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The Effects of Elastane Yarn Type and Fabric Density on Sewing Needle Penetration Forces and Seam Damage of PET/Elastane Woven Fabrics

Abstract
This paper presents the effects of elastane yarn type and fabric density on the seam performance of PET/ elastane woven fabrics. In this study, 12 different weft stretched fabrics were woven with 2 different weft yarns, 2 different weave types and 3 different weft densities. The weft and warp yarns of the weft stretched fabrics were polyester- elastane covered yarn and polyester yarn, respectively. Air-covered and twisted elastane weft yarns were used at twill and plain fabrics. Needle penetration forces were determined on an L&M Sewability tester for seam performance. Besides this, "needle damage index" was calculated for seam damage. The values of the needle penetration forces were between 64 cN and 370 cN and the needle damage index values were between 18% and 73%. Elastane yarn type and fabric density had significant effects on the needle penetration force. Photographs were taken with an optical microscope to show the seam damage during sewing.

Key words: *air-covered elastane yarn, density, needle damage index, needle penetration force, twisted elastane yarn.*

Introduction

The seam performance and quality depends on various factors such as seam strength, slippage, puckering, appearance and yarn severance. Sewing needle penetration forces and fabric deformation during sewing are effective for seam performance, too.

The sewing needle penetration force is the quantitative measure of the damage which appears in a garment as the result of the sewing process [1 - 3]. A high penetration force means a high resistance of the fabric and thus a high risk of damage [4].

Seam damage can be a serious cost problem, often showing only after the garment has been worn [5].

The most important parameters that have an influence on seam damage tendency are fabric construction, chemical treatments of the fabric, needle thickness and sewing machine settings with sewing thread. Fibre content, yarn construction, tightness and density are important parameters for fabric construction on seam damage.

Damage caused to fabrics, particularly elastic , while being sewn during garment manufacture, has long been a concern to the clothing industry.

The use of different types of composite yarn containing elastane, which aim to meet consumer demands in the clothing industry, is continually growing. The most common methods of producing composite yarns containing elastane are air-covered and twisted methods.

Seam damage caused by the needle penetrating through the fabric can create severe sewability problems.

Needle cutting or yarn severance occurs due to the stiffness of the fabric yarn and its lack of the mobility . Instead of moving and deforming when the needle penetrates the fabric structure, the yarn is ruptured or burned [4, 6, 7].

A fabric can be termally damaged if the needle has a high warming- up value and the materials to be sewn melts. Seam damage is the result of high friction between the needle and the fabric. The damage places are generally dense spread. There are especially dense fabrics which are sensitive to sewing damage [8 - 10].

Generally, in the seam operation, finishing with silicone reduces the friction between the fabric and the needle. Consequently, the needle penetration force and damage to the fabric is also decreased [11]. The silicone finish reduces the friction between fabric yarns by increasing their mobility [12].

In this study, the effects of elastane yarn type and fabric density on the needle penetration forces and the damage index were investigated for PET / elastane woven fabrics.

Experimental

PET / elastane weft stretch fabrics were prepared with weft yarns of about 150/40 dtex PET / elastane air- covered and twisted yarns as well as a warp yarn of about 70 dtex air- covered polyester yarn with 85- 110 interming/m. The ratio of elastane was 3 - 4 % and elastane draw ratio was 3.2. Twill 2/1 and plain weave types were used. The fabrics weft densities were approximately 25, 29 and 32 weft/cm. Therefore 12 different fabric samples were obtained. Table 1 shows the properties of the fabrics used. And Table 2 shows the properties of the elastane yarns used.

The tests carried out during this study are listed below.

The sewing thread of 100 % PET was used at the upper and under thread at lockstitch with 5 stitches per cm. The ticket number of sewing thread was 80 and the number of the needle was 90/14 "SES". A 1- needle lockstitch sewing machine Juki DL-5550 was used with an average sewing speed of 3000 stitch/min. The test of "The needle- related damage due to sewing in woven fabrics" was made according to ASTM D 1908-89. Equation 1 was used to calculate needle damage index for each specimen [13].

$$ND\,\% = 100\,(Ny / Pn) \quad (1)$$

where:
ND% - needle damage index due to fusing, severance or deflection, %

Table 1. *The properties of fabrics used; *B - Plain, D - Twill, A - Weft density, P - Air-covered yarn, T - Twisted yarn, **PET, ***PET/Elastomer.*

