Research on the Principle of Suspension-Type Needle Selection and Its Modeling

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Abstract: This paper has proposed a kind of suspension-type needle selecting device, designed its 3D model method and the needle alignment on the circular knitting machine. By making finite element analysis on suspension-type needles based on the driving principles, we can get the needles' force situation and available thickness under conditions of different permanent-magnet thickness and air gaps. The dynamic response experiment model of the suspension-type needle is also given.

Keywords: Suspension-Type Needle, Circular Knitting Machines, Finite Element Analysis, Experimental Model

Introduction

At present, there are two kinds of electronic needle selectors generally used in the world: piezoelectric type and electromagnetic type, as shown in Figure 1. The piezoelectric needle selector implement needle selecting by using the converse piezoelectric effect of piezoelectric ceramics to bend the ceramic chip, while the electromagnetic needle selector realize the motion of needle selecting bit by using the polarity variation of the electromagnetic screw head, or the repulsion and attraction force between electromagnet and permanent magnet[1]. However, both of them rely on the triangular-path part of the circular knitting machine to change the height needles, and realize two-procedure or three-procedure control. Because of factors including high required-precision of triangular-path part, friction among needles, complicated structure of needle selectors, limited rotational speed of circular knitting machines, it is little worth to improve the needle selectors of piezoelectric type or electromagnetic type further. According to data, enterprises are mainly focusing on improving the abrasion resistance, heating processing technology and the shape about needle, but doesn't have any change to the driving method.

There is a couple of magnetic push and magnetic attraction between the electronic device and suspension-type object, which can support the suspension-type object, the paper designs suspension-type needle model according to this principle and needle selecting principle, it can realize no contact, frictionless and not need the triangular rack, and so on. Hereinafter, we are going to demonstrate the jacquard principle of suspension-type needle selecting device from the respect of feasibility based on the theory and experiment research.

1. The principle and structure design of suspension-type needle

1.1 The principle of electronic needle selecting

At present, the principle of the existing needle selecting is: the needle reaches different heights and keeps a moment and implements three knitting movements: tucking, looping and floating thread by the indirect control of needle selector blade. The Figure 1 is piezoelectric needle selector device, the needles makes fro beeline movement to the cylinder by the control of needle selector, pattern bit, needle jack and triangular part rack, and rotates with the cylinder, so it realize continuously knitting movements.

1.2 The principle of suspension-type needle

The principle of suspension-type needle is: the needles are suspension-type in axis by the magnetic suspension technology, they are all fro beeline movement to the cylinder by the action of magnetic push and magnetic attraction which generated by magnetic device，their lifting height and movement speed are controlled by current of the magnetic device, and an realize continuously knitting after load continuously drive current.

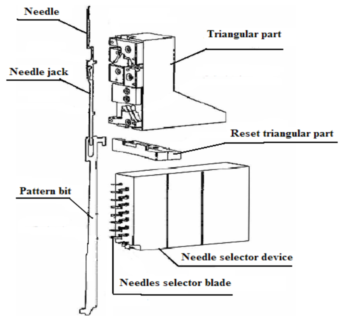

Fig. 1 Piezoelectric needle selector

It integrates the needle selector, pattern bit, needle jack and triangular part into a sole part, and makes the mechanism simpler and the cost lower. Because of it doesn’t need triangular part, and the needle’ trajectory, can be programmed through the soft program which equivalent to triangular rack, it can realize various special needle process and is a new needle selecting principle.

1.3 Structure design of suspension-type needle selector device

The suspension-type needle selector integrates the needle selector, pattern bit, needle jack and triangular part of the electronic needle selector device into a sole part, the needles are and all fro beeline movement to the cylinder by controlling of magnetic device, and it can control the motion mode of needle through changing the loading mode of drive current. According to the characteristic of suspension-type needle, the best shape of selector device is cylindrical, as shown is Fig.2.There exist thousands of needles in circular knitting machines, the suspension-type needles divide into three part: inside needles, middle needles, outside needles, as shown is Fig.3. The middle needles are linear type, there is a fold bending at the head of the inside and outside needles.

