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SEWABILITY (BASED ON NEEDLE PENETRATION FORCE) OF 1 × 1 RIB KNITTED FABRICS PRODUCED WITH SEPARATE ENDS OF YARNS

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Abstract:

Needle penetration force (NPF) is one of the main factors, which is used to determine fabric sewability. In this study, it was aimed to investigate sewability (based on NPF) of 1 × 1 rib knitted fabrics, which were produced by the separate ends of yarns. 18 types of fabrics were knitted with Ne 30/1 yarns with variations of stitch density and number of separate ends, whereas the other parameters were constant. Sewability tests were applied to fabrics after pretreatment and relaxation procedures by using the L&M sewability tester. As a result, it was seen that the number of separate ends and the stitch density have influence on the needle penetration values of 1 × 1 rib knitted fabrics.

Keywords:

Double knit structure, 1 × 1 rib, needle penetration force, sewability

Introduction

The most simple double knit structure 1 × 1 rib is a pattern of repetitive one rib, one flat space knitted fabrics, which is produced by two sets of needles being alternately set or gated between each other. The elastic recovery of 1 × 1 rib fabric is exceptionally high along the width and has twice as much width-wise recoverable stretch. Therefore, the 1 × 1 rib knit type of fabric construction is commonly used for producing various types of designed and structured fabrics including collar, cuff of polo t-shirt, welts, muffler, waistband etc. of outwear knitted garments [1,2].

As all garments, the quality and performance of the garments produced from the 1 × 1 rib knitted fabrics are dependent on various factors such as seam strength, seam slippage and seam puckering. Besides these, the sewing process also has a critical role in the determination of the quality of finished garment. Thus, the high quality of garments also depends on fabric sewability. Sewability is generally defined as the ability and ease with which the fabric components can be seamed effectively without fabric damage and provide a given quality and performance desired for its end use [3,4]. Needle penetration force (NPF) is one of the main factors, which is used to determine fabric sewability. The NPF is mostly based on the friction between material and sewing needle. High NPF indicates that the resistance of the fabric is high and so the fabric is more susceptible to damage. High NPF and the use of an unsuitable needle may cause fabric damages that are not noticeable during sewing on the garment but may occur after the garment has been worn for a certain period. Therefore, NPF helps to determine the damage that may occur in the sewing process [5-8].

The subject of NPF measurement has been studied by several researchers on three aspects as follows: the development of instruments to measure the NPF, studies to relate the material, fabric properties, pretreatment, finishing, machine and needle variables to the NPF and predicting the NPF based on theoretical methods. Leeming and Munden developed the L&M sewability tester as a result of their studies on the factors affecting the thrusting of a sewing needle into a knitted fabric and its relationship to fabric sewability [9]. This device measures the penetration force (gf) exerted by a sewing needle on the fabric and records the NPF counts that are exceeding the threshold force level [10,11]. The L&M sewability tester allowed many laboratorial studies to be carried out, which has also been used for woven fabrics as well as knitted fabrics.

Megeid et al. [5] studied the effect of stitch length, yarn count and needle size on the NPF. Bakıcı and Kadem [10] investigated the influence of physical properties of 100% cotton woven fabrics with different constructions on fabric sewability. Sarhan [12] determined seam strength, seam elongation, sewing NPF and seam efficiency to study seam performance of micropolyester woven fabrics. Pamuk et al. [13] studied the sewability properties of main lining fabrics by using the L& M sewability tester. Yıldız et al. [14] researched the sewability properties of different woven fabrics fused with different woven interlinings and associated the findings with the penetration force, fabric unit weight and fabric thickness. Gürarda and Meriç [15] studied the effects of elastane draw ratio, pre-setting temperature and finishing process on NPF and damage to the elastane fiber during the sewing of cotton/

elastane woven fabrics. Saied et al. [16] investigated the effects of fabric construction and treatments on the sewing needle penetration of cotton/polyester woven fabric to determine any damage that appears in garment. İlleez et al. [17] evaluated the parameters, such as fabric construction, softener type and softener concentration on the sewability and seam puckering in apparel on cotton knitted fabrics.

