Research and Application of Screw Feeding Mechanism for Fiberboard Separation

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Abstract. The main function of the screw feeding mechanism is to force the cooked wood fiber material into the high pressure, high temperature and high humidity grinding chamber for fibrosis heat treatment, which is an important part of the fiberboard fiber separation feeding equipment. Through the analysis of typical screw feeding mechanism, combined with production performance requirements, the improvement measures are put forward and the structure of main functional components is determined, and the design scheme of screw feeding mechanism for fiberboard fiber separation is formulated, so as to effectively improve the feeding efficiency.

1. Introduction
Fiberboard, also known as density board, is usually made of wood or non-wood fibers, which are separated and pretreated by mechanical and chemical methods, and then pressed by high temperature and high pressure with resin adhesive. Fiberboard is widely used in construction engineering, composite floor, interior decoration, furniture and wooden doors, packaging and other industries because of its uniform material, good corrosion resistance and moth resistance, small swelling and shrinkage, smooth surface, small swelling and shrinkage, and not easy to crack.

In terms of production equipment, China has gone through a road of introduction, imitation and innovation. Especially in recent years, through the digestion, absorption and innovation of foreign technology, the level of design and manufacturing has made considerable progress. However, compared with developed countries, there are still major problems of single product, high energy consumption and high pollution. In response to the spirit of national energy conservation and emission reduction, all regions have made great efforts to eliminate backward production capacity, and have eliminated more than 470 production lines for shutting down and dismantling fiberboard.

2. Principle of fiber separation processing and common equipment
Fiber separation, the process of separating plant fibers into fine fibers by specific methods, is also often referred to as pulping or desizing. Fiber separation is a very important process in fiberboard production.

According to different technology, it can be divided into mechanical method (including thermomechanical method method, chemical mechanical method and pure mechanical method) and blasting method.
Thermomechanical method, also known as thermomechanical method, softens pulping raw materials in advance through pressure cooking equipment, and then grinds them by a thermal grinder. This method has the advantages of fast softening speed, less damage to fibers and low energy consumption.

The following figure is a set of common fiber separation equipment layout, as shown in the figure:

This paper focuses on the optimization of the design of a set of fiber separation equipment based on the annual output of 80,000 cubic meters, that is, connected to the vibration discharge mechanism and vertical cooking machine between the screw feeding mechanism.

3. Research on screw feeding mechanism

3.1. Integral design scheme of screw feeding mechanism

The screw feeding mechanism is the raw material conveying part of the fiber separation feeding equipment. Its function is to squeeze the softened fibre material from the preheating bin into the vertical cooker (internal high humidity, high temperature and high pressure) for fibrosis heat treatment. Common types of structures are rotary valve type, piston type and screw type. Because the spiral structure has the advantages of continuous feeding, easy maintenance and high efficiency, we choose this mainstream structure to study.

On the one hand, screw feeding mechanism can transport raw materials, on the other hand, it can achieve pressure balance between normal pressure and high pressure by extruding dense raw materials between preheating bin and cooking cylinder, prevent steam circuit and indirectly play a sealing role.

The dehydration of raw materials (excess water is discharged into the water washing section of wood chips for recycling and reuse) can be completed during the conveying process of screw feeding mechanism extrusion (fixed ribs in the screw tube and screw feeding under the co-extrusion friction), which can effectively reduce the condensate water in the cooking cylinder and the moisture content of wood chips in the drying process, and reduce energy consumption.

3.2. Structure Composition of Spiral Feeding Mechanism

The screw feeding mechanism is mainly composed of motor, coupling, reducer, feeding part and base. The feeding part is composed of the main shaft, bearing box, feeding screw, spiral sleeve, inner and outer plug pipes. This part is the research focus of our whole article, as shown in Figure 2 below.

![Figure 1. Spiral feeding mechanism](image)

1, 2-Electricity and Coupling 3, 4-Reducer and Coupling 5-Bearing box 6-principal axis 7-Feed screw 8-Spiral casing 9, 10-External and internal plug tubes 11-Vertical Cooker

3.2.1. Optimum Design of Feeding Spiral Structure. Known structure: feed helix structure is single helix structure, helix angle is 15 degrees, feed section is cylindrical equidistant helix, extrusion section is unequal conical helix, the existing problem is difficult to feed and low efficiency. New capacity requirements: annual output of density board is 80,000 cubic meters, density is 0.5 g/cm³, vertical
cooker pressure is 8-10 kg/m², wood chips length is about 25 mm, water content in feed stage is 60%, water content in discharge stage is 40%.

Optimum design principle: Single-line tapered helix with variable diameter extrudes raw materials to the plug pipe to form a material plug, prevents the steam body from leaking out in the steam bin, and completes the material transportation through continuous work. The feed helix structure includes two parts: the feed section and the extrusion section.

3.2.2. Structural Design of Feed Section. Raw materials are fed into the feeding section from the preheated silo through the vibration discharging mechanism. The variable diameter cylindrical helical structure can effectively improve the feeding speed. The formula for calculating feed volume is as follows:

\[ Q = 47D^2 \cdot t \cdot n \cdot \phi \cdot r \]

In the formula, the diameter D is 0.3 m, the pitch t is 330 mm, the shaft speed n is 30-80 r/min, the filling coefficient is 0.45, and the volume weight R is 50 kg/m³. The size of the front part of the shaft should be larger than that of the rear part. The diameter of the front part of the shaft should be 375 mm and the diameter of the rear part should be 305 mm, according to the formula of feed volume.

