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The Effect of Softeners on Needle Penetration Forces of Fabrics

Gamze Gülşen Bakıcı[1] 0000-0002-4241-7096
Deniz Mutlu Ala[1] 0000-0002-5864-308X
Zeynep Nihan Kır[2] 0000-0002-6072-8787

[1]Çukurova University, Adana Vocational School of Organized Industrial Site, Department of Textile-Clothing-Shoes and Leather, Adana, Turkiye
[2] Eksoy Chemical Industry, R&D Department, Adana, Turkiye

Corresponding Author: Gamze Gülşen Bakıcı, gamzegulsenbakici@gmail.com

ABSTRACT

This study aims to investigate the effects of various softeners (polyether-modified silicone, amino-modified silicone, and fatty acid ester) on denim fabric, with a particular focus on their needle penetration forces (NPFs). The softening finish was applied according to the impregnation method, followed by the assessment of NPF using the L&M sewability tester. Fabrics subjected to softener treatments typically exhibit reduced NPF values compared to the reference fabric. Denim fabrics treated with polyether-modified silicone exhibited statistically significant differences in NPF values in both the weft and warp directions compared to the reference fabric. The lowest needle penetration force (NPF) values were observed in the warp direction of fabrics treated with polyether-modified silicone. The highest NPF values in both the weft and warp directions were observed in fabrics treated with fatty acid ester softeners.

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1. INTRODUCTION

Finishing encompasses the final stages of the textile processing sequence, aiming to enhance visual appeal, tactile experience, or other aesthetic qualities of textiles, as well as to introduce additional functionalities such as water repellency or flame retardancy. Softening is recognized as a widely used chemical textile finishing method. Virtually all types of clothing and home furnishings textiles are finished with softeners. A softener is described as an additive that, when applied to textile materials, enhances their texture, making them more pleasant to the touch [1]. Textile softeners can be grouped based on their ionic properties into anionic, cationic, amphoteric, and nonionic softeners containing silicones [2]. Silicone softeners can be categorized into three groups: Reactive Silicone Polymers, Non-Reactive Silicone Polymers, and Organo-Functional Silicone Polymers [3]. This study utilized amino-modified silicone compounds and polyether-modified silicone compounds, both of which belong to the organo-functional silicone polymers group. Additionally, a fatty acid ester softener was used to assess and compare sewability properties. Fabric softeners are frequently used to enhance the handle quality of textiles, contributing to properties such as anti-static behavior, water repellency and sewability. The quality of garment seams depends on several factors, including seam strength, seam slippage, seam puckering, seam appearance, seam efficiency, and NPF. The process of softening textile fabrics typically involves reducing the coefficient of friction between the fibers, filaments, and yarn [1]. A low coefficient of friction positively affects the sewability of the fabric. Softeners provide lubrication to the fibers, reduce the coefficient of friction, enhance fabric smoothness, and may potentially decrease the glass transition temperature of the polymer. The lubricating properties of the softeners enhance the sewability of the fabric by minimizing friction between the sewing needle and the yarn in the fabric. Sewability is commonly defined as the ability with which fabric components can be effectively seamed without causing damage. One of the parameters used to assess the sewability of the fabric is the NPF. A high NPF indicates

