SENSITIVITY ANALYSIS AND OPTIMIZATION THE NEEDLE OF KNITTING MACHINE BY STRESS CONSTRAINT

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Abstract
During working, the needle of knitting machine is subjected to complex working environment, so a sensitivity analysis and optimization the needle was performed to consider the change stress of the needle when we change structure parameters of needle and groove as manufacturing tolerant of needle and distance of groove. The paper presents FEA method for analysis that bases on the foundation of contact problem theory to identify the contact areas between two surfaces needle and groove, also the stress of the needle. According to this idea, optimization problem is a crucial aspect to obtain the optimal solution when minimum stress constraints are considered. The result also shows that the new model of needle satisfies various design parameters to carry out the design goal.
Key words: Sensitivity analysis, needle, contact problem

1. Introduction

The needle of knitting machine is a special structure and then used to transfer the loops of yarn from around the pins, either off the pins or to other pins, to produce the knitting. Needles can be placed in holding position to allow short row shaping and control by grooves through cam mechanism. During working, It is subjected apply force from groove. These forces apply in long time and continued period. Therefore, the stress concentrates on the needle structure very high.

In this paper, a study for stress analysis and optimization the needle is considered. Objective of this working is considered changing of stress when we change the parameters of needle structure. After that, optimize structure of needle by minimum stress constrains. Limitation this study consider only in static cases.

1.1. Principle of Needle and Groove

On figure1 is a latch needle. It is produced either as wire ones made of a flattened wire or as stamped ones, pressed from a strip. The rotary latch closing the needle hook made the needle production more complicated. However, the needle that does not need a presser during knitting gave rise to new knitting machines – flat, circular and Raschel ones.

We are only considering the stress caused by contact between surfaces of needle and groove. Therefore, we aren't considered latch and hook components.

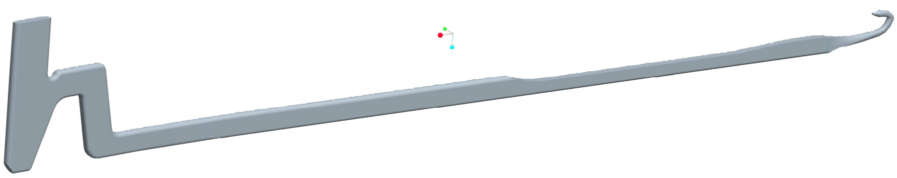


Figure 1. Model of Needle

Groove cam has function hold the needle moving along the length of groove (see figure 2). Dimensions of groove are 65x7x1.6 (mm).

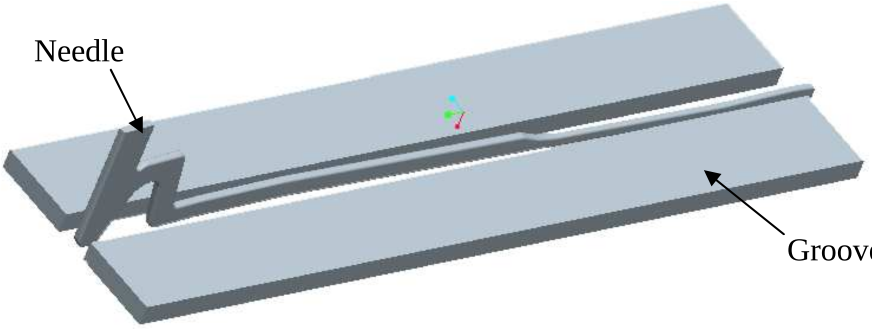


Figure 2. Model of needle and groove

1.2. Discrete model of structure

The accuracy of the FE analysis results solely depends upon the element size and meshing pattern of the parts. Hence, it is essential to give more focus on the meshing of the components. Mesh size is decided based upon the dimension of the critical locations of the parts, which is more important for the analysis. FE meshing is started with the geometry cleanup operation, which is used to make the geometry more appropriate for meshing. It is a common practice used to combine a number of faces into a single smooth surface. This allows the elements to be created on the entire region at once, and prevents unnecessary artificial or accidental edges from being present in the final mesh. On figure 3, Average size of the elements of needle and groove are 3mm, while at critical locations as contact areas the number of elements is increased which size of elements is 0.7mm for accurate stresses at locations with high stress gradients.

