Computer Simulation of Sewing Needle Heating

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Abstract:
The problem of the Sewing Needle Heating during of the sewing process is discussed. The several influences causing the raising of the sewing needle temperature up to 200 Celsius degrees or more are used for the Computer simulation of the Sewing needle temperature with help of the Finite Elements Method. The conditions of the Thermal balance are mentioned before the FEM simulation results are presented.

Key-Words: - FEM, Computer simulation, Sewing Needle, Needle Heating
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1. Introduction:

The knowledge of heat of sewing needle is very important for sewing process with textile materials which are sensible for heat. It is important to know sewing ability of textile materials before sewing, then to try repair results of mistakes a wrong sewing process.

The mechanical energy needed for the needle penetration through the fabric during sewing process is changed in the equivalent amount of the thermal energy. It leads to heating of the needle, the fabric and the melting of fabrics containing thermoplastic fibres. Also, the thread may melt or break. This heat so can make the loss of needle temper and these faults lead to the decreased production. [2]

A various measures of needle temperature have been done, such as measure by infra-red pyrometer, attached thermocouple, separate thermocouple, temperature sensitive waxes, etc. Because the needle is moving very fast under sewing process, a contact method of the measuring needle temperature can't be used. A no contact method of the measurement of needle temperature by is better for its smaller errors. Another problem is that the emission of the needle changes during sewing as the surface characteristics change. [3]

The needle temperature is may be calculated by simulation of sewing conditions, parameters of needle, sewing thread and fabric. No every one has a possibility to measure needle temperature, but anyone has a PC and we can simulate the needle heating, if we have a software for a simulation and know the conditions of sewing process.

2. Problem formulation

Theoretical analysis - Kinematic balance

The needle mechanism is centric hinged and it is connected with mainshaft of sewing machine as driving element. The courses of path and speed of needle motion are calculated by software Arom. The results for sewing machine with lockstitch and sewing speed 5000 st./min. are shown in figure 1 (the stitch desk of sewing machine is in a level of axis X).

Thermal balance

The needle heating process is very complicated. With reasonable accuracy there are some simplified premises:

- the length and volume of the needle are constant,
- the sewing thread is in a needle groove while the needle passes through the fabric, also the friction between the thread and the fabric is neglected,
- the generated heat by friction between the needle and the thread or the fabric will be moving to the needle as the heating conductivity of the needle is more high than the heating conductivity of the fabric or the sewing thread,
- the loss of the heat of the hole that is done after the passing of needle in the fabric is neglected.

The needle needs a amount of the mechanical energy to passing through the fabric.

$$Q_{j-m} = \int_s F_p . ds \qquad (1)$$

where Q_{j-m}: mechanical energy needed for needle penetration through the fabric,

Fp: penetrating force, it is possible to measure and it is generally known, (the course of penetrating force of needle during sewing process with needle normal No 90, fabric denim, four plies is shown in fig. 2),

s: the friction course.

The needle is given a amount of heat, the part of this heat is accumulated in the needle, another part of the heat is transferred to the needle shank, the fabric and the thread by conduction, other part of the heat is transferred to the surrounding by convection and by radiation

$$Q_v = Q_j + Q_{jm} + Q_{jn} + Q_{jd} + Q_{jp} \qquad (2)$$

The condition will be a thermal equilibrium and a amount of the heat in entrance to the needle is identical than a amount of the heat losses of the needle:

$$Q_v = Q_{jm} + Q_{jn} + Q_{jd} + Q_{jp} \qquad (3)$$

The heat generated by friction between the needle with the sewing thread Q_{j-n}:

$$Q_{j-n} = F_n . l_n . \frac{\Delta j_n}{360} \qquad (4)$$

where: F_n: force of the needle thread [N],

l_n: length of the needle thread which is in a contact with the needle during creating one stitch [m],

φ_n: angle in that there is a friction between the thread and the needle [rad].

$$Q_v = Q_{j-m} + Q_{j-n} \qquad (5)$$

Heat losses of needle to the needle holder Q_{jd} [1]

$$Q_{jd} = l_d . \frac{S_{jd}}{d_d} .(T_j - T_d).t_{jm} \qquad (6)$$

where λ_d: conductivity of the needle holder [W/m.K]

S_{jd}: area of the contact of the needle and needle holder [m^2]

d_d: diameter of the holder [m]

T_j: temperature of the needle [K]

T_d: temperature of the needle holder [K]

t_{jm}: time of the needle penetration through the fabric [s]

Heat losses of needle to the fabric Q_{jm} [1]

The losses heat of the needle to the fabric is transferred by conduction.

$$Q_{jm} = a_{jm}.S_{jm}.(T_j - T_m).t_{jm} \qquad (7)$$

where S_{jm}: area of the contact of the needle and fabric [m^2]

