Effects of manufacturing errors on parallel surface thrust bearings operating under TEHD regime

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Abstract*– *In the present study, a numerical investigation on the effect of different manufacturing errors on the performance of a parallel thrust bearing is reported. The calculations have been performed utilising a CFD-based TEHD computational approach. An initial investigation of the pressure build-up mechanism in parallel thrust bearings concluded that the two main reasons of load carrying capacity of parallel thrust bearings are (a) the thermal deformation of the pad upper surface and (b) the initial (non-deformed) "quasi-parallel" pad upper surface, being an outcome of the manufacturing process. The present work investigates the importance of the initial geometry of a "quasi-parallel" thrust bearing, and indicates manufacturing tolerance thresholds, below which, the defects of the pad-fluid interface are not the major factor of pressure generation in the lubricant domain of the bearings.

Keywords*– *Manufacturing Errors, Thermal deformations, TEHD regime, CFD, Parallel thrust bearings.

I. INTRODUCTION

Since the introduction of parallel thrust bearings, experimental studies have demonstrated that parallel bearings are capable of supporting thrust loads, a phenomena that cannot be evaluated with the use of the classic hydrodynamic lubrication theory [1-4]. In the past, numerous theories have been introduced in order to explain this counterintuitive behavior of parallel bearings [1]. In a previous study [5] it was identified that the fluid wedge generated by the thermal expansion of the pad geometry is the main mechanism of pressure build-up in parallel bearings. In addition, the definition of "parallel" surfaces has been deeper examined. In particular, following the outcome of the work in Reference [5], quasi-plane surfaces, with different manufacturing defects and defect amplitudes have been considered and evaluated in order to quantify the amplitude threshold, for which the manufacturing defects affect the tribological characteristics of the slider, and if the imperfections of the pad surface contribute to the load carrying capacity of the parallel thrust bearing. In the experiments done by Henry [4], two identical parallel thrust bearings have been studied. The only difference between the two thrust bearings was the polishing of the pad upper surface. The two thrust bearings exhibited different tribological characteristics. The non polished one accounted for a faster transition to hydrodynamic lubrication, and marginal larger load carrying capacity for the same minimum film thickness. The geometry of both the polished and the unpolished pad upper surfaces has been measured, and each pad exhibited different geometry imperfections, approximated by a superposition of simple manufacturing errors of the pad surface such as waviness, convergence, divergence, concavity and convexity, with different error amplitudes. In the present study the effects of such imperfections on the tribological performance of thrust bearings are addressed, by means of CFD ThermoElastoHydroDynamic modeling.

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II. METHODOLOGY

A. *Geometry*

The bearing of the present study is identical to that of Henry [4], in particular, a 8 pad thrust bearing with outer and inner diameters of 90 mm and 50 mm, respectively. For the reference geometry, the fluid-stator interface is considered to be perfectly parallel. The studied geometrical defects of the fluid pad surface are depicted in Fig. 1. For all five defects, the reference defect amplitude is considered to be 1 micron. The runner is made of steel and the bearing of bronze, both characterized by a thickness of 20 mm.

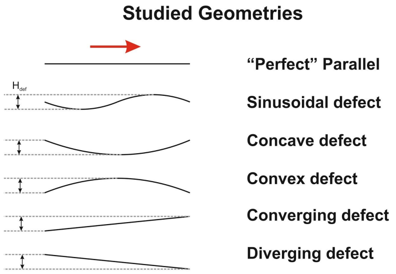

Fig. 1 Geometrical imperfection of fluid pad interface.

