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Examination of the Effects of the Physical Properties of Woven Fabrics on the Heating of Sewing Machine Needles

Abstract

The elementary process of the garment production process is sewing. Sewing, the most important element determining quality and durability in garment production, is the process of getting the sewing thread through the material that will be sewn with the help of a needle, either for the purpose of strengthening or trimming. This process is the backbone of the course of production. Carrying it out as desired will have an effect on utilising production resources and time spent in production more effectively and on achieving the quality level in the final product expected. The heat generated as a result of the needle's friction against the surface of the textile and the properties of the fabric that affect the heating in the sewing process of woven fabrics were examined in this study. Fabrics of seven different weights, densities and blends were used. An Optris CT3M Pyrometer was used in the implementation to measure the heat on the needle.

Key words: sewing machine needle, heating, woven fabric.

Introduction

The elementary process that enables the emergence of ready-made clothing and garment industries is the process of sewing. Sewing is an invaluable process of production in industries like clothing, shoemaking, home textile, automobile etc., which is why the efficiency of production is one of the main elements affecting production quality. It particularly affects production quality in the ready-made clothing industry.

Despite the increased production capacity and changing textile surfaces in recent years and sewing machines that work at very high speeds whilst being able to flawlessly stitch any textile surface, improvements are still ongoing. These new sewing machines and automations, with speeds varying from 2,000 to 6,000 stitches per minute, have brought about an important problem, that is the heating of the needle and consequent mistakes of different kinds, leading to a loss of productivity and quality [1 -3].

The goal of this study was to examine the effects of the physical properties of woven fabrics on the heating of sewing machine needles. The rest of this paper is set out as follows: The next section provides a brief review of literature relating to the sewing machine needle and heating problem, and the third sections sets out the research methods of the study. The findings and discussion are in the fourth section, and Conclusions are in the final section.

Literature review

Process of sewing

The sewing process is the last step of a long serial production process. The items of clothing deteriorating at this stage due to bad stitching causes great losses of time, energy and also material. The most important sewing mistakes are heat-related and mechanical damage caused by the sewing needle. During the process of sewing, the fabric resists the thrust of the sewing needle. The frictional resistance between the sewing needle and fabric causes heat to be released and the needle to overheat during high-speed sewing. The heated needle may punch holes in the fabric by melting the thermoplastic threads in the fabric and result in a weak stitch [2].

Sewing is done by having the sewing thread jabbed into the material to be sewed, and running it through, according to the rules of thread placement in the sewing process. The reasons for this process are assembly, strengthening or embroidering [4].

Another definition of sewing is an assembly technique using needles, threads, fabrics and machines in accordance with certain methods [2].

Turning two-dimensional fabric into three dimensional clothing is the basic research topic of the science of ready wear. The process of sewing is one of the principal factors in the creation of an item of clothing, being the result of the interaction between the fabric and sewing thread. The sewability of the fabric

has a direct effect on the quality of the item of clothing to be made of that fabric. Stitching efficiency is also an important variable that affects the sewability of the fabric [6].

Sewing machine needles

The process of sewing requires machine needles, the properties, shape, measurements and proper application of which have direct effects on the sewing quality [5].

The sewing needle plays an important role in creating the most suitable sewing process. The needles help create stitches by running the thread through the fabric and creating knots by holding the upper yarn [4].

The needle is the sewing element that ensure the completion, beauty and durability of the stitch [5]. There are over 100 different types of industrial sewing needles on the market today, being of varying heights, thicknesses, shapes and points. Typical industrial sewing needles have fifteen parameters, among which are the shape of the needle, its point, number, holes etc. Each one of these parameters has an effect of varying degrees on the heating of the needle [7, 8, 11].

Heating problem of the sewing machine needle

Despite the growing automatisations of the process, ready-made clothing production still retains the quality of being labour intensive, which is why there are great numbers of human-, machine- and process-induced problems. Failure to

Table 1. Properties of fabrics used in the study.

