Research on Axial Forces Balance of Stamping-welding Canned Motor Pump

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Abstract. In order to balance axial forces on stamping-welding canned motor pump for safe and reliable operation, the type PBCY80-65-160 pump was selected as the computational model. Combined with various reasons why axial forces of the pump were generated, the theoretical calculation and methods of numerical simulation were chosen to analyze the size, directions and rules of axial force. At the same time, the distribution and trend of the axial force components of the impeller under different working conditions are studied whether there is the balance hole or not. The results show that, in the theoretical calculation and numerical simulation calculation, the gap and internal impact loss of the internal flow field of axial forces were neglected when the internal flow of the motor was seen as an ideal flow through the resistant elements. Hence, it could not fully represent the internal pressure distribution of the pump, which caused the calculated data a little larger than simulated data. Also, the method of combining the balance hole and impeller rear seal ring could effectively balance the axial force and extend the service life of stamping-welding canned motor pump.

1. Introduction

Stamping-welding canned motor pump [1-3], named as plastic forming light pump, is a new type of pump. Stamping process manufacturing is applied for making the impellers, volutes and other parts of stamping-welding canned motor pump. Its simple structure could not only keep material and energy saving but also has high quality of flow surface and high precision hydraulic positioning, which could greatly improve the efficiency of the pump [⁴]. Balanced design technique of the axial force of the stamping pump is an important part of its safe and reliable operation because large axial force would lead to sliding bearing wear pump damaged. At present, the research on axial force of stamping-welding canned motor pump mainly has been learnt from the research result of Stepanov, Schultz in aspects of traditional pump. Axial force testing device of vertical stamping-welding canned motor pump which could measure the elastic modulus of normal and infiltrating resin Graphite, was designed by Luo Wen. Wang Jingquan introduced the application of axial force self-balancing in shielded pumps; Li Wei, designed a balanced axial force device generated by the auxiliary impeller in the stamping-welding canned motor pump. Zhang Liyuan researched on the measurement of axial thrust in axial shield pump [⁵-⁷]. The axial force of the shield pump has become one of the technical problems that constrain the large-scale. Therefore, it is of great significance to study the balance design of axial force for improving the reliability and economy of the shield pump.

In this paper, through the method of theoretical calculation and numerical simulation, dynamic reaction force and change rule of axial force in stamping-welding canned motor pump have been
analyzed. Besides, a new device is designed with simple structure and easy installation. Furthermore, it could accurately and dynamically test the value and direction of the axial force during the operation of the stamping pump and its measured data would provide reliable basis for reducing the axial force. Meanwhile, the method of double-ring design could balance the axial force. By calculating the size of the stamping pump which is worked in safe and reliable operation double ring.

2. II Structure
Design parameters of Stamping-welding canned motor pump selected in this paper were as follows: Flow $Q = 50\text{m}^3/\text{h}$, head $H = 32\text{m}$, speed $n = 2900\text{r/min}$, motor power $P = 7.5\text{kw}$.

![Figure 1. Stamping molding shield pump structure.](image)

Combined with structural characteristics of punching Impeller, balanced hole and double ring design is applied for balancing the axial force of stamping-welding canned motor pump. In the overall design of the shielded motor, the problem of the axial force balance, cooling circuit design [8], sliding bearing lubrication and wear [9] should be considered, Fig.1 shows the structure of a typical stamping-welding canned motor pump.

3. Theoretical Calculation of Axial Force
Traditional calculation method [10] is used for the axial force of stamping-welding canned motor pump in covering force $T_1$, dynamic reaction $T_2$, the pressure difference of motor rotor at the both ends $T_3$, wheel hub end plate pressure $T_4$.

The axial force $T$ as the whole pump rotor suffered:

$$T = T_1 - T_2 - T_3 + T_4$$  \hspace{1cm} (1)

By calculation, the axial force of PBCY80-65-160 stamping shield pump under design condition is shown in Table 1:

|        | $T_1/N$ | $T_2/N$ | $T_3/N$ | $T_4/N$ | $T/N$   |
|--------|---------|---------|---------|---------|---------|
| $T_1/N$| 628.19  | 64.15   | 34.76   | 111.87  | 641.15  |

Table 1. Axial Force of Pump 80-65-160
4. Numerical Analysis

The force in each fluid domain is extracted directly from CFD. Firstly, the numerical simulation [11-14] of the whole flow field of the stamping pump was carried out. Secondly, the cover force $T_1$, the motor rotor pressure difference $T_2$ and the wheel head end pressure difference $T_4$ are simulated respectively whether there is a balance hole or not.