The objective of this study was to investigate sewability (based on NPF) of 1 × 1 rib knitted fabrics that were produced with the combined separate ends of yarns. The NPF was measured using the L& M sewability tester. The effects of stitch density and combined number of separate ends on NPF, which indicate the fabric sewability, were examined, and the obtained results were statistically evaluated.

Materials and methods

To research the effect of parameters such as stitch density and combined number of separate ends of yarns on NPF of 1 × 1 rib knitted fabrics, first a total of 18 knitted fabrics were produced with flat knitting machines of 10 gauge and 14 gauge. With each machine, fabrics knitted in three different levels of course densities (slack, medium and tight) by altering the carriage movement in flat knitting. When knitting fabrics using a thinner yarn count, it is a common practice to combine two or more separate ends of fine yarn rather than to use a single multifolded yarn [18]. Variation of number of separate ends is obtained by combining the Ne 30/1 yarns that fed to the same yarn feeder from 3, 4 and 5 bobbins, respectively. Thus, the combined separate ends of yarns were included into the fabric structure without being twisted (Figure 1).

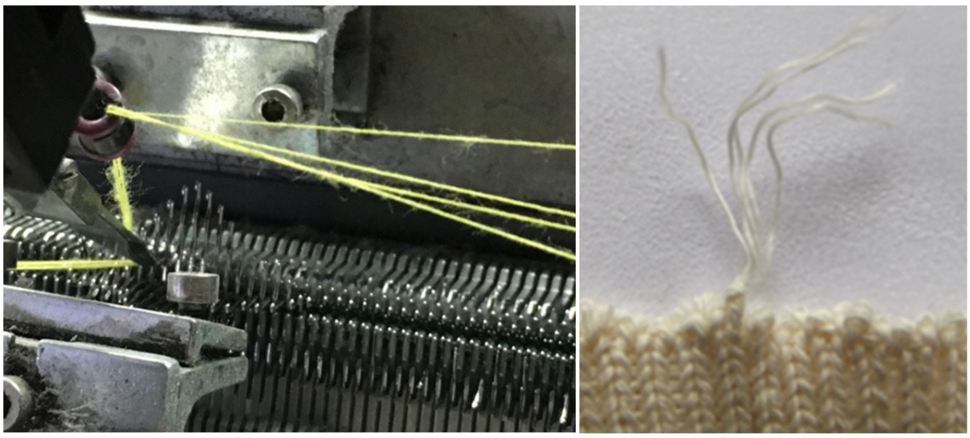
Second, bleaching and relaxation processes were applied to fabrics. Fabrics were subjected to hydrogen peroxide bleaching using a laboratory-type haspel machine under 95°C. Dry relaxation was applied to fabrics by standing on a flat and smooth surface for 1 week under standard atmospheric conditions. By this way, the raw materials and treatment processes of all the knitted fabrics were the same and comparable specimens were produced.

Fabric weight was measured with an electronic weighing balance. Courses per centimeter and wales per centimeter were counted with a looper, and their product was described as the stitch density. This value is, therefore, the number of loops per cm^2 visible on each side of the fabric. Table 1 shows the constructional properties and physical characteristics of the bleached fabrics after dry relaxation.

Finally, NPF tests of the bleached and relaxed fabrics were performed with an L&M sewability tester. This equipment simulated a sewing machine by penetrating the tested fabric with a 90s ball point unthreaded needle, at a rate of 100 penetrations per minute. NPF test was performed 10 times in both wale and course directions for each fabric from the strips of 25 × 350 mm. Force measurement is taken and recorded for 100 penetrations of each test. The sewing NPF is the quantitative measure of the damage, which appears in agreement as a result of the sewing process. To enable the needle to penetrate the fabric, either the loop must break damaging the fabric or the size of the loop must increase by borrowing yarn from adjacent loops. If frictional properties of yarns do not allow the loop size increase, the high forces can rupture the yarn, can heat the sewing thread or give a damaged seam. Therefore, a high penetration force means a high resistance of fabric and thus a high risk of damage. Besides the fact that sewing damage could be predicted by measuring the forces required for multiple penetrations of a needle through the fabric, the sewability value is determined as the number of times which that forces exceeded a specified threshold value and expressed as a percentage. If not more than 10% of the penetrations exceed the threshold level, the fabric sewability was considered good. When sewability value is between 10% and 20%, sewing may be possible but the sewing performance is unlikely to be good. If the sewability value is above 20%, then sewability was considered to be poor [11,16].