Fabric code	Fabric weaving type	Raw material	Surface mass, g/m ²	Fabric thickness, mm	Linear density, tex	Linear density, tex	Weft frequency, thread/cm	Warp frequency, thread/cm
B1	Plain	100% Cotton	125	0.33	9.84	10.01	18	24
B2			318	1.61	26.84	12.56	18	34
D1			211	0.33	11.81	9.52	24	40
D2	Twill	100% Wool	393	1.73	29.53	28.12	18	26
D3			169	0.29	17.24	28.57	41	34
D4			196	0.37	31.25	32.25	29	33
D5			228	0.38	37.03	38.46	26	32

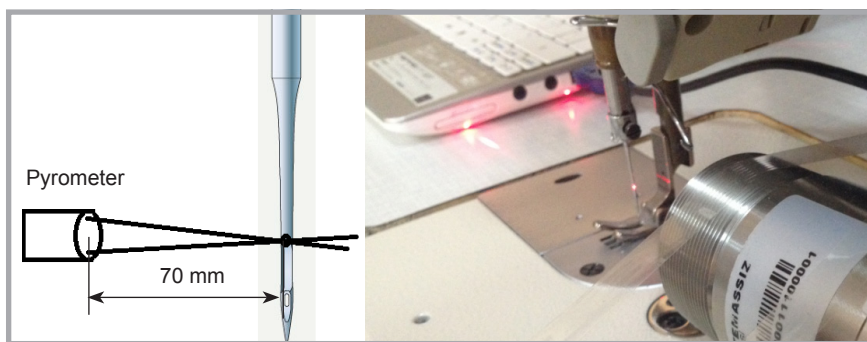


Figure 3. Focus of laser lights on the needle.

spot these mistakes in time may cause great losses in productivity [6].

The heating of the needle causes several problems that affect the process of sewing. It is preferable to keep the needle's temperature below 140 °C [10].

A high amount of heat is produced during the process of sewing as a result of the friction between the sewing machine needle, sewing thread and fabric. The amount of heat depends on the speed of sewing, thickness of fabric and the number of the needle [2].

The main factors that cause the needle to heat are:

- Speed of sewing,
- Properties of the material to be sewn,
- Yarn tension,
- Heat conductivity and specific heat of the material to be sewn.

Among these, the type and number of the needle, the end process applied to it, the thread and fabric are secondary factors [10].

Heat produced during the process of sewing is the result of friction between the fabric and needle. The amount of heat produced depends on the machine's speed, the number, section and surface of the needle, the density, thickness and end processes of the fabric, as well as on the

type, thickness and end processes of the sewing thread [9, 10].

The two primary sources of heat are the area of thread crossing through the fabric and the area of knots stuck between the needle and fabric. Research shows that needle heating may go up to as much as 350 °C [10].

Stitching damage in woven fabrics consists of severed threads or melted threads and yarns, and is usually covered by the sewing yarn. The fabric is weakened in these areas, and can be torn apart at the seamline under pressure of being worn. Stitching damage is far more important in knitted fabrics. Broken threads result in skipped knots and even complete deterioration of the knitting structure. Some stitching mistakes are not recognised during the process of sewing and later become apparent when stretched during wearing, moving and washing [2].

■ Experimental

Materials

In this study, conducted to survey the effects of sewing needle heating on the physical properties of textiles, textile surfaces of 100% cotton and 100% wool mixtures, plain woven and twill woven were used. A total of seven different woven fabrics are utilised. Physical properties of these fabrics are shown in Table 1.

Method and test machines

Properties of the fabrics used in this study were determined under laboratory conditions of 20 ± 2 °C temperature and $65 \pm 2\%$ humidity. Sewing studies where the needle temperature is measured were conducted under the same laboratory conditions. Standards used in analysing the fabric properties are as follows: TS 251 – Woven Fabrics – Determination of the Mass Per Unit Length and the Mass Per Unit Area of the Woven Fabrics to determine the fabric weight, Determination of the frequency of woven fabrics TS 250 – Woven Fabrics – Construction – Methods of Analysis – Determination of the Number of Threads Per Unit Length to determine the density of woven fabrics, TS 255 - Textile - Woven Fabrics - Construction - Methods of Analysis - Determination of Linear Density of Yarn Removed From the Fabric to determine the number of yarns that make up the fabric. An Optris CT3M Pyrometer (Optris GmbH, Germany) was used to determine the needle's temperature. Specifications of the Optris CT3M Pyrometer are shown in Figure 1.

