model can analyze the cavity flow itself effectively. The present authors succeeded in obtaining such solutions for the wide range of Re* up to 300,000. If, however, we try to solve the problem throughout the both regions of cavity and bearing gap, we need some expert scheme because the bearing gap is too small for the same model to be applied consistently. The authors have never succeeded in obtaining this solution yet.

Conclusions

The two-dimensional full Navier-Stokes equations were solved numerically to illustrate the general feature of the inertia effects in submerged multi-pad and/or multi-grooved bearings, and also to evaluate the refined simplified approach.

The convective inertia forces of the lubricant flow around the inlet section of the bearing gap region causes so-called "inlet pressure jump". This effect is not small even if the modified Reynolds number is low enough for the convective inertia forces of the lubricant flow within the gap region to be negligible, and, of course, pronounced as the modified Reynolds number is heightened.

Though the global flow field is widely influenced by the geometry of the cavity region, the velocity distribution of the flow near the runner surface is hardly influenced by it, and this can be well predicted by the simplified approach based on the concept of the boundary layer development on a flat plate.

The simplified approach refined in this paper well predicts the inlet pressure jump for a wide range of the value of modified Reynolds number.

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DISCUSSION

Luis San Andres[1]

The paper presents a numerical study on the flow and pressure fields along the runner surface in a submerged multi-pad/groove bearing. The analysis considers an incompressible, isoviscous fluid and, regards the character of the flow as laminar. Calculations presented are for relatively small values of the Reynolds numbers.

The authors are congratulated for a good paper on the description of fluid inertia effects at the entrance to thin film land regions. The results presented show that the influence of upstream conditions and fluid inertia are of large magnitude even for relatively small values of the circumferential flow Reynolds numbers. The authors are also commended for their interesting approximate analysis on estimation of the inlet pressure although it is somewhat cumbersome to be applied in a practical situation. The flow problem studied is complicated since the abrupt geometry change requires different grid scales and consequently large computational times. Thus, I am not surprised that, using a cartesian grid, convergence has been a great problem for large Reynolds numbers. Perhaps the authors should use another method of solving the flow equations using, say boundary fitted coordinates, so as to aminorate the impact of geometric changes.

Have the authors thought of using their analytical and numerical computations to fit some simple approximate correlations such as those given by Burton et al. (1967) and Smalley et al. (1974). I find these correlations in the form of a Bernoulli

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like equation and as a function of the inlet velocity to be most important for the efficient, though preliminary, design and analysis of high speed hydrostatic pad bearings.

The analysis considers a bearing of infinite extent in the direction normal to the runner speed. Could the authors comment on how far the inlet effect extends on the sides of a typical bearing pad. The side boundary conditions are always pressumed to be equal to the sump pressure. To me it is not very clear how the pressure rise at the inlet changes along the leading edge of the pad. Furthermore, it will be of great interest to know how the entrance pressure is influenced by the side flow leaving the trailing edge of the previous pad.

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Authors' Closure

The authors thank Professor San Andres for his valuable comments, and will try to answer his questions in order.

1) Concerning the numerical methods, the authors agree with Prof. San Andres' proposal. Another problem which will be raised under high Reynolds number may be the introduction of some turbulence model able to relate the viscous dominated flow near the runner surface.

2) The authors have also considered the introduction of some simple approximate correlations. They have, however, given up such an attempt because there are so many parameters affecting the result especially in the case of finite width, while two of them (Mori, A. and Mori, H., 1986) have proposed the simple analysis as an alternative measure.