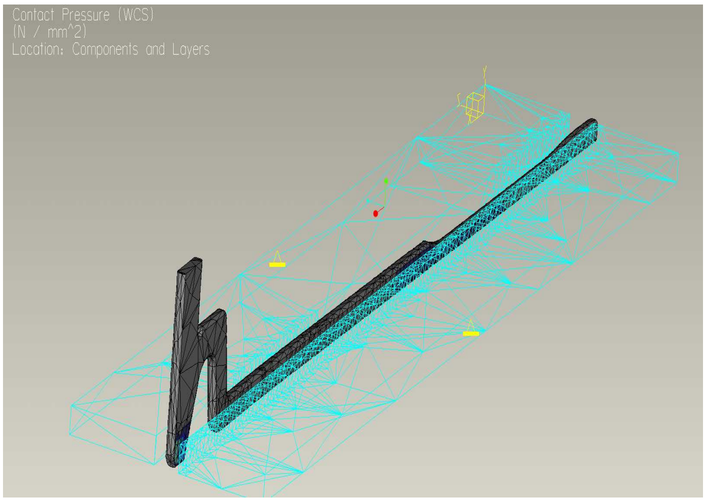


Figure 3. Model of needle and groove are meshed

2. Sensitivity Analysis

In mechanical design, various design parameters are related to the design goal, or design objective, in different ways. To find how these design variables influence the design goal, sensitivity analysis, or sensitivity study, is carried out to identify key design parameters and to better formulate the design optimization problem.

Sensitivity analysis of needle structure bases on the foundation of contact problem between surfaces of needle and groove. Contact problem can be understood as formula (1). Below is an equilibrium equation of two solids.

$$[K]\{U\}=\{P\}+\{R\} \tag{1}$$

Where

[K] – Stiffness matrix

{U} – Transposition vector

{P} – External force vector

{R} – Contact reaction vector

When cam mechanism controls the groove compress the needle, the force will be applied on needle. Therefore, boundary condition for groove is one side fixed in three directions and other side fixed in X and Z directions. Rest of direction is distance b that groove can be moved. On figure 4, there are two cases for sensitivity analysis which two parameters variable are a and b.

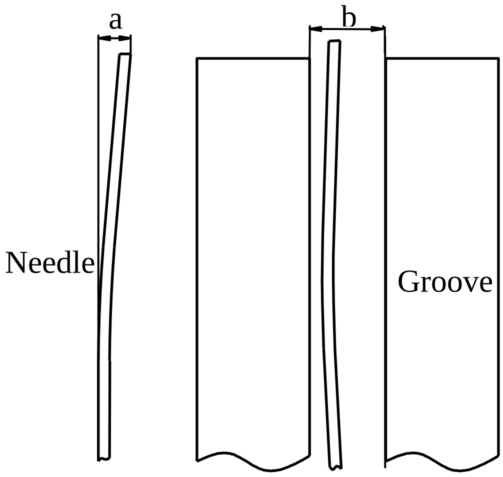


Figure 4. Parameters a and b using for sensitivity analysis

2.1. Sensitivity analysis of needle by change parameter b

The parameter b = 0.75mm is distance to keep needle moving inside but because manufacture tolerance are ±0.02mm so we will analysis how to stress change in range from 0.73mm to 0.77mm while parameter a is fixed. The table 1 shows parameter b and result for analysis.

Table 1. Result of stress analysis of needle by change the parameter b

a (mm)	2				
b (mm)	0.73	0.74	0.75	0.76	0.77
Stress VM (N/mm2)	580.5	556.8	441.8	417.5	364.3
Max Principle stress (N/mm2)	480.6	463.6	390.7	372.4	341.7

As can be seen, on the figure 6, the maximum value of stress VM are 580.5 N/mm^2 at 0.73 and it is reduced to 364.3N/mm^2 because pressure applying on needle structure are reduced. We recognize that the stress Von Mises (VM) rapid change about 216,2N/mm^2 between 0.73 and 0.77 values.

