

Research on the Key Technologies of High-end Warp Knitting Machinery and Application

Zhonghua Yan*,

Changde Textile Machinery Co. Ltd, Hunan, Changde, 415001, P.R.China

*Email: 13873670621@163.com

Xiaowen Zhou, Xiangzhi Gang and Chunmei Li

Changde Textile Machinery Co. Ltd, Hunan, Changde, 415001, P.R.China

Abstract—The development trend of knitting machinery is high speed, high efficiency, high precision, intelligence, diversification, differentiation, good stability and high reliability. For the four urgent key common technologies of high-end knitting machinery, namely, high speed, high density, breadth and mechatronics digitization, we research the crankshaft drive technology of high-end knitting machinery, the program development of high-speed motion curve, the material selection of carbon fiber and its utilization in high-end warp knitting machinery, the application of mechatronics digital technology in the controlling part and researches on the manufacturing technology for key parts. Then, the results are applied to warp knitting machine products which achieve the great improvements on the design and manufacturing of warp knitting machine.

Index Term—warp knitting machinery; high speed; high density; breadth; mechatronics digital technology

I. INTRODUCTION

Textile industry is the pillar industry of national economy. As one of the main branches of textile, knitting is a new quickly-growing textile industry with the advances in traditional processing technology and modern information technology. Warp knitting machine is one of the high-end knitting machineries. Warp knitting industry leads the technological innovation and progress in areas such as new material, machinery manufacturing, agriculture, water conservancy and health care and also played a major role in the new industry of wind power. Warp knitting industry has become one of textile industries with the fastest technological progress, the largest scale of growth and best economic benefit. Chinese annual production of tricot accounts for only about 10% of the whole weaving industry, while this number is 30 ~ 35% in the developed countries and regions. Warp knitting machine is a high-tech and precise machinery product especially the high-end knitting machine. The machines utilized for upscale and special-purpose tricot in Chinese enterprises are mostly imported from abroad. High-end warp knitting machine with proprietary intellectual property needs to be developed as soon as possible to improve the overall level of warp knitting machinery manufacturing in China and meet the rapid development of Chinese warp knitting industry. Knitting machinery is currently developing in

the direction of high speed, high efficiency, high precision, intelligence, diversification, differentiation, good stability and high reliability [1-4]. But the research & development and manufacture technology of China-made warp knitting machine has a considerable gap compared with that of imported equipment, so high-end warp knitting machines were often imported, which increased the cost of knitted products, weakened the international competitiveness and greatly hindered the development of traditional national industries in China. Thus the development and manufacture of high-end warp knitting machine need to be localized and improved to the international advanced level to enhance national brands, revitalize national industries and meet the domestic needs of warp knitting enterprises from multiple angles. Therefore, the research & development and industrialization of high-end warp knitting machinery project have great practical significance.

II. RESEARCH ON THE KEY AND COMMON TECHNOLOGIES

Although Chinese warp knitting machine, especially for high-end warp knitting machine, has gaps in the aspects such as speed, density, stability, mechatronic digital technology application compared to international advanced level, the trend is that these gaps are gradually narrowing. Currently, the research and development of warp knitting machine is still carried out around four key technologies: high speed, high density, breadth and mechatronic digital technology application. The development of crankshaft drive technology and high-speed motion curve programming will be conducted in Changde Textile Machinery through the implementation of the project; carbon fiber will be applied on major parts such as needle bed and ball head; the research & development and application for electronic jacquard device and electronic sliding technology will be enhanced to a new level; the overall assembly quality would be improved through researches on key parts of the process. The main technical performance and indicators of high-end warp knitting machine in China will reach the international advanced level after the project is completed. Chinese warp knitting machine is also cost-effective, convenient in after-sale service compared with imported machinery, so it has obvious competitive advantages in the market.

A. *The research & development of the loop formation driving mechanism*

Eccentric rod transmission was changed into crankshaft rod transmission, which was a key technology to achieve the high speed and low consumption of warp knitting machine. The original development process of crankshaft rod transmission mechanism in Changde Textile Machinery was just through imitation, and they failed to really understand and resolve the principle of loop formation driving mechanism. Therefore, problems such as noise and low speed still existed compared with imported machinery. The maximum machine speed of tricot warp knitting machine was not more than 2500 rev / min.

