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Impact of Sewing Needle and Thread on the Technological Process of Sewing Knitwear

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Abstract

The selection of sewing needles, the fineness of sewing thread, relative air humidity, as well as the thickness and density of knitted fabric play a significant role in the technological process of sewing. Damage to knitted fabric loops during sewing are closely connected with sewing needle penetration force and dynamic tension values of the sewing thread. In this research an instrument for measuring the sewing needle penetration force and dynamic sewing thread tension force was designed.

Key words: sewing, damage to loops, sewing needle, penetration force, thread tension, measuring instrument.

■ Introduction

Despite the very high technical level and automation in the processes of garment manufacture, especially in the production of knitwear, seams of insufficient quality are made. One reason is that not enough attention is dedicated to material quality, in this case to knitted fabric. The consequences of such inferior sewing of knitwear are faults which are recognized too late. This causes greater financial outlay and marketing risks. Therefore, it is very important to recognize all the faults that occur during the technological process of sewing knitwear. This is the reason why greater attention should be paid to measuring systems with online detection of faults for sewing machines [1 - 3].

The sewing needle penetration force, sewing thread tension, the feed of the sewing material, as well as selection of the sewing thread, sewing needle size and shape of the sewing needle point are very important parameters during the sewing of knitted fabric. When sewing knitted fabric, mechanical or thermal material damage may occur, which may be caused by the position of the stitches where the threads have been looped. Damaged loops may tear during use, which is clearly visible, ladders being a typical example [4].

One of the most important parameters in sewing knitwear is also relative air humidity, which affects the quality of seams to a great extent, because at low relative air humidity, it forms static electricity, which negatively affects loop movability.

Needle size is of outstanding importance among numerous factors affecting the production process as well as the final product. Needle size and needlepoint

shape play a very significant role during sewing. Before selecting an appropriate needlepoint, it is necessary to determine the sewing needle size because it greatly depends on the sewing thread used. Sewing thread plays an influential role in seam design; it should be stretchable since knitted fabric has elastic properties in the direction of courses and wales. The size of the needle eyelet and thread thickness should be mutually adjusted in order for the thread to pass through the eyelet with as little friction as possible [5 - 8].

The quality of a sewn seam depends on these two factors, therefore it is necessary to match the thickness and density of the knitted fabric with the fineness of the sewing thread and needle. The point shape of sewing needle mostly used is a small ball needle point marked as SES and medium ball needle point marked as SUK.

The penetration force of a sewing needle is mostly based on the friction occurring between the sewing work piece and sewing needle, and the highest penetration force of the sewing needle occurs at the moment when the sewing needle penetrates the sewing material, which should be taken into consideration, especially with knitted fabrics [9 - 10].

■ Materials used for investigations and methods

Three types of cotton knitted fabrics were used for the investigations and measurements of sewing needle penetration forces and dynamic tensions of the sewing thread:

- single jersey
- double jersey
- interlock fabric as a special group of double jerseys.

All the knitted fabrics were bleached. The bleaching process was performed by boiling the fabric at 60 °C for a period of 30 min, followed by warm steaming at a temperature of 60 °C for a period of 10 min, and finally the fabric was cold rinsed. After bleaching at 98 °C for a period of 45 min and adding suitable agents at a pH of 5 to 6, hot rinsing and double cold rinsing were applied. All the knitted fabrics were made of 100% single cotton yarn of 20 tex.

During experimentation, the following were used: a Brother Exedra Mark II DB-2-B737-913 single needle sewing machine with three types of Groz-Beckert needles: a SAN 10 with a normal conical point, an SES with a small ball point, an SUK with a medium ball point and three different needle sizes of each needle point: Nm 70, Nm 75 and Nm 80. SES and SUK needle points are the most frequently used needle point shapes for sewing knitwear. This is the reason why they were used in this work [11].

