Analysis of Pressure Pulsation in Aviation Gear Pump

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Abstract. In order to analyse the influence of gear parameters on the internal pressure pulsation of the aviation gear pump, the flow field analysis software PumpLinx is used to calculate the internal flow field of the aviation gear pump. By setting monitoring points inside the gear pump under different gear parameters, the pressure pulsation results at different positions under different gear parameters are obtained and analysed. The results show that the larger the modulus, the greater the pressure pulsation in the oil inlet area, oil trapped area and the oil outlet area; the greater the number of teeth, the greater the pressure pulsation in the oil trapped area, and the smaller the impact on the oil inlet area and oil outlet area; the larger the index circle pressure angle, the smaller the pressure pulsation in the trapped area, and the smaller the impact on the oil inlet area and the oil outlet area. The analysis results provide a reference for further optimizing the internal pulsation and oil trapping problems of aviation gear pumps.

1. Introduction

External gear pumps are widely used in the aerospace field because of their simple structure, small size, high reliability, strong anti-pollution ability, and good self-priming [1]. But the pressure pulsation, cavitation and noise caused by oil trapped in aviation fuel pump will affect the working performance of gear pump [2]. Studying the influencing factors of the pressure pulsation in the trapped area of the gear pump has positive significance for reducing the vibration and noise of the aviation gear pump, and improving the performance of the aviation oil pump. Bai Yuxing and others obtained pressure pulsation results at different locations by setting monitoring points [3]. Tang Shanshan et al. adopted a tooth pressure tracking monitoring method to monitor the pressure changes on the teeth in real time [4]. Liu Kun and others studied the influence of helix angle, gear radial clearance, and speed on pressure pulsation [5]. They considered different methods to measure the pressure pulsation, but did not consider the influence of gear parameters on the pressure pulsation at different positions.

This paper uses CFD technology for fluid simulation. By changing the gear parameter modulus, number of teeth and indexing fillet, monitoring points are set in the trapped oil area to obtain the pressure data of different gear parameters at different positions in the trapped oil area, in order to reduce the trapped oil pressure. Gear pump performance provides reference.

2. Modelling and simulation

2.1. numerical model establishment
The gear parameters of an aviation gear pump are as follows: modulus is 5mm, number of teeth is 12, tooth width is 25.5, and indexing circle pressure angle is 30°. The flow field model of the gear pump is established in UG below. The specific model is shown in Figure 1.

![Figure 1. Numerical model of CFD for the external gear pump](image)

The upper part of the gear in Figure 1 is the oil inlet of the gear pump, and the lower part is the oil outlet of the gear pump. The fluid domain of the gear pump mainly includes three parts, namely the oil inlet, the gear part and the oil outlet.

**CFD simulation**

Pumplinx is a CFD software developed by Simerics in the United States for numerical simulation of fluid mechanics. It has great advantages in calculating cavitation prediction, pressure change, flow and heat transfer of pumps, valves and other fluid machinery [6]. Therefore, this paper uses the simulation software to simulate the fluid domain of the gear pump. The actual working conditions of the gear pump are shown in Table 1.

| Working condition of the external gear pump | Rated speed | Inlet pressure | Outlet pressure |
|------------------------------------------|-------------|---------------|-----------------|
| 8500rpm                                  | 2.5MPa      | 12.5MPa       |

The following is the specific numerical simulation process of the gear pump fluid domain in Pumplinx.

![Figure 2. Numerical simulation flowchart](image)
In order to study the pressure changes at different positions in the oil trapped area of the gear pump during the dynamic simulation process, different monitoring points are set in the oil trapped area of the gear pump fluid domain. The positions of the different monitoring points are shown in Figure 3.

![Figure 3. The location of monitoring point](image)

2.2. The result of simulation

The setting of numerical simulation of external gear pump is showing in Table 2.

| Simulation type | Time Definition | Number of Revolution | Number of Iteration | Simulation Time | Number of Time Step | Result Saving Frequency |
|-----------------|-----------------|---------------------|--------------------|----------------|---------------------|------------------------|
| Transient       | Revolutions     | 1                   | 50                 | 0.014s         | 720                 | 360                    |

After the simulation, the pressure values of different monitoring points are derived, and the pressure values of the five monitoring points in the trapped area of the gear pump are obtained in the time domain. The results are shown in Figure 4.

![Figure 4. Pressure pulsation at different monitoring points](image)
It can be seen from the figure 4 that the pressure fluctuation at the inlet of the gear pump is relatively small, and the oil can be stably supplied to the gear pump. The pressure fluctuations are mainly concentrated at points 1, 2, and 3. From the above pressure distribution diagram, it can be seen that the lower pressure at point 2 produces a negative pressure area, and the higher pressure at points 3 and 4 leads to greater pressure pulsation. Monitoring point 2 is the area where cavitation occurs in the gear pump. When cavitation occurs, the oil will precipitate bubbles, and the bubbles will burst when squeezed by the gear to cause pressure pulsation. Monitoring point 1 is the oil trapped area. The size of the oil trapped area changes constantly when the gear rotates, so the pressure pulsation generated is also larger. Monitoring point 3 is located in the oil trapped area close to the oil outlet port, so the radial force and oil squeeze will cause the pressure to rise, resulting in greater pressure pulsation.