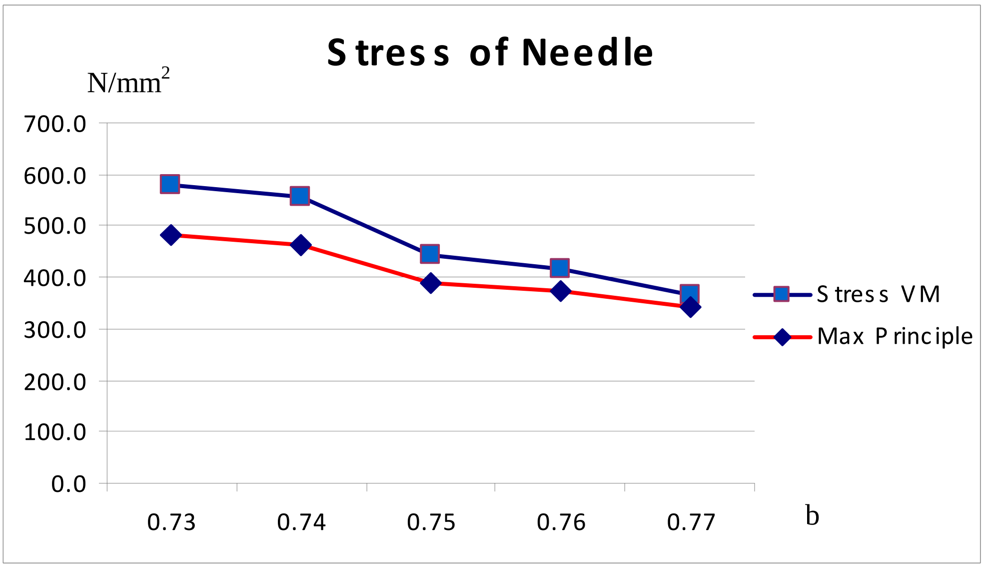


Figure 5. Graph of needle stress

2.2. Sensitivity analysis of the needle by changing the parameter a of needle structure.
Parameter a is corresponding to curvature radius of needle. When it changes, that means the contact are will be changed. Therefore, stress will be changed when force apply to needle. Change stress of needle when the value a changed while value b is constant (see on table 2)

Table 2. Result of stress analysis of needle by change the parameter b

b (mm)	0.75				
a (mm)	1	1.5	2	2.5	3
Stress VM (N/mm2)	52.4	262.6	441.8	1072	1778.9
Max Principle stress (N/mm2)	48	232.6	390.7	742.2	1046

On the Figure 6, we can see the stress VM increase from 52.4 to 1778.9 N/mm^2 corresponding value a from 1 to 3mm. Because, curvature radii of needles rapid change, so contact areas less than before. Therefore, stress concentrate at these positions higher (see on figure 6)

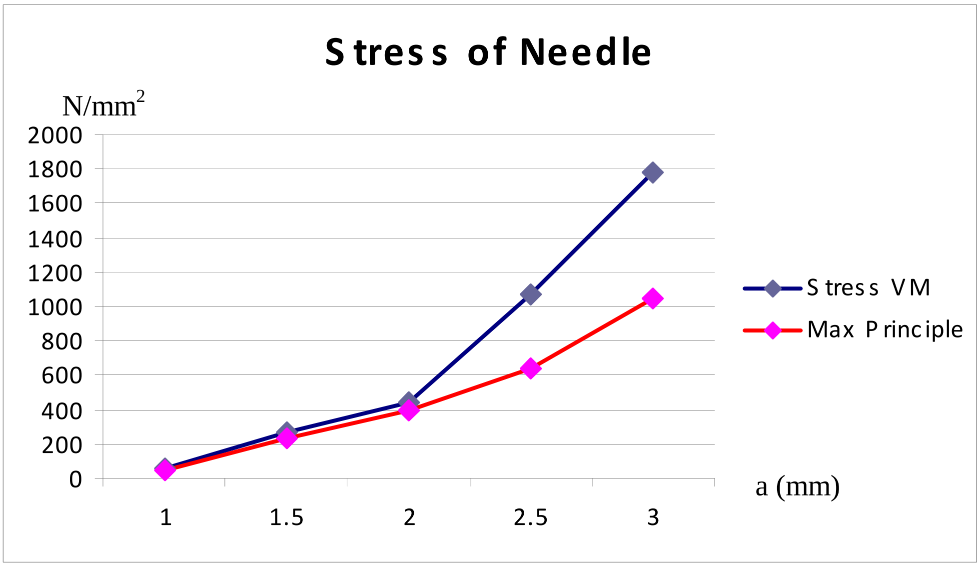


Figure 6. Graph of needle stress when change parameter a

3. Optimal of needle by stress constrain

3.1. Initial condition

Design optimization is the tool that automatically searches for the best value of these design variables, given the user defined design objectives, in most applications, a number of design constraints are also specified to design the boundaries of the allowed design variation.

Because, somewhere in needle have high stress, so we can optimal the needle structure that the stress is satisfied minimum stress. We choose stress optimization by four parameters as radii of needle butt (see on Figure. 7a). Changing the values of these dimensions, or design variables, the stress at these position and other position will change accordingly. In this case, the needle and groove structures using steel material, consider minimum stress as the goal of design, and choose parameters in table 5 as design variables. Other parameters are keeping the same value.

