Application of the principle and structure of a new magnetic drive in the film forming drive system

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Abstract: The new magnetic drive is a practical application of the magnetic coupling principle, which transfers torque and power through the coupling interaction between the magnetic field's N and S poles. The magnetic drive method discussed in this paper involves connecting the power output shaft of an external transmission device to the input shafts of the upper and lower rollers through the magnetic force of high-performance permanent magnets in a magnetic coupling. Leveraging the characteristic that magnetic fields can penetrate a certain spatial distance and material, it achieves non-contact mechanical energy transfer and synchronous transmission of torque inside and outside the rollers of a film forming device under sealed isolation conditions. The practical application of the magnetic drive principle and the use of magnetic couplings have completely solved the problem of harmful process liquid leakage in the dynamic sealing of roller transmission devices inside and outside the process liquid tank, protecting the environment and production safety.

Key words: magnetic drive; magnetic coupling; film forming; transmission system; sealed structure

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With the practical application of magnetic coupling principles and the rise of magnetic drive technology, its superiority in transmission and sealing has become increasingly evident, especially in special production scenarios where direct contact between the driving and driven shafts and zero leakage sealing are required for torque transmission. The film forming device is a key component in production lines for cooling and setting, rinsing and pore formation, and slurry coating of special films (such as microporous films). Its main function is to allow the stretched film to cool and set, rinse and form pores, and be coated with slurry in the forming process liquid, achieving the special process performance required for its products. Since general process liquids are highly volatile and toxic solvents, the structural design of the film forming drive device particularly requires consideration of sealing reliability. This article discusses the advantages and disadvantages of traditional and new drive systems in terms of transmission principle mechanisms and sealing design.

1 Principle of traditional film forming transmission system and design of sealing structure

1.1 Transmission principle

The principle and structure of the traditional transmission system are detailed in Figure 1. Its transmission principle and process are as follows:

The gear motor (8) transmits power to the upper roller I (13) and lower roller (2) of each slot through the T-shaped steering gear I (7) and T-shaped steering gear II (9) installed on the upper and lower brackets, as well as the coupling (6), lower roller drive shaft (5), and gear (4). At the same time, the upper roller I (13) and lower roller (2) transmit power to the upper roller II (14) and other lower rollers (2) through the sprocket II (11), sprocket III (12), sprocket IV (15), and sprocket I (4),

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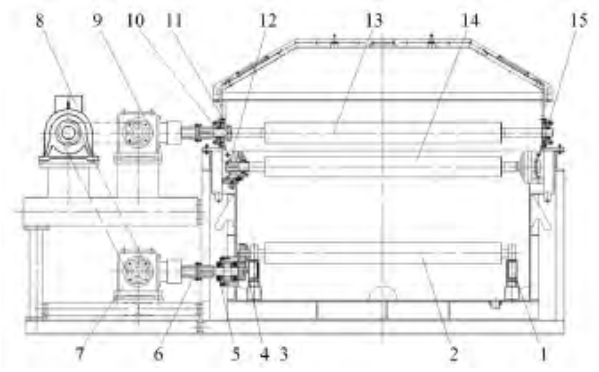
achieving synchronous rotation of all rollers to convey the film.

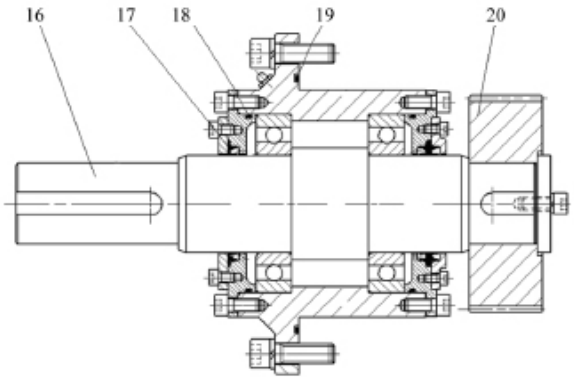


1-Lower roller bracket; 2-Lower roller; 3-Gear; 4-Sprocket I; 5-Lower roller drive shaft; 6-Coupling; 7-T-shaped steering gear I; 8-Reduction motor; 9-T-shaped steering gear II; 10-Bearing with seat; 11-Sprocket II; 12-Sprocket III; 13-Upper roller I; 14-Upper roller II; 15-Sprocket IV

Figure 1 Schematic and structural diagram of traditional structural transmission system

1.2 Principle and structural design of roller drive sealing

Each tank in the film forming process liquid tank is equipped with a drive shaft device (as shown in Figure 2). The drive shaft of the roller is mainly sealed through O-rings (18, 19) for end and radial static sealing. The roller drive shaft (16) is dynamically sealed by skeleton seals (17) arranged both inside and outside the process liquid tank to prevent the leakage of forming process liquid into the external environment and cause pollution.