Fabric code*	Weave	Density, thread/cm		Width, cm	Weight, g/m²	Yarn count, denier	
		Warp	Weft			Warp**	Weft***
BPA1PE	Plain	68	25	151	137	70/72	150/40
BPA2PE	Plain	66	28	151	132	70/72	150/40
BPA3PE	Plain	66	32	152	134	70/72	150/40
DPA1PE	Twill 2/1 S	74	26	136	133	70/72	150/40
DPA2PE	Twill 2/1 S	74	29	136	142	70/72	150/40
DPA3PE	Twill 2/1 S	74	32	136	146	70/72	150/40
BTA1PE	Plain	72	27	140	132	70/72	150/40
BTA2PE	Plain	72	30	140	135	70/72	150/40
BTA3PE	Plain	70	33	141	143	70/72	150/40
DTA1PE	Twill 2/1 S	73	26	134	132	70/72	150/40
DTA2PE	Twill 2/1 S	73	29	134	140	70/72	150/40
DTA3PE	Twill 2/1 S	73	33	134	148	70/72	150/40

Table 2. *The properties of elastane yarns used.*

Properties / Yarn Number	1	2
Product	Air- covered elastane yarn	Twisted elastane yarn
Yarn count, denier	150/72 + Elastane 40	150/40
Composition	PET + Elastane	PET + Elastane
Number of interming, interming/m	80 - 110	-
Twist, twists/m	-	**600 TPM-S**
Elongation, %	350 +/− 30	674
Elasticity, %	79 +/− 3	87
Final count, dtex	195 +/− 10	195 +/− 10
Draw ratio	3.2	3.2

Table 3. *Student- Newman- Keuls results.*

		Needle damage index ND, %	
		Warp	Weft
Weave type	Plain	56.60 a	34.96 a
	Twill	45.22 b	26.74 b
Elastane yarn type	Air-covered	47.04 b	38.16 a
	Twisted	54.77 a	23.55 b
Weft density, weft/cm	26	38.49 c	28.55 b
	29	52.52 b	27.98 b
	32	61.70 a	36.03 a

Ny - number of yarns damaged in direction evaluated
Pn - number of needle penetrations

The needle penetration force tests were performed with a L&M Sewability Tester (John Godrich). The needle penetration action in the L&M sewability tester was 100 r.p.m. and the test was normally run without sewing thread.

The L&M sewability test determined the force required for a 90's ball point needle to penetrate a fabric. 100 penetrations were made. A threshold value was determined based on the fabric mass area. In this study, the threshold value was 75 cN. The average force to penetrate the fabric was recorded.

Photographs were taken with an optical microscope. Optical microscope analysis was carried out using an automatic Trinocüler Stereo Zoom Microscope (Olympus SZ 6045 Model).

Costat was used for all statistical procedures. The results of needle damage index values were evaluated by analysis of variance (Anova) and performing Student Newman Keuls (SNK) tests. The analyses of variance were applied to the data to understand the statistical importance of parameters on the needle damage index. All test results were assesed at significant levels of $\propto \leq 0.05$.

Results and discussion

All tests results were evaluated separately as given below. The results of the Student Newman Keuls (SNK) are given in Table 3.

Needle penetration forces results

Figures 1 and 2 show the variation of needle penetration force in the warp and weft directions of the fabric according to the weft density. The figures show that there were significant effects of weft density on the warp and weft needle penetration force. As can be seen from figures, while weft density was increased, needle penetration forces were increased, too.

As can be seen from Figures 1 and 2, plain fabrics have a higher warp and weft needle penetration force than twill fabrics, because they have a denser structure than twill. The fabrics which used air- covered elastane yarns had a higher warp and weft needle penetration force than those fabrics which used twisted elastane yarn. This can be explained in the voluminous structure of the air- covered elastane yarn. This yarn hasn't got any twist so that it has a more complicated structure because of the intermings on the yarn. Air- covered elastane yarns, on the other hand, will have more overall surface area than twisted elastane yarns leading to a higher yarn-to-needle surface contact area and therefore to a higher yarn-to-needle frictional force.

Needle penetration forces are higher in the warp direction than in the weft because of the high warp density.

The needle penetration force values in the fabrics with 26 weft/cm were between 75 cN and 138 cN, and those with 32 weft/cm were between 218 cN and 370 cN.

