

# EXPERIMENTAL TECHNIQUES FOR MEASURING SEWING NEEDLE TEMPERATURE

## DİKİŞ İĞNESİ SICAKLIĞININ ÖLÇÜMÜ İÇİN DENEYSEL TEKNİKLER

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### ABSTRACT

In this article, three different methods (thermal camera, attached thermocouple and inserted thermocouple) are used to measure sewing needle temperatures on a lockstitch machine. The experiments were conducted at machine speeds from 16 stitches/sec to 66 stitches/sec and for a maximum time of 60 seconds. This research is useful for predicting the real temperature of needles at different sewing speeds and for comparing methods of measurement. The inserted thermocouple method showed the lowest standard deviation and highly reproducible results. The results for all the measurement techniques are compared at different sewing speeds and will be beneficial for researchers who have made theoretical models for sewing needle temperatures and need to verify them using experimental results. The information in this article will also be useful for thread lubricant producers who use thermal cameras for needle temperature measurement. All of our experiments indicate that the needle temperature is always higher when thread is used, which is contradictory to the results of some researchers, who have found that needle temperature is lower when thread is used.

**Key Words:** Sewing needle, needle temperature, needle heat measurement.

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### 1. INTRODUCTION

Industrial sewing is one of the most common manufacturing operations. Its application can be found in the manufacturing of garments, shoes, furniture and automobiles. Every day, millions of products ranging from shirts to automotive airbags are sewn. Hence, even small improvements may result in significant corporate benefits. Heavy industrial sewing, such as that used in the manufacture of automobile seat cushions, backs and airbags, requires not only high production but also high sewing quality (i.e. good appearance and long-lasting stitches). Typically, the material being sewn includes single and multiple plies of synthetic fabric or leather, sometimes backed with plastics,

and needle heat-up is a major problem on the sewing floor. In recent years, in order to increase production, high-speed sewing has been extensively used. Currently, sewing speeds range from 10~100 stitches/sec. In heavy industrial sewing, typical sewing speeds range from 16~50 stitches/sec.

Depending on the sewing conditions, maximum needle temperatures range from 100°C~300°C (1). This high temperature weakens the thread, since thread tensile strength is a function of temperature (1), resulting in decreased production (2). In addition, the final stitched thread has 30~40% less strength than the parent thread (3). Various methods for measuring needle temperature, such

as infrared pyrometer, thermocouple and temperature sensitive waxes, have been used. Because the needle is moving extremely fast during the sewing process, it is quite difficult to measure the exact temperature (4). There are few theoretical models available to predict sewing needle temperature (4, 5), but experimental verification has been done by thermal cameras, which is influenced by emissivity issues (7). Sondhelm (10) used a lacquer painted in the needle groove to observe a change of colour with temperature. Laughlin (11) tried to measure needle temperature through infrared measurement from the needle using a lead-sulphide photocell. Another technique using thermocouples was later developed by Dorkin and Chamberlain (12). As a result of improved understanding of the causes of sewing damage, many technical developments, such as improved needle design (13,15), fabric finishes (16,17,18), thread lubrication and needle coolers (13,14,15), have taken place over the years.

In this research, three different methods (thermal camera, attached thermocouple and inserted thermocouple) are used to measure the sewing needle temperature of a lockstitch machine at different machine speeds. The results are compared to see which method provides the highest accuracy and the most repeatable results. This research will be beneficial for comparing needle temperatures at different machine speeds and can also be used to verify theoretical model predictions. This research will be useful for thread lubricant producers like TEXTILCHEMIE DR. PETRY from Germany, which uses thermal cameras to measure needle temperature to test the effect of lubricants on sewing needle heat (8).

