NUMERICAL MODELLING OF SELF-ACTING GAS LUBRICATED BEARINGS WITH EXPERIMENTAL VERIFICATION

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Abstract

Gas lubricated bearings have conquered a modest place in mechanical engineering. They are applied when it is necessary to work in an oil-free or a grease-free environment or to have an extremely low friction. The present study deals mainly with self-acting gas lubricated bearings. An accurate method is needed for the prediction of the complicated behaviour such as the low load carrying capacity and the persistent vibrations. This method consist of an equation describing the gas and a solution for this equation.

The flow of a gas in a bearing is described by the general equations of fluid dynamics, which are too complex to solve. Well known models are derived by imposing simplifying assumptions, resulting in a model based on the Reynolds equation and a one dimensional model with inertia. The model with inertia presents some limiting criteria for the operating range of the Reynolds equation. The applicability of the Reynolds equation can be extended by including effects such as wall slip, centrifugal forces and turbulence.

A general analytical solution of the Reynolds equation for gas lubrication is not available. However, relations for the load carrying capacity are derived for asymptotically low and high bearing velocities in a periodical bearing.

The main objective of this study is to develop an accurate numerical solution of the Reynolds equation for the prediction of the behaviour of bearings lubricated with a gas. It is based on a Gauss-Seidel relaxation scheme with multigrid to reduce the number of calculations. In order to obtain an efficient multigrid solver, its procedures are based on the locally smooth behaviour of the conservation of mass. The resulting method is efficient, i.e. the number of operations and the memory capacity needed are proportional to the number of grid points involved, and is applicable for a large variety of bearing geometries with a large velocity range. It is also easy to incorporate additional bearing conditions, such as balance equations.

The results are divided into two parts, i.e. verifying experiments and numerical calculations.

Firstly, it is needed to compare the theoretical results with experiments in a thrust bearing with straight radial grooves. This bearing geometry is bi-directional, i.e. the same load capacity is generated in the forward velocity direction and the reverse velocity direction. The experiments verify the theoretical data. The test rig consisted of a stationary grooved disk and a rotor disk. The reliability of the test rig can be improved by mounting the rotor in ball bearings and giving the stator some degrees of freedom. This will exclude some dynamic rotor disturbances.

Secondly, the bearing dimensions of a self-acting bearing with a reversible velocity geometry are optimised. Other numerical results are obtained for the behaviour of a standard, two rail, hard disk slider (the IBM 3370 slider), a herringbone grooved journal bearing and a radial face seal.

It is concluded that the developed numerical method is a robust, efficient and accurate method for the prediction of the solution of the Reynolds equation, even beyond its operational validity. Experiments show that the Reynolds equation predicts the behaviour of a gas in a thrust bearing with straight grooves and that it can be used in two directions. Future research could be directed to the development of a model with a solver that incorporates inertia effects in more than one dimensions for more complicated flows and to design graphs for self-acting gas lubricated bearings.