The upper part of the blade of the SAN 10 needle was reinforced so that the stitch hole was formed like that of a Nm 65 needle. The size of the newly designed needle was Nm 70, whose smaller stitch hole produced less damage to the threads or loops [13]. Samples were sewn using double lock stitches. One part of the tests of sewing needle penetration forces was performed without sewing thread and the other part by using sewing thread. Such tests were done because the intention was to prove how much sewing thread affects sewing needle penetration force values.

100% PES covered thread with a count of 13 tex × 2, called POLYPREN 120, is most widely used for sewing knitwear. In comparison to sewing thread made from natural fibres, it offers certain advantages, in particular concerning tensile strength,

Table 1. Mean values of the physical properties of POLYPREN 120 thread with a count of 13 tex × 2.

Thread count, tex	13.10
CV of thread count, %	0.75
Breaking force, cN	1,160
CV of breaking force, %	2.98
Strength, cN tex ⁻¹	40.00
Elongation at break, %	19.50
CV of elongation at break, %	3.01
Twist level, m ⁻¹	1,100
CV of twist level, %	1.50

elongation, and low shrinkage. The technical data and physical properties of the thread, respectively, come from a manufacturer's laboratory. These tests were performed on 5 windings of each 10 m specimen, and the mean values of the results obtained are shown in *Table 1*.

Sewing needle penetration force

The sewing needle penetration force is one of the most significant technical technological parameters in the sewing process, affected by various factors such as type and amount of layers of the sewing material, needle size, shape of needle point, stitch speed of the sewing machine, and treatment of the sewing material, among others [12].

Measurement of the sewing needle penetration force is based on the physical principle of deformation measurement caused by the action of a certain force transferred from the measuring object to the sensor. Measurement methods mutually differ in the measuring principle and in the way of transferring these forces during measurement [11]. In view of this the following can be differentiated:

- contact measurement methods
- contactless measurement methods.

In contact measurement methods, the blade of the sewing needle is used as a sensor, whereas in contactless methods this is the needle plate of the sewing machine.

The greatest sewing needle penetration force occurs at the moment when the needle eyelet penetrates the material. The sewing needle eyelet, being of a greater diameter, passes through the material at a greater distance from the yarn and fibers, respectively, leading to greater friction against the sewing needle and a increase in the resistance and penetration forces of the material. When the sewing needle leaves the fabric, friction decreases because the needle passes through a previously formed opening, the consequence of which is a great reduction in the absolute value of the penetration section.

The sewing machine with a redesigned needle plate and strain gauges connected to the Wheatstone bridge, a DMC plus amplifier made by the HBM company with a CATMAN software package and personal computer registering the signal as a series of numbers constituted the measurement system of the sewing needle penetration force.

The measurement system of the sewing needle penetration force is meant to measure static and dynamic forces with an individual or periodic impulse shape whose spectrum contains frequencies of up to 4 kHz.

The sewing needle penetration force is transmitted through the sewing work piece to the needle plate, which is made of stainless steel (CrNiCu) and specially designed for measuring.

The needle plate, acting as a sensor, has a uniquely high frequency and an appropriate measuring sensitivity. The measuring part of the instrument on the needle plate is an elastic tape fastened on both sides with a penetration opening for the needle in the middle. Four strain gauges are attached to it, serving as strain detectors. Under the influence of the sewing needle force occurring during penetration of the work piece, the elastic tape bends downward in the middle, which causes deformation and bending on the lower side in the middle of the bridge. In the area of greatest deformation, four 350 Ω strain gauges are connected to the Wheatstone bridge.

Two opposite strain gauges within the bridge are under elongation strain (resistance increases) and two strain gauges are under compressive strain (resistance decreases). Elongation of steel caused by temperature changes is theoretically compensated if the temperature is transferred simultaneously to all four places. Thus, strain gauges with self-compensation of temperature elongation were built, which were adjusted according to the temperature coefficient of the steel used ($\alpha = 10.8 \mu\text{m/K}$).