## 2. MATERIAL AND METHOD

For this research, three different methods (thermal camera, attached thermocouple and inserted thermocouple) are used to measure the sewing needle temperature on an industrial lockstitch machine (BROTHER Industries). Conditions for all experiments were kept constant at 26°C and 65% RH. The devices used for the experiments are listed below:

- Lockstitch machine (Brother Company, DD7100-905).
- Thermal camera (P60) from the FLIR Company, and TS60 from the Fluke Company.
- Thermocouple by Omega (K type 5SC-TT-(K)-36-(36)) for the inserted method.

- Thermocouple by Omega (TJ36-CAIN-010U-6) for the touch method.
- Thermocouple by Omega -wireless device and receiver (MWTC-D-K-868).
- Needles (Groz-Becker 100/16) R- type.
- Sewing thread properties are shown in Table 1.
- Fabric properties are shown in Table 2.

All methods were tested 20 times each and the results are shown with standard deviations. Maximum sewing time was 60 seconds for all techniques. The stitch length was kept constant at 5 stitches/cm and the sewing process was done both with and without thread to determine the temperature difference caused by the sewing thread. All three methods, along with their results, are presented in the next section.

### 2.1. Thermal camera Method

The Fluke TS60 is a manual thermal camera that measure temperature as triggered by the operator, whereas the FLIR P60, as shown in Figure 1, is a continuous filming camera. All thermal cameras work on the principal of emissivity of the object. For this test, the emissivity of the needle was calculated by ASTM standard E 1933 – 99a and determined to be 0.08 for a chromium polished needle at 37°C, as shown in Figure 2. As the needle is thin and shiny, it is complicated to determine the exact emissivity, and most researchers adopt the emissivity of the needle as that for polished chromium, which is 0.06 (9). Even with knowing the emissivity of the needle, measurement is extremely difficult, as the sewing process is fast and the needle moves at a rate of 30~90 stitches per second. Another problem is that the emission of the needle changes during the sewing process, as the surface characteristics change (9). Therefore, the Fluke TS60 was used for the emissivity measurement for the sewing process, and the FLIR P60 was used for measuring the needle temperature during the sewing process. The first experiment was conducted without thread at speeds of 16–50 stitches/sec; the standard deviation increased sharply at 50 stitches/sec. It is not possible to use the camera at speeds higher than that as the needle is moving more than 60 stitches per second, which makes it impossible to focus the camera on the needle. When the experiment was performed with thread even at 2,000 rpm, it was difficult to measure the needle temperature, as the thread, which has an emissivity of nearly 0.9, significantly affects the needle measurement, which has an emissivity of 0.08, as shown in Figure 3.

Table 1. Properties of the sewing thread

Thread type	Company name	Yarn count (tex)	Twist (t/m)	Twist direction (ply/single)	Coefficient of friction $\mu$
Polyester–polyester core spun	AMANN-Saba C-80	22*2	660	Z/S	0.14

Table 2. Properties of the fabric

Fabric type	Weave	Weight (g/m <sup>2</sup> )	Ends/cm	Picks/cm	Thickness(mm)
100%cotton Denim	2/1 Twill	257	25	20	0.35



Figure 1. Thermal camera FLIR P60 with Lockstitch machine

Figure 2 shows a needle with a portion painted with OMEGA paint with of an emissivity 0.96. Figure 3 shows the thermal camera picture of a sewing needle with thread at 50 stitches/sec. Due to the higher emissivity of the thread, it is almost impossible to measure the needle temperature because focusing only on the needle is difficult on machines running at 50 stitches/sec.

