INFLUENCE OF SEWING NEEDLE PENETRATION FORCE ON THE QUALITY OF KNITTED GARMENT

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Abstract

Many processing parameters during the process of garment production influence knitted garment quality. The penetration force required of the sewing needle is primarily based on friction occurring between sewing work piece and sewing needle. The highest penetration force of the sewing needle occurs at the moment when the sewing needle penetrates the sewing material. Needle penetration force is one of the most important parameters affecting the quality of seams. Needle penetration forces that are too high causes damaged loops, known as ladders. Before selecting an appropriate needle point, it is necessary to determine sewing needle size because it greatly depends on the sewing thread used. Sewing thread plays an influential role in seam design because it should be stretchable since knitted fabric has elastic properties in the direction of rows 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 as friction as possible. Penetration force values were observed in view of the quantity and type of softeners, different sewing needle size and number of layers of the stitched sample of a dyed plain jersey. A measuring instrument for testing penetration forces was designed. A measuring instrument with special sensors was used for determining penetration forces of sewing needle. The data acquired with this instrument was saved on computer with the software "Nemess 5.0."

Introduction

On the basis of statistical data from various countries, the share of knitwear in clothing is very significant. Knitted fabric manufacture is a complicated dynamic process. Knitted fabric should be manufactured according to specific standards so that an article of clothing has defined characteristics and dimensions. The technological process of knitted fabric manufacturing should be constantly controlled in order to achieve a high quality of the final product [1]. The parameters, which influence appearance, quality and physico-mechanical properties of the knitted fabric, are divided into three groups:

- machine parameters
- yarn parameters
- environmental parameters

By proper selection of the parameters stated satisfactory conditions, which influence, qualitative properties of articles of clothing are achieved. The previous level of knowledge indicates that sewing needle penetration forces play an essential role and have a technical technological meaning for the quality in the process of garment sewing. Investigations have shown that different parameters influence sewing needle penetration forces in the process of sewing knitwear [2-4].

Knitwear Sewing

Production success in knitwear sewing is only possible when using a specific production technology, whereby properties and structure of the work piece with its technological properties should be taken into account. In knitwear sewing numerous damages of knitted fabric loops occur unexpectedly, which are caused by different technical and technological factors. These damages can be reduced to a high degree by knitted fabric finishing, suitable relative air humidity and sewing needle size.

Over the past years the number of technical publications dealing with problems of sewing knitwear has increased. Due to the position of threads bound in woven and knitted fabrics it comes to mechanical and thermal damages in the technological sewing process. In woven fabrics threads are perpendicular to one another, i.e. warps and wefts. When the needle of the sewing machine feeds the sewing thread into the woven fabric, the needle within the fabric pushes the threads to the side in two directions due to stitch formation. When a thread in the fabric is damaged, there are no substantial consequences because the thread in the fabric is held by other bound threads, and it does not come to spreading the damaged place [5].

In knitted fabric, threads are bound in the form of a loop. The needle point of the sewing needle penetrates and spreads the loop in accordance with increasing the thickness (size) of the sewing needle. In woven fabrics sewing needle penetration force is divided into four threads, and in knitted fabrics it is concentrated on only one thread. When the sewing needle penetrates the thread of the loop, the risk of disrupting the weave or knitted construction increases. When wearing such a garment, visible damage or dropped stitches occur, Figure 1 [6-9].

Figure 1. Damage to knitted fabric.

Relative air humidity

Moisture content in the material depends directly on the relative humidity of the ambient air. If air humidity is constant, it does not come to a dimensional change of the knitted fabric. The moisture of the knitted fabric decreases in the dry room. Therefore, it requires that the air is actively humidified during warming the rooms, since the existing relative air humidity is too low for qualitative manufacturing the final textile product. American experts found out that by increasing relative air humidity from 60 to 79% the elasticity of cotton yarn increases by 15%. It has been proved that low relative air humidity in the sewing process of knitwear causes static electricity and it is the most common cause of disrupting fibers and damaging loops [10-12].

