THE NUMERICAL SIMULATION ANALYSIS OF KEY STRUCTURES OF INTEGRATED POWER SUPPLY IN MOTOR-PUMP

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Abstract

The motor-pump is an organic combination of hydraulic pump and driving motor. It is integrated by means of optimum structure design and performance match. It has no shaft coupling and fixing bracket of pump which are parts of traditional driving mode. It has small capacity, low noise, high reliability and is convenient to fix, so it's a neotype of highly-integrated power supply and will be a important direction of development in the field of electric-hydraulic power supply.

In this paper, we discuss different integration manners and control theories of motor-pump, inaugurate a scheme which integrates brushless DC servo motor and internal meshing gear pump based on the discussion above, and then introduce the overall structure and operating principle of our scheme.

As the stator and rotor of the driving motor in motor-pump both work while dipped in hydraulic oil, this could cause interference to the running characteristic of the motor. Aim at the special structural style of motor-pump in this paper, we analyse some key structures of motor-pump as well as their effects on the whole capacity and efficiency, then we do the numerical simulation analysis by using the Fluent which is a software for liquid analyse and count, the AMESim which is a software for systematic engineering analyse, and also the relevant mathematic theories. In these numerical simulation analysis we work over the distribution of flow field between the stator and rotor of the motor in motor-pump, and also between the rotor and the excircle of internal gear pump. We also study the damping torque of the rotor, the design means of anomalous flow passage used for elimination of heat, and then give the relevant analysis results which provide train of thoughts and appropriate parameters for optimum design and efficiency advancement of the whole products.

0 General Introduction

In the field of modern aerocraft, one important trend of hydraulic development is the integration of mechanism and electron technology. In this way, it can not only widen the application of traditional hydraulic technology, but also minish the volume and the weight of aerocraft. At the same time it has the exclusive advantage of traditional hydraulic technology such as high efficiency , high reliability and good maintenance. Along with the development of technology, the integration of hydraulic pump rotor and stator shows up. More specifically ,the rotor is embedded to within of motor rotor, and it rotates in the rotary magnetic field while the oil sucked by pump can cool machine winding and improve the reliability of motor. Relative to the traditional method , it minish the structure of junction box, pump installation plank and pump shell to reduce the weight, and improve the integration. For so many good respects, it becomes one of ideal transmission solution of future more electronic plane and it can also be applied to other hydraulic fields. This paper analyses the whole blue print, structure and integration of motor-pump and digitally simulate the correlative issues to find the optimization structure parameters which can support the motor-pump design theoretically.

1.Analysis of whole scheme

The variable speed hydraulic control technology using servo-motor can eliminate throttle loss and relief loss basically to improve efficiency and realize displacement , speed and force control by different arithmetic. And the electrical hydraulic integrate actuator in this way has been used at many different occasions.
Base on the variable speed control and high integration, new integration hydraulic power source include servo motor and hydraulic pump was proposed. Brushless DC servo motor has small capacity and inertia, fast response, stable moment, high sensitivity, small dead zone, low noise, long life-span and little disturb to electron device around , so it is the ideal choice. In view of hydraulic pump, the high pressure pump has two type: internal meshing gear pump and piston pump. Internal meshing gear pump has the advantage of small volume and inertia, low flow pulsation and high pollution rejection. Considering variable speed control, it has faster response and low speed stability, so the internal meshing gear pump was choose here. Figure 1 shows the structure of design. The internal

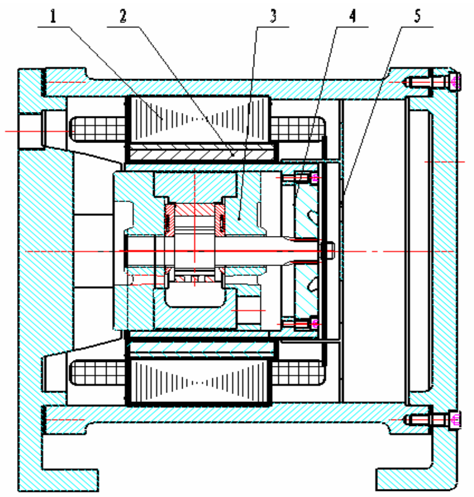

Figure 1 The structure of motor-pump

meshing gear pump 3 is fixed on the left side of the shell. The rotor 2 is supported by the sliding bearing on the both sides of pump. The torque of rotor is transferred to the gear pump shaft by the right side driving flange 4 to drive the pump. The oil entry and outlet is designed on the left side of shell, and there is also clapboard 5 to compart shell so the oil on the right side will not be disturbed by high speed of flange and benefit to impurity deposition and reducing power loss. The oil enter from the left up side of shell and goes through the channel formed by stator and compart to cool the stator winding to the right capacity. Then it passes the hole on driving flange to the suction hole of gear pump. The compact structure design reduce the 35% volume and elements using such as seal packing ring and shaft gland, increasing reliability. the noise is decreased largely because the gear pump is dipped in the oil , without junction box and rolling bearing.