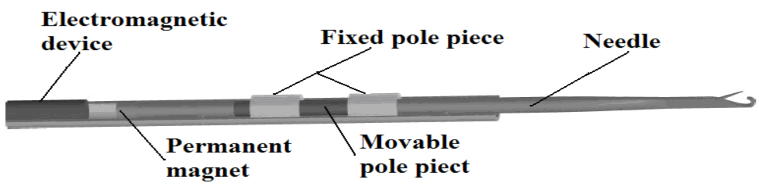

Fig. 2 The structure of suspension-type needle selector device

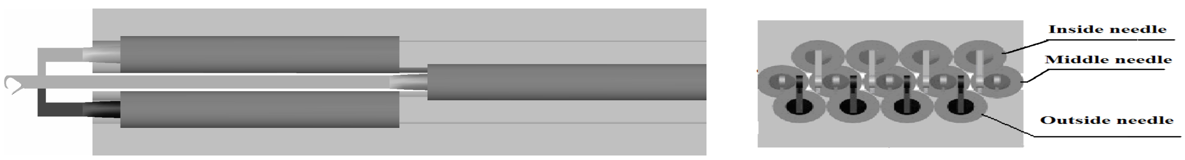

Fig. 3 The suspension-type needle selector devices

2. Research on driving theory suspension-type needle

2.1 Analysis on the driving frequency of suspension-type needle

There have 72-way electronic needle selector and 2256 needles in circular knitting machines, every 8 needles as one group, they arrangement is one step higher than the follow one. Every needle selector blade of electronic needle selector must control the follow group of needles after finish controlling the currently corresponding needle. Take the SDGJ-372 circular knitting machines for example, it has 72 piezoelectric needle selector and 2256 needles in total, the highest speed is 20r/min, the following is how to calculate the frequency of piezoelectric needle selector and suspension-type needle selector.

The calculation formula for action frequency of needle is:

$$f = \frac{n \bullet v}{360} \tag{1}$$

Where: f is action frequency of needle, n is the amount of group, v is the cylinder angular velocity.

Take the SDGJ-372 circular knitting machines for example, when the speed is 15 r/min, and the action frequency of needle is 70.4Hz.

When the highest speed is 20 r/min, the action frequency of needle is 90.74Hz, so the action frequency of piezoelectric is higher than the needle, and this is accord with the actual situation.

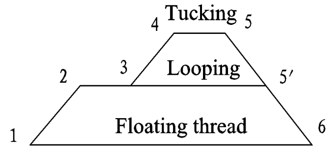

Fig.4 The trajectory of needle

As shown in Fig.4, it is the trajectory of needle, the needle selector controls the needle at position 1 and 2, so the needle realizes the three corresponding knitting movements: tucking, looping and floating thread. The whole knitting movements will be finished between positions 1 to 6, the same as suspension-type needle.

We also take the SDGJ-372 circular knitting machines for example, if we use suspend needle selector device replace the piezoelectric, when the speed is 15 r/min, and the action frequency of needle is 18Hz. As shown in Fig.4, suspension-type needle selector device controls the needle at all time, and it make the best of the limited time, so the frequency is lower. The calculation to the action frequency is conducive to the parametric design of suspension-type needle, and it is an important parameter to driving design, too.

2.2 Research of the driving mode of suspension-type needle

According to the principle of suspension-type needle, the motion situation of needle is relative to the force. As shown is Fig.5, it is analysis of the force condition of needle on the rising and falling, As shown is Fig.(1) ,it is the needle on the rising, the Fig.(2) is on the falling. We can know that, under the two situations, there exist yarn pulling force F_1, friction f_1 and f_2, needle gravity G, magnetic force F, and the force G, f_1 and f_2, is relative to the structure of needle, the force F_1 is relative to the knitting action of needle, the magnetic force F is determined by the driving mode of needle. The driving mode of needle not only affects the efficiency, but also the quality of textile, so it must design an optimum driving mode.

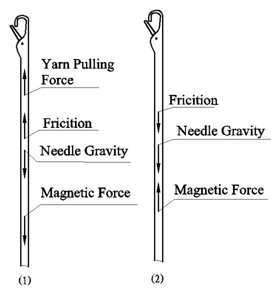

Fig.5 Force analysis for suspension-type needle

According to the theory of electromagnetics, the electromagnetic force, which as the power, between electromagnet and permanent magnet is [2]:

$$F=\int_{0}^{d_1} dz_1 \int_{d_1+h}^{d_1+h+d_2} \frac{3\pi NB_r r_2 r_1 n(z_2-z_1)}{2d_1[(z_2-z_1)^2+r_2^2]^{2.5}} dz_2 I_c = C_e I_c \qquad (2)$$

Where: n is coil turns, N is magnetic induction magnification factors which produce by iron core, Br is remanence rate of permanent magnet, IC is the current in coil. The other parameters are shown in Fig.6.

After the structure of needle selector device is determined, the driving current is just relative to the gap h, the gap h is the displacement of needle, so the driving mode of needle decide the loading mode of the driving current. At present, the needle is as a push rodin triangular cam, according to the movement characteristics of push rod in cam mechanism, it can as the driving mode of needle that is: uniform motion, constant acceleration and deceleration motion, cosine acceleration motion and so on, so we can get the driving mode and type through displacement function of needle.

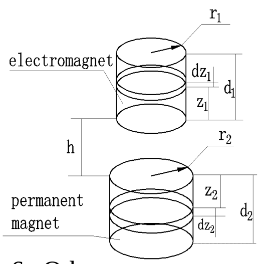

Fig.6 Other parameters of permanent magnet and electromagnet

According to the principle of needle selecting, the needle should hold a time at the highest position, it can realize by adding a DC hold circuit in the driving circuit [3]. The hold circuit will be turned on by trigger signal which is produced by displacement sensor, so the needle will hold a time at the setting height.

3 Establishment and simulation of suspension-type needle selector device

3.1 Establishment of suspension-type needle selector device

FEM (finite element method) can consider the nonlinear characteristic of magnetic material, and calculate magnetic leakage effect and magnetic field distribution in whole magnetic circuit space precisely, its result is very accurate, and so it is suitable to apply to analyzing the model with low cost and high efficiency.

