Working principle and common fault analysis of the cutting system of the steel cord cutting machine's host

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Abstract: This article elaborates on the mechanical structure and working principle of the cutting system of the steel cord cutting machine's host machine, as well as the role, mechanical structure, and working principle of the hydraulic clutch brake in the host machine's transmission system. It analyzes common faults and solutions encountered during equipment operation, providing a reference for equipment maintenance personnel.

Key words: steel cord cutting machine; cutting blade; hydraulic system

Classification number: TQ334.44 **Article number:** 1009-797X (2025)12-0034-08

Document code: B **DOI:** 10.13520/j.cnki.rpte.2025.12.008

0 Preface

Currently, the steel cord cutting machine is one of the main equipment for all-steel radial tire production enterprises. It is divided into 15°~70° small-angle steel cord cutting machines and 90° steel cord cutting machines. Its main function is to cut the steel cord into cord strips according to the set width, and then splice and roll the cord strips. The cutting system of the cutting blade of the steel cord cutting machine host machine is an important part of the overall production line, mainly consisting of the cutting blade mechanism, transmission mechanism, hydraulic system, etc. This article briefly introduces the structure, working principle, common fault analysis, and solutions of the cutting system of the cutting blade of the steel cord cutting machine host machine.

1 Cutting mechanism

The cutting mechanism is one of the core components of the entire equipment, playing a decisive role in its operation. This cutting mechanism adopts a guillotine-style structure, as shown in Figure 1. The motor rotates and mechanically transmits power to the crankshaft through the reduction gearbox. The crankshaft rotates, driving the C-shaped side arm and causing the upper blade holder to perform linear reciprocating motion. The PLC controls the opening and closing of the hydraulic clutch in the reduction gearbox through external switches and related logic algorithms, enabling the blade holder to precisely rise, fall, and stop, thus achieving effective cutting of the cutting blade and realizing automated cutting production of steel cord fabric. During the mechanical transmission process, a flywheel is installed at the input shaft end of the reduction gearbox, and a plum-shaped elastic coupling is installed between the motor and the flywheel. The entire mechanical transmission process is as follows:

Motor → plum blossom elastic coupling → flywheel → reduction gearbox → crankshaft → C-shaped side arm → upper tool post

The main function of the flywheel is to store a portion of the energy transmitted to the crankshaft during the power stroke of the motor. This energy is used to overcome resistance during the lifting process of the upper cutting blade, drive the crank rod mechanism past the upper and lower dead centers, ensure that the rotational angular velocity and output torque of the crankshaft are as uniform as possible, and enable the motor

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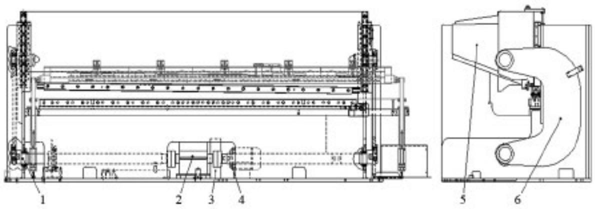
to potentially overcome short-term overload.



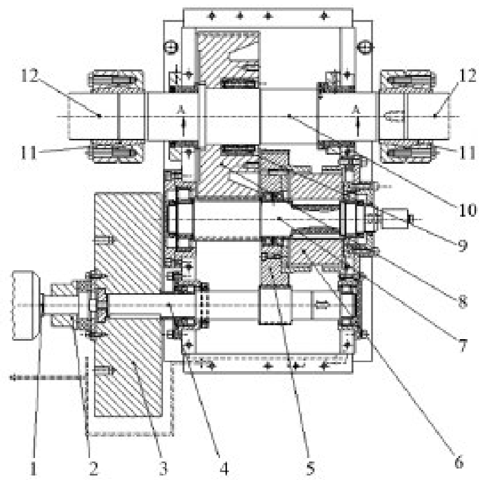
1—Crankshaft; 2—Reduction gearbox; 3—Flywheel; 4—Motor;
5—Upper tool post; 6—C-type side arm

