A New Thermo-Elastohydrodynamic Lubrication Model for Journal and Sliding Bearing Systems

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The present work proposes an integrated finite-volume framework aimed at solving transient mixed thermo-elastohydrodynamic lubrication (TEHL) problems to predict the lubrication performance of conformal bearing systems. The fluid flow effects are considered using the generalised Reynolds equation with the *p*-*θ* Elrod-Adams mass-conserving cavitation model to ensure the mass flowrate conservation throughout the lubricated domain. The thermal behavior of the lubricating oil is described through the solution of three-dimensional energy equation with proper boundary conditions for the fluid-solid interfaces. Advanced numerical techniques are employed to handle the strong nonlinearities exhibited by the system of equations.

Keywords: thermo-elastohydrodynamic lubrication, cavitation, numerical simulation, conformal contacts

1. Introduction

About one-fifth of all energy used around the world is consumed by friction, while one-third of the energy used in transportation is employed to overcome friction [1]. The paramount aim of the current study is to develop a robust computational framework for solving mixed-TEHL problems to explore the application of low viscosity engine oils, surface coatings and textures to improve tribological performances of conformal bearing systems.

2. Methodology

The following coupled system of nonlinear equations is solved while ensuring the algorithm's numerical stability:

$$\frac{\partial}{\partial x}\left(\varepsilon\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(\varepsilon\frac{\partial p}{\partial y}\right)=\frac{\partial \rho_x^*}{\partial x}+\frac{\partial \rho_y^*}{\partial y}+\frac{\partial \rho_e}{\partial t} \quad (1)$$

$$(p_H-p_{cav})(1-\theta)=0 \rightarrow \begin{cases} p_H > p_{cav} & \rightarrow \quad \theta = 1 \\ p_H = p_{cav} & \rightarrow \quad 0 \leq \theta < 1 \end{cases} \quad (2)$$

$$\frac{\partial(\rho\phi)}{\partial t}+div(\rho\phi u)=div(\Gamma grad(\phi))+S_\phi \quad (3)$$

The whole system of equations was solved using the finite volume method (FVM) due to its recognized effectiveness for solving fluid dynamics problems and thermohydrodynamic analysis [2].

2.1. Structure

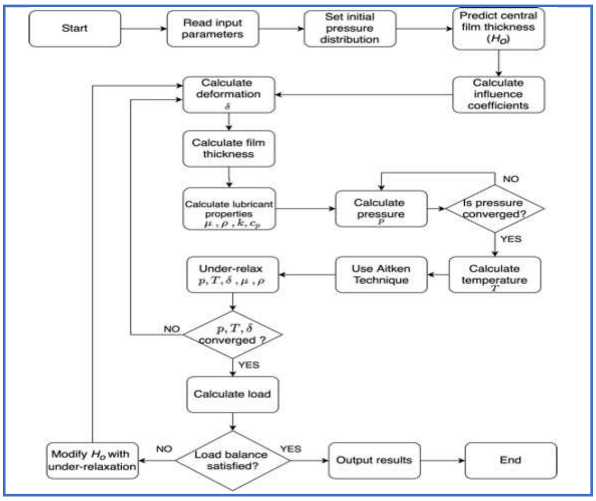

Figure 1: Schematic plan for the proposed framework.

2.2. Results

An example FVM solution of Eq. 1 coupled with complementary conditions for cavitation (Eq. 2) to generate pressure profiles is shown in Fig. 2.

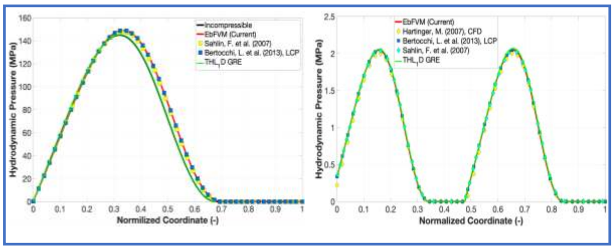

Figure 2: Results for single and double parabolic sliding bearings. *THL₁D GRE* is the current framework.

3. Discussion

The proposed TEHL framework provides for the first time cavitation thermal mapping to investigate the influence of biphasic mixtures on the thermal EHL solution. Vis-à-vis the lubricant domain, the performance of low viscosity oils with different concentration of viscosity index improvers (VII) additives will be studied. Advanced numerical techniques, including coordinate transformation and Aitken relaxation scheme, are being studied. Experimental validations of the proposed work will be based on friction data, ultra-sound film thickness measurements and infra-red thermal maps. The TEHL framework is a unique numerical tool, which correctly captures cavitation boundary conditons and transient behaviour to study thermal effects in bearing systems.

4. References

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