Results and discussion

NPF test was performed 10 times in both wale and course directions of each fabric. The NPF measurement is taken and recorded for 100 penetrations of each test. All test results were evaluated in two sections. In the first section, effects of



(a) (b)

Figure 1. (a) Combination of several separate ends of yarns that fed to the same yarn feeder. (b) 1 × 1 rib fabric knitted with combined separate ends of yarns.

Table 1. Constructional properties and physical characteristics of bleached 1 × 1 rib knitted fabrics

Fabric code	Combined yarn count	Gauge (needle/inch)	Carriage movement	Stitch density (loop/cm²)	Fabric weight (g/m²)
R1	3	10	Low	39.5	320
R2	3		Medium	26.9	265
R3	3		High	25.0	235
R4	4		Low	47.0	474
R5	4		Medium	30.7	385
R6	4		High	28.8	347
R7	5		Low	47.8	620
R8	5		Medium	32.6	517
R9	5		High	28.8	454
R10	3	14	Low	74.9	444
R11	3		Medium	68.0	399
R12	3		High	58.9	377
R13	4		Low	92.2	648
R14	4		Medium	76.2	570
R15	4		High	66.6	540
R16	5		Low	92.4	832
R17	5		Medium	88.4	790
R18	5		High	76.8	575

fabric characteristics on average NPF were investigated. In the second section, sewability was investigated as the number of times that NPF exceeded the determined threshold value.

Effects of physical characteristics on average NPF

NPF test was performed in both wale and course directions for each fabric produced within the scope of the study. Average NPF values are given in Figures 2 and 3, respectively, depending on the stitch density and the combined number of separate ends of yarns.

It is obvious that the higher the needle gauge, the higher the NPF in both walewise and coursewise directions. It is also seen that NPF is influenced by the stitch density and the combined number of separate ends. Fabrics display markedly higher NPF with an increase in the stitch density among fabrics having the same combined number of separate ends. Upon comparing the fabrics that are knitted with same needle gauge and same speed of knitting level (course density), fabrics also display higher NPF with an increase in the combined number of separate ends. When the stitch density or the combined number of separate ends increase, the porosity of the fabric decreases and hence the NPF increases.

Statistical analyses are carried out by using SPSS software. Normality of the experimental data was determined by the Kolmogorov–Smirnov test. Correlation analysis is carried out to determine the statistical relationship between stitch density, fabric weight and NPF values, and the results are given in Table 2.

It is shown in Table 2 that there is a high correlation between both stitch density and fabric weight with NPF of fabrics knitted with a gauge of 14 needles/inch. Pearson correlation coefficient between the stitch density and NPF values was found to be 0.811 (NPF walewise) and 0.806 (NPF coursewise), respectively, whereas it was found to be 0.937 (NPF walewise) and 0.944 (NPF coursewise), respectively, between fabric weight and NPF values. It means that the higher stitch density or the higher fabric weight values provide the higher NPF in both walewise and coursewise directions. Similarly, high correlations were found to be 0.936 (NPF walewise) and 0.940 (NPF coursewise), respectively, between fabric weight and NPF of fabrics knitted with a gauge of 10 needles/inch. However, the correlation 0.696 (NPF walewise) and 0.699 (NPF coursewise) between stitch density and NPF of fabrics knitted with a gauge of 10 needles/inch is found to be comparatively lower.