Sewing needle selection

The quality of sewn seam depends on the harmony of the thickness of work piece, sewing thread and sewing needle. Based on the investigation, the influence of sewing needle size affects the diversity of damages of knitted fabric loops. If the reduction of needle diameter is arbitrary, difficulties concerning the thickness of sewing thread, necessary flexing needle strength and production diversity occur. The main task of sewing needle is to feed the sewing thread to the material for the formation of stitches. When forming a chain stitch, the sewing needle should pass through the former loop when coming to the lower dead point. When needles are too thin, there is a risk that the number of incorrect stitches increases substantially. For the reasons mentioned, sewing needle manufacturers made needles of various needle shapes in order to enable the easier sewing of delicate knitted fabric structure. Thus, loop damages could be avoided. To sew knitted fabric, it is recommended to sew with a small ball point needle designated "SES", and bulkier knitted fabrics require the use of a medium ball point needle designated "SUK" [7].

As a consequence of the rapid development of technique and sewing machines, many machine needle systems were developed for different purposes and in different countries, Figure 2. Each machine needle has two essential designations: the first designation is of system type, and the second one designates needle thickness and size, respectively. In addition to these designations, there is also the designation of the manufacturer, needle point shape, surface treatment, etc., Figure 3 [13-15].

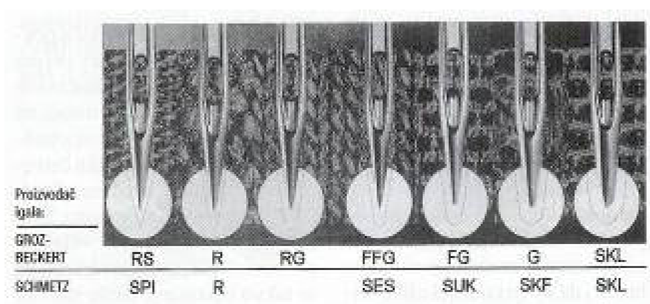

Figure 2. Designations of sewing needle points manufactured by Groz-Beckeret.

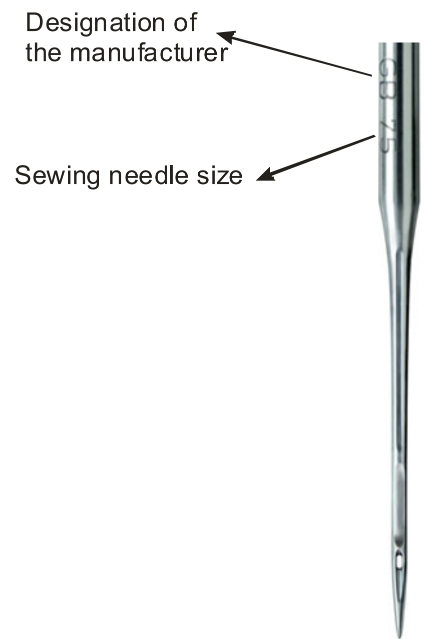

Figure 3. Designations on the sewing needle.

Sewing thread selection

It is important to make an appropriate selection of sewing threads for sewing knitwear, resulting in an appropriate strength. Knitted fabric diversity in different qualities requires a sewing thread that should enable a stable and qualitative seam. One of the properties of knitted fabric is its elasticity in the direction of wales and courses. For this reason certain demands are placed on the sewing thread: high tensile strength, elongation ability, and frictional resistance [4].

Sewing Needle Penetration Force

Sewing needle penetration force is based on the physical principle caused by friction between sewing needle and work piece. The investigations of sewing needle according to several authors differ, both in approach and measurement procedure and processing of measured data. Sewing needle penetration force is tested by measuring and variation of several elements such as: type of knitted fabric, knitted fabric treatment, type and quantity of softeners, sewing needle size, number of knitted fabric layers. To join seams without damages of loops in the knitted fabric, yarn threads are to be separated from adjacent loops, and they should have less tension around the needle than yarn tensile force. When the sewing needle penetrates the knitted fabric structure, penetration force occurs, which depends on the tension of the yarn thread of the enclosed loop.