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increased fabric resistance, making the fabric more prone to damage. Therefore, NPF plays a crucial role in predicting potential damage during the sewing process [4]. Fabric construction, fiber type, yarn count, yarn density, fabric weight, loop length, finishing processes applied to the fabrics, sewing needle, and machine parameters all play a role in the sewability of fabrics and NPF values [5-8]. Different methods, such as seam strength, seam slippage, and seam pucker, are used to determine the sewing quality of fabrics [9-17]. Measuring the NPF values of fabrics with the L&M sewability tester is another method used to determine the sewing quality of fabrics. Recent studies on NPF can be summarized as follows: Ala & Gülşen Bakıcı (2019) investigated the sewability (based on NPF) of 1 × 1 rib knitted fabrics, which were produced with separate yarn ends. It was found that the number of separate ends and the stitch density have an influence on the NPF values of 1 × 1 rib knitted fabrics [4]. Boz et al. (2022) determined the sewing direction, needle point form, needle number, and sewing speed as variables and performed the sewability test using the L&M Sewability test device. According to the acquired data, the needle number emerged as the primary factor responsible for needle damage during sewing [18]. Atta et al. (2021) developed a new feature to be added to state-of-the-art sewing machines by studying the effect of NPF on the motor current. They revealed a correlation of 0.91 between the L&M test results and the results obtained with the proposed technique [19]. Gülşen Bakıcı (2019) introduced varying quantities of sewing facilitator chemicals into the dye bath of 100% polyester fabric to examine its sewability characteristics. Consequently, an increase in the chemical concentration in the dye bath led to a decrease in NPF values in both the weft and warp directions, resulting in an improvement in the fabric's sewability [20]. The aim of this study is to investigate the effect of different types of softeners on NPF values of denim fabric.

2. MATERIAL AND METHOD

2.1 Material

The sewability properties of 100% cotton denim fabrics were measured using different softeners. The properties of the fabric used in the study are given in Table 1.

Polyether-modified silicone, amino-modified silicone, and fatty acid ester softeners, each characterized by distinct chemical compositions and sourced from Eksoy Chemical Industry, were employed in the softening finishing treatments of the fabrics (Table 2). The concentrations of these softeners were meticulously adjusted to achieve homogeneity, taking into account the quantities of solid constituents present. Auxiliary chemicals were sourced from Merck Chemical Industry. Particle sizes and zeta potentials were measured using the Malvern ZetaSizer Nano ZS instrument.

Table 1. The properties of the fabrics

Fabric	Weaving type	Weight (g/m^2)	Linear density		Yarn density (yarns/per cm)	
			Weft	Warp	Weft	Warp
Denim (100% cotton)	2/1 Z twill	340	Ne 20/2	Ne 30/2	10	12

Table 2. Properties of softeners

Softener Code	Softener Type	View	pH	Concentrate (g/L)	Solid Content	Particle Size
P1	Polyether-modified silicon	Yellow liq.	7.3	5	65	103.5
P2	Polyether-modified silicon	Yellow liq.	6.5	5	65	105.2
P3	Polyether-modified silicon	Viscous liq.	5.6	5	65	168.3
P4	Polyether-modified silicon	Colorless liq.	6.2	20	16	34.1
P5	Polyether-modified silicon	Colorless liq.	6.6	20	16	172.5
P6	Polyether-modified silicon	Yellow liq.	7.5	25	14	51.5
P7	Polyether-modified silicon	Viscous liq.	8.4	25	14	23.9
A8	Amino-modified silicon	Colorless liq.	6.5	50	7	24.81
A9	Amino-modified silicon	White liq.	7.9	50	7	67.1
A10	Amino-modified silicon	White liq.	6.7	50	7	2530
A11	Amino-modified silicon	White liq.	5.7	50	7	487.0
A12	Amino-modified silicon	Colorless liq.	6.4	30	12	74.2
F13	Fatty acid ester	White liq.	5.2	50	28	190.0
F14	Fatty acid ester	Cream liq.	7.9	50	28	75.0
F15	Fatty acid ester	Cream liq.	3.2	50	28	128.0

2.2 Method

The pH of the softener solutions was adjusted to 5.5. The softener finishing process was applied to the fabrics employing the impregnation method. This process involved a 1-dip 1-nip cycle within a softener bath, performed using a padding machine to achieve an approximate 85% wet pick-up. The denim fabrics were dried at a temperature of

130°C in the Forlab drying machine. After conditioning of the denim samples under standard atmospheric conditions (20±2°C and 65±4% RH), Needle Penetration Force (NPF) values were determined using the L&M sewability tester (Figure 1).

