Wear and fatigue fracture analysis of knitting Needles

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Abstract

In practical knitting, wear and fatigue fracture occur on some fixed parts of the knitting needles due to the impact from the needle tongue and the yarn. The service life of needles is short, when concerning to the service condition of high stress, high speed and high frequency. However, it is very difficult to elongate the needles' life span for the lack of sufficient knowledge. Therefore, this paper thoroughly studied the cause of wear and fatigue fracture of knitting needles. The results showed that reducing the roughness of the needle surface, creating a hardened layer on the needle surface were effective ways to improve the service life of the knitting needles.

Keywords

Knitting needle, wear, fatigue fracture.

1. Introduction

With the rapid development, knitting products market demand is growing. Knitting industry experiences rapid development, such as more and more sophisticated knitting machine, high-speed, large-diameter cylinder, short stitch length, and high precision. Knitting needles are the main elements of knitting machine, which experience a very high acceleration as much as 20 times odds of the gravity acceleration during running.

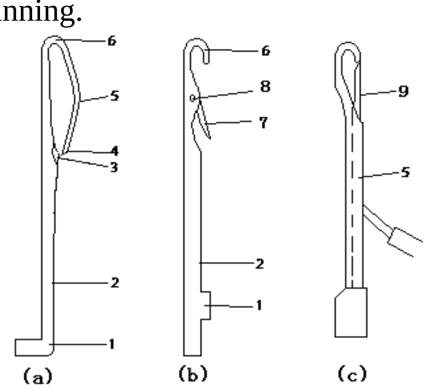

Figure1. Structure of textile needle
(1. root; 2. bar; 3. groove; 4. tip; 5. Channel; 6.head; 7. Tongue; 8.pin; 9. closure)

As known to all, high precision of circular knitting machine requires high precision knitting needles, so needle tongues open and close thousands of times each minute. Consequently, needles have only short service life.There are three types of knitting needles: crochet needles, tongue needles and compound needles[1], as shown in Figure 1.Crochet needle (Figure 1 (a)) is mainly used in trolley and crane which now have basically been eliminated. Tongue needle is mainly the current type. Its shape is shown in Figure 1 (b). Compound needle is illustrated as Figure 1 (c).

2. Needle failure

On the general high-speed multi-knitting machine, relative movements between needle tongue and pin, hook and yarn reach about 16 times/s, and the linear velocity of relative movement of the pin and triangle is about up to 15m/s. Therefore, abrasions between them are very serious. Compared to others parts, needles have the highest movement frequency, therefore, the shortest life, and most likely to fail and damage. In the actual production process, the failure of needle is mainly caused by loosening of needle tongue, wear of needle tongue, pin, and body, and deformation and rupture of needle body[1, 2]. Due to the parts that the needle failed at, the failure formed could be categorized in root fracture, tongue rupture, tongue loose, tongue wear, hook abrasion, needle body wear broken, and deformation. The main factors affecting the service life of the needles are material and heat treatment process, yarn and processing properties, knitting and weaving pattern structure, and quality assurance measures. In order to increase the service life of the needles, the paper focused on the analysis of all the forces employed on the needle during movement therefore, provided a data base to the further improve needle materials.

2.1 Needle wear

The needle is peculiarly prone to get early loosening in tongue, abrasion marks on the inside part of the hook, and milling on the needle root, etc. Needle wear is mainly generated by the friction torque between the yarn and knitting needles.

Friction to torque between tongue and the yean

Because of the uneven friction between the latch needle and yarn, too small friction on the needle tongue, and other reasons, needle tongue will impact the needle hook before the yarn slides over the outside of the needle tongue. It would even cause the needle tongue rebound, if the impact force is too large. Friction torque and slide acceleration maintains after the relative movement of pivot pin and yarn. Therefore, the impact force on needle hook produced by needle tongue is the greatest. Meanwhile, the yarn acceleration is also largest after the stagnation [2].

Stress analysis of the needle hook

Using the finite element analysis, the stress distribution on the hook is drawn on a color grid paper, as shown in Figure 2.