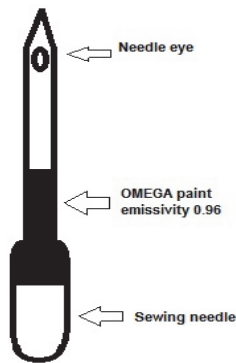


Figure 2. Needle emissivity measurement

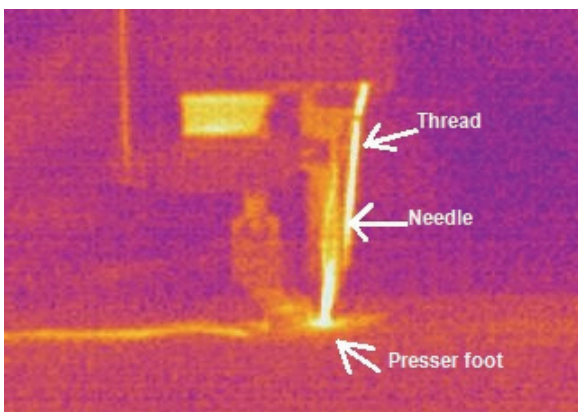


Figure 3. Needle eye temperature measured by camera

Figure 4 shows the increase in the needle temperature (without thread) with an increase of sewing speed, measured by the thermal camera. The maximum machine speed used was 50 stitches/sec, as after this speed, it was not possible to focus on the needle. Even at 50 stitches/sec the standard deviation was much higher than at slower speeds. It can be seen that after 15 seconds of sewing, there was not much difference in the needle temperature as the process stabilizes with the surroundings.

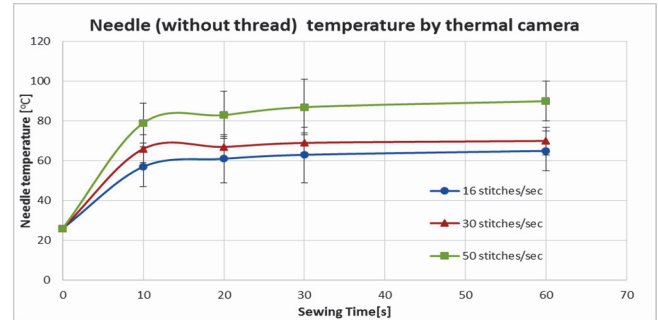


Figure 4. Needle (without thread) temperature measured by thermal camera

Figure 5 shows the increase in needle temperature (with thread) with the increase of sewing speed. The needle temperature (with thread) was higher as compared to the needle temperature without thread. The mean needle temperature reached 135°C at speed of 50 stitches/sec after 60 seconds of sewing.

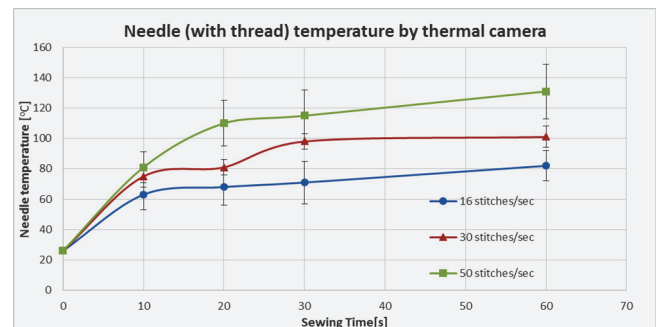


Figure 5. Needle (with thread) temperature measured by thermal camera

The thermal camera was placed at position B, as shown in Figure 6. Even changing the position from A or C caused a significant change in the needle temperature recording; this might be because of surrounding energy sources, which receive reflection from the shiny needle. These energy sources are almost impossible to omit, and performing the sewing process under an enclosed black box is not suitable for determining the exact needle temperature as the surrounding conditions will not be same as those on the sewing floor.

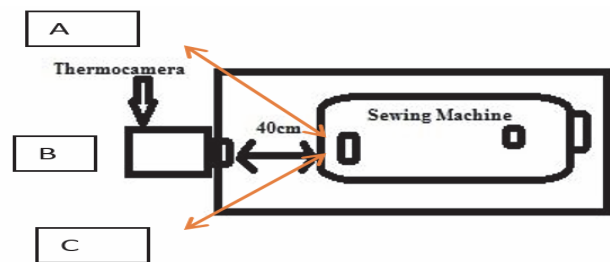


Figure 6. Placement of thermal camera

The needle (without thread) temperature can be measured by thermal camera, but the emissivity of the needle and the external energy sources reflecting off the needle make it difficult to determine the exact temperature.

