The Research Status and Development Prospect of the Cross Air Blow

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Abstract: This paper briefly describes the development situation and present status of the cross air blow for the key components of the spinning equipment at home and abroad. The structural characteristics of the circular blow device are analyzed, and the development prospect of the cross air blow is discussed and predicted. Combined with the current situation of development and application of flexible technology in China's chemical fiber industry, this paper discusses the application of flexible technology in the cross air blow and points out the research methods and technological routes of the new flexible cross air blow.

1 PREFACE

Chemical fiber manufacturing is an important part of basic materials and textile industry in China whichhas strong international competitiveness. The world's manufacturing center for chemical fiber machinery is shifting to China1.

With the continuous growth of China's economy and the increasing consumption capacity of domestic residents, the demand of polyester fiber in China is also increasing. From the polyester fiber production distribution point of view, the proportion of filament production increased year by year. China's polyester fiber production totaled 3917.97million tons in 2015 while filament production was 29.5807 million tons. Filament production increased by 12.26% and accounted for more than 75% of the polyester fiber production[2].When melt spinning is used, the melt is ejected from the spinneret's capillaries, cooled by blowing, stretched, and finally solidified into filaments. Cooling has an important role in melt spinning forming process. Heat exchange between polymer melt and air flow directly affects the velocity distribution,stress distribution and temperature distribution during spinning process so that the linear density uniformity,structural uniformity,stability of surface morphological, the length of solidifying region of fiber are affected.With the increase of the high quality product rate requirements in chemical fiber industry, lateral blow air quenching device has been unable to meet the requirements of filament production. The circular blowair quenching device can effectively solve the problem of wind energy loss due to the large area of the lateral blow air quenching device. In addition, the cross air blow device can also make each wire wind uniformly, with potential economic benefits and broad application prospects. At present, China's polyester fiber single-line production capacity is getting higher and higher, but product homogeneity is serious and the differentiated rate of chemical fiber products is insufficient. Problems like overproduction of general-purpose products, poor quality stability, and large fluctuations in performance make it difficult to meet the increasing demand for consistent product quality. Therefore, achieving flexible processing in high-capacity and continuous equipment and developing small quantities and more varieties of products are urgent technologies.

2 RESEARCH STATUS OF CROSS AIR BLOW DEVICE

2.1 Research Status in China

Since the 1980s, China began to research and develop cross air blow device. At that time the research project was to improve the imported equipment of polyester staple fiber and develop domestic equipment based on the digestion and

absorption of foreign cross air blow device3.With the adaptation to international textile technology development, domestic manufacturers also begin to research and develop cross air blow device used in filament production in recent years.

China Shanghai Pacific Textile Complete Equipment Co.,Ltd.4has developed polyester staple fiber complete sets of equipment with low damping outer cross air blow device which is equipped with a blowing air volume automatic control system.In order to adapt to the complexity of the raw materials in the renewable polyester staple fiber complete equipment, semi-open type outer cross air blow and single-distribution air volume control device are configured, which effectively meets the requirements for the control of the air flow rate and air temperature of the spinning process.Polyester staple fiber spinning machine manufactured by Hunan Shaoyang Textile Machinery Co., Ltd. is equippedwith low damping inner cross air blow device. It solves the problems of high investment and high running cost caused by high wind pressure of some main air ducts of high-damping imported cross air blow device.Beijing Chonglee Machinery Engineering Co., Ltd. has developed a new type of outer cross air blow device for ultrafine fibers. The air rectifier tube has the advantages of uniform air blowing, easy cleaning and replacement. The line sealing technology is used between blow head box and spinning boxwhich ensures tight and reliable sealing. The height of the no-wind zone can be adjusted according to the requirements of the production process. At the same time there is cylinder lift which is supplemented by column-type linear bearing guide rail. The device has the characteristics of uniform lifting and stability, and the positioning pin on the cross air blow device can make the positioning of the ring blowing head more precise.

