

THEORETICAL STUDY ON A NEW TYPE OF HYDRAULIC PUMP: THE INVOLUTE CIRCULAR ARC GEAR PUMP

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ABSTRACT

This paper presents a new type of hydraulic pump: the involute circular arc gear pump. The involute circular arc gear pump has all advantages of the traditional involute gear pump, while its mechanical performance is better than the traditional involute gear pump's. The new pump is especially suitable for the highpressure and highflowrate situation.

KEYWORDS: Hydraulic pump; Involute gear pump; Involute circular arc Gear pump

1.INTRODUCTION

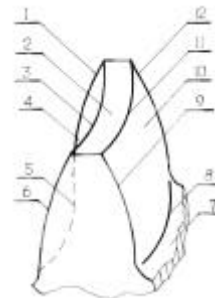
In a long history, gear transmission has been widely used. Involute has been used as ideal gear tooth profile more than 150 years, because involute gear tooth profile transmits motion accuracy and steady, and it has good load bearing capacity^[1]. But it has an obvious disadvantage: the load is not well distributing along gearing touching line caused by gear axis bent and other factors. And effected by gear teeth acted on alternating stress, gear transmission's vibration and noise is bigger than other transmission's. In the equipment of gear transmission, failure proportion of each element is: gear 60%, bearing 19%, axle 10%, gearbox-case 7% and shaft seal 1%, thus it can be seen that gear's failure proportion is the highest in all elements. The gear is the primary factor causing machine failure^[2]. Gear pump is one of hydraulic pumps whose construction is the simplest and cost is the lowest. It also has many merits, such as small volume, light weight, good self-absorb performance, easy to maintain, not sensitive to pollution of hydraulic oil and so on. But its demerits are big flow and pressure pulsation, high noise, and only used for ration pump, so gear pump's use range is limited^[3]. Generally gear pump's flow range is 2.5 ~ 750l/min, pressure range is 10 ~ 31.5MP_a, speed range is 1300 ~ 4000rpm (when used in airplane it can reach 8000rpm), hydraulic efficiency is $\zeta_v = 0.88 \sim 0.96$, over-all efficiency

$$\zeta = 0.78 \sim 0.92^{[4]}.$$

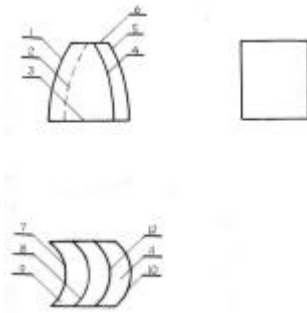
The new type of involute circular arc gear which recently has been invented to be the key part of hydraulic pump^[5] is discussed in the paper, and the involute circular arc gear and the principle of the involute circular arc gear pump are expounded.

2.THE INVOLUTE CIRCULAR ARC GEAR

The touching line of gearing involute tooth profile is a straight line segment, so the traditional involute gear which is widely used today in the world is defined involute - straight line gear. The involute circular arc gear's touching line is a circular arc. Figure 1 shows the stereoscopic tooth profile shape of an involute circular arc gear. Figure 2 illustrates the three views of an involute circular arc gear. Assume that an involute circular arc gear 2 is driven by a pinion 1, the condition for correct gearing is $m_1 = m_2, a_1 = a_2$, the convex involute circular arc curved surface and the concave involute circular arc curved surface meshes with each other of which are two involute circular arc gear 1 and 2, while curvature radius of involute circular arc gear 1 and 2 is equal.



1,6,9,12. Involute
2. Gear tip
3,5,8,11. Circular arc
4. Concave involute circular arc curved surface
7. Gear root
10. Convex involute circular arc curved surface
Fig. 1 The stereoscopic tooth profile shape of an involute circular arc gear



- 1,2,4,5. Involute
- 3. Gear root
- 6. Gear tip
- 7,8,10,12. Circular arc
- 9. Concave involute circular arc curved surface
- 11. Convex involute circular arc curved surface

Fig. 2 The three-dimensional view of an involute circular arc gear

Because the involute circular arc gear's tooth profile is involute just as the same as the traditional involute gear's on each and every cross section, the involute circular arc gear not only has all advantages of the traditional involute gear, but also it can be used to effectively overcome the disadvantages of traditional involute gear whose load not well distributing along gearing touching line caused by gear axis bent and other factors.