Figure 1 Schematic diagram of the cutting mechanism

2 Transmission mechanism of reduction gearbox

The reduction gearbox is the core component of the entire cutting system, playing a decisive role in its operation. This reduction gearbox adopts a helical gear transmission structure, as shown in Figure 2. The motor rotation is mechanically transmitted to the flywheel through a coupling, which in turn drives the input shaft to rotate. The input shaft transfers kinetic energy to the transition gear through helical gears. The transition gear and the transition shaft are mounted together using two sets of deep groove ball bearings. One side of the hydraulic clutch brake is fixed to the transition gear with hexagonal socket screws, while the other side of the hydraulic clutch is fixed to the side wall of the reduction gearbox with hexagonal socket screws. The transition gear transfers kinetic energy to the transition gear shaft through the clutch brake, and the transition gear shaft, together with its meshing output shaft drive gear, transfers kinetic energy to the output shaft. The output shaft transfers kinetic energy to the crankshaft through a shrink fit, achieving the cutting function of the cutting blade. The output shaft and the output shaft drive gear are fastened together with a shrink fit. The entire mechanical transmission process is as follows:

During normal operation, the input gear shaft is always in a high-speed rotating state. When cutting is required, hydraulic oil enters the hydraulic clutch brake, causing the right side of the brake to open and the left side to close, thereby driving the tool post to rise and fall. When stopping is needed, the hydraulic station cuts off the hydraulic oil supply, causing the right side of the hydraulic clutch brake to close and the left side to open, thus ensuring that the tool post stops and is fixed.

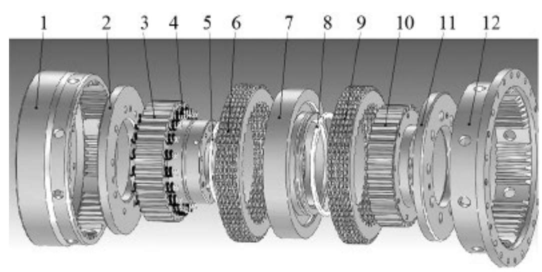


1—Motor; 2—Coupling; 3—Flywheel; 4—Input gear shaft;
5—Transition gear;6—Hydraulic clutch brake; 7—Transition gear shaft;
8—Output shaft transmission gear;9—Expansion sleeve; 10—Output shaft;
11—Expansion sleeve; 12—Crankshaft

Figure 2 Schematic diagram of the gearbox structure

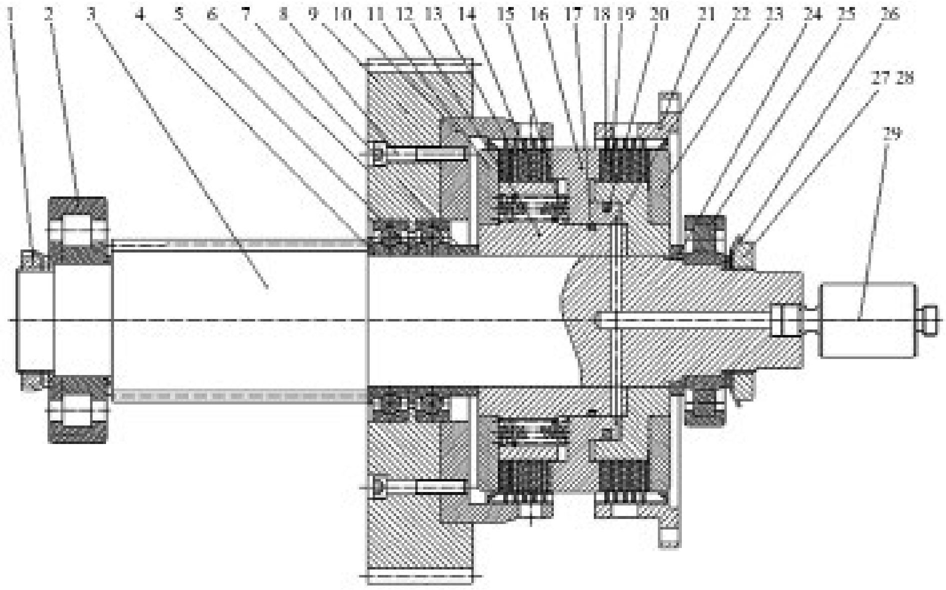
3 Structure and working principle of hydraulic clutch brake

The hydraulic clutch brake is one of the core components of the entire reduction gearbox, and it plays a decisive role in the operation of the entire cutting system. As shown in Figure 3, it is a structural schematic diagram of the hydraulic clutch brake. During normal operation, as shown in Figure 4, the transition gear 9 and the rotating outer gear ring 10 are fastened together with hexagon socket screws. The transition gear and the rotating outer gear ring are always in a high-speed rotating state, and the left outer gear friction plate 13 rotates synchronously at high speed under the meshing action of the rotating outer gear ring gear.