Needle damage index results

The SNK results in Table 2 shows there are significant effects of weave types, elastane yarn types and weft densities on needle damage index values. Figures 3 and 4 show the variation of the needle damage index in the weft and warp direction of the fabric according to the weft density, respectively. As can be seen from the figures, while weft density was increased, the needle damage index was

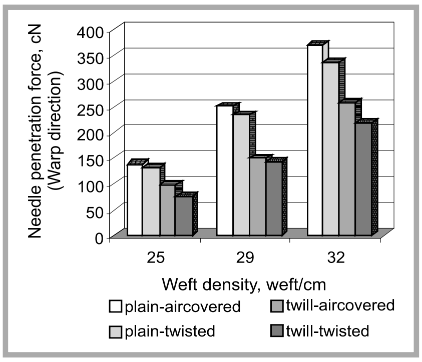

Figure 1. The variation of needle penetration forces in the warp direction, according to the weft density.

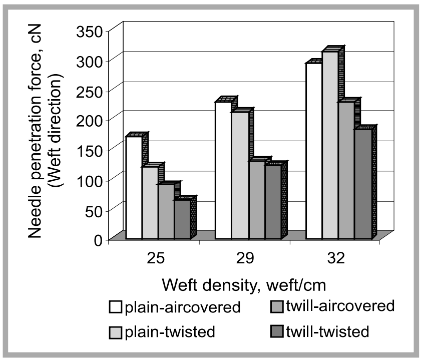

***Figure 2.** The variation of needle penetration forces in the weft direction, according to the weft density.*

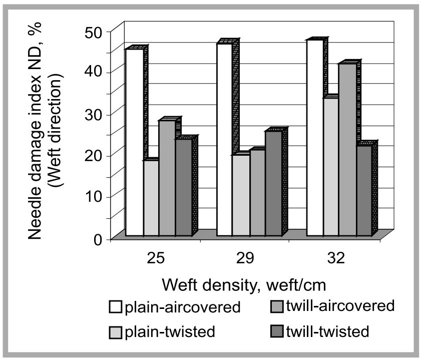

***Figure 3.** The variation of needle damage index in the weft direction, according to weft density.*

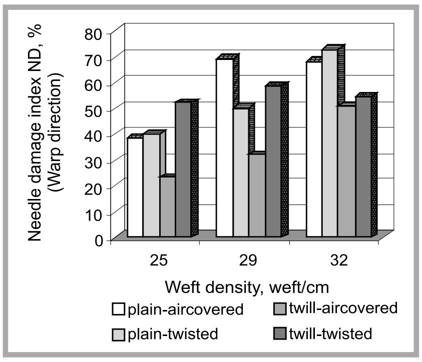

***Figure 4.** The variation of needle damage index in the warp direction, according to weft density.*

increased, too. In addition, weave types and elastane yarn types had significant effects on the needle damage index.

Plain fabrics have higher warp and weft needle damage index values than twill fabrics, because of their dense structure. Twill fabric is more flexible than plain because of its elastic structure. The needle damage index values in the warp direction in plain fabrics were within the range of 39% to 73% and in twill fabrics were within the range of 23% and 59%. For every 100 needle perforation between 39-73 yarns were damaged in plain fabrics and 23-59 yarns were damaged in twill fabrics.

The fabrics which used air-covered elastane weft yarn had a higher weft needle damage index value than the fabrics which used twisted elastane weft yarn, because of the voluminous structure of air- covered elastane weft yarn. Twisted elastane weft yarns made the fabric denser than the air-covered elastane weft yarn. As a result, the fabrics which used twisted elastane weft yarn had a higher warp needle damage index value than the fabrics which used air- covered elastane yarn.

Although it is possible to influence the stretch effect, which is the main reason for the use of complex yarns, their processing properties and their durability are also of importance, and last but least, there are aesthetic aspects. Such yarns are limited in their stretchability due to the covering yarn, and thus have higher retractive forces.

An optical microscope study of fabrics showed that the damage was mainly concentrated at the penetration point of the needle in the stitch. Figures 5 and 6 show an appearance of the lockstitch on our fabric samples.

Figure 7 shows the penetration point of the needle on the plain fabric and Figure 8 shows the penetration point of the needle on the twill fabric. Yarn in contact with the needle at the penetration point was also broken or damaged, as can be seen in Figures 7 and 8.

