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Impact of Machine Parameters on Industrial Sewing Needle Temperature

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Abstract

This article is about measuring sewing needle temperatures of three different coated sewing needlesCr (Chrome), PTFE(Polytetrafluoroethylene) and TiN (Titanium nitride)on an industrial lockstitch machine. The needle temperature testing was performedwith varying needle size, stitch density and machine speed (rpm). To measure the sewing needletemperature 'K' type thermocouple is used.It was established, according to the results obtained at the end of the measurements that there is a strong linear relation between the speed of the sewing machine, and the sewing needle temperature also the materials used in the needle coating and needle numberdirectly affect the heating of the needles. The needles coated with TiN, has been found with less needle heat-up results. The use of minimum stitch density is recommended.

Keywords

Needle Temperature, 'K' type thermocouple, Needle coating, Lockstitch.

1. Introduction

Sewing is the elementary process for the garment production process. Apart from garment production sewing is an important manufacturing operation in industries such as, shoe and leather, automobile sector, carpet, home textiles etc., therefore production efficiency is one of the key elements influencing production quality.

In industrial high-speed sewing, sewing thread is being subjected to frictional heat, torsional forces, and bending forces. Repeatedly, these forces act on the thread, and results decrease in thread tensile properties substantially [1]. Before becoming part of the seam, thread has to pass through the needle eye, fabric, and bobbin case mechanism about 40–80 times [2]. This local abrasion causes sewing needle heat-up and in industrial high-speed sewing needle heat-up is a main problem on the sewing floor. The thread is damaged by this high temperature, because the tensile properties is a function of temperaturethat results in decreased manufacturing [3]. The final stitched sewing thread, in addition, has 30-40 percent less strength than the intact sewing thread [6].

The heating of the needles is influenced by the sewing speed, needle size, shape of the needle point, surface finish of the needle, material sewn, tension of the thread, fabric thickness [5]. In the market there are lots of industrial sewing needle, these having different lengths, thicknesses, shapes, and points. Industrial sewing needle consists of many parameters e.g., needle shape, point, number, eye, proper installation etc. Each of these parameters affects sewing needle heating at different degrees [7]. Researchers found that sewing speed, thread count, sewing time, fabric structure and thickness had a significant effect on the temperature of the sewing needle [8].

To provide resistance to corrosion and mechanical wear, the needles are made of steel and electrolyzed to minimize friction during sewing. The coating material is usually chrome coating. The chrome coating (Cr) protects the needle from corrosion, and the sewing needle has a high resistance to abrasion, especially with hard chrome coating. Chrome-coated needles, however, rust and weaken rapidly. Another significant element that needles coatings are expected to have is to prevent the melted particles of synthetic fabrics or threads from sticking to the needle to some extent when the needle heat-up takes place during sewing.Polymer-impregnated surfaces are non-metal needles such as polytetrafluoroethylene (PTFE) and are said to minimize needle penetration force and thread damage due to their low friction characteristics. They also avoid sticking to the needle with melted material. Nickel-coated needles avoid rusting and protect the needle from heat and-up and corrosion, but at high temperatures, they deteriorate and change colour.Titanium nitride (TiN) coating is used to give needle a homogeneous, tough, and smooth surface. This coating also gives the needle the potential to be incredibly durable and flexible. Titanium nitride may prolong the expected life cycle of sewing machine needles [12].

Heating the needle causes numerous problems that influence the performance of the sewing process. A needle temperature below 140˚C is desirable [13]. It is well known fact that sewing machine and needle parameters also having impact on the sewing needle heating. With the increase of stitch density, needle penetrates more times inside the fabric. This could contribute to greater friction between the thread, fabric and sewing needle [4]. Some of the factors are also reported by previous researchers [7,9, 10] but there are several machine factors that affect the needle temperature and were not discussed earlier. Therefore, aim of this study is to examine the influence of stitch density, needle coating, needle size, machine speed on industrial sewing needle temperature.

2. Material and Method

2.1 Material

The properties of the materials used in study are described as follows.

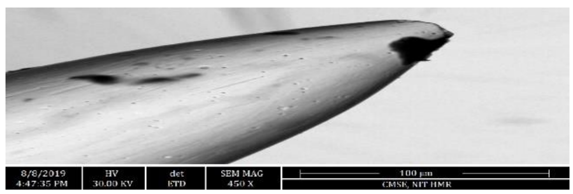
2.1.1 Sewing Machine Needle

In this work, three different needle size (Nm 90/14, Nm 100/16, and Nm 110/18) and three different coated sewing needles Chrome (Cr), Polytetrafluoroethylene (PTFE) and Titanium nitride (TiN) were used to test the needle temperature at high-speed industrial sewing. Average roughness values ofsewing machine needles are discussed in Table 1.

