Advances in oil lubricated plain bearings for high speed applications

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SYNOPSIS Oil lubricated tilting pad plain bearings are widely used in many pumps, fans and compressors. More demanding equipment duties have led in turn to significant advances in the performance capability of tilting pad bearings. This is manifested both in the form of enhanced standard ranges and in special designs which are regularly produced to satisfy ever more demanding customer specifications. This paper presents some of the results of recent work, in experimental research and in engineering design, chosen to illustrate what is now possible. Reference is made to a number of specific designs which include the very large diameter, high speed fan bearings for the European wind tunnel currently being built in Cologne.

1 INTRODUCTION

One of the consistent trends in the development of all plant is the use of more onerous operating conditions as system designers seek to maximise the output from all items of rotating equipment. More demanding equipment duties impose, in turn, new demands on the bearings used to support the shaft and absorb axial and radial loads. Oil lubricated, tilting pad, thrust and journal bearings have been an important design option for the greater part of this century and their use is common in a wide variety of equipment including many pumps, fans and compressors. In recent years, the performance capabilities and cost effectiveness of fluid film bearings have been extended by a combination of enhanced theoretical understanding, experimental work and innovative engineering design.

The purpose of this paper is to present some of the relevant results from current tilting pad bearing research and design development in order to give a greater appreciation of the considerable potential now available. In the sections which follow horizontal and vertical shaft systems are considered separately. Examples of experimental and operating data are given where appropriate and reference made to a number of specific bearings designed to satisfy particular extreme requirements.

2 HORIZONTAL SYSTEMS

2.1 Radial Loads

Horizontal shaft plain bearings are required, like vertical bearings to accommodate radial and axial loads which act perpendicular to and along the shaft respectively. In many instances the principal radial loads are due to gravity. Radial forces are also generated by operation of the system which is being supported. In some cases, such as pelton wheel turbines and certain gearboxes, the radial forces are very considerable and substantially greater than the forces due to gravity. The direction and magnitude of radial loads of this sort are governed by the geometry and nature of the system in question and may vary according to operating conditions. By contrast radial loads due to gravity are constant and act vertically downwards. Additional radial loads can also be caused by out of balance forces which rotate with the turning of the shaft.

There are a number of design options for horizontal shaft radial or journal bearings. The range of choice includes simple circular journal bushes, lemon bore and lobed bearings, bearings constructed with offset halves and tilting pad bearings. The order of these bearing types represents an increase in complexity and cost to provide rotor stability even at very high speeds and light loads.

Tilting journal pad bearings are the most sophisticated in the family of radial bearings and traditionally their main use has been for high speed applications where they can guarantee stability at all speeds and for applications in which the direction of the radial load varies or cannot be predicted with any accuracy. Recent experimental work (1) has extended the range of operation for these bearings while advances in manufacturing methods including the use of computer controlled machine tools, have ensured that they provide a cost effective design option. In the experimental work referred to, a 200 mm diameter, 80 mm axial length, tilting journal pad bearing fitted with centre pivoted pads, figure 1, was operated satisfactorily over a wide range of duties up to a maximum specific load of 4.14 MPa applied at a speed of 10,000 rev/min (equivalent to a sliding speed at the bearing surface of 105 m/s). The experimental programme was designed to isolate some important design parameters and determine their effect on bearing temperatures and energy consumption. It was found that the orientation of the bearing with respect to the direction of the applied radial load has a significant impact on the maximum temperature recorded in the bearing dependent on whether there is a pad directly in line with the load or whether the load line passes between two adjacent pads. Maximum pad temperatures recorded in the latter, load between pads case, were some 15°C to 20°C less than in the former.

Some of the experimental results for the load between pads case are given by figure 2 which shows maximum bearing temperature plotted against rotational speed for a number of applied loads. This figure shows one of the most interesting results from the experimental work which is an inflexion in the relationship between maximum bearing temperature and speed which is thought to be associated with a transition from laminar to turbulent lubricant flow in the bearing and hence to more efficient cooling of the journal pads. Transitions of this sort are common in high speed thrust bearings but are not so well documented in journal bearings.

In these journal pad experiments, lubricant was supplied to the bearing from an external source. The amount of oil delivered was adjusted for each combination of speed and load so that the mean oil temperature rise of the volume passing through the system between supply and drain was 17°C which is a standard figure for temperature rise in many commercial applications. Subsequently the amount of oil delivered to the bearing was reduced and it was found that large reductions in volume were possible, leading to useful energy savings without compromising reliability. Typically, at 10,000 rev/min, a 50% reduction in oil flow from the standard requirement leads to a drop in power absorbed of about 20%.

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