The fabric sewability

A threshold value was determined for each fabric based on the fabric mass per unit area in this section. It is recommended for normal structures without any special treatment, the threshold

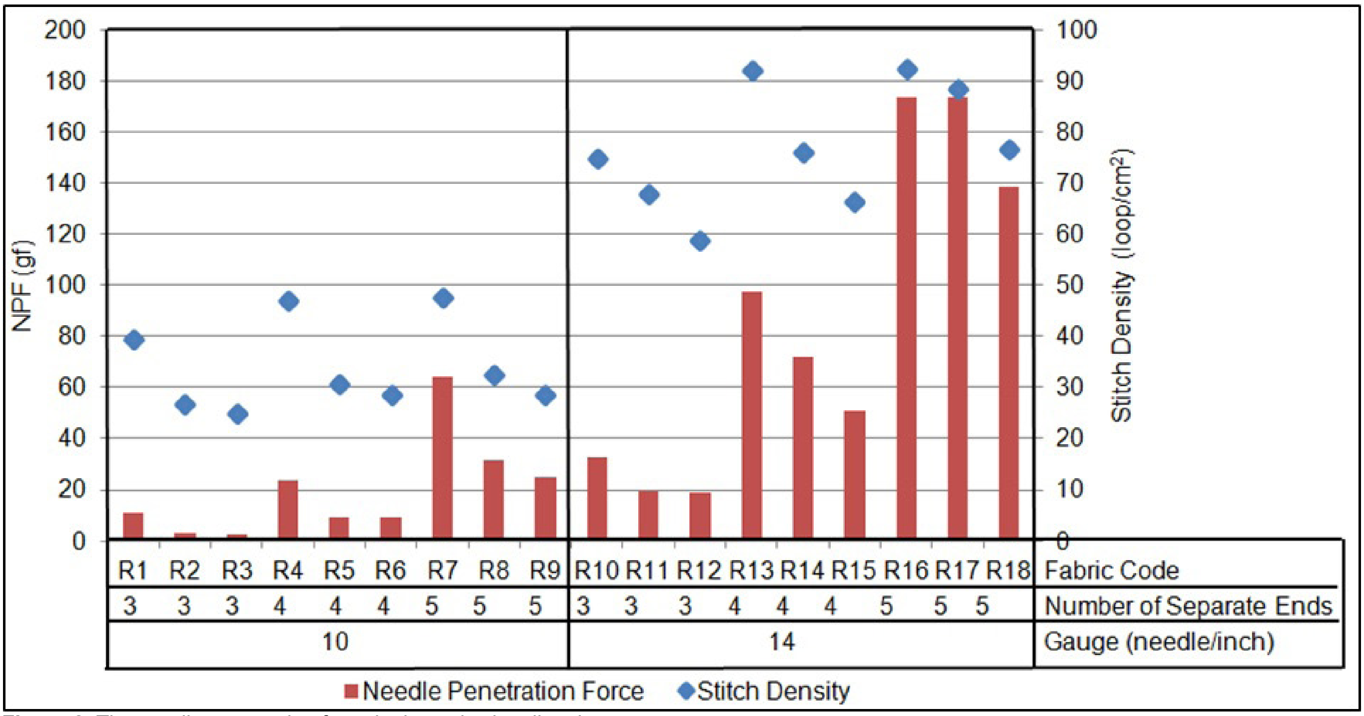


Figure 2. The needle penetration force in the walewise direction.

