INTRODUCTION

The rapid innovative development of modern science and technology in the fields of nuclear engineering, electronics, cryogenic engineering, computer technology and space technology demands high speed bearings with high precision operational characteristics even in adverse working environment. In most of the cases, bearings in use are lubricated by liquids and gases.

Basically, the thick film lubrication of bearings, whether liquid or gas lubricated is divided into two principal categories, eg. (i) Self-acting, (ii) Externally pressurised.

Self-acting bearings generate pressure as a result of their configuration (due to the formation of convergent film) and operation. The pressure developed depends on the shape of the clearance space and relative velocity between the journal and the bearing. Hydrodynamic pressure may also be developed if the lubricating film exists because of the oscillating relative normal motion. A bearing operating under this principle is called squeeze film bearing. The magnitude of the hydrodynamic pressure depends on the relative tangential or normal velocity. If the relative velocity is low, the pressure developed is also low and may not be sufficient to lift heavy load. For externally pressurised bearings, pressurised lubricant is supplied by an external source and the lubricating film is maintained to carry the load. These bearings are also known as hybrid bearings as their operation depends both on the self-acting principle as well as on external pressurisation.

Although gas-lubricated bearing has inferior load capacity compared to oil lubricated bearing of identical size because of reduced lubricant viscosity, gas-lubricated bearings have considerable advantage over oil-lubricated bearings. The bearing can operate over much wider range of speed due to less frictional forces or torques. The heat produced by friction is, in most cases, negligible. A unique quality of gas lubrication is its capacity to operate satisfactorily over wide range of temperature compared to oil lubrication. They are superior to oil bearings in respect of stiffness which enables better alignment of the journal even under dynamic conditions. Another important feature of gas lubrication is that, it presents virtually no problem of contamination and therefore, does not require any seal. Gas-lubricated bearings have some limitations too. Besides having limited load carrying capacity, they are prone to instability. Also high precision is required in manufacturing these bearings.

In conventional self-acting bearings, replenishment of lubricant is a maintenance job which becomes costly if the bearing is not readily accessible. In this case, however, alternative type of bearings called porous bearings can be used with advantage.

In the conventional externally pressurised bearings, the lubricating fluid is admitted into the bearing clearance through a number of orifice-or capillery-compensated discreate holes. But the design of such orifice-or capillary-compensated bearings is complicated and costly. Moreover, these bearings possess low load carrying capacity and stiffness relative to the supply pressure and flow required. In the case of bearings with incompressible lubricant, the use of large recesses ensures effective distribution of flow. This increases the load capacity. But, for bearings with compressible lubricant, a large recess volume leads to bearing instability due to pneumatic hammer. This led the researchers to replace the feed orifices by a bearing with porous material for better distribution of film pressure.

Since most of the porous materials possess a myriad of tiny and tortuous passages, the external pressurisation results in a bearing with a large number of restrictors. From the point of view of performance, the large number of feeders spread the effect of supply pressure over the clearance space more effectively than any other feeding system. This generally should give better load capacity compared to the conventional bearings for the same flow rate. Moreover due to the presence of a permeable surface adjacent to the clearance space, these bearings should exhibit better damping characteristics than the conventional externally pressurised bearings.

Controlled porosity and basic purity are claimed to be the outstanding properties of porous bushes. With no bonding agents added, the bushes are produced from properly proportioned alloys of virgin metal powders. With 20 - 30 % of the bush volume containing oil the risk of failure and destruction due to lack of oil is eliminated. Long bearing life and safe functioning are assured. The material specification and tolerences of porous bushes available in India follow Indian standards, IS 3980 : 1967 and compare with other world standards viz. BS 1131 part V ; 1955 ; ASTM B438 : 67 etc. The advantages of porous bearings include rapid production, reasonable tolerences, self-lubricating easy for design and installation, less costly, silent operation etc.

The porous bearings, however, have their own restrictions. It is difficult to manufacture two identical bearings of specified permeability and porosity. Moreover, due to the obstruction of pores by local deformation, the permeability decreases with increasing service life of the bearing. Despite these limitations, the manifold advantages and the reduction of vibrations in particular, offer great scope for the application of these bearings. These bearings are used in textile industry, automobiles, agriculture industry, trucks, domestic applications, electrical equipments, foot-wear machinery and machine-tools.