1—Rotating outer gear ring; 2—Left fixed gland; 3—Left inner gear sleeve;
4—Composite compression spring; 5—Small piston ring;
6—Left friction plate assembly; 7—Floating cylinder body;
8—Large piston ring;9—Right friction plate assembly;
10—Right inner gear sleeve; 11—Right fixed gland;
12—Fixed external gear ring

Figure 3 Schematic diagram of hydraulic clutch and brake structure



1—Round nut; 2—Cylindrical roller bearing; 3—Gear shaft; 4—Locating sleeve A; 5—Locating sleeve B; 6—Deep groove ball bearing; 7—Locating sleeve C; 8—Hexagon socket screw; 9—Transition gear; 10—Rotating outer gear ring; 11—Left fixed gland; 12—Left inner gear sleeve; 13—Left outer gear friction plate; 14—Left inner gear friction plate; 15—Composite compression spring; 16—Floating cylinder; 17—Small piston ring; 18—Right outer gear friction plate; 19—Right inner gear friction plate; 20—Large piston ring; 21—Fixed outer gear sleeve; 22—Right inner gear sleeve; 23—Right fixed gland; 24—Locating sleeve D; 25—Cylindrical roller bearing; 26—Locating sleeve E; 27—Round nut; 28—Retaining washer; 29—Rotating joint

Figure 4 Schematic diagram of transmission through the transition gear shaft of the reducer

When the C-type side arm cutter is stationary, the gear shaft 3 remains stationary. The transition gear 9 and the rotating outer gear ring are fastened together using hexagonal socket screws. The transition gear and the rotating outer gear ring are always in a high-speed rotating state. The left outer gear friction plate rotates synchronously at high speed under the meshing action of the rotating outer gear ring gear. The fixed outer gear sleeve is fixed to the reducer housing using hexagonal socket screws. The right outer gear friction plate 18 remains stationary under the meshing action of the fixed outer gear sleeve gear. The floating cylinder 16 moves to the right under the action of the combined compression spring 15, compressing the right inner gear friction plate 19 and the right outer gear friction plate. The inner and outer gear friction plates generate a large friction force under external force, maintaining a stationary state. The right inner gear sleeve 22 is keyed to the gear shaft 3. The right inner gear sleeve and the right inner gear friction plate keep the gear shaft 3 stationary under the meshing action of the gears, thus ensuring that the C-type side arm cutter can be stationary at the required position.

When the C-type side arm cutting blade needs to perform cutting, high-pressure hydraulic oil enters the right side of the floating cylinder 16 through the rotary joint 29. The floating cylinder is located within a sealed cavity formed by the large piston ring 20, small piston ring 17, and right inner gear sleeve 22. Under the action of high-pressure hydraulic oil, the floating cylinder is pushed to move leftward against the pressure of the combined compression spring 15, compressing the left inner gear friction plate 14 and the left outer gear friction plate 13 together. The inner and outer gear friction plates generate a large frictional force under external force. With the mutual engagement of the inner and outer gears, components such as the left inner gear sleeve 12, left fixed gland 11, left outer gear friction plate, left inner gear friction plate, and combined compression spring maintain a consistent state. At the same time, after the right outer gear friction plate and right inner lining friction plate lose external force, gaps are formed between the friction plates, which are then in a free state. The transition gear drives the gear shaft to rotate as a whole under the transmission of the upper meshing gear, thereby transmitting kinetic energy to the C-type side arm and driving the upper blade frame to move up and down linearly for material cutting. When the cutting action is completed and the upper blade frame moves to the highest position, an external switch detects the signal, and the electrical system transmits a stop command to the hydraulic system. The hydraulic oil stops supplying, and the floating cylinder in the hydraulic clutch brake moves rightward under the action of the combined compression spring, locking the gear shaft. The C-type side arm stops moving and remains in a stationary state.