Penetration force is calculated according to the expression:

$F = \mu T$ μ – friction coefficient of yarn and needle
T- yarn tension

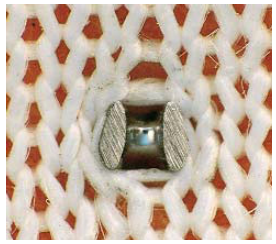

Figure 4. Penetration of F sewing needle through a knitted fabric loop.

A lower penetration force causes a lower number of loop damages of the knitted fabric, and by using softeners, sewing needle penetration force decreases notably as well as the number of knitted fabric damages. The reduction of frictional resistance in sewing is of great importance, especially on modern sewing machines which have a high sewing speed causing higher sewing needle heating, and an overheated sewing needle damages the seam of the article of clothing.

Working Method

To investigate sewing needle penetration force, a dyed plain jersey 30 x 25 cm was used. Penetration force was tested on a knitted fabric sample consisting of two, three and four layers. Three different softener types with two different quantities were used to soften the knitted fabric. Samples were stitched with two different sewing needle sizes: 70 nm and 80 Nm made by Schemtz, and needle point shape with needle designation SES and appropriate sewing thread count. Sewing thread count is 12.5 x 2 Tex. The sewing speed of the machine was 3000 stitches/min and stitch length 2 mm during testing penetration force on the machine. Each sample was stitched over seam length of 100 stitches. The investigation of sewing needle penetration force was made in a laboratory where air temperature wa from 20 to 21 °C and relative air humidity was 60%.

The knitted fabric in tubular form was dyed with reactive dyes on a jet dyeing machine. The following softeners were used to soften the dyed knitted fabric:

- Tubingal SKI, designation 1
- Tubingal NPJ, designation 2 and
- Tubingal KRE, designation 3 [13].

Instrument For Measuring Sewing Needle Penetration Force

The instrument for measuring sewing needle penetration force consists of: a Pfaff 1053 sewing machine, impulse counter, penetration force sensor, analog-to-digital converter, signal amplifier and computer. Knitted fabric samples are stitched on the Pfaff 1053 sewing machine using double lockstitches, stitch type 301. The sewing machine operates with a sewing speed of 6,000 stitches/min. The number of stitches can be adjusted individually, and the sewing speed can be adjusted in intervals of 10 stitches.

Sewing needle penetration force is measured by means of sewing and a special sensor for measuring penetration forces which is located under the throat plate of the sewing machine. When measuring penetration force, the sewing needle penetrates the sample and enters into the throat plate. The analog-to-digital converter converts measuring signals of the sensor from the analog into the digital form; afterwards the data are stored on the computer to process and analyze the data. The Nemess program 5.0 is used for data processing. Its special settings are: time relationships and relationships depending on the swing angle of the machine for at least four simultaneously measured signals at a specific number of revolutions of the main sewing machine. The program makes it possible to represent the results on the monitor in the form of graphs, in cascade principle and histograms.

This measuring instrument is at the Faculty of Textile Technology of The University of Zagreb. It was designed in collaboration with ITV-Denkendorf, Fig. 6 [17].

Figure 6. Instrument for measuring sewing needle penetration forces.

In measuring the curve of the signal of the force sensor can be divided into four areas for one revolution of the main sewing machine:

- swing angles from 10° to 100° show the curve of the tension force of the under thread
- swing angles from 100° to 102° show the curve of the penetration force of the sewing needle point
- swing angles from 100° to 190° show the curve of the penetration force of the sewing needle
- swing angles from 250° to 325° show the curve of the force of the needle thread

The figure shows the curve of the sewing needle.