## 2.2. Thermocouple touch method

In this method, a thermocouple by Omega (TJ36-CAIN-010U-6) was used to measure the sewing needle temperature. The sewing process was done for 10-, 20-, 30- and 60-second time periods, and the thermocouple was manually touched to the eye of the needle to measure the temperature. This method involved a degree of human error, as the thermocouple was applied to the needle just after the sewing process finished. Being quick when applying the thermocouple and taking multiple observations for each time period reduces the percentage of error, however, the needle temperature results were still much lower when compared with the other methods, as the needle dropped heat very quickly. Figure 7 shows the thermocouple and the placement of the thermocouple after each sewing process interval.

Figure 8 shows the needle (without thread) temperature at the different sewing speeds; the maximum machine speed was 66 stitches/sec, which shows a mean temperature of 98°C after 60 seconds of sewing. The recorded temperature was much lower than with the other methods of measurement, which might be due to delay in obtaining the measurement, as the temperature is measured manually after each sewing interval.



Figure 7. Needle temperature measured by the thermocouple touch method (6)

Figure 9 shows the needle (with thread) temperature measured by the thermocouple touch method. At a machine speed of 66 stitches/sec, the needle temperature reached 122°C, which is much higher when compared to the needle temperature without thread.

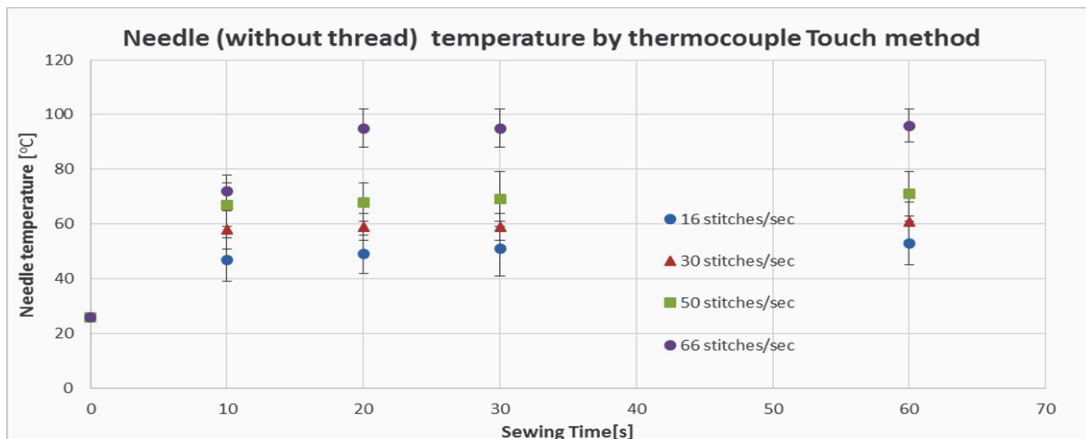


Figure 8. Needle (without thread) temperature measured by the thermocouple touch method