Specifications of Optris CT3M Pyrometer

- Miniaturised Infrared Thermometer with 2.3 µm wave length range for measurements of metals, secondary metal processing, metal oxides and ceramic materials
- Very small sensing head of 14 mm diameter and 28 mm length, able to fit everywhere
- Usable up to 85 °C ambient temperature without cooling
- For measurements we used the exchangeable optics 3ML CF1 which enabled to obtain a measuring spot of 1.2 mm diameter at a distance of $D = 70$ mm.
- For measurements of metal surfaces with a very low start temperature of 50 °C
- Short wave length range of 2.3 µm to reduce the error of reading in measurements of materials with unknown emissivity
- Measurement specifications;
 - Temperature ranges: 50 - 400 °C
 - Spectral ranges: 2.3 µm
 - Optical resolution: 22:1
 - System accuracy (at ambient temperature 23 ± 5 °C): $\pm (0.3\%$ of reading $+2$ °C)

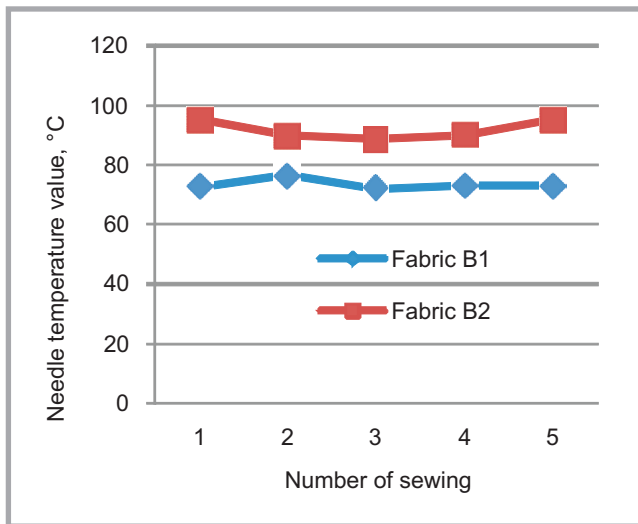


Figure 2. Effects of weight on the needle temperature for 100% cotton fabrics.

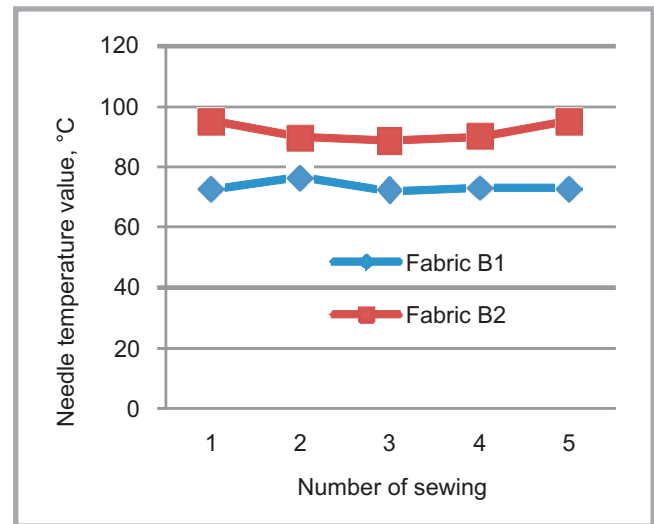


Figure 4. Effects of the weight on the Needle Temperature for 100% wool fabrics.

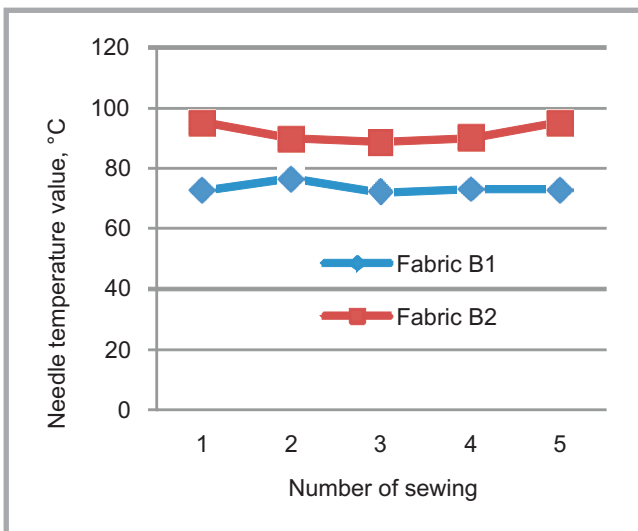


Figure 3. Effects of weaving type on needle temperature.

