Visualization of Air Flow in Externally Pressurized Thrust Gas Bearing Using Heat Curing Oil Film Method

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The heat curing oil film method using thermosetting property oil film is a new oil film method. The heat curing oil film method, in which not only the plane flow pattern in wall surface but also oil film thickness of the steady flow can be measured, was newly developed. The heat curing oil film method was used for visualization of the air flow in the clearance of an externally pressurized circular thrust gas bearing with a central supply hole and was found to provide much useful information about flow.

1. Introduction

It is very important to visualize the flow path of the flow for the evaluation of its basic characteristics. The oil film method is one method of visualizing the steady flow near the surface of the wall. In the conventional oil film method which is applied in the field of fluid mechanics, the plane flow pattern of the steady flow near the surface have been measured [1-4] . However this conventional oil film method is the visualizing method for the two dimensional steady flow.

If a new type of the oil film method visualizing the three dimensional flow pattern of the steady flow can be developed, many new information about the flow will be provided. However studies on this method have not yet been done.

In this paper, the heat curing oil film method, in which not only the plane flow pattern but also the oil film thickness of the steady flow can be measured, is newly developed. The heat curing oil film method is applied for the visualization of the steady flow in the clearance between the thrust gas bearings. The pattern and position of the adhering oil deposits position with the maximum oil film thickness on wall surface of the externally pressurized thrust gas bearing are obtained experimentally. The effect of bearing condition of both supply pressure and bearing clearance on both the pattern and position of the adhering oil deposits position with the maximum oil film thickness on wall surface of this gas bearing are discussed.

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2. Composition of Oil Paste in the Heat Curing Oil Film Method

The oil paste which is used in the heat curing oil film method contains the following components; Silicone, Titanium dioxide, Oleic acid and Hardener. The composition of oil paste in the heat curing oil film method is shown in Table 1.

Table 1 Composition of oil paste

Oil	Additive agents		
Silicon	Titanium dioxide	Hardener	Oleic acid
* 10	5	1	0.2

* Mass ratio

2.1 Oil

Silicone, an odorless, colorless and transparent oil, is chosen for the oil of the heat curing oil film method, because of its wide viscosity range ($0.65\times10^{-6}\sim1\,m^2/s$). It is thus very easy to choose the most suitable viscosity of silicone for the heat curing oil film method.

2.2 Pigment

As silicone oil is a colorless and transparent oil, it is difficult to distinguish the oil pattern. To visualize the oil deposit pattern, titanium dioxide, which is a white pigment, is mixed with the colorless, transparent silicone.

2.3 Additive

A little oleic acid is added to prevent coagulation of the titanium dioxide particles. The more the titanium dioxide particles are dispersed, the more the oil paste stuck to the wall surface, thus the flow pattern can be seen more easily.

2.4 Hardener

The oil paste contains hardener which slowly hardens enabling the hardened oil film thickness to be measured by a profile meter. The condensation reaction involved the hardener in the oil paste, thus the oil paste hardened slowly.

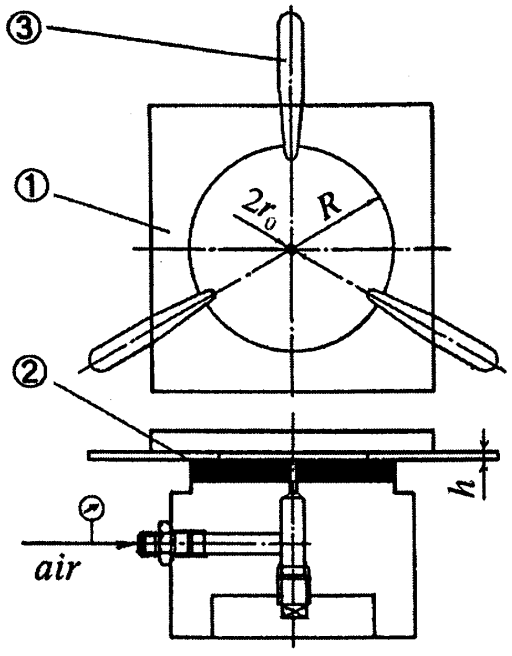
The mixture method of oil paste in the heat curing oil film method is as follows: The oil paste is mixed well so as to remove any lumps of titanium dioxide from the oil paste. The oil paste is then left about 30 minutes for the titanium dioxide to completely disperse throughout the silicone.

