Design of extrusion die for tubular material with turbine-driven biaxial orientation stretching device

Chen Liang[1], Zhang Youxin[2], Wang Pinyang[2], Wu Youcai[2]

(1. Mingyang Smart Energy Group Co. LTD., Tianjin 528437, China;
2. Guangdong Jisu New Material Co. LTD., Dongguan 523527, Guangdong, China)

Abstract: This article introduces a design of an extrusion pipe head utilizing a turbine-traction biaxial orientation stretching device. As the requirements for the use of plastic pipes continue to rise, the application fields of plastic pipes are continuously expanding, and countries are imposing higher standards on the performance of plastic pipes. Especially during the online production of PVC-O pipes, the positioning of the orientation stretching device and precise heating control of the billet temperature are key technologies for the self-reinforcement of biaxially oriented pipes. This not only makes it possible to maintain a stable temperature during the orientation stretching process but also prevent uneven wall thickness and eccentricity of the pipes due to misalignment between the billet and the orientation stretching device during online production. Therefore, a design of an extrusion pipe head using a worm-wheel traction biaxial orientation stretching device has been developed. The results show that by pulling the orientation stretching device at different positions online, the billet can achieve smooth stretching and precise positioning under ideal heating conditions, ensuring the uniformity of the molded pipe after overall expansion and improving the burst resistance and toughness of the pipe.

Key words: turbine; traction; biaxial orientation stretching; position; move

Classification number: TQ330.41　　**Article number:** 1009-797X(2026)03-0052-05

Document code: B　　**DOI:**10.13520/j.cnki.rpte.2026.03.015

With the significant increase in demand for plastic pipes, the application fields of pipes are continuously expanding, and countries have raised higher requirements for the performance of plastic pipes. How to save materials while improving the overall performance of pipes is an important direction in the research of plastic pipes. Biaxial stretching self-reinforcement technology is a new production technology for plastic pipes that has been developed in recent years. To achieve the production of biaxially stretched plastic pipes, the expansion method is commonly used. After secondary heating treatment, the temperature of the pipe billet reaches the expansion temperature, and then it is expanded through an expansion core mold connected to the extruder head under the traction force of a tractor. Since the stretching orientation of polymer materials occurs between the glass transition temperature and the melting temperature, if it is below the glass transition temperature, the molecular chains are in a frozen state. Stretching at this temperature will only cause the material to be forcibly stretched and damaged; if it is above the melting temperature, the molecular chains can move freely, and the stretched molecular chains cannot achieve orientation. Only when the temperature is controlled between the glass transition temperature and the melting temperature is it particularly important, as it directly affects the quality of the pipe. It is best to achieve and maintain the most effective molecular orientation near the softening point of the material.

Biography: Chen Liang (1992-), male, holds a master's degree and is an engineer. He is primarily engaged in the analysis and optimization of mechanical structure simulation performance, as well as research on new materials.

To precisely maintain uniform temperature distribution of the pipe billet, this is not only the key to the forming technology of the orientation process but also the key to avoiding uneven wall thickness and eccentricity. Therefore, the processing temperature control during pipe billet stretching must be evenly distributed. Only in this way can the pipe billet achieve biaxial stretching along the biaxial stretching device and improve the overall performance of the pipe. To this end, an extrusion pipe head structure using a worm gear traction biaxial orientation stretching device has been designed.

1 Analysis of the molding process of extrusion die head for pipe materials

The manufacturing method of the biaxial orientation stretching process typically involves placing a long steel wire rope inside the extrusion pipe head, with one end fixed at the center of the extruder head mandrel and the other end fixed at the center of the expansion head of the biaxial orientation stretching device. This technique is often a two-step process, where the extruded pipe billet is first cooled to room temperature and then heated to the stretching temperature. However, this method poses certain technical challenges in terms of the stability of stretching and heating during actual production. Specifically, after the pipe billet is cooled and solidified, it is pulled into the heating device by the first tractor for secondary heating. After being heated to a highly elastic state, the pipe billet is subjected to bidirectional stretching through an expansion mold. Since the position of the secondary heating device for continuously formed pipes is generally fixed after installation on the production line, and the position of the orientation stretching device is also fixed after adjustment before production, the orientation stretching device cannot move forward or backward during online production, limiting the uniformity of heating of the pipe billet.