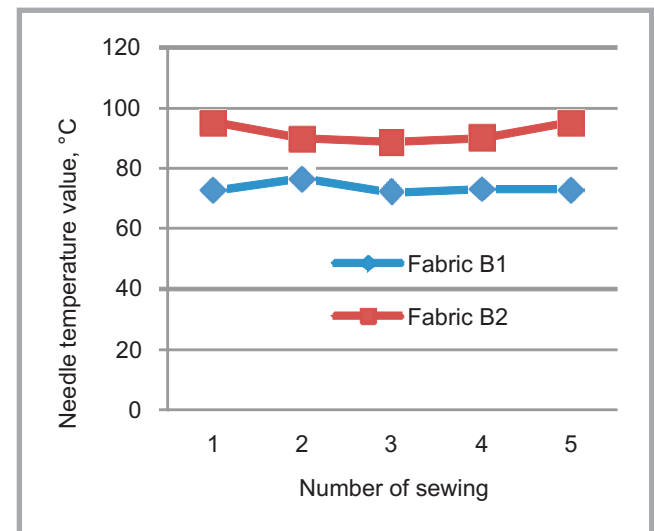


Figure 5. Effects of fibre type on needle temperature.

- Repeatability (at ambient temperature 23 ± 5 °C): \pm (0.1% of reading +1°C)
- Temperature resolution (digital): 0.1 K
- Exposure time (90% signal): 1ms
- Emissivity/gain (adjustable via programming keys or software): 0.100 – 1.100
- Transmissivity/gain (adjustable via programming keys or software): 0.100 – 1.100

- Sewing needle: Nm 80 (12)
- Seam density in 1 cm: 5 seam/cm.

Determining the needle temperature

In this study, conducted to examine the effects of the physical properties of woven fabrics on sewing needle heating, apparatus was set up to determine the needle temperature.

The laser light of the pyrometer used to measure the needle temperature was focused on the sewing needle. The emissivity of the needle was taken as 0.8 for the thermal images due to the needle's material being made of chromium. The system was set up to make 100 measurements per second. Because the laser light was focused on the sewing needle the entire time, while the sewing machine was working, measurements were made

for the entire surface of the needle that comes in contact with the fabric. The distance between the needle and pyrometer was set at 70 mm (see *Figure 1*).

No sewing thread was used in this study as the thread may absorb a certain amount of heat from the needle. Fabrics were cut into pieces of 20×100 cm, ten pieces of each kind. The fabric pieces were kept for a day under laboratory conditions before the process of sewing began. Five processes of sewing were completed with each kind of fabric. Two layers of the fabrics were used in the sewing process. Approximately 100 measurements per second were completed in the measuring study. The process of sewing a 1 m long piece of fabric took approximately 10 seconds. In this time-span, the pyrometer recorded approximately 1,000 temperature values.

Sewing conditions

Experimental studies were done under the sewing conditions listed below:

- Sewing machine: Juki DDL 9000A-SS lock stitch machine (Japan)
- Sewing type: 302 lock stitch
- Sewing machine motor cycle: 3500 r.p.m

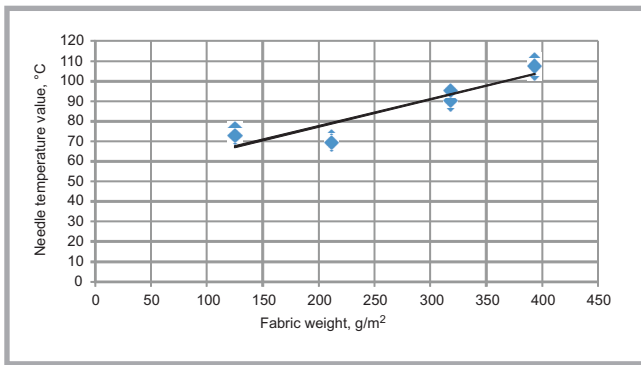


Figure 6. Fabric weight effect on needle temperature for cotton fabrics.

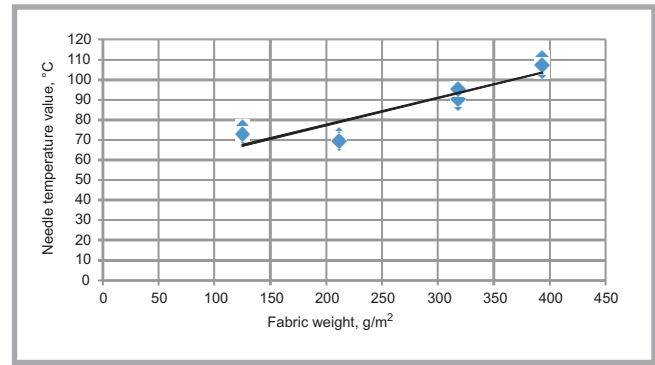


Figure 7. Fabric weight effect on the needle temperature for wool fabrics.