It would affect the efficiency of needle selector device that using different structure of magnetic suspension device. The mainly structure are U-type, E-type, I-type and so on. The structure of magnetic suspension device must meet follow requirement: smaller volume, producing more electromagnetic force and little interference each other.

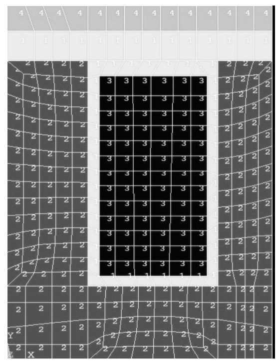
Fig.7 The suspension-type needle finite element model

The U-type is unfit for symmetry structure round baseboard, and I-type would produce severe interference. E-type is fit for the requirements, because its effectively capacity is greater and lower interference with each other and so on.

It only need to consider the force about the permanent magnet when design the finite element model, it means that we regard needle as permanent magnet. Because suspension-type needle structure is axial symmetry, so it only analyses the quarter model. The suspension-type needle finite element model as shown in Fig.7.

The FEM mainly analyses the magnetic force about needle under the action of the magnetic device, and whether the force can fit the knitting requirement, and do optimal design for the magnetic suspension device. Through finite element analysis, we can get an axial magnetic suspension device which is suitable to smaller volume, producing more electromagnetic force and less heat value.

The relationship among the force about permanent magnet with different thickness and gap as shown in Fig.8.

As shown in Fig.8, the force of permanent magnet is increasing by its thickness in a certain range, but after thickness add to a certain value, the force increase slowly or won't again[4]. This is because the magnetic potential increases with the permanent magnet thickness increases, but the reluctance and magnetic flux leakage also increase, after thickness add to a certain value, the increased magnetic potential is counteracted by the increased reluctance and magnetic flux leakage, so the magnetic potential have litter contribution to external magnetic circuit. Base on the diagram, we can find that: while the gap is 3mm, the best permanent magnet thickness is 2mm to 3mm, the gap is 6mm, the best is 2.5mm to 4mm, the gap is 9mm, and the best is 3mm to 5mm.

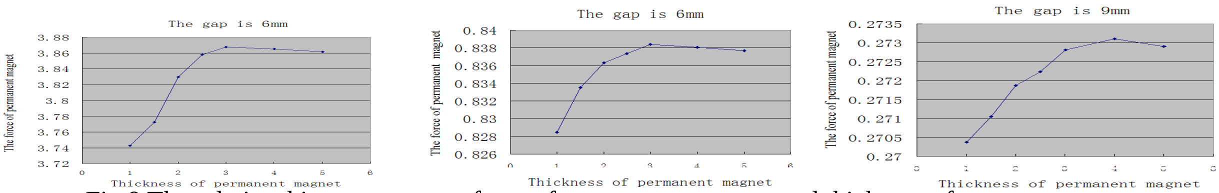

Fig.8 The relationship among gap，force of permanent magnet and thickness of permanent magnet

3.2 The dynamic response experiment of suspension-type needle selector device

The dynamic response characteristics of suspension-type needle selecting device will affect the working efficiency of circular knitting machine and quality of the textile. Therefore, it is necessary to do experiments and research for this characteristics, and make an optimal design for the structure and drive mode of the needle selecting device according to the experimental results, to further increase the technical indexes.

Fig.9 shows the dynamic response characteristics experiment of suspension-type needle selector device. Through computer programming and driving circuit, input different driving electrical signals (e.g. slope signal, sinusoidal signal) by needle selecting device， the data of dynamic response characteristics (e.g. frequency, velocity and acceleration) can be acquired by the sensors on peripheral equipment of the needle selecting device, and be fed back to the computer to check whether the characteristics are identical to the input signal and meet the design requirements. So that we can modify the driving mode fulfill the minimum power consumption can produce higher needle selecting frequency, better stability and reliability.

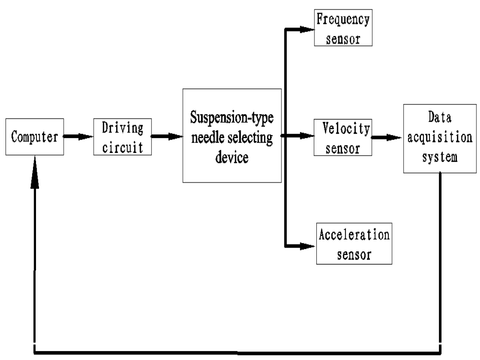

Fig.9 Dynamic response characteristics experiment of suspension-type needle

4. Conclusion

The suspension-type needle selecting device proposed in this paper is a new product that is different from any of the previous needle selecting device. It is characterized in simple, easy to control, high efficient and cost-effective. This paper has researched the working principles and discussed the modeling on suspension-type needles, providing fundamental basis for further researches on suspension-type needle selecting device, including the sensor designing, drive circuits designing, and optimal structure designing.

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