As a result, precise and uniform heating of the pipe billet cannot be achieved, and only heaters can be used to adjust the temperature to suit the heating degree of the pipe billet. This process adjustment is complex, and the pipe billet cannot be heated uniformly in a timely manner, affecting the stability of orientation stretching and making it difficult to control the pipe billet during orientation stretching. This is both crucial for the forming technology of the orientation process and for avoiding uneven wall thickness and eccentricity. Since this extrusion pipe head does not have a structure that allows the orientation stretching device to move forward or backward, the heated pipe billet cannot be uniformly heated at the optimal orientation stretching position, making it difficult to ensure the uniformity of overall expansion of the pipe billet. This results in issues such as uneven wall thickness and easy deformation of the pipe body after stretching, leading to a decline in the performance of the oriented and stretched pipe and seriously affecting its service strength. Additionally, if the temperature control is improper during production, the pipe billet is stretched at a lower temperature, increasing the traction resistance of the material as it passes through the orientation stretching device, leading to unstable production and even downtime. In this case, it is necessary to adjust the length of the steel wire rope and restart production. This affects production efficiency, results in scrap, and increases the cost of forming pipes. Therefore, in response to issues such as uneven heating and low strength of the formed pipes in the online production of the orientation stretching device, an extrusion pipe head utilizing a turbine-driven biaxial orientation stretching device has been designed, allowing the orientation stretching device to flexibly adjust its position and move forward or backward during online production.

The structural feature lies in that an output shaft connected to a worm gear is arranged between the diverter cone and the hollow mandrel inside the extrusion tube head. One end of the output shaft is fixedly connected to a steel wire rope through threads, and the other end of the steel wire rope is connected to an orientation stretching device. The orientation stretching device is driven by the handle of the worm gear, with the output shaft winding around the steel wire rope to pull the orientation stretching device to move back and forth. By adjusting the position of the orientation stretching device online, the tube billet can be heated at an ideal heating temperature, ensuring the uniformity of the overall expansion of the tube billet. At the same time, the entire extrusion tube head structure is designed to be simple, without the need to stop the machine to adjust the position of the orientation stretching device, reducing scrap, time, and labor costs. In addition, traditional plastic tube extrusion heads generally use a solid mandrel and diverter cone structure, which is relatively bulky, time-consuming and laborious to disassemble and assemble, and has relatively long heating and cooling times. In order to save heating energy, reduce disassembly and assembly time, lighten the overall weight of the head, and save material costs.

2 Overall structure of extrusion die head

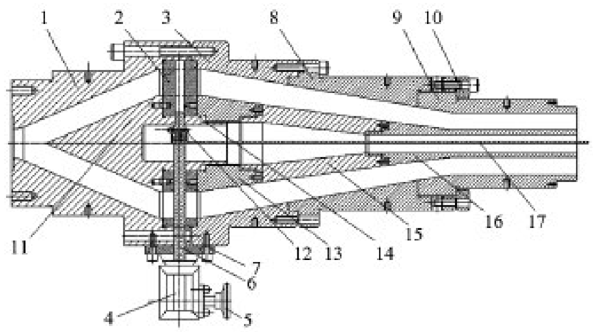
A kind of extrusion pipe head structure utilizing a turbine-driven dual-axis orientation stretching device, as shown in Figure 1, primarily comprises the following components: a head connecting body 1, a splitter bracket 2, a head body 3, a turbine 4, a turbine handle 5, a die 9, and a pressure ring sleeve 10. The interior of the head connecting body, head body, die, and pressure ring sleeve is equipped with a cavity. Within the cavity, components such as a splitter cone 11, bolts 12, steel wire ropes 17, an output shaft 6, a hollow core rod connecting sleeve 13, a hollow core rod transition sleeve 15, and a hollow core rod 16 are arranged, forming a material flow channel. The head connecting body and the head body are fixed together using bolts. The other end of the head body is bolted to the transition sleeve 8, and the other end of the transition sleeve 8 is threadedly fixed to the pressure ring sleeve at the end of the die, thus constituting an internal cavity. One end of the splitter cone within the cavity is equipped with a circular platform 14, onto which the through-holes on the splitter ribs of the splitter bracket are inserted.

The output shaft of the turbine is inserted into the through-holes on the head connecting body and the splitter ribs of the splitter bracket. Subsequently, the steel wire ropes are fixed using bolts. The splitter cone and the hollow core rod connecting sleeve are threadedly fixed together, compressing and securing the splitter bracket. Its characteristics lie in the following: a bolt is provided at one end of the output shaft connected to the turbine between the splitter cone and the hollow core rod connecting sleeve to fix and connect the steel wire rope. The other end of the steel wire rope is connected to the orientation stretching device. The orientation stretching device is rotated by the turbine handle of the turbine, causing the output shaft to wind and pull the steel wire rope, thus moving the orientation stretching device back and forth. The turbine fixing plate 7 is provided with connecting through-holes, through which the threaded holes on the head connecting body and the head body are connected, securing the turbine through the through-holes provided on the turbine fixing plate.