The sewing needle penetration force, which is transferred from the work piece to the needle plate, is measured by the sensors built in for this purpose and the strain gauges connected to the Wheatstone bridge. A DC amplifier plus, made by the company HBM, with a CATMAN software package is installed after the Wheatstone bridge. The software program enables the presentation of the results obtained in the form of tables as well as graphic presentation of the results [11].

Dynamic sewing thread tension

Dynamic sewing thread tension refers to the tensile force affecting the sewing thread in the process of stitch formation

from the bobbin to the last formed stitch. The sewing thread is constantly exposed to higher or lower tension during the process of stitch formation, therefore the moment of stitch formation is very short, amounting to 0.015 s at a sewing speed of 4000 stitches/min. Since the use of modern universal, special, and automatic sewing machines has increased, the application of force during the formation of sewing stitches and the requirements to adjust the thread to these manufacturing conditions have also increased to maintain the properties of the quality of the sewing material. The development of sewing thread with the purpose of meeting high requirements has been directed at the rapid growth of the use of the polyester and cotton component in thread, whose basic properties are high strength, uniform behaviour during stretching, uniform modulus of elasticity, high thread stability, very low shrinkage and thermal stability [4].

The measuring system for determining dynamic thread tension consists of a sewing machine, a measuring sensor which registers the tensile force and dynamic thread tension as a physical quantity, respectively, a Wheatstone bridge, and a DMC plus amplifier, made by the company HBM, with a CATMAN system software and personal computer. The measuring system determines the dynamic forces occurring in sewing thread during sewing on a sewing machine. The measuring sensor should be placed near the entry of the thread into the needle eyelet.

The measuring sensor is made of stainless steel (CrNiCu) with a hardness of 1040 N/mm² and own high frequency (order of magnitude = 10 kHz). The measuring section of the sensor is L-shaped and has a very high section modulus in bending, caused by thread forces.

The measuring system completed and designed by us determines the tensile force and dynamic tension, respectively, which occur in sewing thread during sewing on a sewing machine, by means of four strain gauges connected to a Wheatstone bridge [11].

■ Results and discussion

In *Table 2* (see page 88) the results of sewing needle penetration forces when sewing samples are presented. The samples

of knitted fabric were investigated using different sewing needle points (SAN 10, SES and SUK) and different sewing needle sizes (Nm 70, Nm 75 and Nm 80). The knitted fabric samples were tested in the direction of courses and wales.

The sewing needle penetration force values obtained by sewing a sample of the single jersey in the direction of wales with a SAN 10 needle of size Nm 70 and Nm 75 show an increase in force by 14.17% with the larger needle, whereas with the Nm 80 needle there is an increase in the force of 23.7% in comparison to that of the Nm 70 needle.

When sewing the same sample with the SES point needle, an increase in the penetration force due to needle size was observed. In contrast to the Nm 70 needle, the Nm 75 produces a 0.96% lower penetration force, whereas the penetration force measured with the Nm 80 needle is 16.38% higher.

When sewing the samples with the SUK point needle, the penetration force value of the Nm 75 needle is 10.07% higher than that of the Nm 70 needle, whereas the penetration force value of the Nm 80 needle is 24.35% higher in comparison with that of the lower size needle.

After measurement of the penetration force of the same sample, but in the direction of courses, the following values were obtained: with the SAN 10 sewing needle, the value of penetration force obtained with the Nm 75 needle size, is 12.98% higher than that of the Nm 70 needle, while the penetration force value obtained with the Nm 80 needle is 25.94% higher than that of the Nm 70 needle. With the SES needle point the Nm needle produces a 2.8% higher penetration force than that of the Nm 75 needle, while in comparison to the Nm 80 needle, it is 2.7% lower, and an increase in the penetration force of the higher size needle was observed, respectively.

When sewing the samples with the SUK point needle in the direction of courses, the penetration force value of the needle of size Nm 75 is 6.8% lower in comparison with the needle of size Nm 70, whereas the penetration force of the Nm 80 needle increased by 21.52%.

