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Doctoral thesis

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An analysis of the hydrodynamic lubrication of a conical slide bearing with ferro-oil

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Abstract

This work concerns the theoretical and numerical analysis of stationary hydrodynamic lubrication of a slide conical bearing with ferro-oil. The thesis that the use of ferro-oil as a lubricating oil for a conical slide bearing, gives the possibility of influencing the flow and operating parameters during the bearing operation, by acting on the ferro-oil with an external magnetic field, was verified. Achieving the main objective of the work required the implementation of several specific objectives, namely:

- derivation of a mathematical model, describing the flow of ferro-oil in the lubrication gap of the conical bearing, in the magnetic field and presentation of the obtained equations in a dimensionless form,
- development and writing of a computational algorithm in the Matlab software, based on the Newton method with the finite difference method,
- considering the changes in ferro-oil viscosity as a function of temperature, shear rate, pressure and magnetic field induction, based on adopted and proposed models and values of coefficients, obtained by fitting function described by these models, to the experimental data available in the literature,
- performing simulations for assumed dimensionless bearing lengths and cone angles at different relative eccentricities,
- investigation of the inertia forces effect, resulting from the rotation of the conical shaft and also, the influence of ferro-oil non-Newtonian properties.

The first chapter contains an introduction, a discussion of selected ferro-oil properties and a literature review, concerning the lubrication of slide bearings with ferro-fluids. Next, the thesis, goals and methods used at work were presented.

The second chapter presents the derivation of a mathematical model describing stationary hydrodynamic lubrication of conical slide bearings. Equations of the principle of conservation of momentum, stream continuity, energy conservation and

Maxwell's equations, were written in a conical coordinate system, and then, they were reduced to a dimensionless form. Integration of these equations resulted in obtaining a dimensionless Reynolds type equation, velocity vector component functions, and temperature distribution function. The chapter also presents the adopted viscosity models.

The third chapter concerned the verification of results obtained in numerical calculations. Matlab from MathWorks, was used to write code for simulations. The iterative Newton's method has been implemented, in which the first and second derivatives and mixed derivatives are approximated by finite differences. The results obtained in simulations, were compared with the values obtained with the solutions for simplified cases: of infinitely long and very short journal bearings. In addition, the results were compared with the results obtained using the CFD Fluent software from the Ansys Workbench platform, where calculations were made for bearings lubricated with non-Newtonian ferro-oil, taking into account the effect of temperature changes on viscosity, but omitting the influence of pressure and magnetic field.

The fourth chapter presents the simulation results for the considered conical slide bearings. The constant magnetic induction in the lubrication gap, was concerned and also the cases, where the magnetic induction increases or decreases linearly in the longitudinal direction. Three-dimensional pressure distributions and pressure distributions in cross-section and longitudinal section, were presented. The obtained pressure distributions were used to determine the components of the load carrying capacities in the transverse and longitudinal directions. Using the calculated velocity values, friction forces were determined and the values of friction coefficient were obtained. The analysis of the influence of taking into account the nonlinear effects in the equations of motion and temperature distribution, resulting from the inertia forces generated by the rotation of the conical shaft, was also performed and the importance of considering the non-Newtonian properties of ferro-oil was examined.

The fifth chapter contains a summary and conclusions resulting from the carried out analyzes. The achieved goals in this work, were specified. There were also presented the planned further research.

The investigations presented in this dissertation show, that the conical slide bearing lubricated with ferro-oil can be considered as an smart bearing, because due to the use of ferro-oil and external magnetic field, relative eccentricity can be controlled (i.e. distribution of the lubrication gap height) to gain bearing optimal operating conditions. The conical slide bearing load carrying capacity has a radial and longitudinal components, thus it enables simultaneous transfer of loads acting perpendicularly and along the shaft axis. Despite the simplifications adopted in

the mathematical model, the conducted analysis gives a good insight into the effects occurring in the hydrodynamic lubrication with ferro-oil of the conical slide bearing.