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Simulations of flow resistances in circular and square hydrostatic bearings

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Abstract

In the present study, laminar flows in hydrostatic bearings with circular or square recess are investigated numerically. The parameters affecting the flow resistance investigated include gap height and recess size. The numerical results are used to validate the currently available theoretical formulations. For circular hydrostatic bearing, flow resistances predicted with theoretical formulation agree well with the numerical results. However, for rectangular hydrostatic bearing, the maximum relative error can go up to 15%. This indicates that the corner effect is not accounted for in the theoretical formulation. Based on the numerical results, a modified formulation accounting for the corner effect on the flow resistance of the rectangular hydrostatic bearing is proposed.

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Keywords: hydrostatic bearings; circular and rectangular recess; flow resistance; numerical simulations

1. Introduction

There are several advantages of hydrostatic bearings, such as high levels of precision, stiffness, load-carrying capacity and life durability and low level of contact friction. Because of these advantages, hydrostatic bearings are commonly used in applications required high level of precision, as in precision measurements and advanced machine tools. The hydrostatic bearings is operated by an external pump, where high pressurized fluid flows from the inlet channels into the recess between the bearing surfaces, and this forms a thin pressurized film of fluid, which is then used to generate force to lift the working platform.

For a hydrostatic thrust bearing with circular step pad, the bearing performance such as load-carrying capability and the film stiffness, can be computed using the incompressible Reynolds equation[1,2] with cylindrical coordinate. On the other hand, the analysis becomes more complicated for a hydrostatic thrust bearing with rectangular recess, because the corner effects can not be accounted for with the above approach. One commonly approach was to neglect the corner effect, but this produces inaccurate results when the aspect ratio between recess and land length is small [3]. Another alternative considered the bearing as a series combination of rectangular and corner quadrants plate

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regions [4]. However, this method is too complicated and it necessitates to develop a simple formula incorporating the influence of corner regions.

In the present study, the corner effect is simulated using the Navier-Stokes equation to account for the real geometry of the rectangular hydrostatic bearing. The results are used to modify the previous theoretical derivation [4–6] to account for the corner effect with correctors. Influences of the bearing gap heights and recess sizes are also investigated.

2. Mathematical model

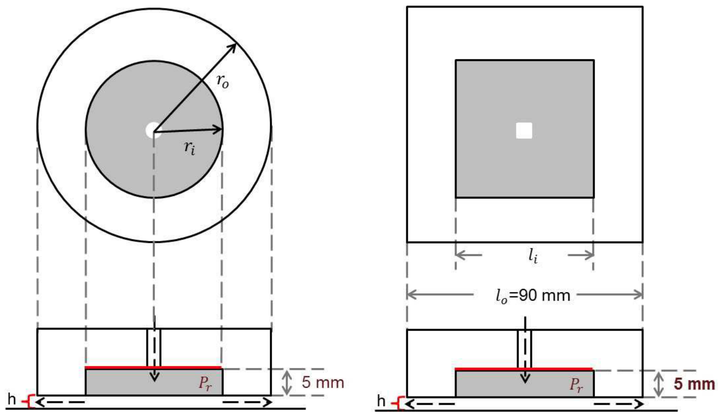
2.1. Governing equations

The governing equations of the numerical analysis are incompressible continuity and Navier-Stokes equations:

$$\frac{\partial(\rho u_i)}{\partial x_i} = 0\,. \tag{1}$$

$$\frac{\partial(\rho u_i v_j)}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \eta_o \frac{\partial^2 u_i}{\partial x_i \partial x_i}\,. \tag{2}$$

where η_0 is viscosity of the working fluid. The present numerical simulation is carried out with the CFD-software–STAR-CD. Center differencing scheme is used for the spatial discretization and PISO algorithm [7] is used for the pressure and velocity coupling.



(a) The circular bearing model. (b) The square bearing model.

Fig. 1. The specification of simulation models.

2.2. Theoretical prediction of flow resistance

2.2.1. Hydrostatic bearing with circular recess

To analyze the circular bearing land, the incompressible Reynolds equation is simplified by assuming the following boundary conditions, such that $p = p_r$ at $r = r_i$ and $p = 0$ at $r = r_o$, where r_i and r_o are the inner and outer diameters of the bearing as shown in Fig. 1. Thus, the pressure equation can be obtained as [2],

$$\frac{dp}{dr} = -\frac{p_r}{r\ln(r_o/r_i)} \tag{3}$$