16-Roller drive shaft; 17-Framework seal; 18-O-ring I; 19-O-ring II; 20-Gear

Figure 2 Traditional roller drive shaft sealing design principle and structural diagram

1.3 Advantages and disadvantages of the transmission principle and sealing structure design of traditional film forming transmission systems

1.3.1 Advantages

(1) Each slot is equipped with a drive shaft device, and the power is transmitted to the lower roller through gears (No. 20), with relatively few leakage points.

(2) The transmission shaft is relatively short, making it easy to disassemble and assemble.

(3) Due to gear transmission, the transmission shaft and the roller are relatively independent, facilitating the adjustment of the roller's levelness and parallelism.

1.3.2 Disadvantages

(1) The skeleton oil seal has high requirements for the processing accuracy of the transmission shaft and bearing seat, including dimensional accuracy, form and position tolerances, and surface finish. If the accuracy is insufficient, it can lead to rapid wear of the sealing ring and subsequent leakage.

(2) During the assembly process, strict attention must be paid to protecting the sealing surface and sealing lip. Improper assembly can lead to leakage of extraction fluid during the operation of the transmission device due to damage to the sealing surface.

(3) This structure is a dynamic seal, and leakage will occur as the skeleton oil seal wears and ages.

(4) The traditional film forming transmission system utilizes structures such as sprocket chains and gear me shing to transmit power, resulting in a cumbersome and complex transmission process. This structure inevitably leads to reduced transmission efficiency, decreased operational smoothness, and poor synchronization of the rollers' rotation, all of which can cause varying degrees of stretching and other defects to the film during the forming and conveying process.

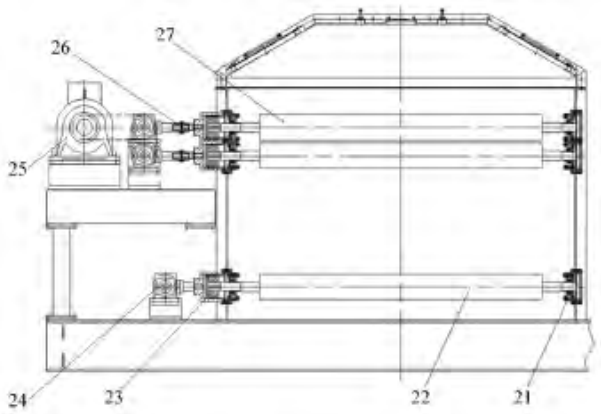
2 Principle and sealing structure design of a new magnetic drive system

2.1 Transmission principle

The new film forming transmission system adopts the magnetic transmission principle and structure, which means that the input and output do not need direct contact, but rather employ a flexible non-contact transmission method that transfers torque and power through the coupling interaction of magnetic field N and S poles. The magnetic transmission principle involves the interaction between a rare earth oxide neodymium-boron-iron permanent magnet at one end and an

induced magnetic field at the other end, generating torque. As a result, the mechanical coupling between the motor and the load is transformed into a magnetic coupling. By adjusting the air gap (typically between 2 mm and 8 mm) between the permanent magnet and the magnetic conductor, the torque and power transmitted by the system can be controlled, enabling adjustable, controllable, and repeatable changes in the load speed.

The new film forming transmission system is a specific example of the practical application of the magnetic coupling transmission principle. As shown in Figure 3, its transmission process is as follows: The gear motor (25) transmits power to the upper roller (27) and the lower roller (22) through the T-shaped steering gear (24) installed on the upper and lower brackets, the roller chain coupling (26), and the magnetic coupling (23), respectively, to achieve active synchronous rotation of the upper and lower rollers for conveying the forming film. Due to the corrosive organic liquid environment of the working environment, ceramic bearings (21) are required for bilateral rotational support of the upper and lower rollers. The new magnetic transmission system mainly utilizes the magnetic coupling effect on the coaxial magnetic coupling structure, eliminating the need for direct mechanical connections or mechanisms such as sprocket chains and gear meshing. Instead, it utilizes the characteristic that magnetic fields can penetrate a certain spatial distance and material, enabling torque transmission between the driving shaft and the driven shaft without direct contact, transforming dynamic sealing into static sealing, and achieving zero leakage of process liquid.

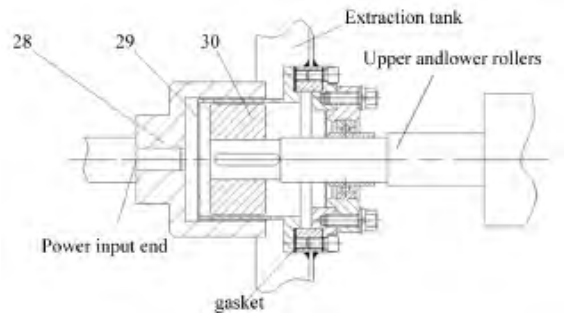


21 - Ceramic bearing; 22 - Lower roller; 23 - Magnetic coupling;
24 - T-shaped steering gear; 25 - Reduction motor;
26 - Roller chain coupling; 27 - Upper roller