When warp and weft densities are high, more yarns are either broken or seperated by the sewing needle. When the needle penetration force increases, the needle damage index also increases.

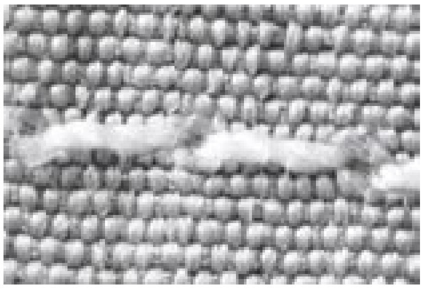

***Figure 5.** Appearance of the lockstitch on fabric BPA3PE.*

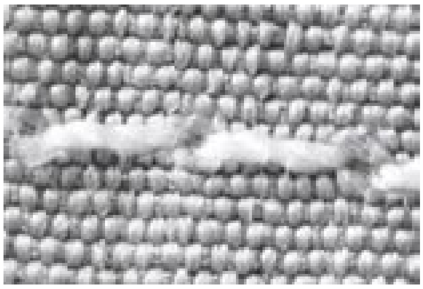

***Figure 6.** Appearance of the lockstitch on fabric BTA1PE.*

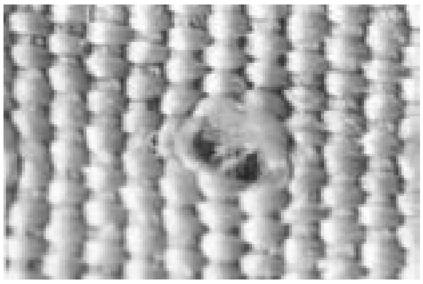

***Figure 7.** Appearance of the needle perforation in the warp direction of fabric BTA3PE.*

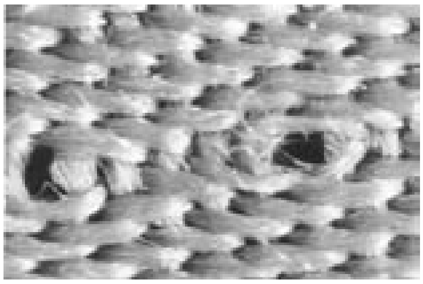

***Figure 8.** Appearance of the needle perforation in the warp direction of fabric DTA1PE.*

Conclusions

Sewing needle penetration force and needle- related damage due to sewing in PET / Elastane woven fabric are affected by the weave type, elastane yarn type and fabric density.

When needle penetrates an elastic fabric, there are two basic causes of elastane damage. The needle penetration damages the elastane yarn or pulls it out of the fabric. The decisive factor when processing elastic fabrics is the correct setting of fabric construction.

It was found that, to prevent potential damage while sewing elastic fabrics, air-covered elastane yarns should be used, and also low density should be preferred. In addition to this, other parameters such as raw material composition, yarn evenness in the warp, weft type of weave and additional finishing of fabric affect the deformation of warp and weft threads. Sewing needle size, thread count and seam length play an important role in product deformation, too.

When the needle penetrates the thread, thread damage comes about. It is necessary, for this reason, to determine the corresponding size of light ball-point needles "SES". Using these needles will decrease thread deformation because the needle will penetrate by gliding more through the spaces formed by the weft and warp yarns and less through the thread itself.

The ease by which a sewing needle can penetrate a fabric is determined by the frictional characteritics of the fabric. In fabrics with low frictional characteristics, the fibres and yarns in the fabric can move easily to allow passage of the needle and hence the penetration force is low and no damage occurs. In fabrics which have high frictional characteristics the fabric components can not move easily and so the force for penetration by the needle is high. This value may exceed the breaking strength of the yarn and so damage occurs, or alternatively the high frictional forces encountered by the needle will cause a generation of heat which in high speed sewing will cause fusing of the fabric. A silicone finish reduces the friction between fabric yarns by increasing their mobility.

Elasticity and sewing stability are characteristics which set special requirements on technological properties especially with relation to high tensile strength, stretching and friction strength as well as on easy care as there are few possible defects.

Seam damage is the result of high friction between the needle and the fabric. Damaged places are generally dense spread. There are especially dense fabrics sensitive to seam damage. Yarns in contact with the needle at the penetration point were also broken or damaged.

