WHICH WILL WIN IN THE GEAR PUMP TECHNOLOGY

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ABSTRACT

There exist three major problems in current gear pumps. They are unbalanced radial force, big excessive flow pulsation and short working life. In order to solve the problems above, a new type of gear pump with flexible ring gear is introduced. Pumping action is achieved through meshing between a flexible ring gear and a rigid external gear. Thus radial pressure forces are hydraulically balanced and the volumetric displacement is doubled for the new pump.

Keywords: gear pump; flexible ring gear; rigid external gear; radial pressure; service life.

QUELLE SERAIT LA MEILLEURE TECHNOLOGIE POUR LES POMPES À ENGRENAGES

RÉSUMÉ

Il y a trois problèmes majeurs concernant les pompes à engrenages actuelles. La force radiale n'est pas équilibrée, la pulsation du flux est excessive, et elle a une courte durée de vie. Dans le but de trouver une solution à ces problèmes, un nouveau type de pompe à engrenages circulaires flexibles est présenté. Le pompage est réalisé par un maillage entre une roue flexible et une roue externe rigide. Ainsi les forces de pression radiale de la nouvelle pompe sont équilibrées hydrauliquement et le déplacement volumétrique est doublé.

Mots-clés : pompe à engrenages ; roue flexible ; roue externe rigide ; pression radiale ; durée de vie.

1. INTRODUCTION

Many industrial machineries contain rotating elements interacting with fluid flow. This is the case in a variety of pumps as stated in [1]. Gear pumps are popular, well suited for handling viscous fluid such as fuel and lubricating oil. Having strong self-priming ability, this simple and robust device can work over a wide range of pressures and rotational speeds. Its main application can be found as lubrication pump in machine tools, as oil pump in engines or in fluid power transfer units. Depending on the application, several designs are available. Nevertheless, the most usual configuration adopts twin gears, it is nothing more than two types of gear pumps, external and internal, in structure, as can be seen in [1–4].

Pressure in the inlet side of the gear pump is lower, and pressure in the outlet side is higher while the pump is in operation. Higher pressure in the outlet side will push two gears towards the inlet side. This unbalanced radial pressure, resulting from the differential pressure between the inlet and outlet sides, will bend the gear shaft and scratch the casing of the pump, which increases the friction and wear of moving parts and the load on the bearings. The load on the bearings is proportional to the differential pressure between the inlet and outlet sides [5]. Higher pressure leads to greater radial force. This deteriorates pump performance and cause premature failure [2–5].

Many researchers have conducted studies to improve radial pressure imbalance. Narrowing the discharge cavity, expanding the suction cavity, opening the groove on the end cover or on the bearing base in the pump, shortening the tooth width and diameter of two gears, employing high-quality bearing or adopting flexible supports, are ways that have been tried [4–9], but the problem mentioned above has not been adequately solved. The service life of gear pump is still far less than the design requirements. This is mainly because of bigger radial force that produces heavier load on the shaft journal and on the bearing. How to reduce the radial force is an important project for improving the performance and lifetime of gear pump.

Predictable from the working principle of gear pump, radial force imbalance is inherent in the structure for traditional gear pump. No matter what measures are taken, the radial force in gear pump can only be reduced, but cannot be eliminated completely.

Therefore, the authors invented a new method of balancing the radial force on the gear shaft, where the displacement doubles, the life of gear pump is improved and the flow pulsation is mitigated. The method provides ideas to design a new gear pump.

2. FEATURES OF GEAR PUMP WITH FLEXIBLE RING GEAR

In a sliding-vane rotary pump (or a balanced vane-type pump) having a number of vanes which are free to slide into or out of slots in the pump rotor, two discharge cavities placed diametrically opposite each other keep the rotor in hydraulic balance, relieving the bearings of heavy loads [6,7]. Inspired by this, we conceived a new gear pump with flexible ring gear by combining the characteristics of harmonic gear drive [10,11] with the working principle of gear pump. Figure 1 presents a sketch of the new gear pump, the main components include pump body (1), end cover, pinion (2), flexible ring gear (4), sealing block (5), roller (3) and side plate (6).

Pinion (2) is a rigid external gear. Flexible ring gear (4), a thin-wall internal ring gear which can produce larger elastic deformation, has the same circular pitches and tooth width as the pinion. The ring gear meshes with the pinion each other and turns freely inside the closed pump body. The rotation centrelines of two mating gears are coincident.

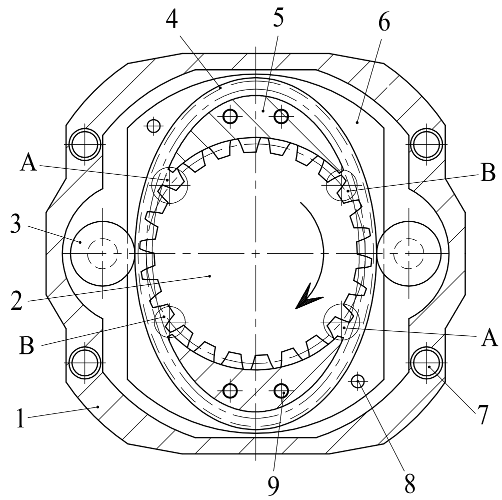

Fig. 1. Main parts of gear pump with flexible ring gear.