3. The Application of the Heat Curing Oil Film Method to the Visualization of the Air Flow in an Externally Pressurized Thrust Gas Bearing

The experimental investigation was carried out to visualize the steady flow in the clearance between the thrust bearing and the flat plate for externally pressurized thrust gas bearings using the heat curing oil film method.

3.1 Experimental Apparatus

The arrangement of the experimental apparatus for the oil deposit is shown in Fig.1. The bearing clearance between the circular thrust gas bearing and a flat plate was established by thickness gauges. To visualize the flow near the surface of the wall of the externally pressurized thrust gas bearing, colorless and transparent acrylic resin sheet was used for the material of the flat plate, and black acrylic resin sheet was used for that of the bearing surface.



① Acrylic resin plate

② Black plate

③ Thickness gauge

Fig.1 Experimental apparatus for the oil deposit.

3.2 Experimental Techniques

An oil paste was first painted on either the bearing surface or the flat plate. When a continuous flow of air was supplied to the bearing clearance from an external pressure source through the central supply hole, an oil paste was blown off by the supplied air, leaving an oil deposit in the form of a plane flow pattern with varying oil film thickness. The oil deposit was left about 30 hours to fix itself sufficiently with the hardener. However, since the hardened oil deposit was not hard enough to be measured by a profile meter, a harder replica of the hardened oil deposit was made from plastic casting materials so that the film thickness of the hardened oil deposit could be measured by a profile meter. As the ratio of contraction of the plastic casting materials was small (less than 0.1 percent), the replica of the hardened oil deposit was an accurate representation. The thickness of the replica of the hardened oil deposit was measured by a profile meter having a contact stylus force $0.05\,N$ and a stylus transverse radius $0.45\,mm$.

4 The Oil Deposit Flow Pattern

4.1 The typical pattern of the oil deposit

An oil paste painted on the bearing surface was blown off by the supplied air, leaving an oil deposit in the form of a plane flow pattern with varying oil film thickness. The typical pattern of the oil deposit on a thrust gas bearing surface non-supply side is shown in Fig.2.

The white ring part shows the oil deposit and the black part shows the surface of the bearing. The adhering oil deposits position with the maximum oil film thickness on wall surface of the externally pressurized thrust gas bearing r_{oil} is obtained as equation $r_{oil} = r_{02} - r_{01}$. Where the parameters both r_{01} and r_{02} of the white ring part in Fig.2 are equivalent to inner and outer positions of adhering oil deposits respectively. The white radial stripes of the flow pattern show the direction of the air flow. If the same total air volume was supplied to each clearance, the size of the pattern was the same in each case.

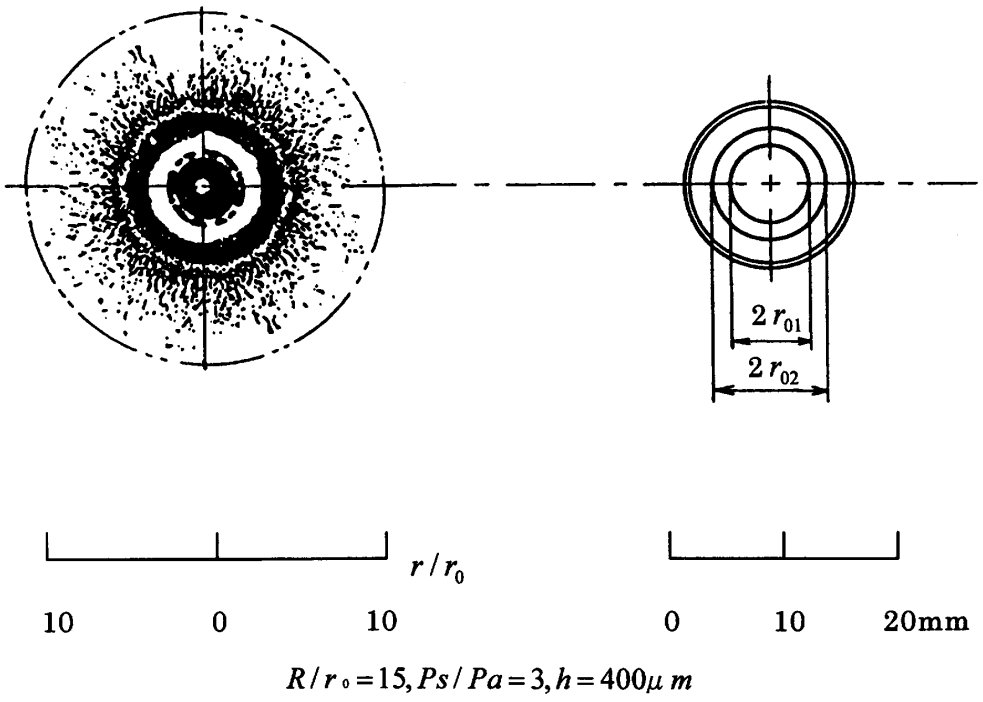


Fig.2 The typical pattern of the oil deposit on a thrust gas bearing surface non-supply side.