4 Operating principle of hydraulic system and accumulator

4.1 Operating principle of hydraulic system

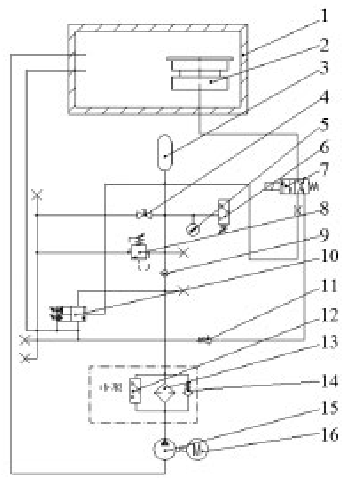
Generally, hydraulic system designs vary slightly among equipment from different manufacturers. This article takes the hydraulic system of the German Fischer 90° steel cord cutting machine as an example, as shown in Figure 5. In this hydraulic system, the reduction gearbox serves as the hydraulic oil tank (typically, domestic equipment hydraulic systems are designed with a separate hydraulic oil tank). During normal operation, the hydraulic oil pump is always in operation under the drive of the motor. The hand valve 4 is in the closed state. To ensure the normal operation of the hydraulic clutch 2, the system's required pressure can be controlled within the range of 4.0~6.5 MPa by adjusting the accumulator charging valve 10. When the cutting system of the cutting machine needs to cut, the electromagnetic directional valve 7 is energized to change direction, and the hydraulic oil flows to the hydraulic clutch 2. Under the action of oil pressure, the internal floating cylinder of the hydraulic clutch switches to achieve the cutting action of the upper blade holder of the cutting system. When the upper blade holder of the cutting system rises to the highest position and needs to be stopped, the electromagnetic directional valve is de-energized and returns to its original position, cutting off the supply of hydraulic oil, and the internal floating cylinder of the hydraulic clutch returns to its initial position. When the cutting system cuts 2~3 times, the pressure of the hydraulic system will decrease to 4.0~4.5 MPa. When the system pressure is lower than 4.0 MPa, the accumulator is pressurized under the action of the accumulator charging valve to ensure that the maximum system pressure is within the range of 6.0~6.5 MPa.

4.2 Structure and working principle of accumulator

The accumulator is one of the crucial components of the hydraulic system. There are three types of gas-charged accumulators in hydraulic systems: bladder-type, piston-type, and diaphragm-type. The hydraulic system utilizes a welded diaphragm accumulator (see Figure 6). The diaphragm accumulator consists of a liquid part and a gas part, with the diaphragm serving as an airtight and medium-separating element. The gas part is pre-charged with nitrogen gas. The function of the diaphragm accumulator is to convert the energy in the system into compressed potential energy at the appropriate time for storage. When the cutting system cuts, the compressed potential energy is converted into hydraulic energy and released to replenish the system. This process of energy storage and release helps to ensure the stability of the hydraulic system pressure. The fluid part of the diaphragm accumulator is connected to the hydraulic circuit, so that when the pressure increases and the gas is compressed, the diaphragm accumulator absorbs liquid. When the pressure decreases, the compressed gas expands and forces the stored liquid into the hydraulic circuit. A valve plate is located at the bottom of the diaphragm. When the accumulator is completely emptied, it closes the hydraulic outlet to prevent damage to the diaphragm.

The basic working principle is as follows:

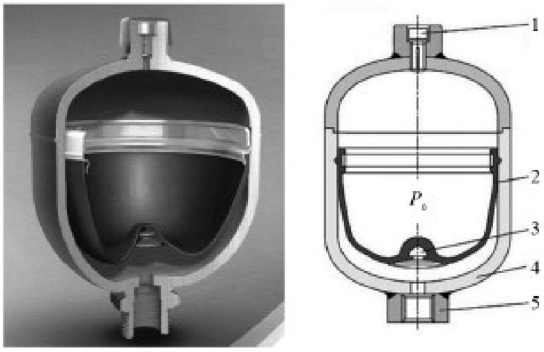
According to the gas law, the pressure of a gas increases



