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Numerical Study on Dynamic Stiffness hydrostatic bearing

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Abstract: The numerical simulation of the hydrostatic bearing of the fluctuating load is carried out by Ansys cfx. The variation law of the oil film thickness with the load is obtained and compared with the static formula. It reveals the influence of periodic variation of the load displacement interface table. The results show that under the fluctuating load, the oil film thickness, the bearing capacity and the dynamic stiffness are changed to some extent, which also provides the important basis for the reliability design of the hydrostatic bearing.

1. Introduction

With the development and progress of modern technology, used in machinery manufacturing, aerospace, astronomy, military and many other fields of metallurgy, for machining accuracy, load capacity and processing methods so put forward higher requirements [1]. Hydrostatic bearing system because of its bearing capacity, small friction, long life, good seismic performance, high accuracy, well stability, especially in the modern machine tool CNC machine tools has been widespread attention and widely used.

Ansys cfx software is used to study the flow field characteristics and bearing characteristics of oil chamber under variable load. Fluctuating load on hydrostatic bearing system dynamics, and do comparison with the theoretical analysis, a detailed analysis of the oil film bearing capacity and stiffness characteristic changes in load fluctuations and the impact on actual working conditions, for the machine tool area of the relevant parts of the support of the accuracy and performance improvement, have a very common practical significance.

2. Physical model

Hydrostatic bearing is the use of a dedicated oil supply means having a certain pressure oil is supplied through the throttle system hydrostatic oil bearing cavity, a flow of the lubricating oil film having a pressure[2]. Oil supply pressure is p_0, the gap between the oil seal is h as Fig. 1.

The flow on the edge of the oil seal can be simplified to two rectangular parallel plates with the upper and lower plate spacing h, and the lower base plate is regularly distributed with four I-shaped oil chambers. And make the following assumptions[3,4]:

(1) Lubricants incompressible Newtonian fluid;
(2) Oil chamber for the steady flow;
(3) Oil flow is laminar flow chamber;

(4) The fluid is uniform along the flow direction;
(5) Flow boundary is no slip;

Fig.2 is the static pressure bearing oil chamber oil pad bearing. p_s represents the pressure in the oil chamber, A_e indicates the effective bearing area. Other dimensions are shown in Table 1.

Table 1. Size parameters

Table length (mm)	Oil sealing edge(mm)	Oil sealing edge(mm)	Tubing radius(mm)
B=L=1500	l_1= l_2=139	b_1= b_2=128	R=1.5