T_m: temperature of the fabric [K]

α_{jm}: coefficient of the thermal transfer [W/m^2.K]

Heat losses of needle to the thread Q_{jn} [1]

The losses heat of the needle to the sewing thread is transferred by conduction too. The thermal calculation of the heat losses of the needle to the sewing thread is similar as the calculation of the heat losses of the needle to the fabric.

$$Q_{jn} = a_{jn}.S_{jn}.(T_j - T_n).t_{jn} \qquad (8)$$

where S_{jn}: area of the contact of the needle and thread [m^2]

T_n: temperature of the thread [K]

α_{jn}: coefficient of the thermal transfer of the thread [W/m^2.K]

Heat losses of needle to the surrounding Q_{jp} [1]

The heat losses of the needle to the surrounding by the convection and by radiation.

$$Q_{jp} = a_{jp}.S_{jp}.(T_j - T_p).t \qquad (9)$$

where α_{jpp}: coefficient of the thermal transfer by convection [W/m^2.K]

α_{jpz}: coefficient of the thermal transfer by radiation [W/m^2.K]

α_{jp}: coefficient of the thermal transfer [W/m^2.K]

$$\alpha_{jp} = \alpha_{jpp} + \alpha_{jpz} \qquad (10)$$

S_{jp}: area of the contact of the needle and the surrounding [m^2]

Needle model in FEM software:

The main idea is a calculation of the needle thermal field by FEM. The sewing process is continual which will be uncontinual in a calculation by FEM. The needle is not only one element now, but it is consisted of several smaller elements. Also the needle is gradually heated on steps. A step and its time accord with a speed of needle motion. The model of the needle is drawn in a PC, where there is use the program for FEM with a thermal module. A number of the needle elements is:

$$a = \frac{l_{jm}}{h_m} \qquad (11)$$

where a: number of the needle elements,

l_{jm}: length of needle which is in a contact with the fabric during passing through the fabric [m],

h_m: thickness of the fabric [m].

In this work the lengths of needle element are identical (identical needle stroke during sewing process) and time of heating or cooling of every needle element is given of fig. 1.

The process of creating one stitch is maybe divided to 2 parts. In the first part of needle entering into fabric to needle going of fabric, the needle is heated by friction and parts of the heat are transferred to fabric, sewing thread and surrounding. In the second part, when the needle is outside of fabric, the needle is cooling by heat losing to sewing thread and surrounding only.

The principle of the heating and the cooling of the needle will be that only one element of needle is heated (by a friction) and cooled by heat losing of the needle to the fabric (Q_{jm}) while the others are cooled by heat losing of the needle to the needle holder, surrounding. The finish calculation of one element will be a opening condition for another needle element.

Also the finish thermal field were gradually calculating and some results are shown in fig. 4, 5 and 6 for sewing with and without sewing thread.

Conclusion:

The problem of the needle heating is interesting. Several measures are done in Institut für Textil- und Bekleidungstechnik and results are shown in fig. 7. The needle is moving very fast during sewing process and the results of the no contact measure depend on the emission of the needle and motion of sewing thread (motion of the sewing thread during sewing process affects the thermal flow of needle to infra-red pyrometer). The calculation of the needle heating is discussed in this work. Some results are shown in fig 4, 5 and 6 (sewing conditions are identical as conditions of measurement: lockstitch sewing machine, rotation speed 5000 stitches/min , stitch length 2 mm, sewing needle No 90, sewing thread PES Nm 80/2, fabric denim, four plies). The results of calculation are not depend on the emission of the needle and this method is maybe applied in any workplace.