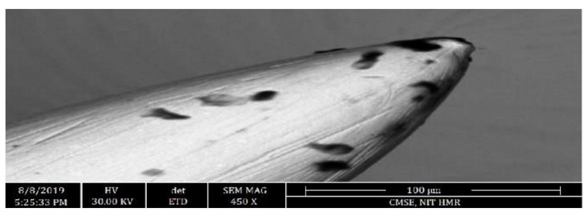
Table 1 Coating Properties of needles

Needle coating Material	Average Roughness Ra
Chrome (Cr)	679.6 nm
Polytetrafluoroethylene (PTFE)	665.3 nm
Titanium nitride (TiN)	653.7 nm

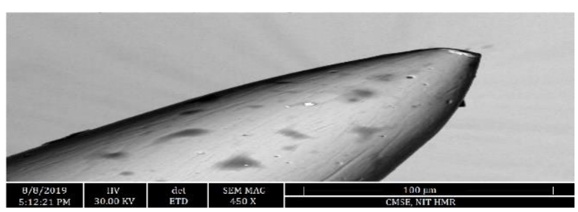
Surface roughness was measured by taking two Scanning electron Microscopy (SEM) images at different tilt angles which was then used for calculating 3D image of the surface using MeX-3D software. SEM images of different coated needles are shown in Figure 1.



(a)



(b)



(c)

Figure 1 Scanning Electron Images of Different Coated Needle (a) Chrome (b) PTFE (c) TiN

2.1.2 Denim Fabric and Sewing Thread

Sewing thread used in the study is 20 tex polyester/polyester core spun, Z twisted with 6.3 twist per centimetre and having coefficient of friction 0.16. 3/1 twill woven 100% cotton denim fabric with GSM 379 and thickness 1.73 mm is used for stitching purpose.

2.1.3 Sewing Machine and Temperature Measuring System

Industrial sewing machine “Brother S-7200C” single -needle direct drive straight lock stitcher is used for the study. This is a full-speed machine with AC servo motor. For measurement of sewing needle temperature K type thermocouple (Omega -K type 5SC-TT-(K)-36-(36)) along with detector/wireless end device (Omega -MWTC-D-K-868) are used.

2.2 Method

Implanted thermocouple for measuring the temperature of a sewing needle consists of a ‘K’ type micro thermocouple (5SC-TT-(K)-36-(36)), which is attached to part of the length along the sewing needle. ‘K’ type micro thermocouple is soldered to the walls of the longitudinal groove formed in the sewing needle. Measuring end of the thermocouple is located within 5 mm by needle hole where the highest temperature reached while sewing, because here, there is a relative movement of the sewing thread with respect to sewing needle which is attached to the sewing mechanism.(Figure 2).

Figure 2 Implanted Thermocouple Method for Needle Heat Measurement

For the analysis, the denim fabric is sewn four-folded since lockstitches are used for sewing inside legs assembly of denim pants. Without stopping, the sewing process was completed for 60 seconds. With distinct stitch density ranging from 3 SPCm to 5 SPCm for each speed, the experiment was designed to run from 1500 rpm to 3500 rpm. Between each test, a five-minute break is given for the needle to reach room temperature.

In this analysis, there are four input parameters (needle coating, needle size, machine speed, stitch density), each of which has three levels. There are 81 sewing processes, and for greater statistical precision of the tests, each process is repeated twenty times. Therefore, 1620 sewing processes are carried out in complete. The conditions for all experiments are kept constant at 27˚C ± 2˚C and 65% ± 2% RH.

3. Results and Dıscussıon

The industrial lock stitch sewing machine is run at speed of 1500, 2500 and 3500 rpm for 60 seconds and needle temperature of different coated needles (Cr, PTFE, and TiN) is measured using implanted thermocouple method for the different needle size and stitch density. Highest temperature value 163 ˚C was obtained at 3500 rpm of machine speed with Nm 110/18, Cr coated needle with stitch density of 5 SPCm whereas, lowest temperature value 89 ˚C was obtained at 1500 rpm of machine speed with Nm 90/14, TiN coated needle with stitch density of 3 SPCm.