Each of the five samples, measuring 35 mm × 350 mm, were prepared in both the weft and warp directions. Two tests were performed on each sample. Needle Penetration Force (NPF) represents the average force exerted during 100 needle penetrations in a sewability test. Two tests were conducted on each of the 5 weft and 5 warp samples prepared for each fabric, resulting in a total of 10 tests in both the weft and warp directions. Given that each test represents the average of 100 needle penetrations, the Needle Penetration Force (NPF) values in both the weft and warp directions for each fabric were derived from the mean value of 1000 needle penetrations. Using a Nm90/14 sewing needle (SES), the apparatus allowed the needle to penetrate the fabric at a rate of 100 penetrations per minute along the long edge of the sample. The force values resulting from the needle penetrating the sample were measured in gram-force (gf).

Figure 1. L&M sewability tester

3. DISCUSSION

The measured Needle Penetration Force (NPF) values of the reference fabric, without any softener, and the fabrics treated with fifteen different softeners are presented in Figure 2. Typically, fabrics treated with softeners exhibited reduced NPF values compared to the reference fabric. Among the fabrics treated with polyether-modified silicone, P1, P2, and P7 showed decreased Needle Penetration Force (NPF) values in both the weft and warp directions. Due to their chemical structure, polyether-modified silicones impart hydrophilic properties to the fabric and penetrate its inner regions, thereby providing internal softness. Their inherent capacity for internal softening is particularly influential. Consequently, lower Needle Penetration Force (NPF) values have been observed in fabrics treated with polyether-modified silicones. Among fabrics treated with amino-modified silicone, A8 and A9 exhibited the highest Needle Penetration Force (NPF) values in both the weft and warp directions. Unlike polyether-modified silicons, amino-modified silicones do not provide inner softness to the fabric; instead, they form a surface coating on the fabric. This coating imparts surface smoothness and slipperiness. The effectiveness of amino-modified silicones in producing a slippery texture depends on the particle size, with larger particle sizes providing better surface coverage and a smoother tactile sensation. In contrast, smaller particle sizes result in reduced surface slipperiness. For this reason, the NPF values of the fabrics treated with A8 and A9 softeners, which have smaller particle sizes, were higher than those of the other treatments. Analysis of the Needle Penetration Force (NPF) values of fabrics treated with fatty acid esters revealed that the F15 softener exhibited the lowest value. However, upon examining the fabrics treated with fatty acid esters, no definitive coclusion be drawn regarding the relationship between NPF values and particle size.

The Needle Penetration Force (NPF) values of denim fabric demonstrate a normal distribution in both the weft and warp directions. Homogeneity of variances was assessed using the Levene test, and the results are presented in Table 3. The p-values for NPFwarp and NPFweft were calculated as 0.010 and 0.007, respectively, indicating non-uniform variances. Since the variances are unequal, the Welch test was conducted to determine whether there are differences between the groups (Table 4). As shown in Table 4, a statistically significant difference was observed in the mean Needle Penetration Force (NPF) values of fabrics treated with softeners in both the warp and weft directions (p-value=0.000 <0.05). Consequently, it can be concluded that there are differences in the avarage NPF values among the fabric groups in both the weft and warp directions.

Table 3. Homogeneity of variances test results

Dependent variable	Levene Statistic	df1	df2	p-value
NPFwarp	3.873	3	156	.010
NPFweft	4.221	3	156	.007

Table 4. Welch Test

Dependent variable	Statistic	df1	df2	P-value	Level of significance
NPFwarp	68.944	3	37.414	.000	significant
NPFweft	10.305	3	36.639	.000	significant