The penetration force values of the sewing needle when sewing the double jersey sample in the direction of wales with SAN 10 sewing needles of Nm 70 and

Nm 75 increased by 18.66% with the larger needle, whereas the Nm 80 needle shows an increase in the force of 8.08% in comparison to that of the Nm 70 needle.

When sewing the double jersey sample in the direction of wales with the SES point needle, an increase in the penetration force of 16.21% was observed.

When sewing the samples with the SUK point needle in the direction of wales of the double jersey, the penetration force value of the Nm 75 needle is 3.8% lower than that of the Nm 70 needle, and the increase in the penetration force of the Nm 80 needle was 23.5%.

In the direction of courses and wales, very similar relationships of increasing penetration forces concerning needle size were observed.

When sewing the interlock sample in the direction of wales with SAN 10 needles of size Nm 70 and Nm 75, the sewing needle penetration force values show an increase in force of 28.93% with the needle of larger size, whereas the needle of size Nm 80 shows an increase in force of 30.87% in comparison to the needle of size Nm 70.

When sewing the same sample with the SES point needle, an increase in the penetration force value caused by needle sizes was observed. The needle of size Nm 80 in comparison to the needle of size Nm 70 produces a 22.22% higher force, while the needle of size Nm 80 shows an increase in the penetration force of 22.56% in comparison to the needle of size Nm 70.

When sewing the samples with the SUK point needle in the direction of the wales of the interlock sample, the penetration force value of the needle of size Nm 70 is 5.05% higher than that of the needle of size Nm 75, whereas the needle of size Nm 80 shows an increase in the penetration force of 26.83%. In the direction of courses, very similar relationships of increasing penetration forces concerning needle size are observed.

The measured values of the dynamic thread tension (*Table 2*, see page 88) of the single jersey in the direction of wales with the SAN 10 needle of size Nm 70 show an increase of 0.7% compared to that of the needle of size Nm, and an increase of 1.1% in comparison to that of the needle of size Nm 80.

Table 2. Parameters of the distribution of sewing needle penetration forces and dynamic sewing thread tension depending on the influence parameters during the sewing of samples.