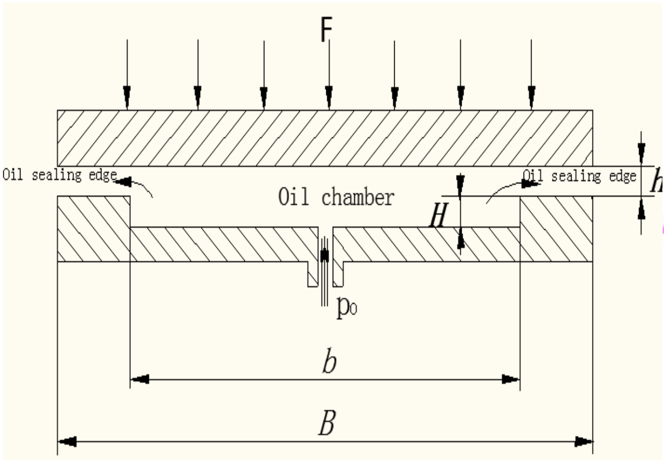

Figure 1 hydrostatic bearing model

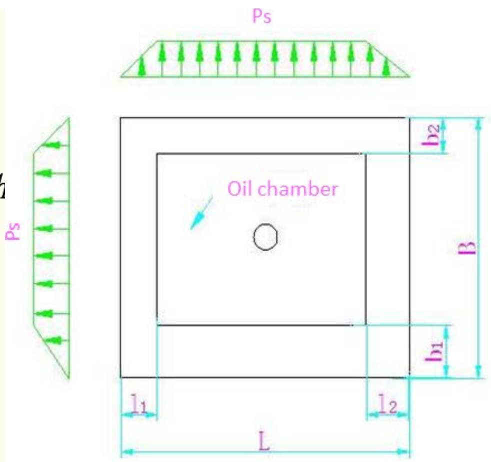

Figure 2 Oil chamber surface oil cushion

Because the depth of the oil chamber is much larger than the support clearance, the hydraulic pressure in the bottom of the oil area can be regarded as equal pressure distribution. Seal oil pressure distribution close to the edge of the linear law. The sum of the hydraulic loads is the load capacity [5,6]:

$$W = p_s A_e = \frac{p_s}{2}\left[LB + \left(B - b_1 - b_2\right)\left(L - l_1 - l_2\right)\right] \tag{1}$$

Where the effective correlation bearing area A_e is:

$$A_e = \frac{1}{2}\left[LB + \left(B - b_1 - b_2\right)\left(L - l_1 - l_2\right)\right] \tag{2}$$

The oil chamber pressure [5] for

$$p_s = \frac{p_0}{1 + Ch^3} \tag{3}$$

By the balance of the conditions available to the table pressure F expression:

$$F = \frac{W}{A} = \frac{p_0 A_e}{A\left(1 + Ch^3\right)} \tag{4}$$

We can get the stiffness function model

$$k = -\frac{dF}{dh} = \frac{Bh^2}{\left(1 + Ch^3\right)^2} \quad (B,\ C \text{ is a constant}) \tag{5}$$

3. Numerical model

The oil cavity model is partially simplified. Solid part, due to the main study of the flow field and dynamic performance of the oil film, the deformation of the supported solid part during the loading process is negligible with respect to the thickness of the oil film, so it is considered as a rigid body. Table 2 shows the data parameter settings [7].

Table 2 Data parameter settings

	Actual parameters	Simulation parameters
Skateboard quality	212*kg*	212*kg*
The true thickness	50*mm*	5*mm*
Skateboard density	1740kg/m^3	17400kg/m^3
Young's modulus	$4\times10^{10}pa$	$2\times10^{25}pa$

Fluid part, lubricating oil for the 46 anti-wear hydraulic oil [8,9], the oil density ρ =866kg/m^3, the dynamic viscosity μ=0.041*pa·s*. The influence of fluctuating load on hydrostatic bearing performance was analyzed. This paper simulates the oil pressure is 0.3*Mpa*, the sine load is:

$$p = 210 + 10 \times \sin 20\pi t \text{ (The unit is kpa)} \tag{6}$$

Fig. 3 shows the change in load *F* with time. Fig. 4 shows the variation of the interface displacement of the flow with time. After reaching the steady state, the displacement of each cycle of the crest or trough is a fixed value.

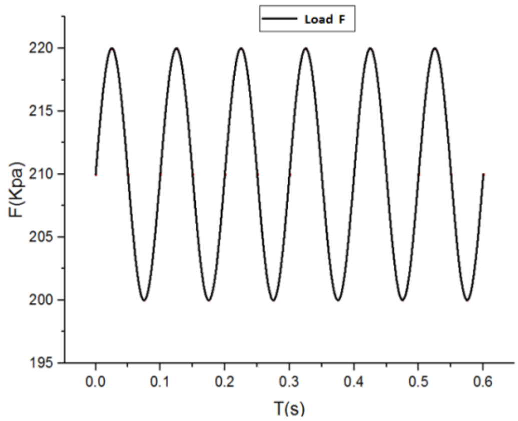

Figure 3 Load change with time

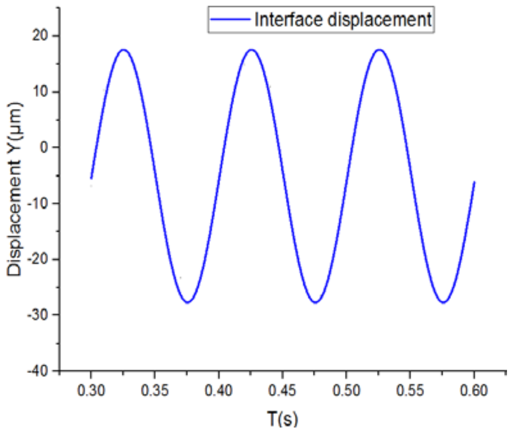

Figure 4 Interface displacement with time

The change of the thickness of the oil film can be obtained by the change of the displacement of the interface. Fig.5 shows the changes in film thickness with time. w_y is the displacement *Y*.