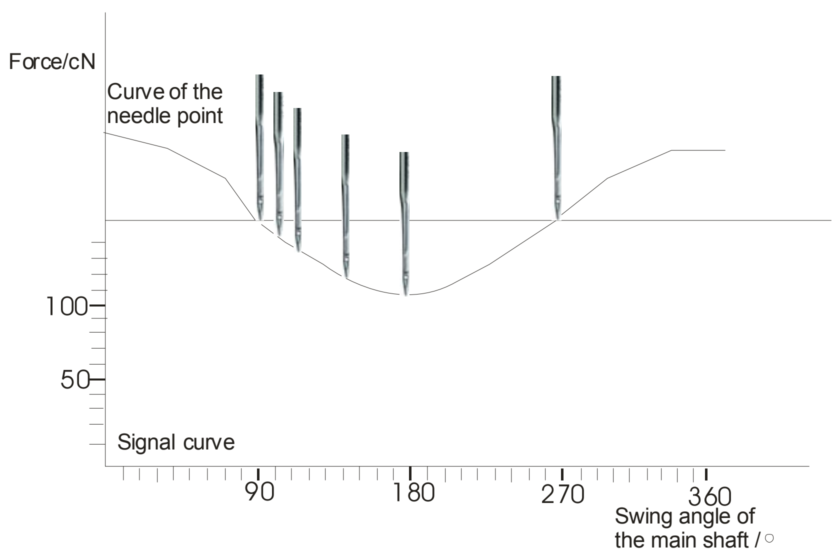

Figure 7. Curve of the signal of the force sensor during one rotation of the shaft of the sewing machine.

Properties of the softener

Tubingal SkI with designation 1 is a nonionic/pseudo-cationic softener based on condensed products of fatty acids and silicones with addition of special products. This softener was applied in the exhaust method on the jet dyeing machine in a bath with the softener amount: 1.5% and 3.0% at pH 5.5 modified with acetic acid at 40° over 20 minutes. Afterwards it was dried, and the knitted fabric was not rinsed after softening. Tubingal KRE with designation 2 is a nonionic softener based on condensed products of fatty acids with addition of wax emulsion.

Tubingal KRE with designation 3 is a cation-active softener based on condensed products of fatty acids.
The exhaust method was used for softening knitted fabric samples on the dyeing machine in a bath with softener quantity: 1.5% and 3.0% at pH 5.5 modified with acetic acid over 20 minutes. Afterwards it was dried, and the knitted fabric was not rinsed after softening [13].

Results

Based on the test conditions the results obtained for sewing needle penetration forces are shown in the following tables. The test results obtained are classified according to knitted fabric treatment, type and quantity of softener, sewing needle sizes and number of layers of the sewn knitted fabric sample. Table 1 shows the test results of sewing needle penetration force depending on softener type and quantity, and sewing needle size by stitching two layers of knitted fabric layers. Table 2 shows the test results of sewing needle penetration force depending on softener type and quantity and sewing needle size by stitching three layers of knitted fabric. Table 3 shows the test results of sewing needle penetration force depending on the softener type and quantity and sewing needle size by stitching four layers of knitted fabric.

Table 1: Results of the average values of sewing needle penetration force F depending on the softener type and quantity, needle size for the stitched samples consisting of two layers of dyed, dyed and softened knitted fabric at a stitching speed of 3000 stitches/min.

				Sewing needle size, Nm	
Sample designation	**Knitted fabric treatment**	**Softener type**	**Quantity of softener [%]**	**70**	**80**
				Penetration force F [cN]	
01	Dyed and softened	1	1.5	191.2	335.3
02	Dyed and softened	1	3.0	188.4	311.7
03	Dyed and softened	2	1.5	192.5	348.7
04	Dyed and softened	2	3.0	184.2	305.4
05	Dyed and softened	3	1.5	362.1	618.5
06	Dyed and softened	3	3.0	349.5	602.3
07	Dyed	-	-	580.3	846.5

Table 2: Results of the average values of sewing needle penetration force F depending on the softener type and quantity, needle size for the stitched samples consisting of three layers of dyed, dyed and softened knitted fabric at a stitching speed of 3000 stitches/min.

				Sweing needle size, Nm	
Sample designation	**Knitted fabric treatment**	**Softener type**	**Quantity of softener [%]**	**70**	**80**
				Penetration force F [cN]	
08	Dyed and softened	1	1.5	311.3	384.6
09	Dyed and softened	1	3.0	307.6	347.1
10	Dyed and softened	2	1.5	318.9	391.4
11	Dyed and softened	2	3.0	301.5	376.8
12	Dyed and softened	3	1.5	541.6	798.8
13	Dyed and softened	3	3.0	528.9	749.5
14	Dyed	-	-	895.8	1254.9

Table 3: Results of the average values of sewing needle penetration force F depending on the softener type and quantity, needle size for the stitched samples consisting of four layers of dyed, dyed and softened knitted fabric at a stitching speed of 3000 stitches/min.