Although the first experimental work on externally pressurised porous gas bearings was reported in the year 1955, the theoretical investigations on such bearings were taken up at a comparatively later stage. Till the recent past, in the analysis of such bearings, it was customery to assume that the lubricating fluid enters the clearance space with a zero tangential velocity at the porous interface. As there is a migration of fluid tangent to the boundary within the porous medium, the assumption of no tangential velocity in the immediate neighbourhood used in the past analyses is at best approximate. Rather there is some net tangential drag due to the transfer of the forward momentum across this permeable boundary and there comes the concept of the 'slip velocity'.

Beavers and Joseph[1] proposed an empirical boundary condition to predict the velocity slip. The validity of Beavers - Joseph condition has been subsequently established by many investigators both theoretically and experimentally. In the initial stage, eventhough the velocity slip boundary condition was verified for incompressible lubricants, such as oil and water, afterwards, its validity was justified also for gaseous lubricants. Since the prediction of the velocity slip by Beavers and Joseph, the International Research Committee on

Lubrication[2] recommended recomputation of all the earlier data of porous bearings incorporating the condition of tangential velocity slip at the porous interface.

The Beavers - Joseph model has been subsequently modified by neglecting the Darcy's velocity component. Another slip model that considers the velocity slip to be the same as Darcy's law, is sometimes adopted. Solutions for infinitely long and short and finite self-acting journal bearings based on modified slip model, are available. Investigations on the externally pressurised porous oil journal bearings, incorporating the effect of velocity slip, are scarce in the open literature.

ABOUT THE THESIS

The aim of this thesis is to investigate and predict theoretically the stability characteristics of both self - acting and externally pressurised porous journal bearings subjected to conical mode of vibration and lubricated with incompressible and compressible fluid. In the analysis, the velocity slip at the porous interface has been taken into account by assuming the Beavers - Joseph criterion. An unloaded journal is subjected to two periodic angular displacements about two orthogonal transverse axes at the midplane of the bearing. With the usual assumptions of viscous, laminar flow, the theoretical prediction of hydrodynamic pressures developed in the bearing due to these angular displacements is obtained by the simultaneous solution of the equation of continuity (Darcy's law) in the porous medium and the modified Reynolds equation satisfying the appropriate boundary conditions. Using a first order perturbation technique, the governing equations are transformed into a set of equations for perturbed film pressures. These equations are then expressed in finite difference form and solved numerically using Gauss-Seidel iteration method with a successive overrelaxation scheme. A knowledge of perturbed pressures enable one to obtain tilting stiffness and damping coefficients. With the help of these tilting stiffness and damping coefficients, stability characteristics in terms of stability parameter and whirl ratio can be determined. Based on the principle of gyroscopic motion, the equations of motion of rigid journal, executing conical whirl due to small periodic angular displacements about two orthogonal transverse axes, have been written along two mutually perpendicular directions and the resulting equations have been solved following the method of Lund[124]. Stability characteristics in terms of conical stability parameter and whirl ratio are then obtained numerically using a digital computer (H.P. 9000) for various design parameters viz. bearing feeding parameter, thickness parameter, slenderness ratio, slip coefficient, permeability factor, anisotropic factors, speed parameter, porosity parameter, supply pressure and moment of inertia ratio.

The dissertation has been divided into seven chapters. A brief review of the relevant literature is included in Chapter I. The basic governing equations have been derived in generalised forms and are presented in Chapter II for easy reference. A parametric study has been carried into the stability characteristics of porous journal bearings subjected to conical mode of vibration and are reported in the following four chapters.

Chapter - III : gives the theoretical investigation of conical stability characteristics of self-acting porous oil journal bearings considering tangential velocity slip.

Chapter - IV : deals with the stability characteristics of externally pressurised porous oil journal bearings considering tangential velocity slip.

Chapter - V : presents the stability characteristics of self-acting porous gas journal bearing with slip flow.

Chapter - VI : contains the theoretical investigation of the stability characteristics of externally pressurised porous gas journal bearings with velocity slip.

Chapter - VII : gives the important conclusions based on the work presented in earlier chapters of this dissertation and indicates also the scope of further work in the area of research.

A list of references and listing of computer programmes are given at the end of the thesis.