Findings

The values obtained from the mechanism set up were transferred to a computer and analysed, then organised in a way that takes only maximum temperature values into consideration. Findings gathered from the analyses were interpreted in four different ways.

100% cotton fabric - two different weight

Considering sewing machine needle temperature values for fabrics of 100% cotton and two different weights, see *Figure 2*, it was determined that temperature values are raised along with the weight of the fabric. When physical properties belonging to fabrics B1 and B2 in *Table 1* are examined, thickness and warp sets of the fabric change along with the weight. Increased thickness and warp sets in the fabric results in a greater friction surface between the fabric and needle in the process of sewing. It is safe to assume that this is the cause of the increase in needle temperature.

100% cotton fabric - two different weaving types

Considering sewing machine needle temperature values for fabrics of 100% cotton and of two different kinds of weaving (plain and twill), see *Figure 3*, it was determined that the style of weaving has a small effect on the needle temperature value. As seen in *Table 1*, B1 and B2 are fabrics belonging to the plain weaving class, whereas D1 and D2 are thrill. But the increase in weight for fabrics of both kinds of weaving is accompanied by an increase in the needle temperature.

100% wool fabric – three different weights

Regarding sewing machine needle temperature values for fabrics of 100% wool and of three different weights, see *Fig-*

ure 4, it was determined that the temperature values rise as the fabric weight changes. When physical properties for fabrics D3, D4 and D5 in *Table 1* are examined, it is observed that the thickness of the fabric and threads used change along with the weight of the fabric. An increase in the thickness of the fabric and weft/warp threads leads to a greater friction surface between the fabric and needle in the process of sewing. It can be assumed that this raises the needle temperature.

Twill weaving type – two different fibre types

When sewing machine needle temperature values belonging to twill woven fabrics of two different kinds of fibre were studied, see *Figure 5*, it was observed that the kind of fibre has an insignificant effect on the needle temperature value.

Correlation analysis

Correlation between fabric weight and needle temperature

In this stage the relationship between the temperature of the needle and weight of woven fabrics used in the experimental studies was analysed. Analyses were performed separately for cotton and woollen fabrics.

Needle temperature values were obtained from four different 100% cotton woven fabrics which have different weight values. Results show that there is a positive high correlation between the temperature values of the needle and fabric weight. (see *Figure 6*) $r = 0.915$.

Needle temperature values were obtained from three different 100% wool woven fabrics which have different weight values. Results show that there is a positive high correlation between the temperature values of the needle and the fabric weight (see *Figure 7*) $r = 0.914$.

Correlation between the fabric thickness and needle temperature

Needle temperature values were obtained from six different 100% wool and 100% cotton woven fabrics which have different thickness values. Results show that there is a positive high correlation between the temperature values of the needle and the fabric weight (see *Figure 7*) $r = 0.923$.

When cotton and wool fabrics were analysed separately results show that there is an important difference between the correlation values. For cotton fabrics the correlation coefficient between the fabric thickness and needle temperature values is $r = 0.938$, and that for wool fabric is $r = 0.85$.

Summary

In this study, which examines the effects of woven fabric properties on the heating of sewing machine needles, a total of thirty-five sewing processes were applied to pieces of different types of woven fabric of various densities, weights and fibre types. The temperature value of the needle was measured contact-free with a pyrometer. At the end of the measurement, only the highest values were taken into consideration.

At the end of the sewing processes, a correlation between the basic properties of the woven fabrics and the temperature of the sewing machine needle was established. Particularly in cotton fabrics, the increase in fabric weight, followed by changes in other basic properties (density, thickness etc.), leads to an increased needle temperature. The results obtained can be summarised as follows;

■ Regarding sewing machine needle temperature values for fabrics of 100% cotton and two different weights, it was determined that temperature val-

ues rise along with the weight of the fabric.

- Considering sewing machine needle temperature values for fabrics of 100% cotton and two different kinds of weave (plain and twill), it was determined that the weave type has a small effect on the needle temperature value.
- When sewing machine needle temperature values for fabrics of 100% wool and three different weights were studied, it was determined that the temperature values rise as the fabric weight changes.
- When sewing machine needle temperature values belonging to twill woven fabrics of two different kinds of fibre were studied, it was observed that the kind of fibre has an insignificant effect on the needle temperature value.
- The needle temperature increases as the fabric gets thicker, because during the sewing process the needle punches through and withdraws from the fabric. Hence the thicker the fabric is the more needle friction occurs, and this results in an increase in needle heating.

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Received 29.10.2013 Received 04.04.2014



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