3) In their analysis applied to the case of finite width pads, the side boundary condition was set to the sump pressure not only for the film pressure but also for the inlet pressure in order to avoid discontinuity between them at the corners of the pad. Under such a boundary condition, the flow through the leading edge was bent outward and accelerated for the inlet pressure to fall toward the sump pressure at the corners of the pad. The inlet pressure profile along the leading edge was then calculated as shown in Fig. A-1. This is the result for one of the loaded pads of a nonpreloaded, center-pivoted, tilting pad journal bearing shown in Fig. A-2. The operating eccentricity ratio was assumed to be 0.5. For small values of Re^*, the inlet pressure fell monotonically toward the sump pressure. The profiles are likely ones. As the value of Re^* was increased, however, the profile turned into unnatural ones. When the value of Re^* was increased higher than 3.0, the calculation became impossible to hold the conservation equation of mass flow rate, because the development of the upstream flow was predicted insufficient to fill the entrance gap near the corners. Assuming that such results are attributable to the flow model not considering the effect of the side flow, the present authors carried out the experiment to measure the flow just upstream of the pad by traversing the anemometer probe. The results are shown schematically in Fig. A-3. As shown in the figure, near the corners, the development of the flow was accelerated by the side flow of Couette type contrary to the prediction by the proposed simplified model and, just at the corners, it almost approached to this side flow. Based on such an experimental flow field, the present authors tried to modify the simplified model, and then obtained the result shown by the dashed line in Fig. A-1 for $\mathrm{Re}^* = 3.0$. The profile was reformed into a likely one. This is not certified experimentally, but implies that the side boundary condition of sump pressure is a likely one in itself, and that the revision of the model for the development of the upstream flow considering the effect of side flow is the key to the problem which will be raised in application of the simplified approach to the case of finite width pads under high Reynolds number.

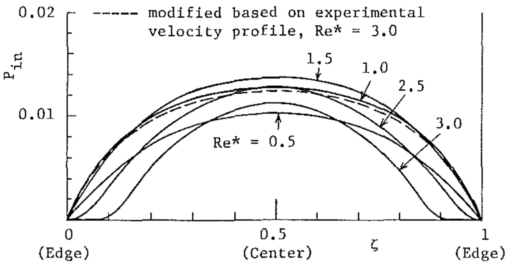

Fig. A-1 Inlet pressure profile along the leading edge

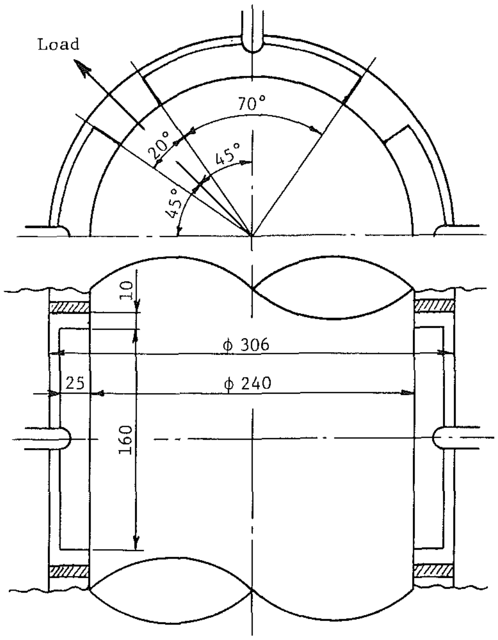

Fig. A-2 Schematic of the test bearing

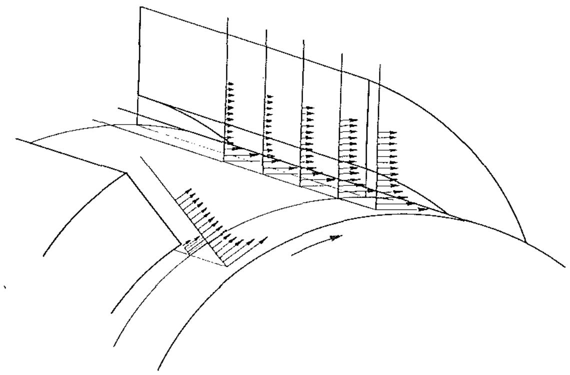

Fig. A-3 Velocity profile just upstream of the leading edge