In the specific study, the design was combined with kinetics and kinematics. The mathematical model for the motion of drive mechanism was established. Computer simulation was conducted on motion law and force condition of each part in the crankshaft mechanism, and the kinematic acceleration and jerk in the mechanism were reduced to the lowest. The machine vibration and mechanical deformation were effectively controlled, and the purposes of high speed and low power for warp knitting machine were achieved. Planned maximum speed of tricot machine could be up to 3,500 r/ min.

The loop formation mechanism of crankshaft connecting rod in main drive was studied and designed. The eccentric rod drive mechanism in the loop formation mechanism of warp knitting machine was changed into crankshaft rod drive mechanism, and rolling bearings were changed into sliding bearings. The mathematical model for the motion of drive mechanism was established combined with kinetics and kinematics principle. The stress condition and motion law of each part in the crankshaft mechanism were analyzed, and the kinematic acceleration and jerk in the mechanism were reduced to the lowest. The machine vibration and mechanical deformation were effectively controlled to make the high-speed transmission more stable with less impact. All parts of the motion mechanism more reasonably coordinated with each other, and the weaving efficiency was improved; the purposes of high speed and low power for warp knitting machine were achieved.

B. *Programming techniques for loop formation system*

The system programming of loop formation mechanism for high-end warp knitting machine was entirely and autonomously completed by research & development personnel in Changde Textile Machinery. The system program development would accelerate the research pace of high-end warp knitting machine and greatly improve the knitting machine technology in China.

The mathematical model of each motion in the system was established for the system program of loop formation mechanism combined with advanced computer technology, dynamics and kinematics. Every motion of loop formation mechanism was displayed on computer in the way of animation, which provided great convenience for the analysis of every motion in the loop formation

mechanism. The coordination time of various needles was reasonably allocate to further achieve the purposes of high speed and energy consumption at the same time of reducing the acceleration and jerk of the mechanism, reducing movement inertia of every components in the mechanism and effectively controlling the vibration and mechanical deformation.

The mathematical models of various motions in loop formation mechanism, through the utilization of advanced computer technology, was established combined with dynamics and kinematics, and the loop formation motion of the machine was displayed on the computer in animated manner, which provided great convenience for the analysis of every motion in loop formation mechanism. The coordination time between various needles needs to be reasonably allocated to further achieve the loop formation system diagram of high-speed warp knitting machine, at the same time of reducing the kinematic acceleration and jerk in the mechanism, reducing the motion inertia of various parts in the mechanism and effectively controlling the machine vibration and mechanical deformation.

C. *Development and application technology of new materials*

A major problem for the speed of warp knitting machine is the problem about the material of longitudinal part (such as needle bed) in the loop formation mechanism. The material needs to be light and small in cross-sectional area as much as possible, and also the rigidity of the longitudinal parts must be ensured to avoid deformation in high-speed movement. The material must have good processing property, so that the straightness and flatness of longitudinal part could meet the requirement of high-speed loop formation. The needle bed material of original high-speed warp knitting machine is mainly aluminum alloy and magnesium alloy. The speed for high-speed warp knitting machine in China has not been resolved due to weight, unstable thermal expansion coefficient, processing technology and other issues. Carbon fiber was determined as the material of main part such as needle bed by long-term exploration and study. The characteristics of the material can solve the problems such as the weight of moving parts, the moment of inertia and dynamic load of the transmission part to effectively reduce the gauge variation of main part due to thermal expansion. The utilization of carbon fiber material in high-speed warp knitting machine currently has no precedent in China, so cooperative research and development of the special group, as one of the special key common technologies, has already begun.

The material of needle bed in the original high-speed knitting machine made in China was mostly aluminum alloy and magnesium alloy. Not only the inertia moment and dynamic load brought by the heavy weight of these materials would affect the high-speed operation, but also the gauge change caused by thermal expansion would lead to needle scrape and yarn broken. Development of carbon fiber as the material of main key parts like needle bed can be a better solution to the problems of the weight of moving parts, the inertia moment of transmission parts

and the dynamic loads, and effectively reduce the gauge change of needle bed due to thermal expansion (Fig. 1).