1	casing	2	pinion	3	roller
4	flexible ring gear	5	sealing block	6	side plate
7	bolt	8	position pin	9	stop pin
A	suction cavity	B	discharge cavity		

Two crescent-shaped sealing blocks (one is on the left and the other on the right, as shown in Fig. l) are installed between the addendum circle of the pinion and the addendum arc surface of the ring gear. Side plates are closely placed on both sides of two gears in the axial direction. The sealing blocks are fixed on the side plates by stop pins (9), two end covers bind the pump body using bolts (7) shown in Fig. l.

The ring gear and the pinion are close running fit with sealing blocks and side plates. The airtight space between the pinion and the flexible ring gear is separated into four cavities, they are two symmetrical cavities A for admitting fluid and two symmetrical cavities B for expelling higher pressure fluid, radial load on the shaft is then symmetrical.

Two axial holes for suction (corresponding to lower pressure cavity, A), two axial holes for discharge (corresponding to higher pressure cavity, B) are opened on the side plates. The inlet and outlet ports opened on the end covers are connected with suction and delivery hoses outside of the pump body respectively.

The excircle diameter of the ring gear, before it is deformed, is bigger than the length inside of two rollers. Bound by the rollers, the ring gear's profile turns out to be an oval-shape when the ring gear is embeded between two rollers, as shown in Fig. 1. Ring gear's teeth near two ends of the short axis of the oval mesh completely with the teeth on the pinion, and teeth near the major axis of the oval separate completely from the teeth on the pinion. The ring gear is driven to rotate while the pinion turns clockwise. The deformation of the ring gear, and the mating condition of two gears change constantly.

3. PRINCIPLE OF GEAR PUMP WITH FLEXIBLE RING GEAR

The new pump belongs to a family of positive displacement pump. Based on a gear within a gear principle [4], it intakes and expells fluid also via periodic changes of closed working volume with rotation of gears [12].

Refer to Fig. 1, when the pinion, driven by transmission shaft, rotates in the direction of arrow as shown, the flexible ring gear will turn in the same direction. Partial vacuum is created in the cavity A where two gears come out of mesh and create an expanding volume which helps draw the fluid from a reservoir under atmospheric pressure into two suction cavities A through an external suction pipe, the inlet port on the end cover and the suction holes on the side plate. The grooves between teeth are then filled with fluid. This is the suction process of the new pump.

As two gears rotate, the grooves full of fluid turn to the delivery cavities B where two gears come into mesh and create a decreasing volume gradually, the fluid trapped between adjacent teeth is forced out of the cavity and into a delivery pipe through drainage holes on the side plate and the outlet port on the end cover. This is the discharge process of the new pump.

Meshing effect happens twice. Four independent closed cavities are formed automatically in an engagement process between the ring gear and the pinion. Rotation of two mating gears contributes to keep cavity A in a vacuum state, more fluid is drawn into the voids between unmeshing teeth, it is squeezed out as they re-mesh since the pressure in cavity B is higher. The pumping function, suction in approach action and discharge during mesh, is then achieved. It is the working principle of the new gear pump.

The cavities for suction and for expelling are separated by the meshing line along the axial direction. The flow path for the new gear pump is as follows. Fluid from the reservoir comes into the inlet port on the end cover, and into two axial suction holes on the side plate, then into two suction cavities A arranged symmetrically. Route for pressurized fluid is from two cavities B arranged symmetrically to two axial discharge holes on the side plate and then into the outlet port on the end cover.

4. STRONG POINTS OF THE GEAR PUMP WITH FLEXIBLE RING GEAR

The new pump presented in this paper has the following superiorities compared with gear pumps now available:

1. The drive shaft of the pump is hydraulically balanced, which reduces the load on bearings and improves greatly the performance and life of the gear pump, because of its symmetry, two lower pressure cavities and two higher pressure cavities are placed symmetrically to the centerline of the pinion respectively.

2. Double volume of fluid discharges from two cavities B. It can be said that one new pump contains two equivalent gear pumps, so the total displacement increases and the flow is smooth which makes the running quiet. Two output flows can export and transport respectively to different actuators to move the piston in a cylinder or to turn the shaft of a hydraulic motor. Also, the two flows can merge and produce bigger displacement suitable for a given application where the rapid movement of actuator is required.

3. The relative sliding velocity of the tooth surfaces is lower during the meshing process because two gears rotate in the same direction, noise and wear on the tooth surfaces are less.

4. The load per unit area is smaller and the operation is smooth and silent with higher bearing capacity, since the tooth surfaces of two engaging gears contact on a surface, and more teeth mesh at the same time.

Have overcome the shortcomings of current gear pumps effectively, the new gear pump has better performance, and can be used to upgrade a product using traditional gear pumps.

5. CONCLUSION

Traditional gear pump with two gears is a hydraulic component suffered radial pressure. Bigger radial pressure causes premature damage to the pump. Therefore it offers a solution to an important problem mentioned above.

The authors have discarded traditional gear pump design to construct a new internal gear pump with flexible ring gear for the first time. The radial pressure is balanced, the performance and service life are greatly extended with this new gear pump, which provides an innovative idea to replace existing gear pumps.

Flexible internal gear, undergoing alternating stress during operation, is a core element in the new type of gear pump. Chrome molybdenum alloy steel series having higher strength and good fatigue performance, or soft composite material with higher fatigue strength could be selected to produce flexible internal gear in order to avoid early fatigue failure. The next step of our work is to design and test the prototype of the new pump, and try to lay a foundation for further improvement through the experimental research on the pump.

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