3. The influence of gear parameters on pressure pulsation
There are many influencing factors of pressure pulsation in the oil-trapped area [7]. By studying the law of the influence of different influencing factors on pressure pulsation, we can draw a law that is valuable for reducing the pressure pulsation in the oil-trapped area. The following analyses the gear parameters of the gear pump, the modulus, the number of teeth and the pressure angle of the indexing circle affect the pressure pulsation at different positions in the oil trapped area of the gear pump.

**Table 3. The parameter settings of the external gear pump**

| Modulus/mm | Number of teeth | Index circle pressure angle/° |
|------------|-----------------|-----------------------------|
| 4          | 11              | 20                          |
| 5          | 12              | 25                          |
| 6          | 13              | 30                          |
| 8          |                 |                             |

3.1. The effect of Modulus
Figure 5. Pressure pulsation at different positions of different modules

It can be seen from Figure 5 that as the gear modulus increases, the pressure pulsation in the oil inlet area, oil trap area and oil outlet area increases. The pressure pulsation is the largest when the modulus is 8mm, and the pressure pulsation is smaller when the modulus is 4 and 5mm. Therefore, the modulus of the gear design should be as small as possible, because the increase of the modulus increases the radius of the gear, and due to the high-speed operation of the aviation gear pump, the oil is not easy to transport stably in the gear pump, resulting in greater pressure pulsation.

3.2. The effect of number of teeth

It can be seen from Figure 5 that as the gear modulus increases, the pressure pulsation in the oil inlet area, oil trap area and oil outlet area increases. The pressure pulsation is the largest when the modulus is 8mm, and the pressure pulsation is smaller when the modulus is 4 and 5mm. Therefore, the modulus of the gear design should be as small as possible, because the increase of the modulus increases the radius of the gear, and due to the high-speed operation of the aviation gear pump, the oil is not easy to transport stably in the gear pump, resulting in greater pressure pulsation.

3.2. The effect of number of teeth

It can be seen from Figure 5 that as the gear modulus increases, the pressure pulsation in the oil inlet area, oil trap area and oil outlet area increases. The pressure pulsation is the largest when the modulus is 8mm, and the pressure pulsation is smaller when the modulus is 4 and 5mm. Therefore, the modulus of the gear design should be as small as possible, because the increase of the modulus increases the radius of the gear, and due to the high-speed operation of the aviation gear pump, the oil is not easy to transport stably in the gear pump, resulting in greater pressure pulsation.
It can be seen from the Figure 6 that in the oil trapped area (1, 2, 3), the change of the number of teeth has a greater impact on the pressure pulsation, and has a small impact on the pressure pulsation in the oil inlet and oil outlet area. The monitoring points under different numbers of teeth the average values of pressures at 4 and 5 are about 1.5MPa and 13.4MPa respectively. Increasing the number of teeth increases the pressure pulsation in the oil trapped area, because the size of the oil trapped area changes constantly when the gear rotates, which causes the pressure to change continuously, which will cause pressure pulsation. If the number of teeth increases, the pressure pulsation in the oil trapped area increases. Therefore, effectively reducing the number of teeth can reduce the pressure pulsation in the oil trapped area.

3.3. The effect of Index circle pressure angle
Figure 7. Pressure pulsation at different positions of different Index circle pressure angle

It can be seen from the Figure 7 that for the oil trapped area (1, 2, 3), the pressure pulsation gradually decreases with the increase of the pressure angle of the index circle, which has a small impact on the oil inlet area and the oil outlet area. The average pressure values of the oil inlet area and the oil outlet area corresponding to different index circle pressure angles are about 1.47MPa and 13MPa respectively. The pressure angle of the indexing circle determines the shape of a single tooth. With the increase of the indexing circle pressure angle, the tooth root width increases, while the value of the tooth tip width relatively decreases. From the shape of a single tooth, the indexing circle The shape of the larger teeth is fuller, so the bearing capacity of a single tooth will increase, but the oil will flow through the teeth faster and more fully. Therefore, the pressure pulsation in the oil trapped area decreases with the increase of the pressure angle of the index circle, so an appropriate increase in the index circle pressure angle can reduce the pressure pulsation in the oil trapped area.

4. Conclusion
With the help of CFD simulation software, the pressure pulsation in the internal flow field of an aviation gear pump is analysed, and the influence of the modulus, the number of teeth and the pressure angle of the indexing circle on the pressure pulsation in the oil inlet area, oil trap and oil outlet area of the gear pump is obtained. Numerical simulation results show that with the increase of the modulus, the pressure pulsation in the oil inlet area, the oil trapped area and the oil outlet area gradually increase; With the increase of the number of teeth, the pressure pulsation in the trapped oil area increases, which has little effect on the pressure pulsation in the oil inlet and oil outlet area.; with the increase of the pressure angle of the graduation circle, the pressure pulsation in the trapped oil area decreases, which has a smaller influence on the pressure pulsation in the oil inlet area and the oil outlet area. Therefore, the reduction of the number of modulus teeth and the increase of the pressure angle of the indexing circle help to reduce the pressure pulsation.

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