1—Reduction gearbox; 2—Hydraulic clutch brake; 3—Accumulator; 4—Hand valve; 5—Pressure gauge; 6—Pressure switch; 7—Electromagnetic directional valve; 8—Relief valve; 9—Check valve; 10—Accumulator charging valve; 11—Check valve; 12—Pressure switch; 13—Filter; 14—Check valve; 15—Hydraulic pump; 16—Hydraulic pump motor

Figure 5 Schematic diagram of hydraulic system operation

as it is compressed. The volume of a certain amount of gas is roughly inversely proportional to its pressure, which is the basic principle of an accumulator.



1—Gas filling screw;2—Diaphragm; 3—Valve plate; 4—Shell;
5—Liquid connection port

Figure 6 Schematic diagram of diaphragm accumulator structure

Before use, the gas inside the accumulator is usually precharged to a precharge pressure P0, at which the volume V0 of the gas corresponds to the capacity of the accumulator.

When the pressure of the hydraulic oil is lower than P0, it cannot enter the accumulator, and the accumulator does not function at this time. Only when the pressure of the hydraulic oil is higher than the gas pressure P0 can it enter the accumulator. As the pressure oil enters, the gas is compressed, and the pressure continues to rise. Therefore, in order for the hydraulic oil to continuously enter the accumulator, its pressure also needs to rise accordingly. When the pressure of the hydraulic oil stops rising, it can no longer enter the accumulator.

The pressure of the gas and hydraulic oil together constitutes the stored energy. When the port pressure drops, the gas will push the hydraulic oil out of the accumulator. Once the hydraulic oil is completely expelled, the gas pressure will decrease to P0.

Due to limitations in the pressure resistance and safety of the shell, each accumulator has a maximum allowable pressure limit. Once the shell ruptures, the accumulator may explode. To avoid potential combustion risks, nitrogen is usually used as the working gas in accumulators. During the inflation process, it is necessary to strictly follow the product instructions.

4.3 Method for charging nitrogen into accumulator

When charging the accumulator with nitrogen, it can be done offline separately or on-site without dismantling the equipment. The following method and steps for charging the accumulator with nitrogen are exemplified by online charging. During the charging process, use the accompanying FPU-1 charging and testing device. The specific operation is as follows (see Figure 7):

(1) Check the nitrogen cylinder, accessories, and warning labels for completeness to ensure the safety and effectiveness of nitrogen filling. If they do not meet the requirements, they should be properly disposed of.

(2) Disconnect the power supply of the hydraulic system, and keep the hydraulic system in a stopped state.

(3) Open the pressure relief hand valve of the hydraulic system and observe the pressure gauge on the hydraulic system until the system pressure drops to 0 MPa. At this point, all the oil in the accumulator flows back to the oil tank.

(4) Open the top cover of the accumulator, connect the inflation and testing device to the accumulator, connect vone end of the nitrogen hose to the connection port (at C) and the other end to the nitrogen cylinder (not required for pressure measurement).

(5) Rotate the handle of the FPU-1 inflation and detection device to its maximum position (rotate counterclockwise to the maximum), and close the deflation valve (at position B).

(6) Install the nitrogen pressure regulating valve onto the nitrogen cylinder, connect the nitrogen hose to the pressure regulating valve, and connect the other end to the check valve port (at C) of the inflation and testing device.

(7) Rotate the handle of the accumulator's inflation and testing device counterclockwise. When you hear the sound of gas escaping, observe the pressure gauge on the tool (this pressure represents the nitrogen pressure inside the accumulator). Based on the value displayed on the pressure gauge, determine whether inflation is necessary. After making the determination, rotate the handle of the inflation and testing device clockwise again to tighten the inflation screw on the accumulator.

(8) Slowly open the handle on the nitrogen cylinder, observe the pressure gauge on the inflation and detection device (note that the pressure inside the nitrogen cylinder must be higher than the inflation pressure), adjust its outlet pressure

to 4.0~4.5 MPa, rotate the handle on the inflation and detection device counterclockwise, slowly open the accumulator inflation screw, and gradually inflate the nitrogen. When the pressure gauge reaches 30% of the rated pressure, the inflation speed can be increased to reach the required inflation pressure. Do not inflate the gas into the accumulator all at once to avoid rupture due to uneven expansion of the airbag during inflation. When the pressure gauge reaches the required inflation pressure, close the handle on the nitrogen cylinder, then rotate the handle of the inflation and detection device clockwise, tighten the inflation screw on the accumulator, open the deflation valve handle (at B) to relieve the pressure inside the tube, remove the special tool, screw on the top cover of the accumulator, and complete the inflation process.