Table 2 Analysis of Variance for Sewing Needle Temperature

	Sum of Square (SS)	**Degree of Freedom (df)**	**Mean Sum of Square (MSS)**	**Fcal.**	**Ftable**	**Contribution (%)**
Machine Speed	20391	2	10195.5	1935.7	3.15	76.79
Stitch Density	1270	2	635	120.6	3.15	4.75
Needle Size	1614	2	807	153.2	3.15	6.04
Coating	2610	2	1305	247.8	3.15	9.79
Machine Speed*Coating	286	4	71.5	13.6	2.53	1.00
Machine Speed*Stitch Density	47	4	11.8	2.2	2.53	-----
Machine Speed*Needle Size	53	4	13.3	2.5	2.53	-----
Needle Size*Coating	51	4	12.8	2.4	2.53	-----
Stitch Density*Coating	17	4	4.3	0.8	2.53	-----
Stitch Density*Needle Size	5	4	1.3	0.2	2.53	-----
Error	198	48	4.1	-----	-----	-----
Pooled Error	316	60	5.267	-----	-----	-----
Total	26542	80	-----	-----	-----	-----

The ANOVA technique was used to determine the influence of individual variables and their interaction on the sewing needle temperature. The contribution of various variables was assessed using the following expression from the analysis: Contribution (%) = (SS_f− df_f.MSS_{pe}) / SS_T. Where, SS_f = Sum of square of the factor, df_f = Degree of freedom, MSS_{pe} = Mean square of pooled error, and SS_T = Total sum of squares. The contribution of machine speed, Type of needle coating, needle size and stitch density on sewing needle temperature was found to be approximately 77%, 10%, 6% and 5% respectively.

3.1 Effect of Sewing Machine Speed

From result obtained it is evident that there is a strong linear relation between the speed of the sewing machine, and the sewing needle temperature. Each 1000 rpm increase in machine speed triggers an approximately 20 ˚C increase in needle temperature. For 1500 rpm of the machine speed, average sewing needle temperature 105.8 ˚C was noted followed by sewing machine speed of 2500 rpm where average sewing needle temperature was 123.9˚C and maximum average temperature 144.1˚C was observed for 3500 rpm machine speed. The greater thermal conductivity of the sewing needle as compared to sewing thread and fabric, is the significant reason for this sewing needle temperature rise. During each step of enhanced sewing speed, more frictional heat goes through the sewing needle.

3.2 Effect of Type of Needle Coating

From figure 3,4,5 it was clear that TiN coated needles give lower sewing needle temperature values in all conditions whereas results of Cr and PTFE shows almost same values. Mean sewing needle temperature of Cr coated is 129.74 ˚C followed by PTFE coated needle (126.85 ˚C) and TiN coated needle (116.51 ˚C). The low surface roughness of TiN-coated needles causes a decrease in the frictional heat between fabric and the sewing needle compared to the other coating types used. Surface coating of sewing machine needles is one of the most significant factors that influences not only the needle's lifespan, but also the needle's temperature during the sewing process and, consequently, the performance of the sewn items.

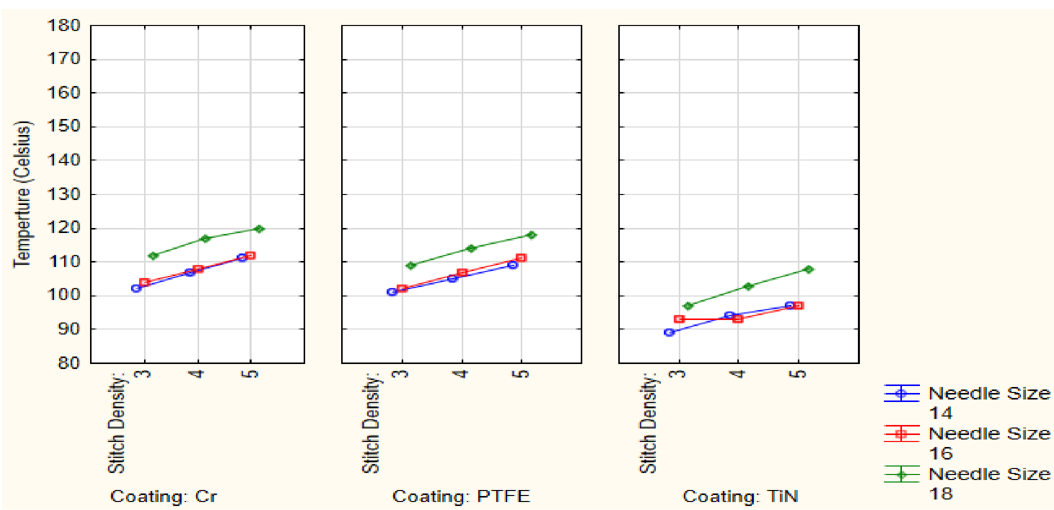


Figure 3.Impact of Needle Size, Type of Coating and Stitch Density at Machine speed of 1500 rpm on Temperature