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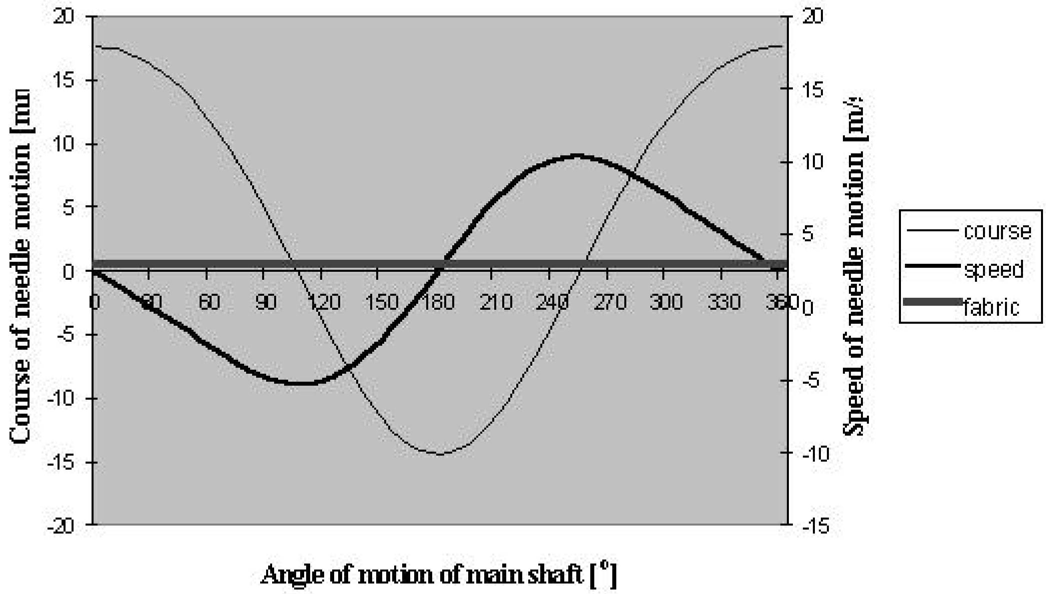
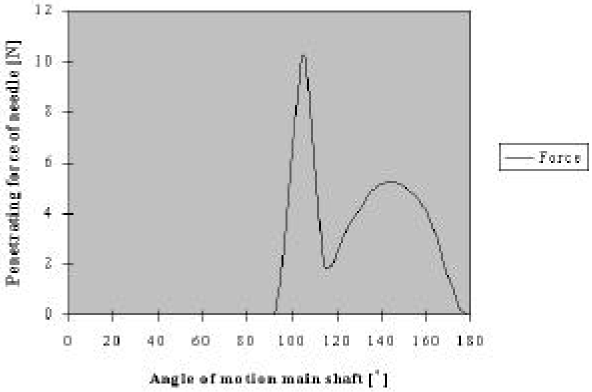


Fig. 1



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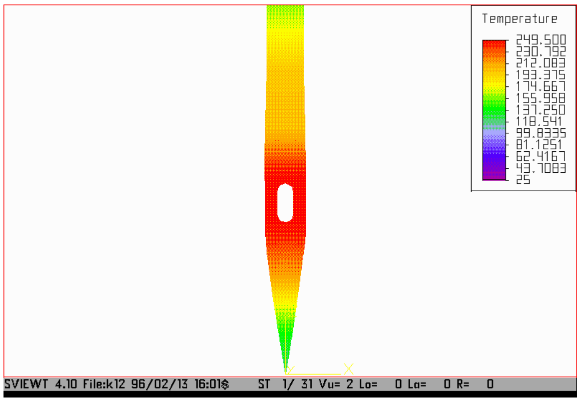

Fig.3

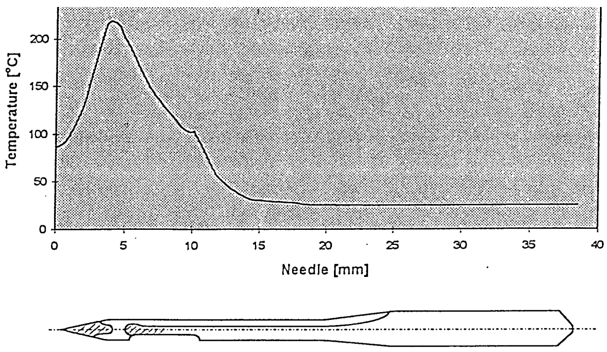

Fig. 5

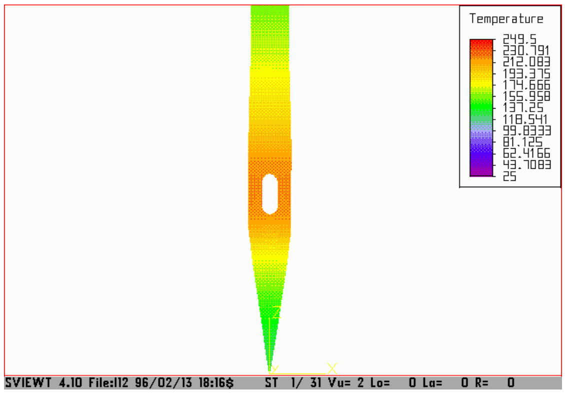

Fig.4

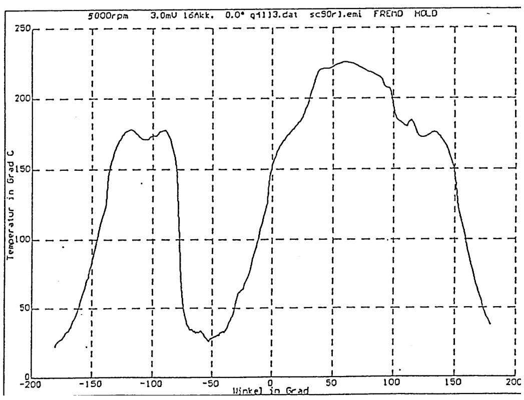

Fig.6