Table 5. Design variables

Parameters	R1	R2	R3	R4
Origin (mm)	0.80	0.30	1.4	1.0
Limit range	[2 4]	[0.3 0.5]	[1 3]	[1 3]

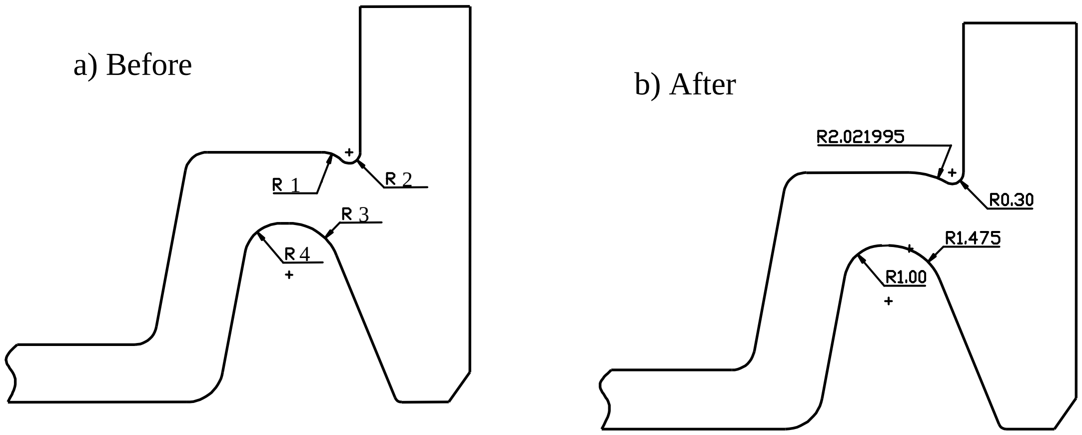


Figure 7. Parameters of needle butt before and after optimization

3.2. Optimization result

The results of the design optimization can be obtained and reported in the same manner as the structure analysis. This design optimization should give the results as on figure 7b.

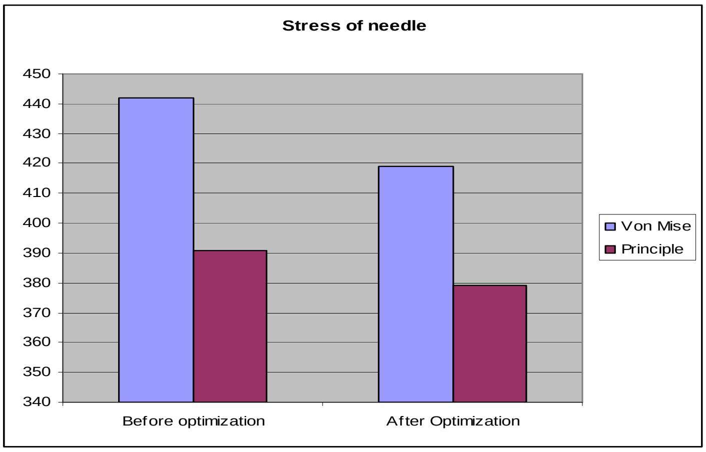
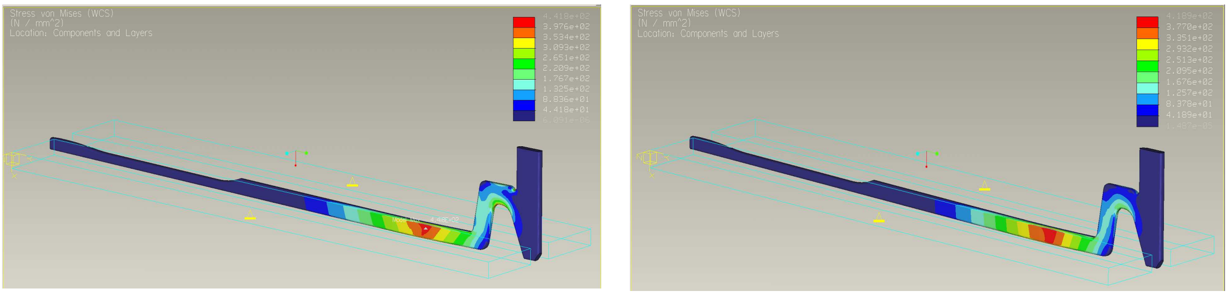


Figure 8. Stress of needle before and after optimization

The VM stress of needle is reduced from 441.8 to 418.9N/mm^2 as shown in the figure 8. The maximum VM stress acting on the needle is 418.9 N/mm^2 and stress spectrum are steady transition, The maximum stress is located on curvature of needle, somewhere as radii of R1, R2, R3, R4 the stress is small, that is good for working condition of needle. The result of stress shows in the figure 9.



a) Before optimization b) After optimization

Figure 9. Stress of needle before and after optimization

4. Conclusion

This study shown the sensitivity analysis method intended for reducing stress acting on the needle. These results were used in optimization the structure of needle by constrains stress. Result shows the stress increase when we change curvature radii of needle. Sensitivity analysis shows that limit range of stress when parameter b has error while manufacturing. It also is carried out to identify key design parameters and to better formulate the design optimization problem. The result of optimization shows that stress in needle structure is reduced 5.2% and it is a best model.

5. References

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