At present, the most widely used technology is the outer cross air blow technology. However,no matter inner cooling or outer cooling, the volume flow of the cross air blow increases geometrically as the diameter of the spinneret and the cooling air passing radius increase. The effect on the cooling uniformity of the inner and outer fiber is also magnified.Due to the high quality and technical difficulty of producing differentiated fiber filaments, such as fine and ultra-fine fibers, the requirements for uniformity of filament cooling are higher.In particular, it is required that the circumferential wind speed be uniform, andthe range of wind speed is extremely small, and the wind speed is stable and smooth. The axial wind speed change curve is gentle while the unevenness of wind speed is less than 4%. However, the uniformity and stability of the wind speed of the cross air flow device and the sealing of the equipment still need to be further improved to meet the quality requirements of the products.

2.2International Research Status

Internationally, the cross air blow devices for short-fiber production have been developed and applied as early as the 1970s. Such as Germany's Gemma, Neumag, Inventa, and the Du Pont Co. have a lot of research on the cross air blow device and formed their own proprietary technologies. With the growing demand for filament in the textile market, cross air blow technology is increasingly used in filament yarn production. In order to solve the high quality requirements of filament cooling, foreign manufacturers of cross air blow device are also ongoing researching and improving. Three typical technical schools of filament cooling were formed gradually, namely TMT in Japan, Barmag in Germany, and Samsung in Korea3.

TMT Machinery Co., Ltd. has developed a CIQ outer cross air blow device for spinning fine denier fiber. It can ensure the uniformity of the wind received by each bundle, but the wind resistance of the wind direction rectification cylinder is large so that the energy consumption is relatively large.In addition, it has excellent processability for porous ultrafine fibers such as 0.3D monofilaments since the reduction between rectifier holes. Spinning more than 288 holes can be performed on spinnerets with an outer diameter of 85mm.As shown in Fig. 1, the EcoQuench outer cross air blow device developed by OerlikonBarmag4not only reduces the amount of air-conditioning air flow needed for the cooling process of the strands silk by about 40%, but also effectively saves energy consumption. The quality of fine denier yarns is significantly improved, and the CV value of the product can be reduced to 1.0 or less.Inventa and Neumag have researched and developed the inner cross air blow equipment, and Zimmer has developed the outer cross air blow technology.Most blowing heads were designed with high damping in 1970swhose damping rectifier element was made of microporous sintered material or microporous non-metallic material while the air pressure of the air duct is between 6000-8000 Pa. The advantage of the high damping blower is that the speed of the blowing cool air is stable and the wind speed difference between the upper and lower parts of the blower is small. The disadvantage is that the energy consumption and the energy cost is high.

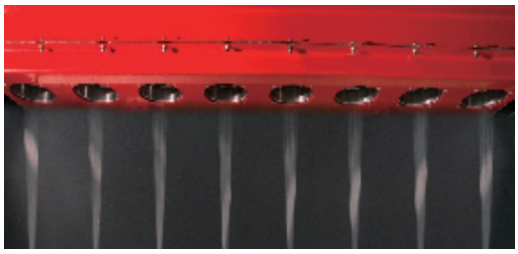

Figure 1: Eco Quench outer cross air blow system.

3 INTRODUCTION TO THE STRUCTURE OF THE CROSS AIR BLOW DEVICE

Such as the outercross air blowshown in Fig. 2. The working principle of the device is as follows: After the cooling air enters the air duct, rectification is performed through the perforated plate 6 to enter the lower air chamber, and then the second rectification is performed through the perforated plate 4 to enter the upper air chamber. Next, the cooling air is rectified and homogenized through the outer porous plate 1 and the inner porous plate 2. The cooling air is then evenly blown from the wire mesh 3 to cool the tow and finally to the surrounding air.The cooling air finally blow out evenly from the wire mesh 3 to cool the tow and dissipate to the surrounding air.

The cooling air of the outer cross air blow is blown circumferentially uniformly from the outside of the tow to the arranged tow endlessly. The wind is very close to the tow to make excellent use of energy. Since the cooling air does not need to cross the multi-layer fibers, the rise of the cooling air temperature is small and the cooling conditions of the tow are similar.