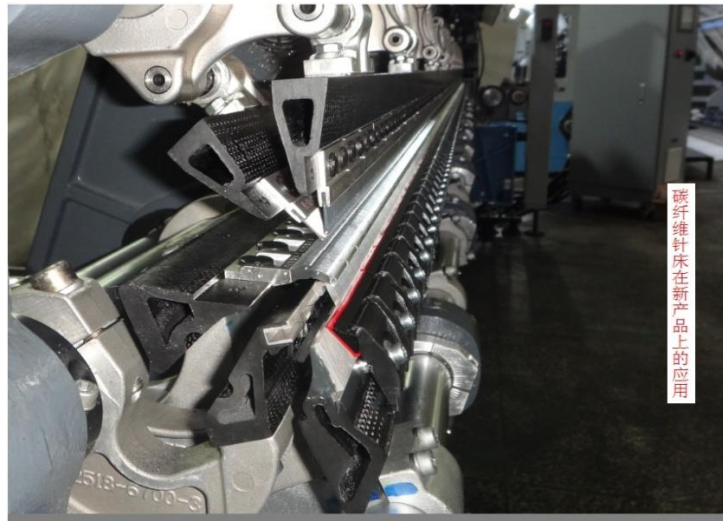


Figure 1. Concept diagram of carbon fiber machine

D. Development and application of new composite needle

The compound needles used in the past were mainly imported from Germany, and the constraint of intellectual property rights had an impact on the development of enterprises. The company, based on the developed proprietary compound needles, will continue to develop new compound needle, break the monopoly and constraints and lay the foundation for industrialization in order to guarantee the industrialization of high-end knitting machinery.

The weight of each needle bed and needle block was reduced for the high-speed operation of the machine, and

new type of plastic-base yarn needle and magnesium alloy needle was design to ensure that the needle was firmly bonded on the needle block.

The main compound needles utilized in past warp knitting machines all relied on imports. The development and commercialization of new products were seriously affected by the constraints of intellectual property rights, the high price of import compound needles and not-in-time delivery. Compound needles with proprietary intellectual property rights will be developed and applied the project. The structure for the groove pin of new composite needle is shown in Fig. 2.



Figure 2. Structure of groove pin

E. Development and application of mechatronics digital technology

The technique of EAC electronic stretching and coiling: electronic stretching and coiling technique is equivalent to mechanical stretch coiling. So the stability of coiling tension would be ensured, and it could bring some convenience to cropping.

The technique of EL electronic traverse mechanism: sliding impact, from the traversing motion of guide bar, needs to be reduced and the speed and stability of electronic traversing system for warp knitting machine need to be improved to achieve its intermittent sliding with high positioning accuracy. Several electronic traverse systems were researched based on the requirements of warp knitting machine for the traversing motion process of guide bar. Their advantages, disadvantages and several factors that might affect the

traversing motion precision of guide bar were analyzed, and some methods were proposed to reduce the influence of these factors on guide bar.

The traverse mechanism of EL electronic guide bar is suitable for continuous and rapid pattern transformation. The rotational motion of servo motor was changed into controllable linear motion by using actuator, so the traverse motion could be directly transferred to the yarn guide comb. Power was controlled by computer. Traversing motion controlled by EL was more precise than the motion controlled by faceplate, and the sliding motion was also larger. The capacity of the storage could allow 30,000 rows of pattern cycle. EL system could calculate a continuous requiring amount and the respective feeding amount of yarn. The yarn feeding amount, if necessary, can be adjusted. Tricot warp knitting machines with four and five combs are generally

utilized in EL system.

The technologies of piezo electronic jacquard device: (1) The speed of the machine was improved by 50%; (2) The dynamic performance of the machine was improved, and the loop formation machine was simplified with the utilization of needles, pillows, slough-off plate, sinkers, etc.; (3) New types of pattern fabrics can be produced; (4) Jacquard comb can be made very small, which narrows the requirement for space; (5) long service life of piezo

components; (6) low power consumption; (7) convenient yarn processing.

The project, meeting customers' strict requirements such as high speed and high performance, will utilize the electronic let-off (EBA), electronic stretching and coiling (EAC) technology, electronic jacquard system, the sliding mechanism of electronic guide bar and other electronic integration digital technologies. The EBA control system is shown in Fig. 3.