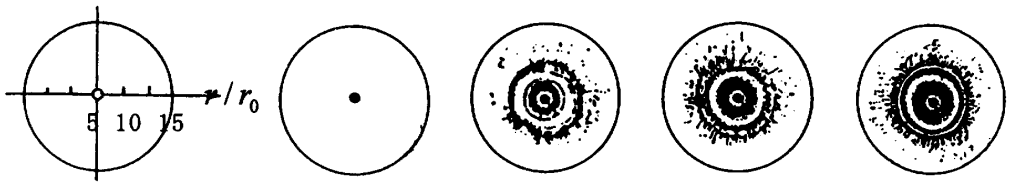
4.2 The relationship between the oil deposit flow pattern and the air supply time

The relationship between the deposit pattern on a thrust gas bearing in supply side and the air supply time is shown in Fig.3. It can be seen from Fig.3 that for flow periods over two seconds the patterns remained constant.

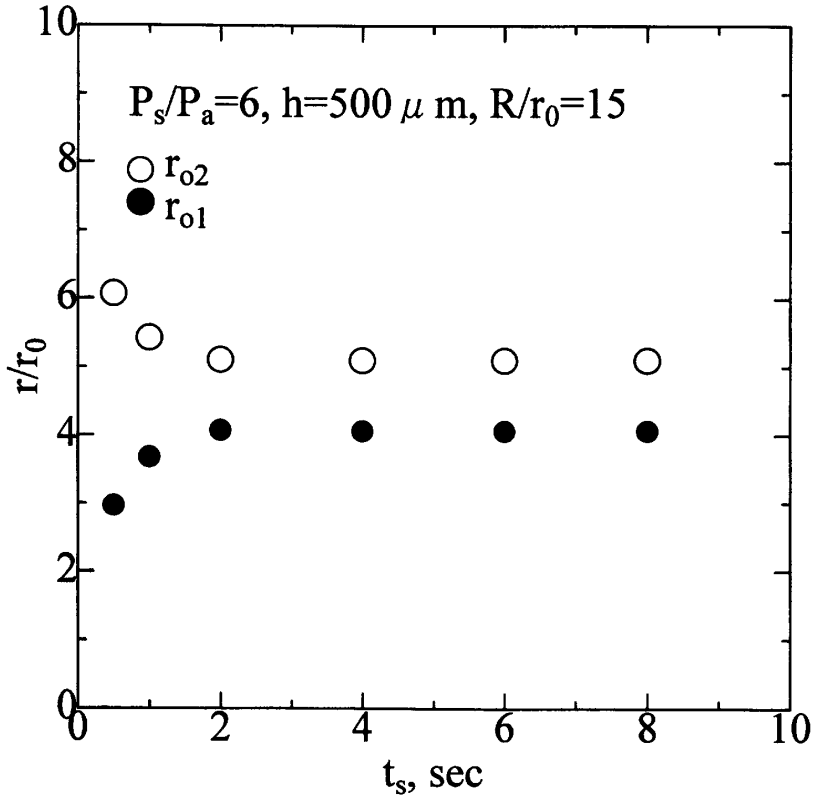
4.3 The Effect of supply pressure and bearing clearance on the position of adhering oil deposits

The effect of supply pressure p_s / p_a and bearing clearance h on the position of adhering oil deposits r_{01} and r_{02} are shown in Fig.4. It can be seen from Fig.4 (a) that positions of adhering oil deposits r_{01} , r_{02} and r_{oil} $(=r_{02}-r_{01})$ are increasing with increasing p_s / p_a. As the result, positions of adhering oil deposits r_{01}, r_{02} and r_{oil} go away from bearing air supply hole.

The effect of h on the position of adhering oil deposits r_{01} and r_{02} is shown in Fig.4(b). It can be seen from Fig.4(b) that r_{01} and r_{02} are decreasing with increasing h, and that r_{oil} has little effect on h.