The involute circular arc gear's finite element calculating and analyzing are carried out, by setting up the involute circular arc gear's finite element model, deriving the relation with the geometric parameters, applying the structural analyze program of ANSYS to make strength calculation. After taking further step to obtain the involute circular arc gear's optimal parameters by using different geometric parameters to analyse and calculate, the calculating results are gained which indicate that the involute circular arc gear's mechanical performance is better than the traditional involute gear's.

In short, the involute circular arc gear which is adopted from the traditional involute gear improves load bearing capacity, transmission efficiency and reliability, comparing with the traditional involute gear's, so it is especially suitable for the high-speed and heavy loading gear transmission, such as navigation engine, heavy duty mining and metallurgical machinery's gear transmission, and especially suitable for the high pressure and high flowrate hydraulic system as well.

3.THE PRINCIPLE OF THE INVOLUTE CIRCULAR ARC GEAR PUMP

The principle of an involute circular arc gear pump is as the same as the traditional involute gear pump's, because the involute circular arc gear's tooth profile is involute just as the same as the traditional involute gear's on each and every cross section.

3.1 The Principle of An involute circular arc Gear-on-Gear Pump

Figure 3 shows the schematic drawing of an involute circular arc gear-on-gear pump. A pair involute circular arc gears have the same parameters meshing with each other, which is contained in a seal space formed by pump body and cover(axle sleeve or side board). The gap between gear tip and the surface of pump body's inside hole is so small, and the gap between gear's cross section and cover(axle sleeve or side board) is also so small that two separated seal cavity along touching line facewidth of gearing involute circular arc teeth profile is formed. When the driving gear rotates at counterclockwise, according to Fig.3, the contained volume of touching point left-hand becomes big creating partial vacuum, which forms absorbent oil cavity where hydraulic oil in reservoir acted of atmospheric pressure enters. On the right hand, the contained volume becomes small, which forms pressed oil cavity where hydraulic oil is pressed outs. This is the working process of an involute circular arc gear pump's absorbent oil and pressed oil. When the involute circular arc gear pump is continuously rotating, volumes of absorbent oil cavity and pressed oil cavity are constantly changed, which forms the continuous process of an involute circular arc gear pump's absorbent oil and pressed oil.

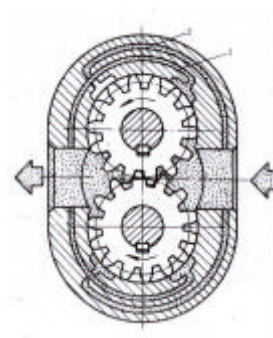


Fig. 3 The principle of an involute circular arc gear-on-gear pump schematic drawing

3.2 The Principle of An involute circular arc Gear-within-Gear Pump

Figure 4 shows the schematic drawing of an involute-circular arc gear-within-gear pump. An involute circular arc gear-within-gear pump consists of a pair involute circular arc gears among which one is a pinion and another is an inner gear-

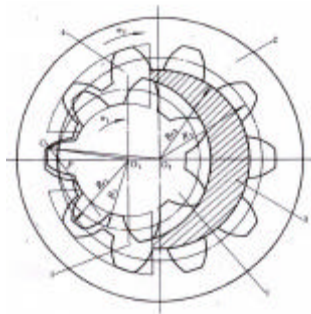
ring meshing with each other. Its volume forms two contained volumes by two-hand covers and cross sections, which is separated by crescent moon board and touching point. When the pinion and gear-ring rotate at the same direction, contained volume of one-hand of the touching line becomes big to create partial vacuum, which forms absorbent oil cavity where hydraulic oil in reservoir acted on atmospheric pressure enters. Another-hand contained volume becomes small, which forms pressed oil cavity where hydraulic oil is pressed out.

4.CONCLUSIONS

The involute circular arc gear pump keeps all advantages of the traditional involute gear pump. It has better load bearing capacity, transmission efficiency and reliability than the traditional involute gear pump's, so it is especially used as a high pressure and high flowrate hydraulic pump.

The mechanical performance of the involute circular arc gear pump, such as pressure, speed, flow, life, noise and so on, needs to be taken further experimental study.

The involute circular arc gear pump also needs a series of pressurized measures as the same as a traditional involute gear pump's, such as reducing involute circular arc gear pump's noise, compensating leakage and gap, balancing hydraulic radial force, solving trapping and unloading measures and so on.



1. Pinion (driving)
2. Inside gear-ring (driven)
3. Crescent moon board
4. Absorbent oil cavity
5. Pressed oil cavity

Fig. 4 The schematic drawing of an involute circular arc gear-within-gear pump

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