Type of knitted fabric (P1)	Sewing direction (P2)	Shape of sewing needle point (P3)	Sewing needle size (P4)	Number of measurements	Penetration force			Dynamic sewing thread tension			
					Arithmetic mean, N	Standard deviation, N	CV, %	Arithmetic mean, N	Standard deviation, N	CV, %	
Single jersey	Wales	SAN 10	Nm 70	175	2.162	0.452	20.9	1.441	0.084	5.8	
			Nm 75	175	2.519	0.608	24.1	1.430	0.058	4.1	
			Nm 80	175	2.836	0.814	28.7	1.425	0.070	4.9	
		SES	Nm 70	175	2.480	0.448	18.1	1.442	0.052	3.6	
			Nm 75	175	2.456	0.711	28.9	1.383	0.056	4.0	
			Nm 80	160	2.966	0.750	25.3	1.384	0.061	4.4	
		SUK	Nm 70	175	2.183	0.568	26.0	1.432	0.052	3.6	
			Nm 75	175	1.963	0.497	25.3	1.395	0.074	5.3	
			Nm 80	175	2.886	0.913	31.6	1.438	0.058	4.0	
	Courses	SAN 10	Nm 70	175	2.118	0.506	23.9	1.476	0.069	4.7	
			Nm 75	175	2.434	0.689	28.3	1.480	0.059	4.0	
			Nm 80	175	2.860	0.935	32.7	1.481	0.063	4.3	
		SES	Nm 70	140	2.441	0.404	16.6	1.454	0.056	3.9	
			Nm 75	175	2.371	0.599	25.3	1.438	0.078	5.4	
			Nm 80	160	2.509	0.809	32.2	1.405	0.059	4.2	
		SUK	Nm 70	175	2.140	0.410	19.2	1.563	0.121	7.7	
			Nm 75	175	1.993	0.472	23.7	1.475	0.065	4.4	
			Nm 80	175	2.727	0.747	27.4	1.446	0.057	3.9	
	Double jersey	Wales	SAN 10	Nm 70	175	3.446	0.798	23.2	0.782	0.071	9.1
				Nm 75	160	3.749	0.899	24.0	0.741	0.066	8.9
				Nm 80	140	4.237	1.169	27.6	0.770	0.082	10.6
			SES	Nm 70	175	3.302	0.638	19.3	0.822	0.054	6.6
				Nm 75	175	3.941	1.034	26.2	1.183	0.069	5.8
				Nm 80	175	3.943	0.933	23.7	1.223	0.067	5.5
SUK			Nm 70	175	3.220	0.719	22.3	1.463	0.090	6.2	
			Nm 75	175	3.350	0.810	24.2	1.603	0.077	4.8	
			Nm 80	175	4.185	1.473	35.2	1.068	0.140	13.1	
Courses		SAN 10	Nm 70	175	3.371	0.559	16.6	0.793	0.050	6.3	
			Nm 75	175	3.565	0.623	17.5	0.813	0.049	6.0	
			Nm 80	175	3.784	0.724	19.1	0.802	0.059	7.4	
		SES	Nm 70	175	3.376	0.541	16.0	1.004	0.196	19.5	
			Nm 75	175	3.465	0.655	18.9	1.270	0.061	4.8	
			Nm 80	175	3.601	0.672	18.7	1.222	0.062	5.1	
		SUK	Nm 70	175	3.262	0.481	14.7	1.397	0.169	12.1	
			Nm 75	175	3.065	0.458	14.9	1.644	0.077	4.7	
			Nm 80	140	3.548	0.950	26.8	1.022	0.107	10.5	
Interlock		Wales	SAN 10	Nm 70	175	3.304	0.699	21.2	1.070	0.055	5.1
				Nm 75	175	4.649	0.459	9.9	1.070	0.080	7.5
				Nm 80	175	4.780	1.088	22.8	1.089	0.056	5.1
			SES	Nm 70	175	3.126	0.517	16.5	1.014	0.156	15.4
				Nm 75	175	4.020	1.084	27.0	1.069	0.074	6.9
				Nm 80	175	4.037	1.153	28.6	0.885	0.185	20.9
	SUK		Nm 70	175	3.120	1.203	38.6	1.272	0.070	5.5	
			Nm 75	175	3.286	1.110	33.8	0.927	0.149	16.1	
			Nm 80	175	4.221	1.777	42.1	1.082	0.205	18.9	
	Courses	SAN 10	Nm 70	175	3.904	0.695	17.8	1.122	0.067	6.0	
			Nm 75	175	5.041	0.796	15.8	1.147	0.059	5.1	
			Nm 80	175	5.348	0.853	15.9	1.077	0.085	7.9	
		SES	Nm 70	175	4.053	0.813	20.1	1.113	0.072	6.5	
			Nm 75	175	4.306	1.000	23.2	1.021	0.121	11.9	
			Nm 80	175	4.626	0.947	20.5	1.014	0.102	10.1	
		SUK	Nm 70	175	3.854	1.190	30.9	1.315	0.063	4.8	
			Nm 75	175	3.700	0.749	20.2	0.990	0.147	14.8	
			Nm 80	140	5.237	2.050	39.1	1.113	0.171	15.4	

With the SAN 10 needle it was observed that thread tension is the highest in the case of the needle of size Nm 70 as well as in the case of other needle points (SES and SUK).

There are no noticeable differences in the values of dynamic thread tension in the direction of courses for the single jersey sample with regard to the direction of wales.

In the case of the double jersey, the values of the dynamic thread tension measured in the direction of wales with the SAN 10 needle do not show noticeable differences in the increase of dynamic thread tension with regard to needle size.