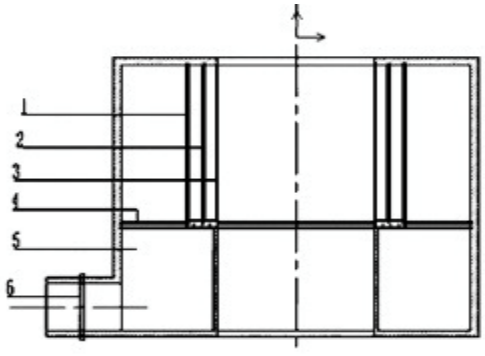

Figure2:Cross air blow structure diagram.

1-outer porous plate 2-inner porous plate 3-wire mesh 4-horizontal porous plate 5- air chamber6-perforated plate.

4 NEW FLEXIBLE CROSS AIR BLOW DEVICE

Flexible manufacturing system (FMS) is a group of CNC machine tools and other automated process equipment, which is composed of computer information control system and material automatic storage system. The so-called flexible fiber spinning technology[5]refers to adopting or replacing different functional modules or devices on the same fiber spinning equipment to produce different varieties and different functions of differentiated fiber to meet the production requirements of small batches and varieties.

4.1Research on Flexible Cross Air Blow Device

In recent years, due to the continuous growth of domestic chemical fiber production capacity, the growth rate of corporate profits has declined. Against this background, the chemical fiber industry as a whole is trying hard to adapt itself to the complicated external environment such as sluggish demand in the international market, the upgrading of domestic consumption structure, the fluctuation of raw material prices, and the high manufacturing costs. The industry has basically maintained steady growth by focusing on technological innovation, smart manufacturing, and green circulation to improve supply quality. Flexible and multifunctional differential modification technologies will continue to be the focus for the development of chemical fiber companies in the near future. In addition, China's “13th Five-Year Development Guidance Opinions for Chemical Fiber Industry”6also listed flexible technology as a key development area and direction, and proposed to build an innovative platform for chemical fiber efficient and flexible manufacturing technologies to solve the technical bottleneck of product development .At present, the design processing and production of China's chemical fiber equipment are becoming more mature and ever-growing. The standardization, modularization and multi-functionalization of spinning equipment are still the main development directions in the future. In addition, it is imperative to realize the interchange of cross air blow and lateral blow, as well as the development of flexible cross air blow systems that adapt to small batches and varieties.

The term "flexibility" can be understood from an engineering perspective as the ability and characteristics to adapt to change. Specifically: (1)

Adapt to product changes such as product modification and new product development; (2) Adapt to changes in production systems such as new equipment, new production methods, new control systems, and new production personnel; (3) Adapt to changes of requirements, such as changes in product quantity and instability during the production cycle. The flexibility of the flexible cross air blow device can be embodied in four aspects, namely product flexibility, mechanical flexibility, process flexibility, and control system flexibility.

The main sign of product flexibility is the range of flexibly adapted products which refers to the range of differentiated and functionalized fibers that can be blown and cooled by the flexible cross air blow device. Mechanical flexibility refers to the adaptability that machinery exhibits when the product type changes, such as the requirement to produce a certain size of fiber. It shows whether the flexible cross air blow system has the necessary functional devices, the adjustable range of the machine output, and the ability to achieve fiber performance. Process flexibility mainly depends on the richness and reliability of the process. It is required to provide the optimum blowing conditions and the constraint parameters or evaluation functions for blowing process control on all kinds of fibers processed. The flexibility of the control system is controlled by the computer and therefore depends on the level and ability of the computer system to operate in real time. The adoption of flexible systems has greatly increased the degree of influence of random factors. The computer system must monitor the actual operating conditions of the processing system at any time and correct the process parameters and conditions in a timely manner so that the production can maintain the best state. The computer system must monitor the actual operating state of the processing system at any time, and correct the process parameters and conditions in time to keep the production in the best condition. As shown in Fig. 3, the machine flexibility and process flexibility complement each other, and the flexibility of the control system controls the mechanical flexibility and process flexibility to achieve product flexibility.

