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Criterion Study of Fluid Transition Flow from Laminar to Turbulent of Hydrostatic Bearing

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Abstract. Based on the lubrication properties of the heavy-duty hydrostatic bearing, and use many oil pad circular guide hydrostatic bearing on the Heavy-duty CNC machine which is widely used as the research object. Under the condition of changing viscosity, establish the equation of lubricant viscosity-temperature, and calculate the fluid critical flow from laminar to turbulent from hydrostatic bearing gap. Use the finite volume method, based on the actual working condition of the factory. When the rotational speed is 6r/min, simulate the value of hydrostatic bearing inner flow field at different flow, verify the reliability of the calculation results. The results showed that, in this paper the transition critical inlet fluid flow from laminar flow to turbulent of the hydrostatic bearing is 22L/min. Through the above analysis and research, reveals the flow rule of the hydrostatic bearing oil film bearing gap, provides a theoretical basis for actual hydrostatic bearing for engineering structural optimization design.

Keywords: hydrostatic bearing, flow field, finite volume method, flow criterion

1 Introduction

Currently, scholars have studied on film lubrication performance to a certain degree. Scholars Sharma, Satish C. using the finite element method theoretically studied the performance of four containers hydrostatic tapered bearing system. Establish the bearing clearance space control flow lubrication Reynolds equation. Calculate the numerical values of different external load bearing static and dynamic performance. The simulation results show that the oil flow is also a greater impact on the capacity of the tapered bearing [1] .In 2012, Maher, Bilal M. A.studied on the Stokes movement of viscous fluid oil in the fluid hydrostatic bearing, which is elliptical outer boundary, and concentric circle inner boundary. Through analysis in the form of graphics, given a two-dimensional pressure distribution, and calculate the total thrust approximate estimates, derived the result consistent with the aforementioned theoretical results [2].

This paper summarizes the vertical lathe workbench at home and abroad and the performance of hydrostatic guide-ways, study for vertical lathe hydrostatic bearing,

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establish hydrostatic bearing fluid model. Calculate the numerical values of gap fluid flow field under different inlet flow, and get the flow state distribution of the gap fluid.

2 Hydrostatic Guide-way Gap Fluid Model and Control Equation

2.1 Gap Fluid Model

A three-dimensional geometric solid model of the intermediate film in many oil pad circular guide hydrostatic bearing is generated by UG, which is the specialized three-dimensional CAD software, as is shown in figure 1.

Fig.1. Rectangular cavity clearance fluid model

2.2 Control Equation

The influence of centrifugal force should be taken into consideration due to the rotating motion droved by the rotating worktable. When the fluid rotates at a constant angular velocity of in the rotating frame, the new kinetic energy should take the influence of the coriolis force and the centrifugal force into account .The relevant formulas are shown as follows:

$$S_{cor} = -2\rho\omega \times U$$
$$S_{cfg} = -\rho\omega \times (\omega \times r)$$
$$S_{M,rot} = S_{Cor} + S_{cfg} \quad (1)$$

Where S_{Cor} is the coriolis force, S_{cfg} is centrifugal force, r is the position vector of the micro-control element under rotational coordinate, U is the velocity vector, ω is the rotational angle-velocity vector.

In the energy equation, the equation of total enthalpy is:

$$h_{tot} = h_{stat} + \frac{1}{2}U^2 - \frac{1}{2}\omega^2 R^2 \quad (2)$$

Where h_{stat} is the static enthalpy.

The mass conservation equation, the momentum conservation equation and the energy conservation equation can be listed out considering the centrifugal force through the above equation.

The mass conservation equation is:

$$\frac{\partial \rho}{\partial t}+\nabla \cdot(\rho U)=0 \tag{3}$$

Where ρ is the density, t is the time. The density is a constant value for that the research fluid is incompressible fluid, i.e. $\frac{\partial \rho}{\partial t}=0$, ∇ is the divergence.

In the article, it is necessary to point out that the energy conservation can be ignored for the incompressible flow and without considering the heat transfer.

3 Theoretical Calculations and Numerical Simulation Analysis

3.1 Theoretical Calculations

The state of the hydrostatic bearing fluid flow can be calculated by calculating the Reynolds number. Reynolds number is calculated as follows:

$$Re=0.001 v \rho h / \nu \delta 1000 \tag{4}$$

In the formula, ρ is the fluid density, v is average velocity of the fluid, ν is the kinematic viscosity of the fluid, h is the bearing gap.

In the case of the workbench rotational speed constant, which use the working commonly speed of 6r/min. The critical Reynolds number is Re=1000, then the inlet flow is 22L/min. For comparison, also calculate the inlet flow correspondence rates of 12L/min, 22L/min, 24L/min, 36L/min, 48L/min Reynolds number. as shown in Table 1.

Table 1. Reynolds number in different inlet flow

Flow (L/min)	12	22	24	36	48
Reynolds number	733	1000	1065	1384	1729

3.2 Numerical simulation analysis

When considering changed viscosity conditions, other boundary conditions constant, set the workbench rotational speed of 6r/min constant. The inlet flow rates of 12L/min, 22L/min, 48L/min, and obtain the flow chart in CFX. Are shown in figure 2, figure 3.

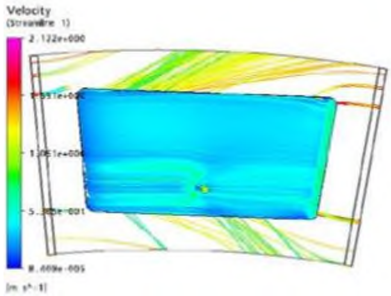

Fig.2. Streamlines of 12L/min inlet flow

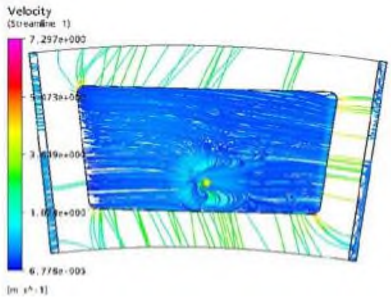

Fig.3. Streamlines of 36L/min inlet flow

It can be seen from figure 2, when the inlet flow is 12L/min, The flowing lines in oil chamber is very smooth, no flow lines and lines cross, no any swirl. We can determine the flow is a laminar flow. figure 3 shows that when the oil chamber inlet flow is 36L/min, there are lots of significant flow lines and lines cross in oil chamber and a large number of swirl. Its flow state is a typical turbulent flow.

4 Conclusion

Using the finite volume method for large size hydrostatic bearing gap fluid numerical analysis, reveals a gap of fluid flow state under different flow. Based on the flow chart simulated from CFX, when the workbench rotational speed is 6r/min constant, critical inlet flow is 22L/min, compare and analysis the results of numerical simulation and calculation data in table 1. Simulation flow chart and calculated values match, simulate realistic, true and reliable.

The numerical simulation result does not appear divergence phenomena, indicates that the equation using finite volume method is stable. At the same time, the flow distribution of interstitial fluid on hydrostatic guide accord with the practical, testify that the research method is credible.

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