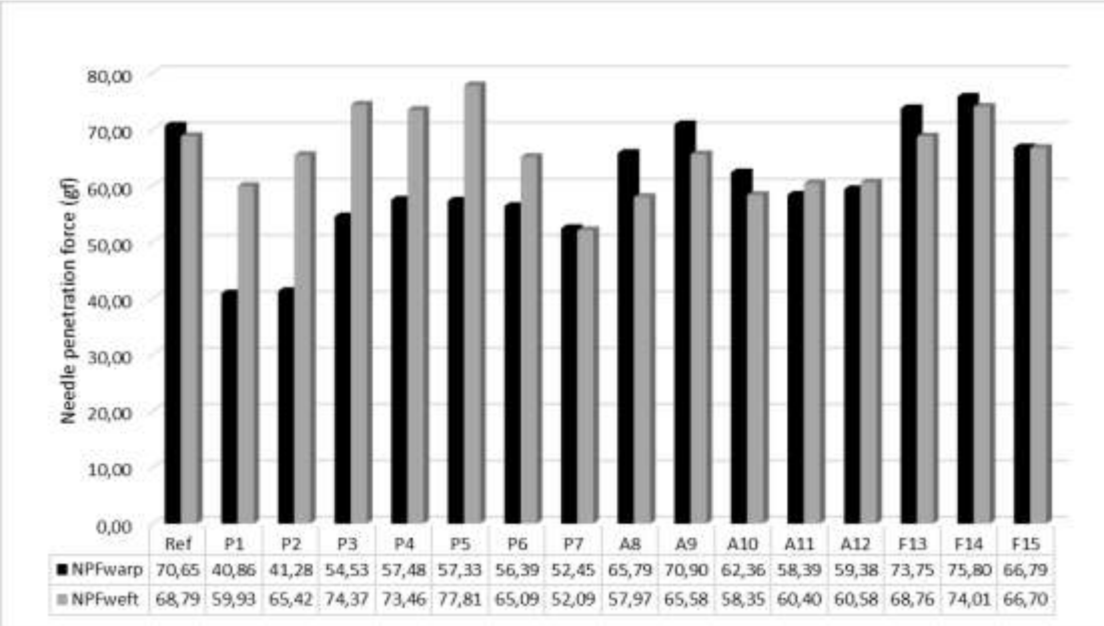

Figure 2. NPF means of denim fabrics finished with softeners

Subsequently, Tamhane's post hoc test was performed to assess group differences, and the results are presented in Table 5. When evaluating the NPF values in the warp direction as the dependent variable, it was observed that the mean NPF values differed significantly between the reference fabric and the fabric treated with polyether-modified silicone. However, no statistically significant difference was observed in the average NPF values between the reference fabric and fabrics treated with amino-modified silicone or fatty acid ester. Thus, the reference fabric, along with fabrics treated with amino-modified silicone and fatty acid ester softeners, were statistically grouped together, whereas the fabric treated with polyether-modified silicone was classified separately.

When the NPF values in the weft direction were evaluated as the dependent variable, no statistical differences were observed between the reference fabric and those treated with other softeners. However, the avarage NPF values in the weft direction for fabrics treated with amino-modified silicone were found to differ from those of fabrics treated with polyether-modified silicone and fatty acid-treated fabrics.

3.4 Correlations

The relationship between NPF values in the weft and warp directions, particle size and zeta potential was examined using Spearman Correlation Analysis. The results are given in the Table 6. The correlation between particle size and NPF values in both the warp and weft directions is not considered significant. In the warp direction, the relationship between NPF values and zeta potential is found to be significant, indicating a strong negative correlation (correlation coefficient = -0.903). Conversely, in the weft direction, the relationship between NPF values and zeta potential is not considered significant.