4.2 The Research Line of Flexible Cross Air Blow Device

4.2.1 Establishing a Database Between System Functional Structure and Product Variety

The study of the flexible cross air blow device must begin with fiber cooling forming theory. Combined with the knowledge of heat transfer, a design calculation method for the cross air blow would be summarized firstly. The calculation of some parameters provide sufficient theoretical basis for the design of the device and ensure the rationality of the windless area and the length of the blowing area, such as cooling capacity, the volumetric flow of the wind, the height of the air outlet, the inner and outer diameters of the cross air blow head, the curve equation of the pressure stabilizing chamberouter wall. However, it's difficult to calculate these parameters due to the large number of parameters and less research, the dependent variables between parameters such as the length of the windless zone and the blowing zone. On the basis of theoretical calculation, the thermodynamic and kinetic mathematical model of the complex system of the cross air blow system would be established based on the ansys simulation platform to study the different wind pressure and wind speed distribution in the cross air blow duct, as well as the relationship of pressure difference between inside and outside of the blowpipe. The rational air flow velocity and temperature distribution would be studied by simulating the entire spin cooling process to establish a database between the functional structure of the cross air blow system and the flexible modified varieties to realize the flexibility interchange between components and varieties.

4.2.2 Product Grouping Technology

The flexible modified varieties are grouped according to the database between the functional structure of the cross air blow system and the flexible modified varieties to study the evolution of fiber orientation and crystal structure in the process of blowing. Designing flexibility with type-group features can greatly reduce the workload of research and design of flexible cross air blow systems, as well as with the success or failure of flexible design and with good technical and economic benefits.

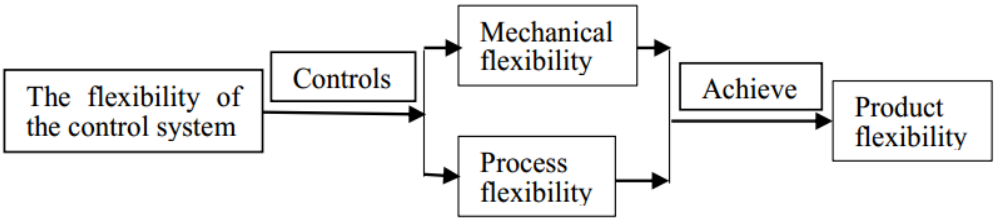

Figure 3: The relation graph among Product Flexibility, Mechanical Flexibility, Process Flexibility, and Flexibility of Control Systems.

4.2.3 Research and Design of Flexible Cross Air Blow Device

The cross air blow device that can adjust temperature and pressure would be designed according to the distribution of the wind speed and temperature in the cooling blower. Through the selection of rectifying material and the design of the air chamber, the cooling wind speed is ensured to be stable, and the inner and outer layers of the tow are cooled evenly. Wind temperature, air pressure, wind speed, length of windless zone can be adjusted according to the fiber to achieve modularity and interchange ability of components and the cross air blow device to meet the requirements of flexible cooling in fiber production.

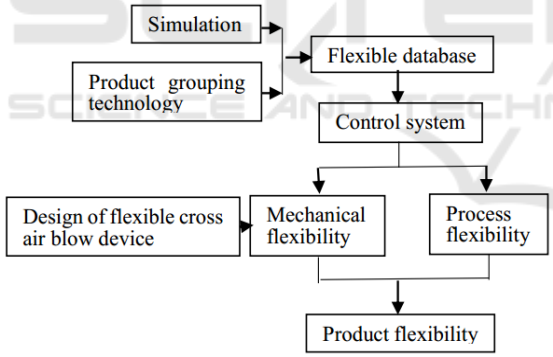

Figure4: The research roadmap of flexible cross air blow device.

5CONCLUSIONS

Cross air blow device has shown the advantages in terms of productivity, energy savings, and reduced operating costson the spinning fine and ultrafine fiber yarn. With the improvement of domestic chemical fiber machining precision, domestic production of cross air blow device has approached or reached the international advanced level. The cross air blow technology develops from single blow heads, high damping and high energy consumption to multiple blow heads, low damping, low energy consumption, high efficiency and high blow quality. However, there is still room for greater improvement in avoiding overcapacity of general-purpose products, increasing the differentiation rate of chemical fiber products, and satisfying the increasingly higher demands of users on the consistency of product quality. It's an urgent need to break through the technology to achieve flexible blow cooling and develop the small-batch and multi-variety productsin the high-capacity continuous equipment.

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