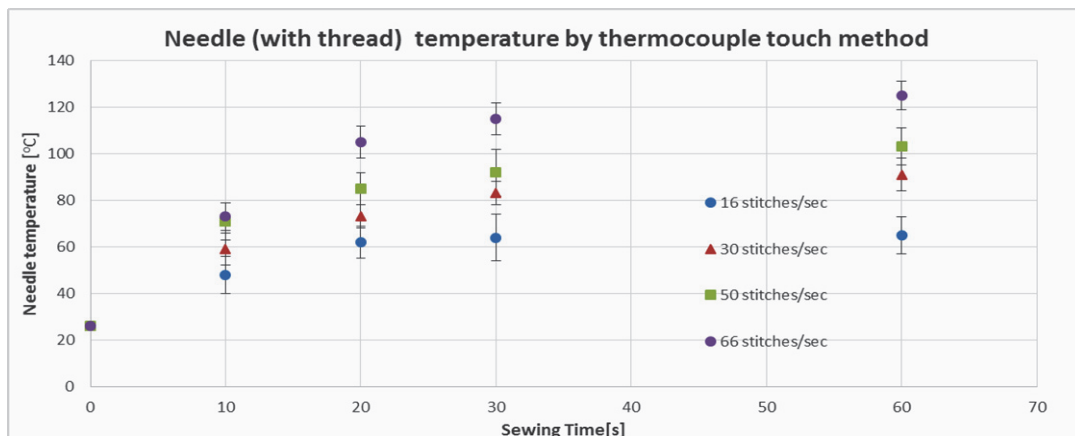


Figure 9. Needle (with thread) temperature measured by the thermocouple touch method

### 2.3. Inserted thermocouple method

In this unique method for measuring sewing needle temperature, a thermocouple by Omega (K type 5SC-TT-(K)-36-(36)) was inserted into the groove of the sewing needle and soldered. The thermocouple was located near the eye of the needle to measure the exact needle temperature, and the temperature was measured at different sewing speeds. This method proved to be very efficient as it provided continuous changes in needle temperature every second and it had a low standard deviation. Figures 10 and 11 show the placement of the thermocouple inside the needle groove. The thermocouple remained inside the needle groove during the sewing process and measurements were recorded wirelessly on a computer through a wireless end device (MWTC-D-K-868).

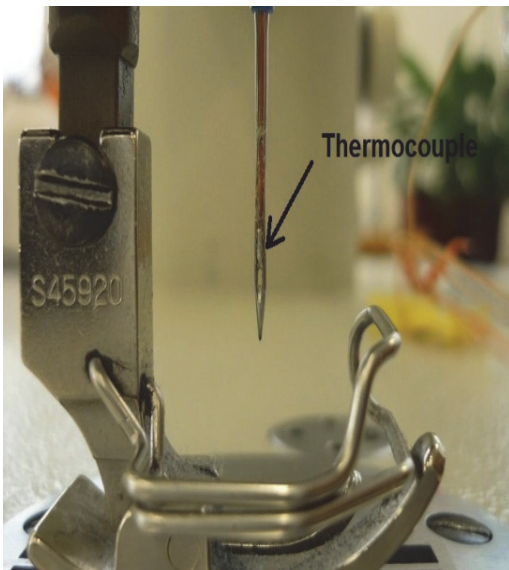


Figure 10. Inserted thermocouple

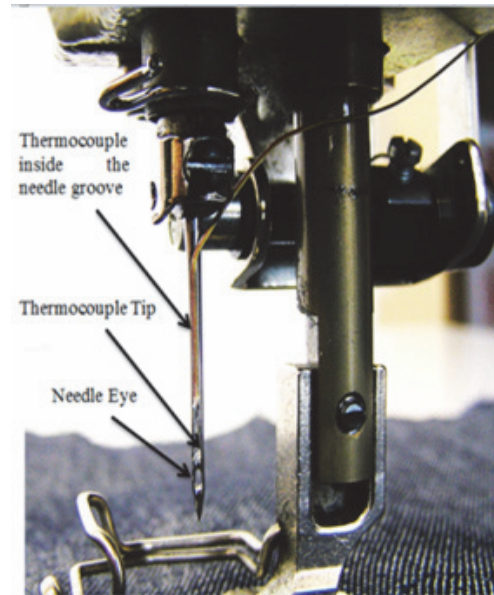


Figure 11. Placement of the thermocouple

Figure 12 shows the needle temperature measured by the inserted thermocouple method without thread. At a sewing machine speed of 66 stitches/sec, the needle temperature reached 110°C, which is almost 20°C higher than the temperature measured by the touch method. This method proved to be efficient for the different machine speeds and had a lower standard deviation as compared to the other methods of measurement.

Figure 13 shows the needle (with thread) temperature measured by the inserted thermocouple method at the different machine speeds. At 66 stitches/sec, the needle reached an average temperature of 202°C after 60 seconds of sewing, which is almost twice the needle temperature recorded in the trial without thread.