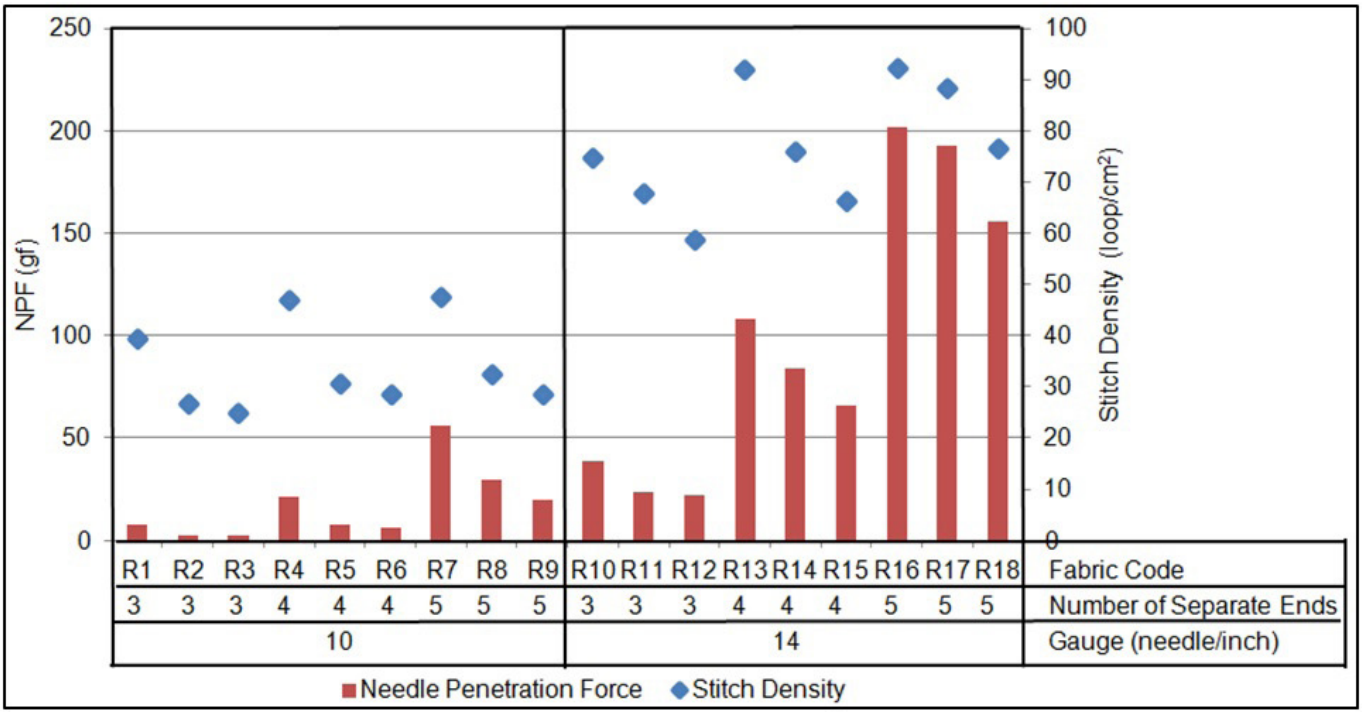


Figure 3. The needle penetration force in the coursewise direction.

level (gf) is conveniently set at half of the fabric mass per unit area (g/m^2) rounded up to the nearest whole 25 g for double jersey fabric [11]. Percentage of the counts of high recordings that exceed the threshold value is given as the sewability value in Table 3.

As shown in Table 3, sewability values for each construction of fabrics in the walewise and coursewise directions are 0. This means that the sewability of the fabrics are considered good when evaluated with the threshold value that was set according to unit weight of each individual fabric. To compare the fabrics among themselves, the threshold value was defined approximately close to total average of NPFs, which was 50 gf. The sewability values were defined as the percentage of the counts of NPFs that exceed 50 gf (Table 4).

It is shown in Table 4 that the higher the needle gauge, the higher the sewability value in both walewise and coursewise directions. Among the fabrics that are knitted with the same needle gauge and combined number of separate ends, fabrics display higher sewability values with increasing stitch density. Furthermore, increasing the combined number of separate ends also resulted in higher sewability values. This means that sewability of fabric becomes more hard. Sewability was

Table 2. Pearson correlation

			NPF (walewise)	NPF (coursewise)
Gauge (10 needles/inch)	Stitch density	Pearson correlation	0.696*	0.699*
		Sig. (two-tailed)	0.037	0.036
		N	9	9
	Fabric weight	Pearson correlation	0.936**	0.940**
		Sig. (two-tailed)	0.000	0.000
		N	9	9
Gauge (14 needles/inch)	Stitch density	Pearson correlation	0.811**	0.806**
		Sig. (two-tailed)	0.008	0.009
		N	9	9
	Fabric weight	Pearson correlation	0.937**	0.944**
		Sig. (two-tailed)	0.000	0.000
		N	9	9

*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).
NPF, needle penetration force.