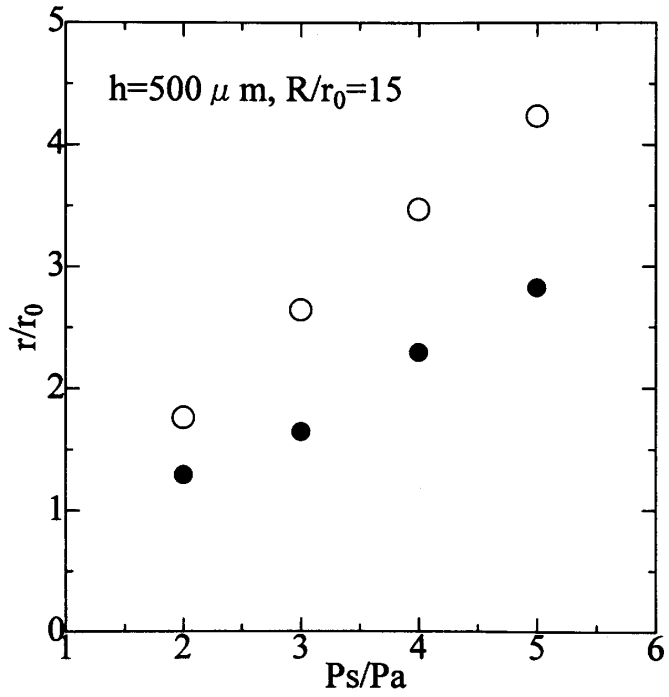


Air supply time t_s, sec $t_s = 0$ $t_s = 0.5$ $t_s = 1$ $t_s = 10$

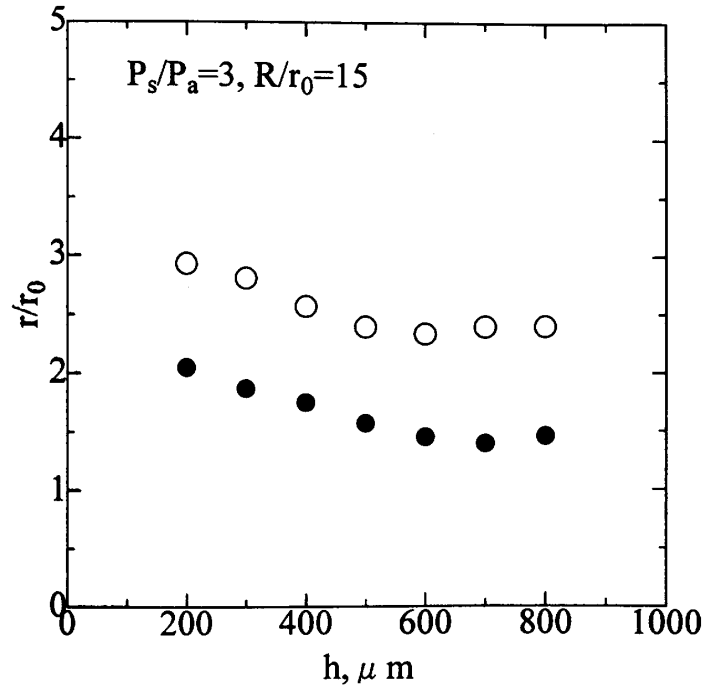


$R/r_o = 15, Ps/Pa = 6, h = 500\mu\, m$

Fig.3 The relationship between the deposit pattern on a thrust gas bearing in supply side and the air supply time.



(a) Effect of p_s / p_a on r_{01} and r_{02}



(b) Effect of h on r_{01} and r_{02}

Fig.4 The effect of supply pressure p_s / p_a and bearing clearance h on the position of adhering oil deposits r_{01} and r_{02}.

5. Conclusions

The heat curing oil film method, in which not only the plane flow pattern but also the oil film thickness of the steady flow can be measured, was proposed. The experimental investigation was carried out to visualize the steady flow in the clearance between the thrust bearing and the flat plate for externally pressurized thrust gas bearings using the heat curing oil film method.

The pattern and position of the adhering oil deposits position with the maximum oil film thickness on wall surface of the externally pressurized thrust gas bearing were obtained experimentally. The effect of bearing condition of both supply pressure and bearing clearance on both the pattern and position of the adhering oil deposits position with the maximum oil film thickness on wall surface of this gas bearing were discussed. The heat curing oil film method was very useful to visualize the steady flow in the clearance of the externally pressurized thrust gas bearing.

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