2 Structure analysis

The highly compact of motor and pump brings a lot of advantages, but also disadvantages to the gear pump and motor respectively. To make sure work reliability, the research for these disadvantages must done and design the system in reason.
In theory, work state of gear pump is not changed after integration but for the high rotate speed of driving ring flange some resistance is created on the sucking route , the pressure of sucking side of gear pump reduced. Generally, higher rotate speed, lower pressure of the gear pump may cause cavitation erosion phenomena which will affect the normal work of gear pump; therefore there must be some more work to do. In the design , the driving flange was designed specially. There is a incline hole on the driving flange which is similar to centrifugal pump. So when the driving flange is running , oil is supplied by the centrifugal force. In theory, using special transition curved surface can work better, but considering of the difficulty of machining, straight hole was used.
For the motor, the main influence is focused on the rotor of motor. There are following differences comparing with normal brushless

DC servo motor. (1) Because of structure, motor rotor diameter is bigger , so is the moment of inertia.(2) Using oil cooling by digging the rotor into the oil when the motor rotates highly there is oil damping additional between the rotor and stator.(3)There is additional frictional force and oil damping between the rotor and bush bearing. The additional force by (2) and (3) is determined by the size of clearance and character of oil. Small clearance can ensure the working efficiency of rotating magnetic field and decrease magnetic(-flux) leakage but increase the damping of oil; the big clearance can decrease the damping of oil but influence the rotating magnetic field a lot. So the appropriate size of clearance can improve the performance of the system and overall efficiency.

3 Optimization design of key structure

3.1 Optimization design of driving flange

In this structure ,the drive special flange was designed. There is a declining hole in the driving flange which is simulate to the structure of centrifugal pump. So when the driving flange rotation, the centrifugal force will supply oil for gear pump. The structure shows as figure 2. Theoretical, the using of specifically transition curved surface hole will work better , but considering the difficulty of machining, the

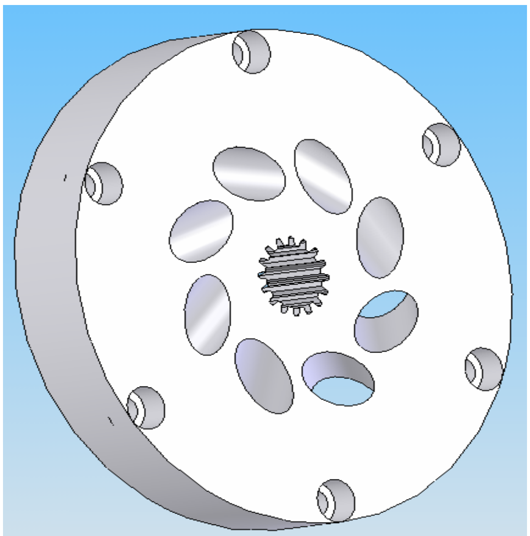

Figure 2 The structure of driving flange

uprightness hole was used. The computation hydrodynamics software “Fluent” was used here to optimize the angle of hole for better result. The main angle of whole is two: (1) the angle between axes of hole and transmission shaft ;(2) the angle between axes of whole and direction of radius. The data shows as table 2 was used to analyze in process. And the result of data group 11 shows as figure 3. The result indicated that the using of special declining hole can ameliorate the pressure of input. According to the analysis result, the data group 11 was used to as the base of design.

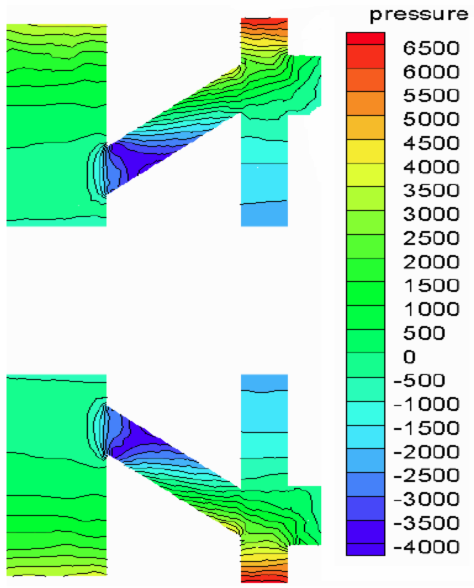

Figure 3 Flow filed analysis of driving flange

Table1 Table of analysis

组别	1	2	3	4	5	6	7	8	9	10	11	12
α	0	0	0	0	30	30	30	30	45	45	45	45
β	0	20	30	45	0	20	30	45	0	20	30	45