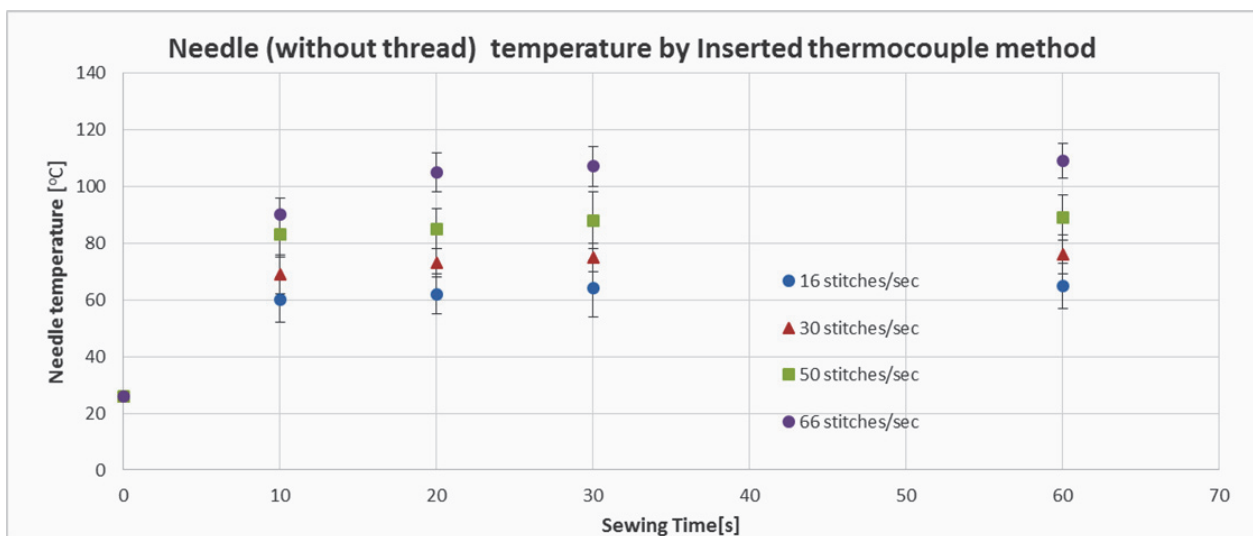


Figure 12. Needle (without thread) temperature measured by the inserted thermocouple method

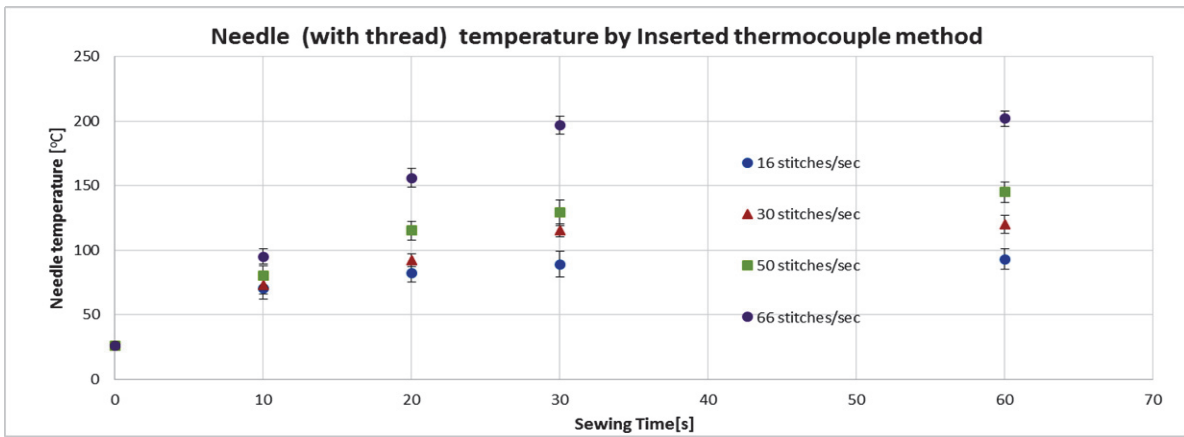


Figure 13. Needle (with thread) temperature measured by the inserted thermocouple method