Table 5. Multiple comparison results

Dependent Variable: NPFwarp					Dependent Variable: NPFweft				
(I) softener type	(J) softener type	Mean Difference (I-J)	Std. Error	Sig.	(I) softener type	(J) softener type	Mean Difference (I-J)	Std. Error	Sig.
REF	Polyether-modified silicon	19.17786*	3.288	0.001	REF	Polyether-modified silicon	1.914	3.944	0.998
	Amino-modified silicon	7.288	3.356	0.267		Amino-modified silicon	8.216	3.953	0.320
	Fatty acid ester	-1.476	3.253	0.998		Fatty acid ester	-1.029	3.962	1.000
Polyether-modified silicon	REF	-19.17786*	3.288	0.001	Polyether-modified silicon	REF	-1.914	3.944	0.998
	Amino-modified silicon	-11.89006*	1.652	0.000		Amino-modified silicon	6.30209*	1.650	0.001
	Fatty acid ester	-20.65352*	1.431	0.000		Fatty acid ester	-2.942	1.672	0.403
Amino-modified silicon	REF	-7.288	3.356	0.267	Amino-modified silicon	REF	-8.216	3.953	0.320
	Polyether-modified silicon	11.89006*	1.652	0.000		Polyether-modified silicon	-6.30209*	1.650	0.001
	Fatty acid ester	-8.76347*	1.582	0.000		Fatty acid ester	-9.24447*	1.693	0.000
Fatty acid ester	REF	1.476	3.253	0.998	Fatty acid ester	REF	1.029	3.962	1.000
	Polyether-modified silicon	20.65352*	1.431	0.000		Polyether-modified silicon	2.942	1.672	0.403
	Amino-modified silicon	8.76347*	1.582	0.000		Amino-modified silicon	9.24447*	1.693	0.000

Table 6. Spearman Correlation Analysis

Variables		**NPFwarp**	**NPFweft**
Particul size	Correlation Coefficient	.152	.182
	Sig. (2-tailed)	.605	.533
Zeta potential	Correlation Coefficient	-.903**	-.516
	Sig. (2-tailed)	.000	.059

4. CONCLUSION

This study investigated the effects of polyether-modified silicone, amino-modified silicone, and fatty acid ester softeners on the sewability properties of denim fabrics. The softening-finishing procedures were applied via the impregnation method. Following this treatment, Needle Penetration Force (NPF) values were measured using the L&M sewability tester, thereby providing data regarding the sewability attributes of the fabrics.

Fabric construction, comprising variables such as fiber type, yarn count, yarn density, fabric weight, and loop length, in conjunction with the diverse finishing processes applied to the fabrics, the type of sewing needle utilized, and machine parameters collectively exert an influence on the sewability and Needle Penetration Force (NPF) values of fabrics [5-8, 21]. In the L&M sewability test procedure, the sewing needle penetrates the fabric from bottom to top. When encountering minimal resistance and smoothly passing through the threads during insertion, it results in a decrease in NPF values. The softeners employed in this study contributed to enhancing the fabric's softness, thereby facilitating the passage of the needle through the threads and subsequently reducing the NPF values.

Fabrics finished with a softener generally showed lower NPF values compared to the reference fabric. The lowest NPF values were obtained in the warp direction of fabrics treated with polyether-modified silicone. NPF values of fabrics treated with softeners having smaller particle sizes were found to be higher than those of fabrics treated with amino-modified silicone. The highest NPF values in both the weft and warp directions were observed in fabrics treated with fatty acid ester softeners. In the warp direction, a significant relationship was observed between Needle Penetration Force (NPF) values and zeta potential, indicating a strong negative correlation. Conversely, in the weft direction, the correlation between NPF values and zeta potential is insignificant. Subsequent research studies aim to estimate needle penetration force values by maintaining uniform fabric properties while varying parameters in the softening process.