				Sewing needle size, Nm	
Sample designation	**Knitted fabric sample**	**Softener type**	**Quantity of softener [%]**	**70**	**80**
				Penetration force [cN]	
15	Dyed and softened	1	1.5	457.2	691.3
16	Dyed and softened	1	3.0	405.6	580.2
17	Dyed and softened	2	1.5	403.4	650.8
18	Dyed and softened	2	3.0	375.8	510.4
19	Dyed and softened	3	1.5	716.3	902.5
20	Dyed and softened	3	3.0	695.8	906.2
21	Dyed	-	-	1115.8	1390.5

Discussion

On the basis of the above results of the investigation of controlling technical technological parameters on the number of loops damaged during sewing knitwear, it became evident that the number of layers of the sewn knitted fabric, the softener type and quantity, and the sewing needle size all have notable influence. In view of the results in Table 1, a notably higher penetration force value on the dyed knitted fabric in relation to the dyed and softened knitted fabric on average of 53.7% in stitching the two-layered samples using a needle size of 70 Nm was observed. By stitching two layers of the dyed knitted fabric using a needle size of 70 Nm, penetration force is lower by 31.4% in relation to stitching the same sample using a needle size of 80 Nm.

Using a needle size of 70 Nm and softener designated 1 with a concentration of 1.5% penetration force is lower by 1.46% in relation a softener concentration of 3.0%. Using the same needle size and softener designated 2 with a concentration of 1.5% penetration force is lower by 4.3% in relation to a softener concentration of 3.0%. Penetration force in the case of softener designed 3 with a concentration of 1.5% is lower by 3.5% in relation to a concentration of 3.0% of the same softener.

When stitching the sample using a needle size of 80 Nm, the penetration force value of the dyed and softened knitted fabric designated 1 with a softener concentration of 1.5% is higher by 42.9% in relation to stitching the samples using a needle size of 70 Nm, and for the sample of the dyed and softened knitted fabric with a softener concentration of 3.0% it is higher by 39.5%. Using softener designated 2 with a concentration of 1.5% penetration force is higher by 44.8% when stitching the samples with a needle size of 80 Nm in relation to stitching the samples using a needle size of 70 Nm, and for the sample of the bleached and softened knitted fabric with a softener of 3.0% it is higher by 39.7% in relation to stitching the sample using a needle size of 70 Nm.

Using softener designated 3 with a concentration of 1.5%, penetration force is higher by 32.2% when stitching the samples using a needle size of 80 Nm, relative to stitching the samples with a needle size of 70 Nm, and for the sample of dyed and softened knitted fabric with a softener concentration of 3.0% it is higher by 29.4% in relation to stitching the sample with a needle size of 70 Nm.

The penetration force value for stitching 3 layers of the dyed knitted fabric with a needle size of 70 Nm in relation to the dyed and softened knitted fabric is on average higher by 57.1%. By stitching two layers of the dyed knitted fabric with a needle size of 70 Nm, penetration force is lower by 28.6% in relation to stitching the same sample with a needle size of 80 Nm. By using a needle size of 70 Nm and softener designated 1 with a concentration of 1.5%, penetration force is lower by 1.2% in relation to a softener concentration of 3.0%. By using the same needle size and softener designed 2 with a concentration of 1.5%, penetration force is lower by 5.2% in relation to a softener concentration of 3.0%, for softener designated 3 with a concentration 1.5% penetration force is lower by 2.3% in relation to a concentration of 3.0% for the same softener.

By stitching the sample using a needle size of 80 Nm the penetration force value for thedyed and softened knitted fabric designated 1 with a softener concentration of 1.5% is higher by 19.6% in relation to stitching the sample with a needle size of 70 Nm, and for the sample of the dyed and softened knitted fabric with a softener concentration of 3.0% it is higher by 11.4%. Using softener designated 2 with a concentration of 1.5% penetration force is higher by 18.5% by stitching the samples using a needle size of 80 Nm in relation to stitching the samples using a needle size of 70 Nm, and for the sample of the bleached and softened knitted fabric with a softener concentration of 3.0% it is higher by 20% in relation to stitching the sample using a needle size of 70 Nm.

