1. Title of PhD thesis:

Performance studies of new micro-pocketed and bionic textured fixed and tilting pad thrust bearings using FEM approach

2. Candidate: Jeewan Chandra Atwal (2016MEZ8276)

3. Supervisor: Prof. R. K. Pandey, Dept. of Mechanical Engineering, IIT Delhi

Abstract

Fluid film thrust pad bearings are employed to sustain and guide the axial/thrust loads in hydraulic and steam turbines, large size air compressors, medium to large size impeller pumps, and high-power rated helical gearboxes. Such bearings possess inherent high damping capacity; however, at the same time consume significant amount of shaft power in overcoming the friction of lubricated film. But due to growing awareness for energy conservation and need of performance improvement of bearings at elevated operating conditions, great attempts are being made globally by the research community to address the concerns i.e., minimizing the power loss without sacrificing the load-carrying capacity and having desirable minimum film thickness. It is worth noting that since recent past, micro/nano geometries containing surface textures and pockets have emerged as potential technology to reduce the frictional power loss and enhance the operational life of pads at elevated operating conditions. In light of encouraging results achieved in presence of surface textures, there is a scope of study by conceiving and developing new surface textures/pockets for exploring the performance improvements of hydrodynamically lubricated fixed and tilting pad thrust bearings.

The main objective of study presented in this thesis is to investigate the performance parameters of fixed and tilting pad thrust bearings employing new conceived bionic texture design inspired from the micro-structures of the fish scales. However, the additional objective reported in the thesis involves the exploration of role of micro-pockets (including new pocket) on the performance behaviours of water lubricated fixed pad thrust bearing operating at the elevated speeds. Moreover, a chapter has been added in the thesis having new design charts involving two different micro-pockets on pads and empirical relations for finding the performance parameters of tiling thrust pad bearings. The governing lubrication equation incorporating mass-conserving issue has been discretized using the finite element method (FEM) and the solution of the non-linear algebraic equations has been found employing the Newton-Schur method. The mathematical model employed in the thesis has been validated with numerical and experimental results available in the published literature for developing the confidence in the numerical results presented in the thesis.

The performance behaviours of sector-shaped fixed thrust pad bearings incorporating new pad surface designs namely, (1) Labeo rohita fish scale textured pad, (2) Micro-rectangular pocketed pad, and (3) Micro-rectangular pocketed pad with fish scale texture towards exit side, have been presented. The effects of texture parameters such as pocket/texture depth, extend of pocket and fish texture spread in the circumferential and radial directions, the number of scale texture waves in circumferential and radial directions, have been investigated for improving the performance of the bearings. On the basis of the investigations reported in this thesis, it has been found that the fixed pad surface having micro-rectangular pocketed pad with fish scale texture towards exit side, yields substantial increase (10-45%) in minimum film thickness and reduction (5-18%) in friction coefficient as compared to conventional pad design. Investigations were also carried out for determining the performance of fixed pad bearings employing a new conceived texture (i.e., trapezoidal pocket followed by scale texture) on pads' surface. It has been concluded that minimum film thickness has increased up to 48%, and the friction coefficient reduced up to 24% in comparison to conventional plain pad case. Moreover, the new textured pad has more metal surface area over the pad as compared to the conventional rectangular pocketed pad, which is beneficial in terms of reduction in load per unit area during the stopping/starting and mixed lubrication regimes.

To explore the effect of pocket/texture on a water lubricated thrust pad bearing operating in the turbulent flow regime, the performance parameters (minimum film thickness, friction coefficient, and bearing dynamic coefficients) of the bearings have been analysed. The performance behaviours achieved with a new pocketed pad bearing have been compared with the findings of the plain pad (without any pocket), and rectangular (conventional) pocketed bearing. With a new pocket, the minimum film thickness has increased in the range of 11–38% and friction coefficient has decreased up to 2% as compared to the conventional rectangular pocked pad. The difference between bearing dynamic coefficients of new and conventional pocket has been found be negligible.

Performance parameters of the sector shaped tilting pad thrust bearings employing the new micro-structural geometries (i.e., trapezoidal-textured, and trapezoidal-pocketed pads) on pad surfaces have been investigated. The pad equilibrium in the analysis is established using the Newton-Raphson and Braydon methods. The influence of attributes of microstructures such as depth, circumferential and radial positioning extents have been explored on the performance behaviours. In comparison to the rectangular-pocketed pad, the trapezoidal-textured and trapezoidal-pocketed pads have produced enhancement in the minimum film thickness varying in the range of 10-28.5% and 18-37%, respectively. The reduction in the power loss has also been found up to 3% and 5.5% with trapezoidal-textured and trapezoidal-pocketed pads, respectively. However, the percentage decrease in maximum temperature is observed up to 5% and 10% with trapezoidal-textured and trapezoidal-pocketed pads, respectively.

Finally at the end, the thesis presents, new design charts and associated empirical relations for design of hydrodynamically lubricated rectangular-pocketed & trapezoidal-pocketed tilting pad thrust bearings. Numerical examples have been provided to demonstrate the use of the charts. The empirical relations are useful for developing the computer programs for speedy design of pad thrust bearings.