REFERENCES

1. Bajaj P. 2002. Finishing of textile materials. *Journal of Applied Polymer Science* 83(3), 631-659.
2. Fahmy HM, Okda HMY, Hassabo AG, El-Rafie MH, Youssef MA. 2021. Synthesis of new silicone-based adducts to functionalize cotton fabric. *Silicon* 14, 7613–7621.
3. Mohamed AL, Hassabo AG. 2019. Review of silicon-based materials for cellulosic fabrics with functional applications. *Journal of Textiles Coloration and Polymer Science* 16(2), 139-157.
4. Ala DM, Gülşen Bakıcı G. 2019. Sewability (based on NPF) of 1× 1 rib knitted fabrics produced with separate ends of yarns. *Autex Research Journal* 19(4), 340-346.
5. Bansal P, Sikka M, Choudhary AK. 2021. Effect of yarn count and loop length on NPF and needle cut index in single jersey fabrics. *Indian Journal of Fibre & Textile Research* 45(4), 388-394.
6. Carvalho M, Rocha AM, Carvalho H. 2020. Comparative study of NPFs in sewing hems on toweling terry fabrics: Influence of needle type and size. *Autex Research Journal* 20(2), 194-202.
7. Choudhary AK, Sikka MP, Bansal P. 2018. The study of sewing damage and defects in garments. *Research Journal of Textile and Apparel* 22(2), 109-125.
8. Mansouri S, Chaabouni Y, Cheikhrouhou M. 2022. Influence of finishing products on mechanical seam's behavior of natural fabrics. *Journal of Natural Fibers* 19(15), 11404-11412.
9. Gürarda A, Meriç B. 2010. Slippage and grinning behaviour of lockstitch seams in elastic fabrics under cyclic loading conditions. *Tekstil ve Konfeksiyon* 20(1), 65-69.
10. Ateş M, Gürarda A, Çeven EK. 2019. Investigation of seam performance of chain stitch and lockstitch used in denim trousers. *Tekstil ve Mühendis* 26(115), 263-270.
11. Faizur RM, Alam MA, Hossain KR, Baral LM, Sarkar MH, Sarkar P, Rashid MR. 2023. Impact of modified feed mechanism on seam quality of garments. *Annals of the University of Oradea. Fascicle of Textiles, Leatherwork* 24(1), 89-96.
12. Sülar V, Meşegül C, Kefsiz H, Seki Y. 2015. A comparative study on seam performance of cotton and polyester woven fabrics. *The Journal of the Textile Institute* 106(1), 19-30.
13. Zervent Ünal B. 2012. The prediction of seam strength of denim fabrics with mathematical equations. *Journal of the Textile Institute* 103(7), 744-751.
14. Stylios GK, Zhu R. 1998. The mechanism of sewing damage in knitted fabrics. *The Journal of the Textile Institute* 89(2), 411-421.
15. Malek S, Jaouachi B, Khedher F, Ben Said S, Cheikhrouhou M. 2017. Influence of some sewing parameters upon the sewing efficiency of denim fabrics. *The Journal of the Textile Institute* 108(12), 2073-2085.
16. Malek S, Khedher F, Jaouachi B, Cheikrouhou M. 2018. Determination of a sewing quality index of denim fabrics. *The Journal of the Textile Institute* 109(7), 920-932.
17. Birkocak DT. 2022. Effects of needle size and sewing thread on seam quality of traditional fabrics. *Tekstil ve Konfeksiyon* 32(3), 277-287.
18. Boz S, Birkocak DT, Necef ÖK, Kiliç A, Öndoğan Z. 2022. June. Investigation of sewing parameters caused fabric damages. Proceedings of the 21st World Textile Conference-AUTEX 2022 (40-44), Lodz, Poland.
19. Atta RM, El-Sayed I, Mohamed AAH. 2021. Fabric properties measurements using real-time sewing machine motor current signature. *Measurement* 173, 108669.
20. Gülşen Bakıcı G. 2019. Eylül. Polyester esaslı kumaşların tek banyoda boyanması ve dikilebilirlik özelliğinin iyileştirilmesi. Ulusal Çukurova Tekstil Kongresi-UÇTEK'2019. Adana, Türkiye.
21. Gülşen Bakıcı G, Doba Kadem F. 2018. An experimental study on sewability properties of 100% cotton denim fabrics. *Tekstil ve Konfeksiyon* 28(2), 170-176.