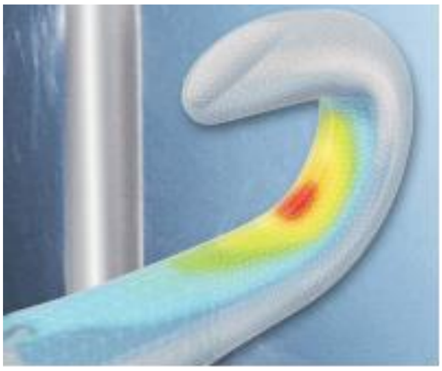

Figure2. Stress analysis of needle hook

Analysis results show that the bending force of needle hook which has a circular cylindrical cross-section is quite large. The force usually exceeds the elastic limit, resulting in permanent needle deformation. Inside and outside of the tapered needle hook have been optimized to flat, the stress of this region is obviously decreased, and rigidity and elastic limit are increased.

Generation of abrasive grains

Wear is mainly caused by the interaction of needle groove wall and the tongue, needle tongue and pin, needle hook and yarn, pin and triangular. Therefore, there are many grains on their surfaces. When these interacting surfaces move relatively, abrasive grains on the surface will produce the cutting effect. The wear resistance of material is increased with the increase of the hardness of material. From the view of engineering material, to obtain high hardness, high wear resistance, the optimum materials must have sufficient carbon content and plenty of carbide phases.

2.2 Needle fatigure fracture.

Fatigue stress would generate under the condition of periodically changing yarn tensions and the impacts on the needle tongue base by the needle tongue during kinking. Micro cracks in the needle surface could develop and expand and in turn, leading to fatigue fracture.

analysis of yarn tension during knitting

The needle is affected by the yarn tension during kinking. The tension of any point of yarn could be described in Eq.(1). As stated in the equation, the tension increases with the increase of coefficient of friction between yarn and knitting needles, and so with the angle of yarn and the knitting elements.

$$T_n = T_i e^{\mu(\sum \theta_n)} \tag{1}$$

T_i: initial yarn tension.

μ: coefficient of friction between yarn and knitting needles

$\Sigma\theta_n$: Total wrap angle formed by former yarn and knitting elements (needle and sinker).

When the traction is consistent on each yarn, starting from the middle position, then the tension T_k is to the maximum as following:

$$T_k = T_0 e^{\mu(\sum \theta - \sum \theta_k)} \tag{2}$$

T_0: traction on of each yarn force.

Σ_θ: Total wrap angle by former yarn and knitting elements (needle and sinker).

$\Sigma\theta_k$: the sum of the angle formed between the yarn package and knitting elements from the feed point to the maximum stitch tension point.

The location and size of maximum tension can be jointly determined by Equation (1) and (2). Stitch knitting needles in the process of cyclic loading force is a pulsating force that gradually increases from zero to a maximum and then gradually decreased to zero at the end of the stitch[3].

2.2.2 The impact of the tongue

A complete coil can be formed by each open and close in the high-speed circular knitting machine. During a circle, the tongue is driven to be closed and opened by the yarn. Due to the machine vibration, the needle tongue impacts the tongue base at a high speed during the kintting and withdrawal process. From the impact theory, the equation of the force for needle tongue could be draw as Eq. (3):

$$k\int_0^{\Delta t} R(t)dt = I_0\omega(1 + e) \tag{3}$$

$k\int_0^{\Delta t} R(t)dt$: the impulse of impact force in time. I0: moment of inertia of the tongue. e: the regression coefficients between the tongue and the needle. Δt: the impact time.From the Eq. (3), it can be concluded that the force peak depends on the size and the momentum of the impact force [4,5].

Under the action of alternative pressure, the crack of the needle is gradually expanded, and the new micro crack appears, ultimately, the failure is caused. On the other hand, the more the strength of steel is, the more sensitive to stress concentration, the more great the effect of surface roughness on the fatigue strength. Further, the work piece surface residual stress (compressive stress or tensile stress) and size could also directly affect the fatigue strength. If the surface residual stress is tensile stress, tensile stress and load forces add together, it is possible to exceed the yield strength of the metal material and then cause cracks. On the contrary, if the surface residual stress is compressive stress, it is possible to offset part of the tensile stress generated by the load and delay the generation of cracks. Such early failure phenomenon appears in the tongue, particularly appears in structurally weak position of the needles.

3. Conclusion

To improve the wear resistance of the needle, the main issues lay on increasing the wear resistance of hook and pin. The largest stress concentration part and weakest position of the needles is the hook portion. On the hook portion, the cross-section is relatively small, the geometry changes dramatically, and there might have residual stress produced by punching, bending and other machining procedures or by high-speed, overload conditions. Therefore, failure most easily occurs on the needle hook. Reducing the roughness of the needle surface by choosing reasonable finishing process, creating a hardened layer on the needle surface were effective ways to improve the service life of the knitting needles.

Acknowledgements

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