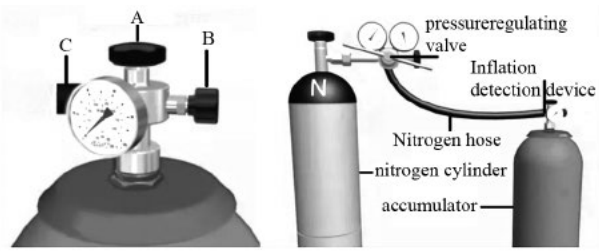


Figure 7 Schematic diagram of nitrogen charging for accumulator

5 Common fault analysis and troublesho oting methods

5.1 During the cutting process of the upper blade holder, the cutting blade wallboard sways from side to side

During the normal operation of the cutting mechanism of the cutting machine, there may be a phenomenon where the entire wallboard of the upper blade holder swings from side to side while the upper blade holder moves up and down for cutting. The main reason for this phenomenon is that the crankshaft is not aligned horizontally, resulting in an angular difference in the circumferential direction. During operation, due to the dynamic imbalance of the crankshaft, overall vibration is generated and transmitted to the wallboard of the blade holder. Prolonged operation may cause the C-shaped side wall to fracture or other parts to be damaged due to long-term uneven stress.

Handling method: Utilize professional tools, with one end of the crankshaft as the benchmark, loosen the shrink fit between the gearbox output shaft and the crankshaft, readjust the circumferential angle of the crankshaft on the other end, and restore the circumferential consistency between the left and right ends of the crankshaft.

5.2 When the upper blade holder is cutting, it suddenly falls off and cannot be raised

The possible reasons for this phenomenon are as follows:

(1) The internal friction plate of the hydraulic clutch brake is worn, leading to an increased gap between the inner and outer friction plates, which in turn reduces the overall braking torque of the hydraulic clutch brake.

Treatment method: Replace the hydraulic clutch brake as a whole or replace the inner and outer friction plates of the hydraulic clutch brake.

(2) Wear of the gear pump in the hydraulic system causes a decrease in pressure or pressure fluctuations in the hydraulic system, resulting in reduced friction between the inner and outer friction plates of the calender clutch, and a decrease in the overall braking torque of the hydraulic clutch brake. In this situation, a typical phenomenon occurs: the oil temperature in the hydraulic system rises, and the gear pump housing feels hot to the touch. When measured with an infrared thermometer, the surface temperature of the gear pump is expected to be above 50℃.

Treatment method: Clean the hydraulic system oil circuit thoroughly and replace it with new hydraulic oil and gear pump. To avoid damage to the gear pump, regularly replace the filter of the oil circuit system.

(3) Insufficient nitrogen pressure in the accumulator leads to the loss of its function in compensating and stabilizing the pressure of the hydraulic system, resulting in pressure reduction or pressure fluctuations during cutting by the cutting blade. In this situation, a typical phenomenon occurs: during cutting by the cutting blade, the pressure in the hydraulic system fluctuates significantly, with the pressure rapidly dropping with each cut and quickly returning to normal when the cutting stops. The pressure gauge needle swings widely within a short period of time.

Treatment method: Utilize the FPU-1 inflation and testing device to measure the pressure of the accumulator, and then re-inflate the accumulator with nitrogen gas.

(4) The hydraulic system's overflow valve or accumulator

charging valve is faulty, resulting in insufficient system pressure. A typical symptom is that the system pressure is low and fails to reach the standard value.

Handling method: Clean the overflow valve and accumulator charging valve with gasoline, kerosene, or other organic solvents. If necessary, replace them with new spare parts of the overflow valve and accumulator charging valve.