### 3. RESULTS AND DISCUSSION

Figure 14 shows the needle (without thread) temperature comparison for the different methods of measurement at a machine speed of 50 stitches/sec. The inserted thermocouple method and the thermal camera show nearly the same average needle temperature after 60 seconds of sewing, but the standard deviation is much higher for the thermal camera measurements. The thermocouple touch method shows an almost 20°C lower temperature as compared to the other methods of measurement.

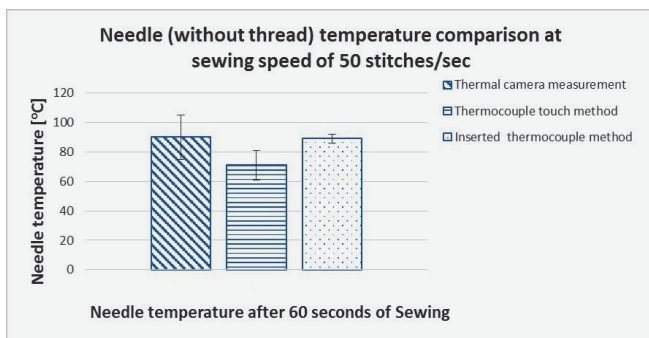


Figure 14. Comparison of the needle (without thread) temperature measurement methods

Figure 15 shows the needle temperature (with thread) comparison for the different methods of measurement at a machine speed of 50 stitches/sec. The inserted thermocouple method shows the highest needle temperature after 60 seconds of sewing with the lowest standard deviation, followed by the thermal camera measurement, which had the highest standard deviation. The thermocouple touch method shows the lowest temperature of the three methods of measurement.

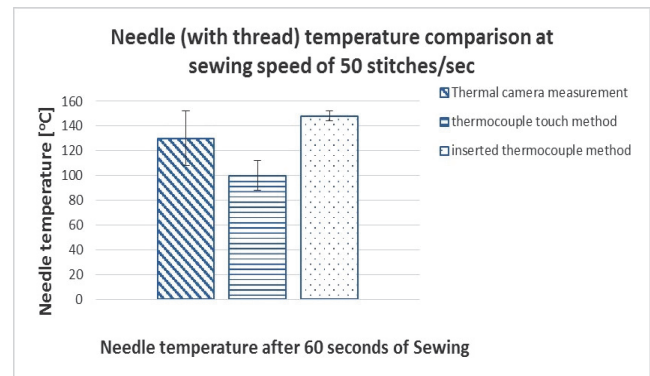


Figure 15. Comparison of the needle (with thread) temperature measurement methods