Using softener designated 3 with a concentration of 1.5% penetration force is higher by 32.2% by stitching the samples using a needle size of 80 Nm in relation to stitching the samples using a needle size of 70 Nm, and for the sample of the bleached and softened knitted fabric with a softener concentration of 3.0% it is higher by 29.4% in relation to stitching the sample using a needle size of 70 Nm. In the case of testing sewing needle penetration forces by stitching the sample of three-layered dyed knitted fabric using a needle size of 70 Nm it is noticed that penetration force is higher by 35.2% in relation to stitching the two-layered dyed knitted fabric with a needle size of 70 Nm, by stitching with a needle size of 80 Nm it is higher by 32.5%.

By stitching four layers of the dyed knitted fabric using a needle size of 70 Nm in relation to the dyed and softened knitted fabric the penetration force value is on average higher by 54.4%. By stitching the four-layered dyed knitted fabric using needle size of 70 Nm penetration force is lower by 19.8% in relation to stitching the same sample using a needle size of 80 Nm. Using a needle size of 70 Nm and softener designated 1 with a concentration of 1.5% penetration force is lower by 11.3% in relation to a softener concentration of 3.0%. Using the same needle size and softener designated 2 with a concentration of 1.5% penetration force is lower by 6.8% in relation to a softener concentration of 3% penetration force for the softener designated 3 with a concentration of 1.5% is lower 2.8% in relation to a concentration of 3% of the same softener.

By stitching the sample using a needle size of 80 Nm the penetration force value for the dyed and softened knitted fabric designated 1 with a softener concentration of 1.5% is higher by 33.9% in relation to stitching the sample with a needle size of 70 Nm, and for the sample of the dyed and softened knitted fabric with a softener concentration of 3.0% it is higher by 30.1%. Using softener designated 2 with a concentration of 1.5% penetration force is higher by 38.0% by stitching the samples using a needle size of 80 Nm in relation to stitching the samples using a needle size of 70 Nm, and for the sample of the bleached and softened knitted fabric with a softener concentration of 3.0% it is higher by 26.4% in relation to stitching the sample using a needle size of 70 Nm.

Using softener designated 3 with a concentration of 1.5% penetration force is higher by 20.6% by stitching the samples using a needle size of 80 Nm in relation to stitching the samples using a needle size of 70 Nm, and for the sample of the bleached and softened knitted fabric with a softener concentration of 3.0% it is higher by 23.2% in relation to stitching the sample using a needle size of 70 Nm.
In the case of testing sewing needle penetration forces by stitching the sample of four-layered dyed knitted fabric using a needle size of 70 Nm it is noticed that penetration force is higher by 19.7% in relation to stitching the three-layered dyed knitted fabric with a needle size of 70 Nm, by stitching with a needle size of 80 Nm it is higher by 9.7%.

Conclusion

Based on the measurements and results obtained for the investigation of sewing needle penetration force, using different types of softeners and their quantities, sewing needle size, number of layers of stitched materials it can be concluded:

- The reduction of sewing needle penetration force depends on knitted fabric finishing, type and quantity of softeners, their quantity, sewing needle size and number of layers of the stitched sample.
- On a dyed and unsoftened sample high values for the sewing needle were found, ranging form 580 cN to 1390.5 cN. Using softeners designated 1, 2 and 3, penetration force values decrease significantly.
- The highest reduction of penetration force was observed when using softener designated 2, and the lowest one when using softener designated 3.
- Sewing needle size also influences penetration force values; by increasing sewing needle size penetration force value increases too.
- By increasing the number of layers of the stitched sample an increase in the value of sewing needle penetration force was also observed.

Joint work and collaboration between knitted fabric manufacturers, knitted fabric finishing and garment manufacturers are essential in order to satisfy high demands of the market and consumers.

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