7th World Tribology Congress, WTC 2022
July 10-15, 2022, Lyon, France

Comparison between the P-θ formulation and the Rayleigh-Plesset equation for modeling cavitation in starved lubricated thin films

Anthony Voitus[1,2,*], Mihai Arghir[1] and Mohamed-Amine Hassini[2]
[1]Institut PPRIME, UPR CNRS 3346, Université de Poitiers, ISAE ENSMA, France
[2]EDF, R&D, Saclay, France
*Corresponding author: anthony.voitus@edf.fr

The present work deals with modeling cavitation in starved thin fluid films. Two ways of handling the problem are presented: the FBNS algorithm for solving the JFO model [1] and a simplified version of the Rayleigh-Plesset equation [2]. The first model is built on physical observations of the cavitation phenomenon and on mathematical constraints that approximate it. The second model describes the physical behaviour of bubbles in an incompressible fluid and permits, under certain simplifications, to accurately detect the cavitation zones. It is hereby shown that both models can describe the variation of the gas volume fraction and of the pressure in starved thin films.

Keywords (from 3 to 5 max): cavitation, Rayleigh-Plesset, gas fraction

1. Introduction

Cavitation models are used to represent the physical behaviour of fluids subjected to large depressions. They complete the Reynolds equation and predict a cavitation pressure threshold accompanied by the appearance of gas pockets. The formation of the latter can be due to two phenomena: the release of dissolved gases or the vaporisation of the fluid inside small pre-existing bubbles. A method based on the behavior of bubbles uniformly distributed in an incompressible fluid is used in the present work to simulate cavitation in starved thin films. The results are compared with the predictions of the P-θ formulation for film formation and rupture [1] and show that the two approaches give very close results.

2. Reynolds/Rayleigh-Plesset coupling

The flow inside an eccentric cylindrical journal bearing is used to illustrate cavitation under starved feeding conditions. The ratio between the maximum and the minimum film thickness is 2. The origin of the coordinate system is at the maximum film thickness. So, the thin film starts with a convergent zone followed by a divergent one. In all cases, the divergent zone leads to a rapid decrease in pressure and triggers cavitation instantly followed by film rupture.
For starved feeding conditions, the fluid entrained in the convergent part of the bearing contains an important gas volume fraction. This corresponds to θ in the JFO cavitation model [1]. Another way is to consider that the volume fraction of gas corresponds to uniformly distributed gas bubbles that contaminate the lubricant. These bubbles have a predefined limit pressure (the cavitation pressure) below which they will grow and coalesce. The variation of the bubble radius with pressure is described by Rayleigh-Plesset (RP) equation. The equation is strongly simplified in [2] by neglecting damping, inertia terms and surface tension and stipulates that the pressure inside the bubble is equal to the pressure of the surrounding liquid. It is then possible to express the local gas volume fraction as a function of feeding fluid characteristics and of the local liquid pressure.

3. Results

Figure 1 shows the pressure distribution in the bearing mid-plane given by both models. Figure 2 depicts the corresponding gas fraction. The starved thin film conditions are described by θ=*0.4* boundary condition in the inlet section. This corresponds to a large volume fraction of gas which will prevent the formation of the pressurized film. The results depicted in Figure 1 show that film the formation zone corresponds to an important bearing length required for pressure build-up. A film rupture appears in the divergent part. The variations of the pressure and of the gas volume fraction given by the two models are very close. The use of RP equation leads to a continuous pressure field, while the P-θ method induces a discontinuous transition.

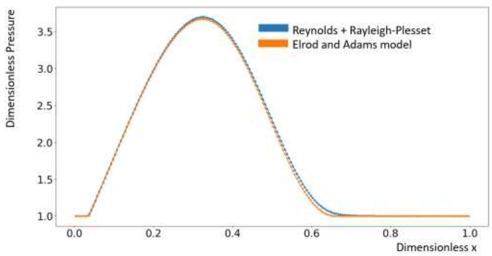

Figure 1: Pressure in the bearing mid-plane

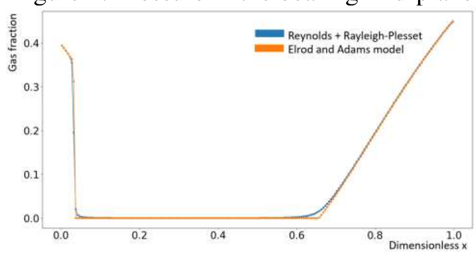

Figure 2: Corresponding gas volume fraction

4. References

[1] Elrod, H.G., and M. Adams, 1974, "A Computer Program for Cavitation and Starvation Problems,"
[2] Diaz, S. E., 1999, "The effect of air entrapment on the performance of squeeze film dampers: experiments and analysis," Ph. D Dissertation.