Figure 3 Principle and structure of the new magnetic drive system

2.2 Principle and structural design of roller drive sealing

As shown in Figure 4, magnetic transmission is achieved through a permanent magnetic coupling. The permanent magnetic coupling mainly consists of components such as an inner magnetic ring (30), an outer magnetic ring (28), and an isolation sleeve (29). The power input shaft is coupled with the outer magnetic ring, and the upper/lower rollers are coupled with the inner magnetic ring. A fully sealed isolation sleeve is positioned between them, completely separating the inner and outer magnetic rings. This allows the inner magnetic ring to be immersed in the extraction liquid. Although the upper/lower rollers extend outside the extraction tank, they form a closed and static sealing unit with the inner magnetic ring, isolation sleeve, sealing gasket, and extraction tank. There are no static and dynamic sealing structures such as O-rings or frame seals found in the original extraction tank transmission device. The variable seal is a static seal, thus achieving fully enclosed and absolute sealing of the extraction liquid.



28 - Outer magnetic ring; 29 - Isolation sleeve; 30 - Inner magnetic ring

Figure 4 Schematic diagram of the basic structure of synchronous magnetic transmission

2.3 Transmission principle and pros and cons of sealing structure design of the new film forming transmission system

2.3.1 Advantages

(1) The ability to transmit energy and control speed is not affected by small angles or small offsets caused by misalignment during installation between components such as gear motors, T-steering gears, and the upper and lower roller shafts. Magnetic drive allows for larger installation alignment errors, as well as larger shaft misalignments and angular deviations from the axis, greatly simplifying the installation and commissioning process. It completely eliminates the

impact of thermal expansion on installation alignment and eliminates the resulting operational vibration issues;

(2) Through the magnetic coupling, the input torque of the upper roller and the lower roller is always equal to the output torque of the gear motor. Therefore, the gear motor only needs to generate the torque required by the load, reducing system operating costs and achieving energy conservation and environmental protection.

(3) Due to the absence of mechanical coupling, vibration or abrupt power transmission can be avoided, effectively reducing the vibration problem of the entire system and achieving synchronous and stable operation of the upper and lower rollers,

(4) With a small installation space, compact structure, relatively small size and weight, and fewer failure points, it boasts high reliability. Compared to ordinary mechanical transmission devices, it features a simple structure, easy to assemble, disassemble, maintain, and debug. This not only reduces the difficulty and labor intensity of equipment maintenance but also enhances the equipment's working efficiency;

(5) During the rotation of the gear motor, the magnetic coupling can achieve different torque and speed transmission requirements by adjusting the gap size between the inner and outer magnetic rings within a certain range;

(6) By utilizing the absolutely sealed characteristic of magnetic drive, the dynamic seal can be transformed into a static seal, achieving zero leakage of the extraction agent.

2.3.2 Disadvantages

(1) Due to the influence of permanent magnet materials losing their magnetism to varying degrees when heated to a certain temperature, magnetic transmission devices are not suitable for operation at higher temperatures, thus demanding high heat dissipation. During the operation of magnetic couplings, there are both eddy current losses caused by the severe "power generation" effect generated by the isolation sleeve and slip losses, resulting in significant heat generation. Due to structural limitations, the heat dissipation issue of magnetic transmission has not been well solved to date.

(2) The permanent magnet material in magnetic couplings is a brittle material. When the rotational speed reaches a certain level, due to the influence of centrifugal force, if the material strength is insufficient to resist the centrifugal force, damage will inevitably occur. This undoubtedly limits its linear velocity and restricts its certain range of use.

(3) Magnetic couplings are all made of expensive permanent magnet materials and other relatively expensive metal materials, which may increase costs and selling prices.

(4) In magnetic couplings, permanent magnet materials may undergo magnetic decay over a certain period of time due to factors such as time and temperature.

3 Conclusion

The application of the new magnetic drive principle and structure in the film forming transmission system addresses issues such as direct contact between the input and output shafts of the rollers inside and outside the process liquid tank, which can lead to difficulties in axial alignment and unreliable sealing. During the film forming production process, the new magnetic drive structure primarily achieves the following functions: Firstly, it ensures that both the upper and lower rollers are active rollers and operate synchronously, preventing micro-stretching deformation and other forming defects during film conveyance. Secondly, the use of magnetic couplings simplifies the transmission sealing structure, making it easy to manufacture and assemble, with a long service life. It converts dynamic sealing in the transmission into static sealing, completely solving the problem of process liquid leakage due to wear, aging, installation, and other issues of sealing components. This allows for zero leakage transmission of power, achieving good overall sealing performance and preventing the leakage of extraction agents during normal production. This realizes true zero leakage, which is beneficial for environmental protection.

The application of magnetic coupling principle in the novel magnetic drive system for film forming has solved problems such as process fluid leakage and low transmission accuracy that exist in actual production. Through user application, it has achieved good results.