(5) Faults such as jamming and internal leakage in the clutch oil supply solenoid valve of the hydraulic system cause rapid pressure loss and insufficient pressure in the system. A typical phenomenon is that the system pressure is low and fails to reach the standard value.

Treatment method: Clean the solenoid valve with gasoline, kerosene, or other organic solvents, and replace it with a new solenoid valve spare part if necessary.

5.3 Oil leakage from the output shaft of the cutting gearbox during cutting

The main reason for this phenomenon is the wear of the bearing shells on both ends of the reducer output shaft, which results in a large gap between the shaft and the bearing shell, causing hydraulic oil leakage.

Treatment method: Replace with new bearing shell spare parts.

5.4 The air switch of the motor connected to the reduction gearbox trips during cutting by the cutting blade

The primary possible cause of this phenomenon is as follows: (refer to Figure 4) The round nuts on one or both ends of the transition gear shaft become loose and backlash, causing friction between the round nut and the bearing gland during the cutting process. This increases the resistance during gear transmission, leading to an increase in motor load and current, and ultimately triggering a protective trip of the air switch.

Handling method: Open the bearing pressure covers at both ends, inspect the condition of the round nuts and anti-backout washers, and then retighten and lock the anti-backout washers.

5.5 The upper blade is not at the highest position after the cutting blade stops cutting

Taking the German Fischer 90° cutting machine as an example, the main possible reason for this phenomenon is as follows: (see Figure 8) After long-term use of the reduction gearbox, the clearance between the friction plates of the hydraulic clutch brake becomes larger, and the braking time is prolonged, resulting in the upper blade not stopping exactly at the highest position when the cutting stops. At this ti me, the original position of the upper limit position detection proximity switch is not suitable and needs to be readjusted. If it is operated in this state for a long time, it will accelerate the wear of the inner and outer teeth friction plates of the hydraulic clutch, shortening the service life of the friction plates.

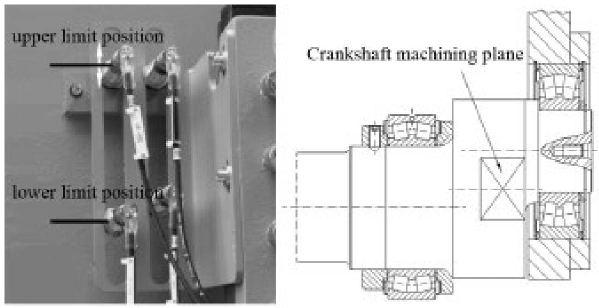


Figure 8 Schematic diagram of the limit detection switch and crankshaft structure

Troubleshooting method: Readjust the position of the proximity switch for detecting the upper position of the cutting blade. Use a professional tool to measure the perpendicularity between the machined surface of the crankshaft at both ends and the ground, ensuring that the upper cutting blade always stops at its highest position.

5.6 The cutting blade and the cutting gearbox produce loud noise during operation

The primary possible reasons for this phenomenon are as follows:

(1) The poor concentricity between the motor and the reduction gearbox causes wear on the elastic pad of the elastic coupling between the motor output shaft and the reduction gearbox input shaft. When the motor rotates at high speed, the coupling and the elastic pad collide and rub against each other.

Treatment method: Use professional tools to readjust the concentricity between the two halves of the flexible coupling, ensuring a concentricity error of ≤0.1 mm, and guaranteeing the concentricity between the motor and the reduction gearbox.

(2) The bearings on both ends of the input gear shaft inside the reduction gearbox (see Figure 2) are worn and pitted, causing noise when the motor rotates at high speed.

Treatment method: Replace the cylindrical roller bearings on both ends of the input gear shaft inside the reducer.

6 Conclusion

As an important component of the steel cord fabric cutting machine, the host machine cutting system plays a crucial role in the entire cutting production line. Its stability is essential. During use, it is necessary to strictly follow the operating procedures and conduct regular maintenance and care according to the equipment maintenance system to ensure its efficient and safe operation. When equipment malfunctions, there are various causes and multiple triggering factors. Only by having a comprehensive understanding of its operating principle and component functions can we quickly and accurately solve the problem. If there is a complex equipment malfunction, we can conduct troubleshooting item by item based on the system's working principle. If necessary, we can consult relevant equipment manufacturers or other professional maintenance personnel.