4.1. Model

Taking the stamping molding shield pump as the research object, three-dimensional model of the entity for the main flow passage is shown in Fig 2:

![Figure 2. Three-dimensional model of the entity for the main flow passage.](image)

4.2. Meshing

When a tetrahedron unstructured grid is used to mesh the small-sized gap flow in the fluid domain of the cooling cycle, it is difficult to ensure the grid quality and quantity at the gap. Therefore, the hexahedral structured grid is used to divide the fluid regions to ensure that there are more grid layers in the direction of the smaller gap thickness. After several numerical calculations, when the number of grid is 2.5 million, the calculation result is less affected by the number of grids. So it could be considered to satisfy the grid independence hypothesis. The number of grid cells in the pump-side calculation area is shown in Fig. 3 and Table 2:

### Table 2. Number of Grid Cells in Calculated Area of Pump End

| Model                  | Import extension | Import ring | Rear pump chamber | Impeller | Export extension | Front pump chamber | Volute | Sum  |
|------------------------|------------------|-------------|-------------------|----------|------------------|--------------------|--------|------|
| Number of Grids        | 160388           | 11000       | 372200            | 264659   | 177488           | 173844            | 335300 | 1494879 |

![Figure 3. Grid calculation model.](image)
5. Result Analysis

5.1. Cover force \( T_j \) simulation

Numerical simulation could extract the internal force of the impeller cover and the surface force of the blade which could not be calculated accurately in the theoretical calculation. Impeller force mainly includes: Outside cover force \( F_1 \) of impeller front and rear cover; Impeller front and rear cover plate inner surface axial force \( F_2 \), blade surface axial force \( F_3 \). Fig.4 shows the axial force distribution of the impeller.

5.2. Outside Cover Force \( F_j \)

The outside cover force includes: Lateral force of rear cover \( N_1 \); Lateral force of front cover \( N_2 \); Impeller seal end force \( N_3 \); Rear cover impeller of import part of the force \( N_4 \); Outside cover force \( F_1 = N_1 + N_2 + N_3 + N_4 \); Fig.5 shows the change of the external force of the impeller front and rear cover plates without the equilibrium hole and the counterbalance hole in each working condition.

![Figure 4. Impeller axial force distribution.](image)

![Figure 5. (a) Variation of external force of impeller front cover.](image)
From Fig. 5(a), it could be concluded that lateral force of front cover is not changed whether there is a balance hole or not, and it tends to decrease with the rise of the flow rate. As well, the force is positive. It means that the direction of force is to the shielded motor side.

From Fig. 5(b), it is showed that the change of rear panel lateral force whether there is a balance hole. In another word, the lateral force of the rear cover is significantly reduced with balance hole, so that the axial force of pump inlet direction is reduced to balance axial force. But the change of the force also makes the lateral force $F_1$ of the cover larger. The $F_1$ difference decreases first and then climbs up with the increase of $q$, and reaches the minimum value near the working point. The reason for the phenomenon may be that near the balance hole, The leakage of balance hole reach the maximum value and force the pressure on the lower liquid of seal ring to drop. Then, pressure difference of front and rear cover would be improved and to the most extent, the axial force on the cover plate is reduced. As a result, the force $F_1$ reaches the minimum value near the working point. As it is seen in Fig.5(c).

5.3. The Inner Surface Axial Force of Impeller Front and Rear Cover Plate $F_2$
Figure 6. Axial force $F_2$ of inner surface of impeller front and rear cover plate.

Fig. 6 is the $F_2$-$Q$ axial force curve of front and rear cover plate under different conditions in the balance hole and unbalanced hole and the force points to shield the motor side. Its value increases with the rise of flow. From the figure, the axial force of the inner and surfaces of the impeller front and rear cover plates is greater than that of the balance hole. It means the opening of the balance hole could reduce the pressure difference between the front and rear covers and achieve the purpose of reducing the axial force. However, the axial load is consistent with the flow rate in the state of the balanced and unbalanced hole.

Fig. 7 shows axial force of blade surface. The blade is a cylindrical double circular blade, as shown in Fig. 8, the blade is suffered by axial force in numerical simulation. Because the inlet edge of the blade has a certain angle with axial direction, so that the pressure on the inlet side produces a separated force on axial direction. Owing to low pressure and average area on the inlet edge of the blade, the axial force of the blade is smaller. A negative value in the fig. 7 indicates that the force points to the pump inlet. It could be seen from the fig. 8 that the axial force of the blade surface decreases with the rise of the flow rate when the equilibrium hole is added. However, when the balance hole is not added, the axial force of the blade increases with the rise of the flow rate.

5.4. Blade Surface Axial Force $F_3$
6. Conclusion
1. This paper analyzes the causes of the axial force of the shielded pump, including the asymmetry of the front and rear cover of the impeller, the reaction force and the rotor structure of the shield pump motor. It is reasonable to use the method of combining the balance hole and the impeller seal ring.
2. Compared with the theoretical calculation, numerical analysis obtains the value of the axial force in the ideal situation, and the overall value is larger.

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Figure 8. The Surface Pressure Diagram of Blade under Design Conditions.
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