3.2 Mathematical analysis of rotor clearance

The oil film generated between motor rotor and stator and between motor stator and pump can express as the following formula

$$T = 4\pi^2 r^3 \mu \omega_m \frac{w}{h} \qquad (1)$$

Where T -torque, r -radiation of rotor, μ -hydraulic oil viscosity, ω_m -the rotate speed of rotor, w -the length of fit between stator and rotor, h -the size of clearance。

View from formula (1) , there are five parameters. Once the key structure design finished, the main adjustable parameter is the size of clearance.10# aero oil was used in the design, its character of viscosity and temperature is shows in figure 4. The usually working temperature 20oC、40 oC and 70 oC was applied in analysis. The radius of clearance is 0.2mm, 0.3mm and 0.35mm respectively, and the speed of pump is 3000r/min. The result of table 2 is computed by formula 1. View from table 2 and formula (1), the damping moment is direct ratio with oil viscosity, and decrease with the temperature increase. Above the 40 oC, the oil viscosity change follow temperature is smaller and so is the damping moment. According to formula (1), the change curve of clearance and damping moment under the invariable temperature (assuming 20 oC) can be get, it shows in figure 5. View from figure 5, the curve of clearance bigger than 0.3mm is relative flatness and the change of damping moment is smaller. The result above fit to the clearance between rotor and gear pump. The software Amesim was used to analysis the motor-pump integrated according to result of computing and diagrams. The key parameters are : working temperature is 40oC ; speed of inner gear pump 3000r/min ;discharge 10ml/r ; speed of brushless direct current motor. The modeling result shows in figure 6

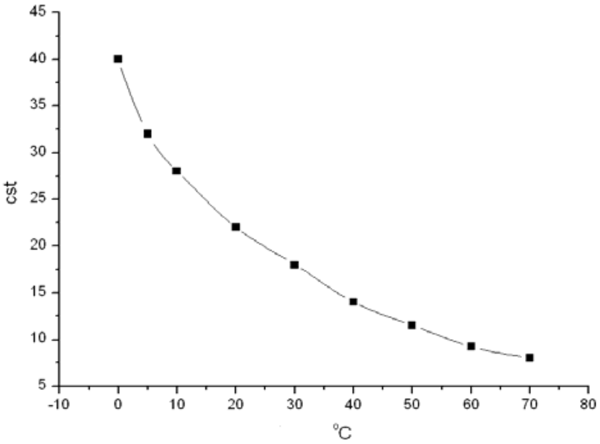

Figure 4 the character of oil viscosity and temperature

Table 2 damping torque at different clearance and temperature

clearance (mm) / temperature (°C)	0. 2	0. 25	0. 3	0. 35
20	3. 184	2. 548	2. 123	1. 82
40	1. 8	1. 44	1. 2	1. 028
70	1. 108	0. 866	0. 738	0. 633

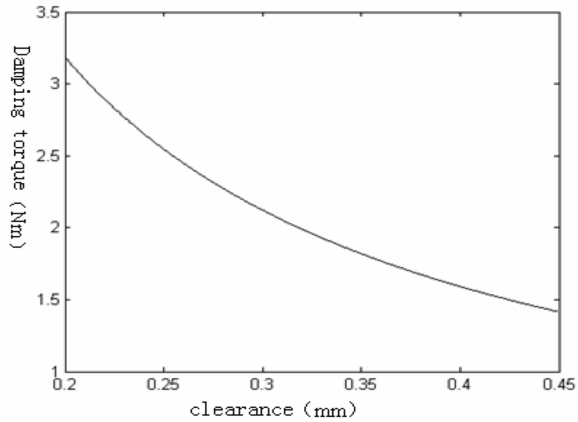

Figure 5 the character of rotor clearance and damping torque

View from the result , the clearance size of 0.3mm will make little damping moment and little influence to motor gas gap magnet field and the choosing oil which have better viscosity and temperature character will make better result.

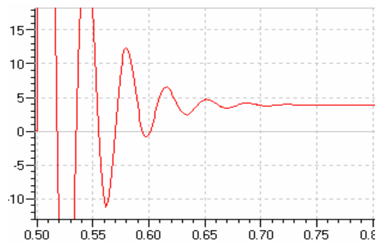

Figure 6 the motor output at the effect of damping torque

4 conclusion

The highly integration of motor and pump has a lot of advantages. After analyses and computes the disadvantages caused by integration detailedly, the results described as follow.

1） The using of driving flange with centrifugal pump structure can make better pressure of input and reasonable design and select of angle of hole will work better.

2）The analysis of air gap indicated that clearance will cause additional damping moment of motor, and appropriate clearance will reduce the power loss.

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