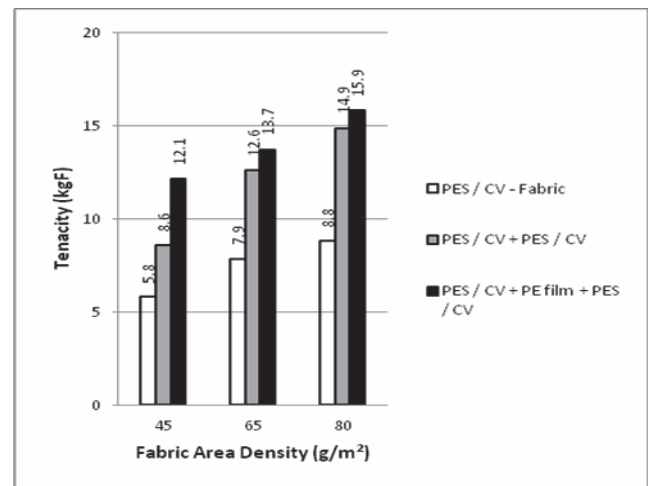


Figure 9. Tenacity properties of the polyester/viscose nonwoven fabric based 2 and 3 layered structures

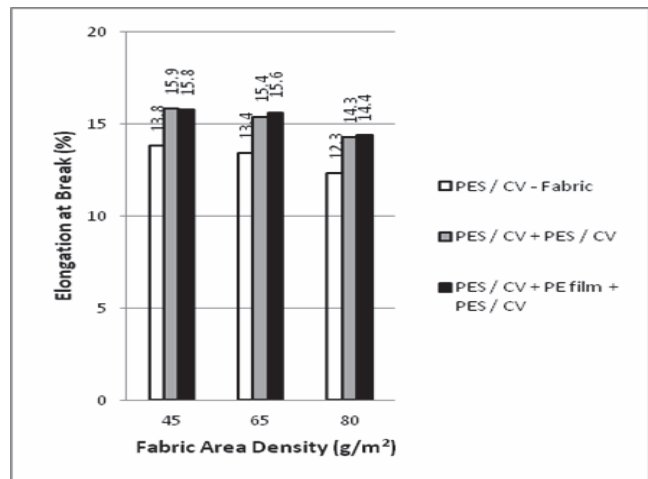


Figure 10. Elongation at break properties of the polyester /viscose nonwoven fabric based 2 and 3 structures

According to Figure 9 tenacity properties of the single PES/CV fabric, 2 and 3 layered PES/CV based structures were increased with the increase in the fabric area density. 2 and 3 layered PES/CV structures have higher tenacity properties than single PES/CV fabric. And 3 layered PES/CV structure has the highest tenacity properties. PE film has positive effect on the tenacity properties of the PES/CV structures.

Tenacity properties of the 2 and 3 layered structures were 1.82 times higher than the tenacity properties of the single PES fabric for each fabric area density.

According to Figure 10 elongation at break properties of the single PES/CV fabric, 2 and 3 layered PES/CV based structures were decreased with the increase in the fabric area density. Single PES/CV fabric has the lowest elongation at break properties. Single PES/CV fabric, 2 and 3 layered PES/CV based structures have highest elongation at break properties at 45 g/m².

Tenacity and elongation at break properties of the different 2 layered structures are given in figures 11 and 12.

According to the Figure 11, PP + PP structures have the highest tenacity properties. PP and PP combined structures have the highest tenacity values, PES/CV + PES/CV structures have the lowest tenacity properties. It can be said that PP fibers are more compatible to ultrasonic sewing process than PES fibers due to their thermal properties. CV fibers do not have any positive effect on ultrasonic sewing process due to its non-thermoplastic properties.

Tenacity properties of the PP + PES structures were higher than the PP + PES/CV and PES + PES/CV structures. It shows that ultrasonic sewing process is more effective on thermoplastic structures. And structures contain PP nonwoven fabric have higher tenacity properties due to low melting temperature of the PP fibers. Shi and Little reported that better ultrasonic bonding was achieved by using polypropylene-polypropylene and polyester-polyester fabrics (21).

According to Figure 12, PP + PP and PP + PES structures have the highest elongation at break properties. And PES/CV + PES/CV structures have the lowest elongation at break properties.

When tenacity and elongation at break values of 2 layered fabrics compared, it was seen that order of the tenacity and elongation at break values of the fabrics was almost the same. Although tenacity values of PP + PES / CV fabric was higher than PES + PES fabric, elongation at break values of PES + PES fabric was higher than PP + PES / CV fabric. It can be said that CV fiber has negative effect on the elongation at break properties of the nonwoven fabrics.