3 Further introduction based on the attached drawing of the overall structure of the pipe extrusion head

3.1 A kind of extrusion pipe die utilizing a turbine-driven biaxial orientation stretching device

As shown in Figure 1, an extrusion pipe head utilizing a turbine-traction biaxial orientation stretching device mainly comprises a head body connector, a splitter bracket, a head body, a turbine, a turbine handle, a die, and a pressure ring sleeve. The head connector, head body, die, and pressure ring sleeve also include components such as a splitter cone, bolt, steel wire rope, output shaft, hollow core rod connecting sleeve, hollow core rod transition sleeve, and hollow core rod, which are connected in sequence. The main features of the extrusion pipe head are as follows:



1-Head body connector; 2-Diverter bracket; 3-Head body; 4-Turbine; 5-Turbine handle; 6-Output shaft; 7-Turbine fixing plate; 8-Transition sleeve; 9-Die nozzle; 10-Pressure ring sleeve; 14-Diverging cone; 12-Bolt; 13-Core rod connecting sleeve; 14-Circular cone; 15-Hollow core rod transition sleeve; 16-Hollow core rod; 17-Steel wire rope.

Figure 1 Schematic diagram of the overall structure of the extrusion die head for the turbine-traction biaxial orientation stretching device

3.2 Turbine device structure

As shown in Figures 2 and 3, the turbine device structure mainly consists of components such as the turbine 4, turbine handle 5, output shaft 6, turbine fixing plate 7, bolt 12, and steel wire rope 17. The interior of the turbine device is equipped with the turbine and output shaft. One side of the turbine is equipped with a turbine handle, and directly in front of the turbine is a turbine fixing plate. The said turbine fixing plate is equipped with a connecting through hole, through which the entire turbine device is connected and fixed with the threaded hole provided on the head connecting body and head body. By rotating the turbine handle, the turbine is driven to move the steel wire rope fixed on the output shaft, which is then wound and pulled to move the orientation stretching device forward and backward. When the orientation stretching device moves forward, the steel wire rope is loosened by rotating the turbine handle, and under the friction force generated between the tube blank and the orientation stretching device, the orientation stretching device is driven to move forward. When the orientation stretching device moves backward, the direction of rotation of the turbine handle is opposite to that of the steel wire rope loosening, causing the steel wire rope to tighten and drive the orientation stretching device to move backward.

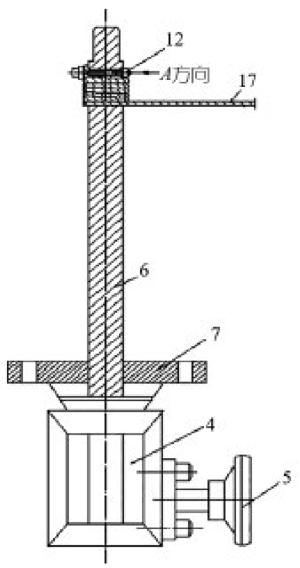


Figure 2 Schematic diagram of turbine device structure

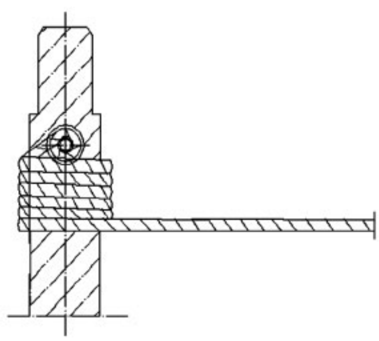


Figure 3 Enlarged schematic diagram of bolt-fixed steel wire rope structure in direction A of the structure in figure 2

3.3 Flow diverter cone

The role of the diverter cone is to gradually thin the layer of plastic melt, facilitating uniform heating and generating shear friction to further homogenize and plasticize it. Traditional diverter cones are mostly solid structures, as shown in Figure 4, and there are also designs where the diverter and the bracket are integrated into a single structure, as shown in Figure 5. However, these structures are relatively bulky, time-consuming and laborious to assemble and disassemble, and require relatively long heating and cooling times. In order to save heating energy and assembly/disassembly time, reduce the mass of the diverter cone, and accommodate the increased steel wire rope for storage, the diverter is designed to be hollow, as shown in Figure 6. A through hole is provided in the axial diameter of the diverter cone's circular cone, and the output shaft of the turbine passes through the through hole provided in the head connector and the diverter bracket 2's diverter rib. The steel wire rope is then fixed with bolts. The outer diameter of the diverter cone's circular cone is fitted into the inner hole provided in the diverter cone bracket, and the diverter cone is then connected to the hollow core rod through threads to securely press the diverter bracket. The diverter 11 is designed to be hollow, effectively storing the increased steel wire rope in the hollow cavity, allowing the steel wire rope to smoothly pull and guide the stretching device to move smoothly.