In the case of the SES point needle, there is a difference in the value of thread tension in the double jersey sample. The needle of size Nm 75 compared to the needle of size Nm 70 shows a noticeable increase in the value by 30%, and the Nm 80 compared to the Nm 70 it is 32.78% higher.

Dynamic thread tension in the case of the SUK point needle of size Nm 70 is 23% lower in comparison to that of the needle of size Nm 70, and compared to the needle of size Nm 75 it is 3.8% lower.

In the direction of courses, there are no noticeable differences in the values of dynamic thread tension with regard to the direction of wales for the double jersey sample.

In the case of the interlock sample, the highest dynamic thread tension was ob-

served. With the SUN 10 needle, there are no noticeable differences with regard to the increase in needle sizes. The highest value of thread tension was observed in the needle of size Nm 70 with the SES and SUK points, and there are no noticeable differences in the SAN 10 needle. **Figure 1** shows that there is no noticeable difference when measuring the sewing needle penetration force if the samples are sewn with or without the sewing thread.

Conclusions

The quality of sewn knitwear depends on various factors: type of knitted fabric, sewing needle size, sewing thread count etc. Loop damage during sewing is closely related to sewing needle penetration force values and sewing thread tension. A high sewing needle penetration force value is the most frequent cause of loop damage.

- Sewing needle penetration forces increase proportionally with needle sizes, from Nm 70 to Nm 80.
- Sewing needle penetration forces are the highest in interlock fabric, where the SAN 10 needle shows the highest differences of sewing needle penetration forces in view of needle size.
- By increasing the needle size, the penetration force value also rises, and a change in the penetration force with regard to the point shape used is observable; a great difference is present in the SAN 10 needle with regard to needle size
- Sewing direction in the relation to the loops of knitted fabric exerts no con-

siderable influence on the needle penetration force value.

- There is no noticeable difference when measuring the sewing needle penetration force and dynamic tension of sewing thread if the samples are sewn with or without this.
- The highest dynamic tension is measured in the needle of size Nm 70 in all types of knitted fabric investigated.
- The highest dynamic tension of the sewing thread was measured for the Interlock fabric with an SES shaped needle point.

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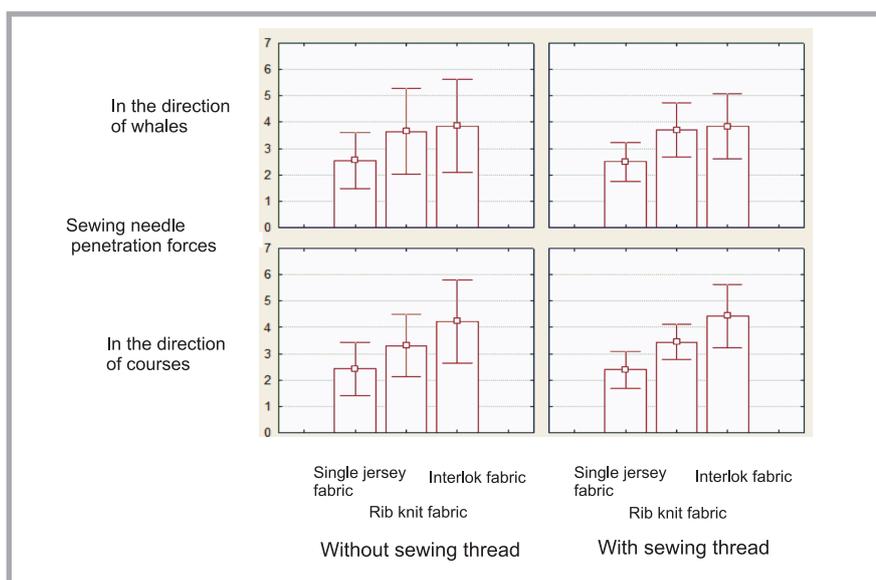


Figure 1. Average values of sewing needle penetration forces according to fabric type and sewing direction during sewing samples with and without sewing thread.

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