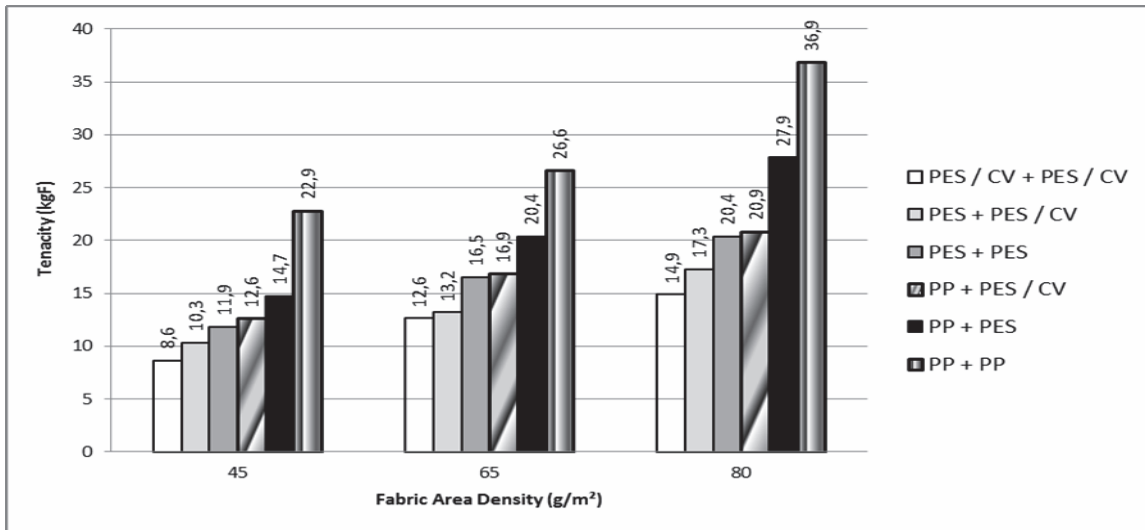


Figure 11. Tenacity properties of the different 2 layered structures

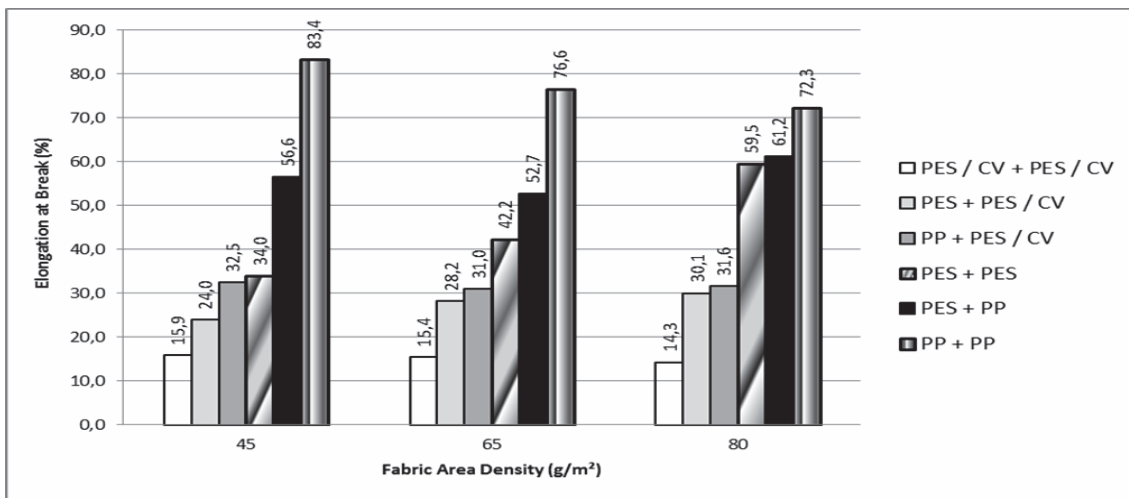


Figure 12. Elongation at break properties of the different 2 layered structures

4. CONCLUSION

This study was aimed to investigate the effects of the polypropylene, polyester and viscose fibers and polyethylene film on the mechanical properties of the ultrasonically bonded multi-layer nonwoven fabrics. For this purpose, the fabric samples were prepared by sewing with ultrasonic sewing machine and then they were evaluated in terms of tenacity and elongation at break properties.

PP + PP and PP blended structures have higher tenacity and elongation at break properties than PES + PES and PES blended structures. The reason of this property is compatibility of PP fiber to ultrasonic sewing process due to low melting point of PP fiber. Also adding PE film slightly increased the tenacity properties of the structures. This means that PE film increased the effect of the ultrasonic sewing process between PP, PES and PES/CV structures.

In addition, tenacity properties of the ultrasonically sewn 2 and 3 layered fabrics were increased with the increase in the fabric area density.

The advantage of this ultrasonic sewing process is that different thermoplastic or thermoplastic blended surfaces can be combined and two different properties can be obtained in one structure.

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