Air- covered elastane yarn has a voluminous and less dense structure than twisted elastane yarn. Elastane yarn types effected the needle penetration force and needle damage index.

Stretching and form retention are influenced by the contraction forces of the elastic material, overall stretching ratio and friction relations in the fabric. The contraction forces result from the type or combination of elastane material in the respective thread system.

The friction relations in the elastic fabric are influenced by the type of yarn, weaving settings, interlacing, finishing and many other factors.

The needle damage index values in the warp direction at the fabrics with air-covered elastane yarns were between 23% and 69% and in the fabrics with twisted elastane yarns were between 40% and 73%.

Weave type and fabric density effected the needle penetration force and needle damage index, too. While the weft density increased at both twill and plain fabrics, the needle penetration forces and the needle damage index values increased, too. The needle penetration force values in the warp direction in plain fabrics were within the 132 cN to 370 cN and in twill fabrics were within the range of 75 cN to 260 cN.

The suitable needle size mainly depends on the density and sensitivity of the fabric. Needle sizes between 70 Nm and 90 Nm should be used to avoid elastane damage.

Even a slightest damage to the needle point harms the fabric when it is penetrated by the needle. As a preventative measure, the needle should be replaced frequently. The sewing conditions (nature of the material, sewing machine speed, etc.) determine how often the needle should be replaced.

If damage to the elastane continues, even following implentation of the above recommendations, it may help to try a slower sewing speed.

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References

1. Carr H., Latham B.; " The Technology of Clothing Manufacture", BSP Professional Books, 1988, pp. 113, ISBN 0-632-02193-4.
2. Gotlih K.; "Sewing Needle Penetration Force Study", International Journal of Clothing Science and Technology, 1997, Vol. 9 , No.3, pp. 241-248.
3. Gotlih K., Lojen D.; "The Relation Between The Viscoelastic Properties of the Thread and Sewing Needle Penetration Force", 78th World Conference of The Textile Institute in Association with 5th Textile Symposium of Seve and Sepve, Greece, 1997, pp. 133-147.
4. Meinander H., Jylha A., Kelloniemi E.; "Textile Objective Measurement and Automation in Garment Manufacture" , Ellis Horwood Lmt.England, 1991, pp. 151.
5. Hunter L., Cawood M.P.; "The Correlation Between Two Different Sewability Tests and the Effect of Certain Wool Fibre and Fabric Properties on the Sewability of woven Fabrics", Sawtri Technical Report, 1982, No: 510.
6. Mehta V. H.; "An Introduction of Quality Control for the Apparel Industry", ASQC Milwaukee Wisconsin, 1992, pp. 87.
7. Mukhopadhyay A, Sikka M, Karmakar A. K.; "Impact of Laundering on the Seam Tensile Properties of Suiting Fabric", International Journal of Clothing Science and Technology, 2004, Vol. 16, No. 4, pp. 394-403.
8. Gersak J.; "Study of Relationship Between Fabric Elastic Potential and Garment Appearance Quality", International Journal of Clothing Science and Technology, 2004, Vol. 16, pp. 238-251.
9. Lomov S.; " A Predictive Model for Penetration Force of a Woven Fabric by a Needle" ,International Journal of Clothing Science and Technology,1998, Vol. 10, pp. 91-103.
10. Ujevic D., Kovacevic S., Hadina J., Karabegovic I.; "Influence of Seam on Deformation of Yarn in Woven and Knitted Fabrics", International Textile, Clothing and Design Conference, Dubrovnik, Croatia, 2002, pp. 419-424.
11. Gurarda A., Meric B.; " Sewing Needle Penetration Forces and Elastane Fibre Damage during the Sewing of Cotton/ Elastane Woven Fabrics", Textile Research Journal, 2005, Vol. 75, No. 8, pp. 628-633.
12. Gurarda A., Meric B.; "The Effect of Silicone and Pre-Fixation Temperature on the Elastic Properties of Cotton/Elastane Woven Fabrics", AATCC Review, 2005, Vol. 5, No. 9, pp. 53-56.
13. American Society for Testing and Materials, Annual Book of ASTM Standards, Textiles and Yarns, Fabrics and General test Methods, Standard Specification for Tensile Testing For Textiles, "The Needle-Related Damage Due to Sewing in woven Fabrics", ASTM Designation: D 1908-89, ASTM, Easton, PA,1990.

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