$$h = h_0 - w_y \tag{7}$$

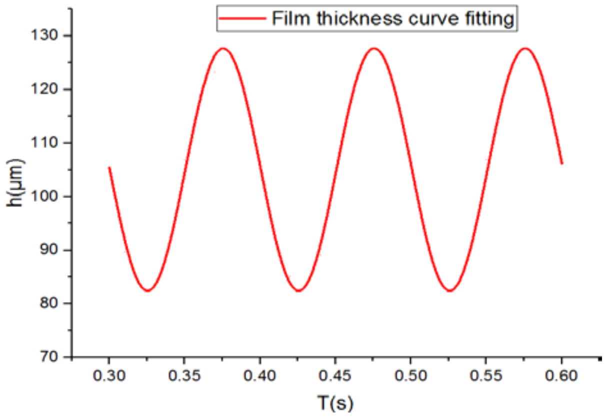

Figure 5 Changes in film thickness with time

Fig. 6 is a displacement curve of the interface with the load. Fig. 7 shows the variation of oil film thickness with load during fluctuation. The interface moves under the load, and the fundamental principle lies in the balance of forces at the interface. During the movement of the interface, the oil chamber pressure gradually changes until the oil chamber pressure is equal to the solid load pressure, the interface on both sides of the balance, the interface no longer move.

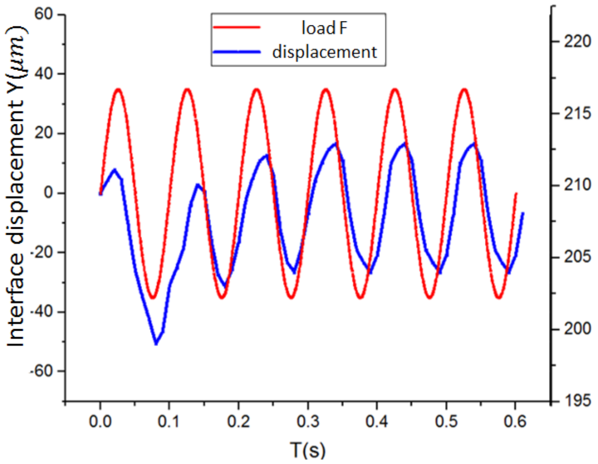

Figure 6 Interface displacement with load

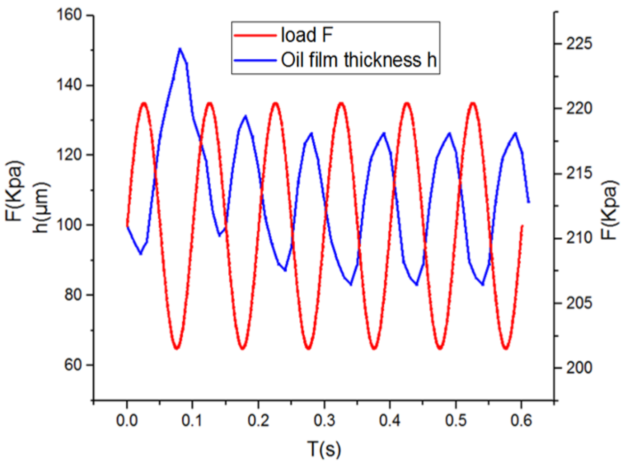

Figure 7 Oil film thickness with load

Fig. 8 shows the change in oil film thickness with the table pressure. Fig. 9 shows the change in stiffness with the thickness of the film. As can be seen from the figure, the black line represents a static process, and the green line represents a dynamic process. Static and dynamic stiffness also decreases with the increase of oil film thickness, and is non-linear. As with pressure changes, the dynamic stiffness changes more slowly when it is relatively static.