Table 3. The sewability values of fabrics (varying threshold value)

Fabric code	Knit structure			Threshold value (gf)	Sewability value (%)	
	Number of separate ends	Gauge (needle/inch)	Stitch density (loop/cm^2)		Walewise	Coursewise
R1	3	10	39.5	150	0	0
R2	3		26.9	125	0	0
R3	3		25.0	125	0	0
R4	4		47.0	225	0	0
R5	4		30.7	200	0	0
R6	4		28.8	175	0	0
R7	5		47.8	300	0	0
R8	5		32.6	250	0	0
R9	5		28.8	225	0	0
R10	3	14	74.9	225	0	0
R11	3		68.0	200	0	0
R12	3		58.9	200	0	0
R13	4		92.2	325	0	0
R14	4		76.2	275	0	0
R15	4		66.6	275	0	0
R16	5		92.4	425	0	0
R17	5		88.4	400	0	0
R18	5		76.8	300	0	0

Table 4. The sewability values of fabrics (constant threshold value)

Fabric code	Knit structure			Threshold value (gf)	Sewability value (%)	
	Number of separate ends	Gauge (needle/inch)	Stitch density (loop/cm²)		Walewise	Coursewise
R1	3	10	39.5	50	0.2	0.1
R2	3		26.9	50	0.0	0.0
R3	3		25.0	50	0.0	0.0
R4	4		47.0	50	7.2	5.2
R5	4		30.7	50	0.6	0.2
R6	4		28.8	50	0.2	0.0
R7	5		47.8	50	59.7	50.4
R8	5		32.6	50	15	12.1
R9	5		28.8	50	6.3	2.3
R10	3	14	74.9	50	21.2	28.9
R11	3		68.0	50	6.2	9.9
R12	3		58.9	50	3.4	6.4
R13	4		92.2	50	79.1	84.3
R14	4		76.2	50	65.8	70.8
R15	4		66.6	50	41.4	50.0
R16	5		92.4	50	100.0	100.0
R17	5		88.4	50	99.7	99.9
R18	5		76.8	50	89.3	91.9

considered good in walewise and coursewise directions for fabrics knitted with the flat knitting machine of 10 gauge, except fabrics R7 and R8. Because of the high sewability values in both directions, the sewability of R7 was considered poor, and the sewing performance of R8 was considered bad. Fabric R7 has the highest stitch density that can be shown as a reason of poor sewability. However, fabric R8 has a stitch density of 32.6 loops/cm^2, which is less than the stitch density of R1 or R4. While sewability of R1 and R4 was considered good, the sewing performance of R8 was considered bad. This can be explained by the increase in the combined number of separate ends. On the other hand, sewability of fabrics knitted with the flat knitting machine of 14 gauge was considered poor except fabrics R11 and R12. Fabric R12 has the lowest stitch density that can be shown as a reason of good sewability. Although the stitch density of R11 is higher than R15, sewability of R11 was considered good, whereas sewability of R15 was considered poor. This can also be explained by the increase in the combined number of separate ends.

CONCLUSION

This paper presents an experimental study of sewability (based on NPF) of 1 × 1 rib knitted fabrics produced with combined separate ends of yarns. In this study, 18 types of 1 × 1 rib knitted fabrics that were produced in two different wale densities and three different course densities (slack, medium and tight) by combining the Ne 30/1 yarns that fed to needles from 3, 4 and 5 bobbins, respectively, without twisting are used. It is shown that stitch density and combined number of separate ends have influence on NPF and sewability value of 1 × 1 rib knitted fabrics. It is seen that the higher the needle gauge, the higher the NPF in both walewise and coursewise directions. Among the fabrics that are knitted with the matching needle gauge and combined separate ends of yarns, NPF of fabrics increases when the stitch density of fabrics increases. Increasing the combined number of separate ends of yarns without changing the speed of knitting level (course density), fabrics also display higher NPF. Moreover, the statistical analysis provided that there is a high correlation between both stitch density and fabric weight values with NPF of fabrics.

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