3.2.3. Structural Design of Extrusion Section. The function of extrusion section is to use conical spiral groove structure with different screw blades and equal pitch to reduce the moisture content of raw materials from 60% to about 40%. Compression ratio and pitch directly affect the extrusion effect.

Compression ratio is the volume ratio of spiral grooves at both ends of the extrusion section. With the increase of compression ratio, the softening and drying effect of fibers is better (the extrusion force becomes larger), which can effectively reduce the energy consumption in the process of fiber separation.

The volume calculation formula of spiral groove is as follows:

\[ V = \frac{\pi (t - e)}{12}
\]

\[ \left(D_2^2 - D_1 + D_2d_2 - D_1d_1 + d_2^2 - d_1^2\right) \]

In the formula, t is pitch, e is thickness of helical blade, D1, D2 is diameter size of large end axile and helical blade, D1 is diameter size of small end axile and helical blade.

The screw compression ratio of the extrusion section is proved to be the best by a large number of practical data. In order to avoid the slippage of feed and the phenomenon of back-injection, it can be considered that the effect of three conical spirals is the best.

3.2.4. Structural Design of Helical Tube Parts. The raw material is dehydrated under the action of extrusion and friction between the ribs in the spiral tube fixed in the screw feeding mechanism and the screw feeding, and the excess water is discharged into the wood chip washing section.

The raw material is extruded simultaneously by the friction force of the inner and outer plug pipes and the rotating thrust of the feed screw to form a dry and compact packing.

In order to improve the extrusion forming effect, the spiral pipe is processed into the upper and lower separated structure with the same length of the compression section of the feed screw, which is convenient for manufacture, installation and maintenance.

During the normal rotation of the feed screw, the filler will wear the surface of the screw pipe, and the service life of the screw pipe can be effectively improved by increasing the ribs. The setting of the outer plug pipe and the inner plug pipe can add less stuffing retention. The structure of spiral tube parts is shown in Fig. 5.
3.2.5. **Design of spindle structure.** The spindle is arranged between the motor and the feeding screw, which can output torque, transfer power and adjust the clearance of the equipment.

During the production process, the spindle is subjected to radial and axial forces, which include the steam thrust in the vertical cooker, the friction resistance of raw materials in the process of rotation between the screw tube and the feed screw, and the gravity of itself. The load is enormous. The material of the spindle is 40Cr, which is processed roughly and modulated to improve the fatigue strength and rigidity of the spindle.

**Working Principle:** The reducer reduces the speed of DC motor and drives the spindle coupling to drive the feed helix to rotate. During the operation of the equipment, the spindle is floating up and down. In order to improve the spindle rotation accuracy and maximize the service life of bearings, the reasonable selection of bearings is very important.

Choosing the appropriate spindle support structure can improve the operation accuracy of the equipment and avoid the impact of vibration on the equipment. The existing equipment is supported by thrust ball bearings and centering bearings. Although the force is reasonable, it does not have floating centering function and its accuracy is not high.

The self-aligning bearing mainly bears radial force, and automatically adjusts the position of the center of the circle within a certain clearance allowable range after the axial force is applied, so as to adapt to the change of the axial displacement. The main application occasions are when there may be deflection or coaxiality error of the axle.

**Optimum design of spindle structure scheme:**

The vibration of the feed screw during the rotation will cause slight elastic deformation of the spindle. After the axial displacement, the aligning position of the aligning bearing and the thrust aligning bearing will coincide, and the spindle will maintain the floating adjustment posture to effectively improve the positioning accuracy of the spindle.

At the same time, the self-aligning bearing can withstand part of the impact load to offset the impact of vibration and effectively improve the stability of the spindle.

3.2.6. **Structural Design and Calculation of Spindle.** Known technical parameters: cork helical diameter size, main motor power \( P = 355\text{KW}, \) spindle speed \( 30 \text{~} 80\text{r/min}. \) From the axle's torque formula:

\[
T = 9550 \times 10^3 \frac{P}{n} 
\]

After calculation, the shaft torque is obtained: \( T=4.23\text{~}11.3\times10^3\text{N.mm} \)

**Preliminary formula for calculating axlediameter:**

\[
d \geq \sqrt[3]{\frac{9.55 \times 10^6}{0.2}} \frac{P}{n} = C \sqrt[3]{\frac{P}{n}} \text{ mm}
\]
The coefficient C of the table material 40Cr is 102, which is calculated to be \( \geq 167 \text{mm} \). In order to avoid the influence of keyway opening on the overall strength of the shaft, the diameter value of slotting safety calculation method is increased by 4\%, that is, 173 mm. Finally, the standard diameter is rounded and 170 mm is the smallest part of the spindle is reasonable. The structural layout of the spindle is shown in Figure 8 below.

![Figure 3. Drawing of spindle parts](image)

On the one hand, screw feeding mechanism can convey raw materials, on the other hand, it can achieve pressure balance between normal pressure and high pressure by extruding dense raw materials between preheating bin and cooking cylinder, prevent steam circuit and indirectly play a sealing role. Spiral feeding mechanism is an important structure of fiberboard separating feeding equipment. Through the analysis of typical screw feeding mechanism, the overall optimization design of screw feeding mechanism is carried out. The screw feeding and purchasing, screw pipe, spindle and its supporting mechanism are emphatically studied, which effectively improves the feeding efficiency and solves the practical production problems.

4. References

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