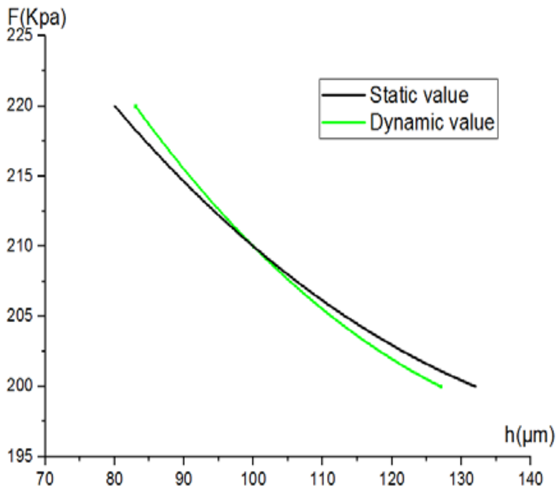

Figure 8 Oil thickness changes with pressure

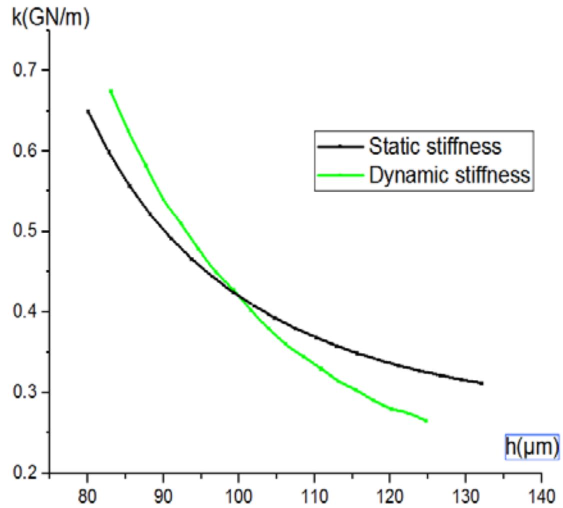

Figure 9 Stiffness varies with film thickness

The numerical results are obtained by the numerical results according to the theoretical function model (5):

Static pressure: $F_1 = \dfrac{618}{1+110h^3}$ (8)

Static stiffness: $k_1 = -\dfrac{dF}{dh} = \dfrac{2\times10^5 h^2}{\left(1+110h^3\right)^2}$ (9)

The dynamic value curve function is obtained by fitting the static value function model as follows:

Dynamic pressure: $F_2 = \dfrac{364}{1+116h^3}$ (10)

Dynamic stiffness: $k_2 = -\dfrac{dF}{dh} = \dfrac{1.2\times10^5 h^2}{\left(1+116h^3\right)^2}$ (11)

It is obtained by the theoretical function model, the static stiffness parameter B_1 is 2×10^5, C_1 is 110; the dynamic stiffness parameter B_2 is 1.2×10^5, C_2 is 116; the contrast dynamic parameter and the static parameter, C_2 and C_1 are approximately equal, and B_1 is close to B_2 2 times.

4. Conclusion

We got the following conclusions through above results and discussions.

1. Under fluctuating load, the interface displacement, oil film thickness variation and load have the same cycle;
2. Under the fluctuating load, the steady - state response of the oil film has a certain phase lag and a delay of 0.011s.
3. When the load change center of the same circumstances, the dynamic value decreases. The increase was 27μm, the relative static reduction was 5μm, the decrease was 17μm, and the relative static was reduced by 3μm.
4. The dynamic stiffness of the oil film decreases with the increase of the oil film thickness, and is non-linear.
5. The comparison between the dynamic parameters and static parameters, C_2 and C_1 are similar, and B_1 is almost 2 times that of B_2

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