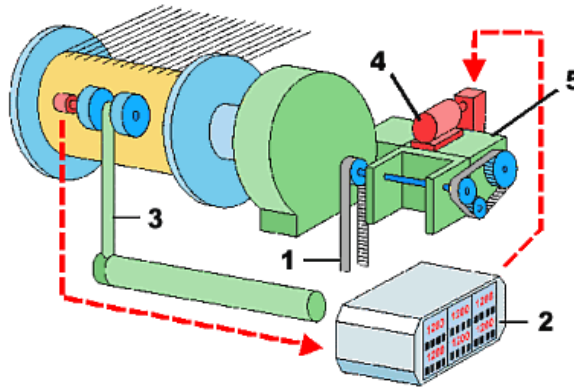


Figure 3. Schematic of electronic let-off (EBA)

F. Technology of air-water cooling and oil heat exchange through the pendulum shaft

Heat exchange, during the operation, becomes extremely important with the improving speed of high-end warp knitting machine. The technical staff explored to change the traditional air-water heat exchange technology in order to ensure the temperature equilibrium of the whole machine during operation. They broke the constraints of traditional thinking and innovatively combined air-cooled with water-cooled together, which was good for the convenience of the users and the improvement of the heat exchange efficiency for the whole machine. The impact of deformation on the speed caused by temperature difference in the host machine especially the loop formation part must be avoided. Heat exchange technology could be conducted in loop formation part by oil flowing through the pendulum shaft to ensure the temperature consistency of the whole machine. The synthesis technology would be firstly utilized in the high-speed warp knitting machine newly developed in China.

G. Process researching of main and key parts

The techniques of crankshaft machining research: the original crankshaft was mainly processed by ordinary equipment and homemade tooling, which was very slow and inconsistent in quality. Some special equipment was added in the new plant in the implementation of our specific plan to build production lines for special parts and achieve industrial production.

The research on the processing of carbon fiber needle bed; the needle bed of carbon fiber cannot be directly processed by milling groove machining, and the matrix needs to be bonded with magnesium alloy first. So the

research of the process also includes selection of adhesive material and cutting fluid.

The processing technology research of guide yarn needle based on plastic and magnesium alloy; the processing of plastic-based yarn needle and magnesium alloy is: the design and manufacture of the mold, the pouring temperature and time control of the needles and the selection and configuration of equipment in the production line.

III. APPLICATIONS

The common key technologies were applied to the development of warp knitting machine: (1) Tricot warp knitting machine is a new model with four combs and the application of carbon fiber needle bed. The sliding mechanism of electronic guide bar was designed so that the speed of the machine could maintain at 3000 rev / min; (2) Raschel warp knitting machine: electronic servo drive was utilized to control the let-off mechanism and stretching coiling mechanism. Automatic oil lubrication and circulation system with constant temperature and pressure was adopted. The breadth for the series of products was increased to 190 inches, and the number of guide bars was increased to five or six. the application of carbon fiber could ensure the maximum knitting speed of 2500 rows / min; (3) warp knitting machine with double needle bed: Piezo electronic jacquard mechanism was increased to the series of products, and the intelligence level of the machine was continuously improving; high-speed yarn path and tension controlling system was explored to ensure high-speed and smooth operation above the knitting speed of 650 rows/min. The simplification and optimization of the mechanism are good for adjusting and operating.

IV. CONCLUSIONS

The development trend of high-end knitting machinery is high speed, high density, breadth and mechatronics digitization. The crankshaft drive technology of high-end knitting machinery, the program development of high-speed motion curve, the material selection of carbon fiber and its utilization in high-end warp knitting machinery, the application of mechatronics digital technology in the controlling part and researches on the manufacturing technology for key parts were conducted. These researches have been applied to warp knitting machine products and achieved good results.

REFERENCES

- [1] Q. Zhang, G. M. Jiang, F. L. Xia, "Warp knitting machine CNC system key technology and its development," *Textile Leader*, 2013, vol. 4, pp. 77-80.
- [2] B. Li, Y. Wu, "high-speed warp knitting machine with double needle beds: key breakthroughs: breaking the foreign monopoly," *Textile Leader*, 2013, vol. 3, pp. 101.
- [3] Q. L. Cao, "Studies on the loop formation process and motion realization of warp knitting machine with double needle beds," *Textile Leader*, 2012, vol.11, pp. 71-74.
- [4] N. Liu, F. L. Xia, Q. D. Zhang, "The dynamics analysis for the guide bar traversing mechanism of warp knitting machine," *Textile Research*, 2012, vol.11, pp. 121-125.