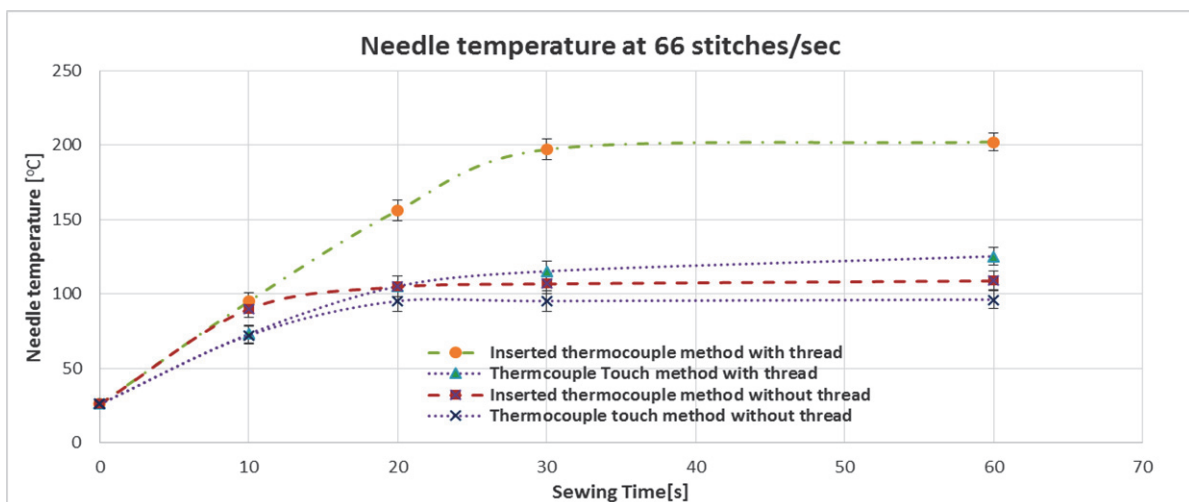


Figure 16. Needle temperature comparison of the thermocouple touch method and the inserted thermocouple method, with and without thread, at a sewing speed of 66 stitches/sec

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It was impossible to measure the needle temperature with the thermal camera at speeds higher than 50 stitches/sec; therefore, the thermocouple touch method and the inserted thermocouple method were used to measure needle temperatures at sewing speeds of 66 stitches/sec, both with and without thread. The inserted thermocouple method shows significant temperature differences between the tests performed with and without thread. Each experiment was repeated 30 times.

The thermal camera was not the best method for sewing needle temperature measurement. The emissivity of the needle posed a major problem and changed the surface properties (7); during the normal sewing process, surrounding energy sources reflected off the needle surface. Keeping the same emissivity caused a large standard deviation in the needle temperature measurement—and it was even higher when sewing was done with thread. The thermal camera works on emissivity, and a needle with low emissivity and thread with high emissivity might have caused this result for some researchers (8, 9). In our results, the needle temperature always increased when sewing thread was used.

The thermocouple touch method resulted in the lowest needle temperature, which was most likely due to measurement time delays. Some researchers (12) have proposed this method; however, the time it takes to touch the needle with the thermocouple always causes a lower temperature reading.

The inserted thermocouple appeared to be a unique method of measurement. Wireless data transfer makes it possible to record needle temperatures each second at all sewing speeds.

#### 4. CONCLUSION

- Thermal camera is not the most effective method for measuring sewing needle temperature because the emissivity of the needle and external energy sources reflecting from the needle surface causes problems in measurement.
- Needle temperature is always higher when thread is used, difference is much higher at higher speeds of sewing machine.

- The thermocouple touch method shows lowest needle temperatures as compared to the other methods, which is due to delay in measurement time. This method is quick and easy for estimating the temperature, but actual needle temperatures are always much higher. The thermocouple touch method shows an almost 20°C lower temperature as compared to the other methods of measurement.
- The inserted thermocouple method and the thermal camera method show nearly the same average needle temperature after 60 seconds of sewing for sewing speed of 50 stitches/sec, but the standard deviation is much higher for the thermal camera measurements.
- For sewing speed of 30 stitches /second and after 60 seconds of sewing, inserted thermocouple method shows almost 17% increase of needle temperature as compared to needle (without thread) temperature. Thermal camera shows 14% increase followed by touch thermocouple method showing 12% increase of needle temperature as compared to needle (without thread) temperature.
- The inserted thermocouple method shows the highest needle temperature after 60 seconds of sewing with the lowest standard deviation, followed by the thermal camera measurement, which had the highest standard deviation for machine speed of 50 stitches/sec. The thermocouple touch method shows the lowest temperature of the three methods of measurement.
- For sewing speed of 66 stitches /second and after 60 seconds of sewing, thermocouple touch method shows 15% increase in temperature of needle (with thread) as compared to needle (without thread) temperature. Whereas inserted thermocouple method shows almost 60% increase of needle (with thread) temperature.
- Experimental results from the inserted thermocouple method can be used to predict the exact sewing needle temperature.

#### ACKNOWLEDGEMENTS

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