There are three main dimensions in the design of the diverter here: the divergence angle α, the length L of the diverging cone, and the radius R of the top fillet of the diverter,

(1)The selection of the diverter expansion angle α is related to the viscosity of the plastic. For plastics with lower viscosity, the melt flow resistance is smaller, and α is usually taken as 30°~60°; for plastics with higher viscosity, the melt flow resistance is greater, and α is usually taken as 30°~45°.

(2) The length L of the diverging cone is calculated according to the following formula:

$$L=(0.6-1.5)D_0$$

Where:

L—length of the diverging cone, mm;

D_0—Diameter at the outlet of the filter plate, mm.

(3) The fillet radius (R) at the top of the diverter is generally taken as 0.5~2.0 mm.

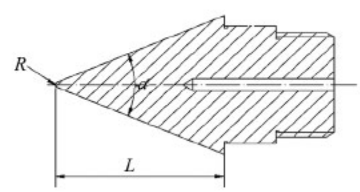


Figure 4 Solid structure diagram of diverging cone

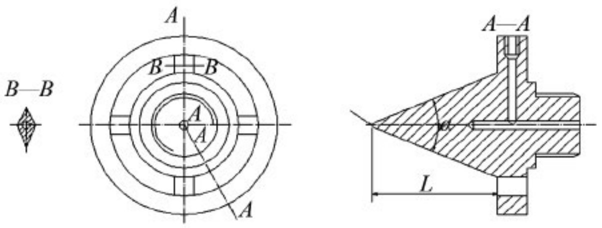


Figure 5 Overall structural diagram of shunt and bracket design

3.4 Diverter bracket

As shown in Figure 7, the splitter bracket is equipped with an inner hole, which is fitted onto the outer diameter of the splitter cone's circular cone. The splitter bracket 2 is equipped with 4 to 8 splitter ribs. The through hole located at the center of the splitter bracket's shaft diameter is connected to the through hole located on the splitter rib. Since the front end of the splitter cone is equipped with a circular cone, and the front end of the circular cone is equipped with external threads, the splitter cone bracket is fixed and compressed by the external threads and the core rod connecting sleeve. Then, the output shaft of the turbine is passed through the through holes provided on the head connecting body and the splitter bracket, and the turbine is fixed through the through holes provided on the turbine fixing plate and the threaded holes provided on the head connecting body and the head body.

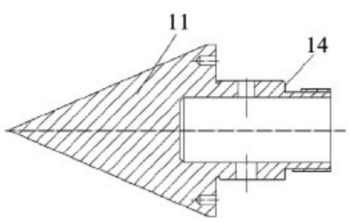


Figure 6 Schematic diagram of the diverging cone structure

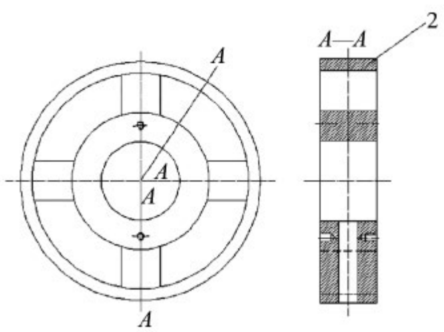


Figure 7 Schematic diagram of the shunt bracket structure

4 Molding principle of the head

The forming principle of the extrusion die head for the turbine-traction dual-axis orientation stretching device involves first cooling the extruded tube blank to room temperature and then heating it to the stretching temperature. Specifically, when the tube blank is pulled into the heating device by the first traction machine for secondary heating, it is heated to a highly elastic state, and then undergoes bidirectional stretching through an online production process using a movable orientation stretching device. The specific forming process involves a turbine-connected output shaft located between the diverging cone and the hollow core rod inside the extrusion die head. One end of the output shaft is equipped with a threaded fixed connection for a steel wire rope, and the other end of the steel wire rope is connected to the orientation stretching device. The orientation stretching device is rotated by the turbine handle, causing the output shaft to wind and pull the steel wire rope, which moves the orientation stretching device back and forth. This ensures that the tube blank is heated at an ideal heating temperature, maintaining uniform expansion throughout the tube blank to achieve bidirectional stretching and form the pipe.

5 Conclusion

(1) By utilizing turbine traction, the online movement of the orientation stretching device is achieved, ensuring that the tube billet is at an ideal heating temperature state, resulting in uniform expansion of the entire tube billet and improving the burst resistance and toughness of the tube material.

(2) Through online traction via turbines, there is no downtime, and production efficiency and scrap are not affected by adjusting the length of steel wire ropes, thus reducing the cost of forming pipes.

(3) The hollow structure designed with a diverging cone can effectively store the increased steel wire rope wound inside the cavity, enabling the steel wire rope to smoothly pull and guide the stretching device to move steadily.

(4) By designing the connecting sleeve, transition sleeve, and structure of the hollow mandrel as hollow structures, the overall weight of the head can be reduced, material costs can be saved, and heating and cooling times can be increased, thereby saving heating energy.