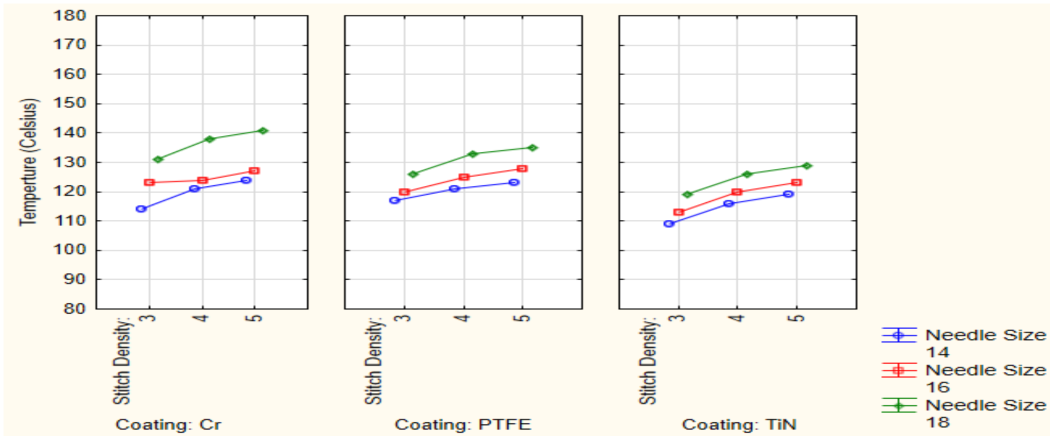


Figure 4.Impact of Needle Size, type of Coating and Stitch Density at Machine speed of 2500 rpm on Temperature

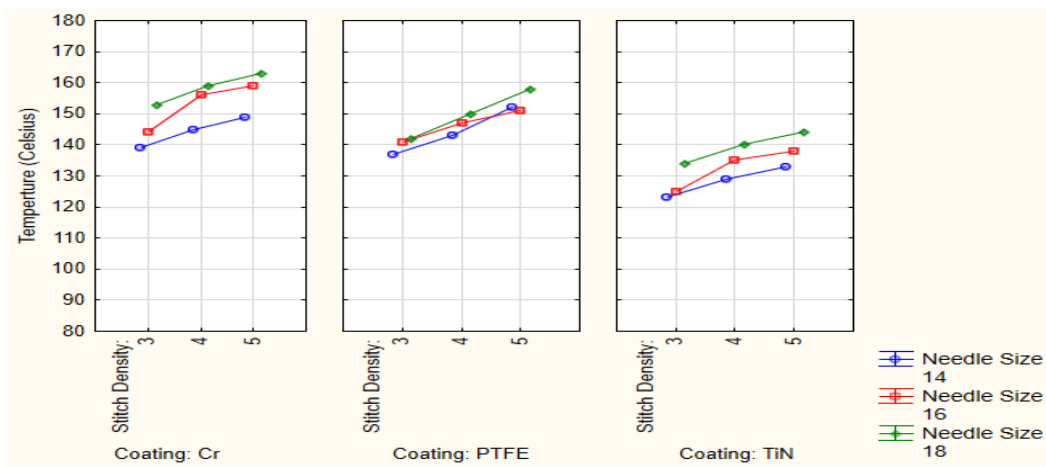


Figure 5.Impact of Needle Size, type of Coating and Stitch Density at Machine speed of 3500 rpm on Temperature

3.3 Effect of Stitch Density

The findings suggest that the needle temperature is influenced by stitch density. The temperature of the sewing needle changes with an increase in SPCm. Average mean temperature values for stitch density 3,4 and 5 is around 119˚C, 125˚C and 129˚C, respectively. As the needle needs to go into fabric several times with the rise of stitch density, which creates greater frictional forces between the needle, fabric, and the sewing thread. These frictional forces result in riseof needle temperature.

3.4 Effect of Needle Diameters

It was observed that size of needle diameters also influences the needle temperature. Different needle diameters (90 to 110Nm), which are universal needles for stitching denim fabric, were used in this analysis. Average mean temperature values for needle size 90Nm, 100Nm and 110Nm is around 120

˚C, 123 ˚C and 130 ˚C, respectively. There is a raise in the needle surface area with the increase in needle diameter, which also contributes to changes in frictional heat. Consequently, the temperature of the needle would rise.

4. Conclusıon

The effect of various factors on sewing needle temperature is discussed in this research work; it was discovered that sewing speed and surface coating had a significant impact on sewing needle temperature. Stitch density and needle size, on the other hand, had only a minor impact on the sewing needle's heating. Sewing machines used in the garment industry are becoming faster by the day thanks to technological and electronic advancements. Because of the increased machine speed, it is much more important to avoid the needle heating issue so that sewing machines can be used more efficiently. While stitch density and needle size have a smaller effect on needle heating than the other factors examined, their significance in needle heating cannot be ignored.

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