B. *ThermoElastoHydroDynamic Modelling*

A ThemoElastoHydroDynamic (TEHD) model has been generated using the commercial codes Ansys CFX and Ansys Mechanical. A two-way FSI has been set in the fluid-slider interface, by exchanging temperature and pressure field data between the CFD and the FE models. The bearing geometry is able to deform due to (a) the temperature gradient, and (b) the pressure generated within the lubricant. In the simulations, lubricant properties, operating parameters and boundary conditions are considered to be the same as those in [6]. In

Fig. 2, the logical diagram of the TEHD model is depicted. In the beginning, the thermal distortion of the pad when its temperature rises from ambient to an initial value of 40 ºC is calculated, in order to minimise the time needed to convergence. Next, the lubricating oil wedge geometry is calculated and transferred to the CFD solver, for flow calculations. The calculated pressure and temperature profiles are transferred to the FE solver, where heat transfer and mechanical deformations are calculated, leading to updated values of bearing temperature and geometry. The process is repeated until convergence is reached, which for the present case requires approximately 25 iterations. After the final iteration, the pressure and temperature profiles with the corresponding final fluid geometry are exported, and all the tribological characteristics of the bearing are evaluated.

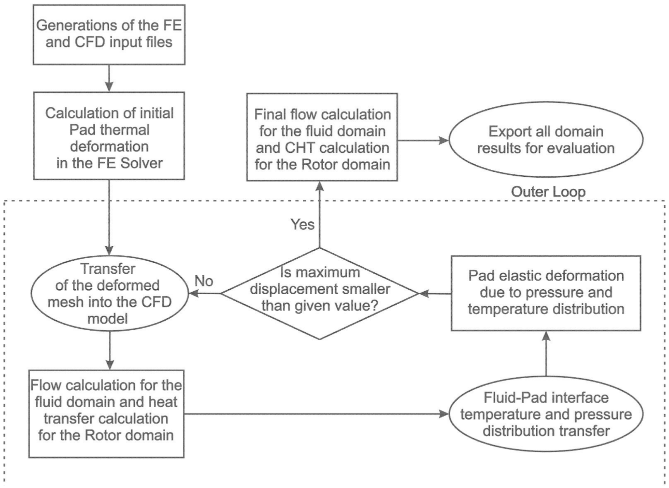

Fig. 2 TEHD model logical diagram

C. *Parametric analysis*

A parametric study has been performed for different values of minimum film thickness (H_{min}), defect patterns (waviness, concavity, convexity, convergence and divergence of the bearing pad) and corresponding amplitudes. The results have been compared to those of a parallel bearing without defects, so as to quantify the additional effect of manufacturing errors on the pressure build-up of the parallel thrust bearing. Based on the obtained results, manufacturing tolerance thresholds have been identified, below which, the defects of the pad-fluid interface are not a major factor of pressure generation in the lubricant domain of the bearing.

III. RESULTS

Preliminary results demonstrate that even small deviations from the perfectly parallel thrust bearing modify substantially the tribological characteristics of the bearing. In Fig. 3 the pressure and temperature profiles of a perfect parallel thrust bearing are depicted. Fig. 4 presents the final pad geometry, taking into consideration the mechanical deformations due to temperature gradients and oil pressure.

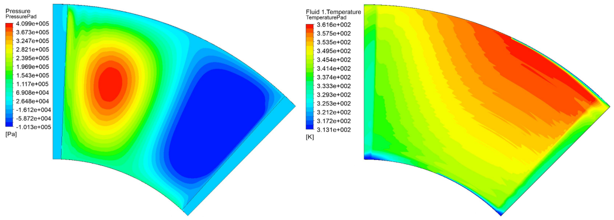

Fig. 3 Pressure and Temperature profiles of a perfect parallel thrust bearing

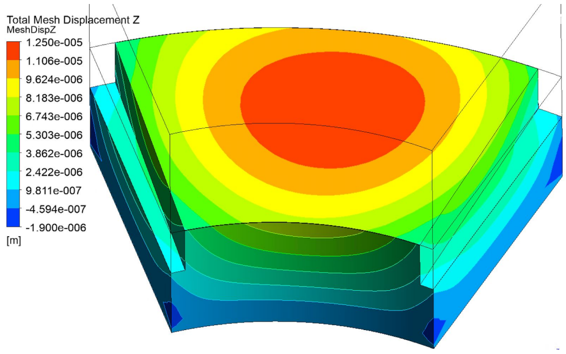

Fig. 4 Mesh displacement of the pad domain of a perfect parallel thrust bearing

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