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CFD Modeling of Cavitation Flow in Journal Bearing Lubrication

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1. Introduction

According to Richardson [1], Mechanical friction takes away 4-15% of total energy from a fired engine of which 40-55% is due to the losses in the pistons, rings and connection rod bearings. The rod bearings are responsible for around 0.3 to 2.7% of total energy loss in an engine. Therefore, in order to reduce power loss and improve engine performance, it is important for tribologists to have a deep understanding of lubrication phenomena at the connection rod bearings.

2. Governing Equations and Simulation Method

A schematic of the big end bearing used in the IC engines is shown in Figure 1.

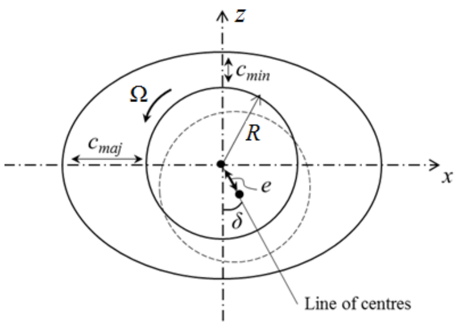

Figure 1: An elliptic big end bearing configuration

The contact is divided into two distinct regions: (i) full film, (ii) film rupture and cavitation (Figure 2). To describe the physics of fluid flow in the cavitated region, in which two state phases of lubricant co-exist at the same time, a suitable two-phase flow model needs to be employed alongside with the Navier-Stokes equations.

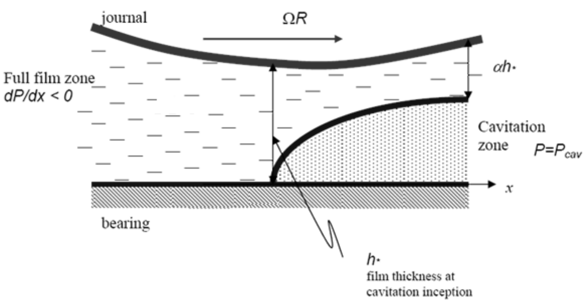

Figure 2: Fluid flow through cavitation zone

The fluid flow is governed by the 3D compressible Navier–Stokes equations:

$$\frac{D\rho}{Dt}+\rho\nabla.\vec{V}=0 \tag{1}$$

$$\rho\frac{D\vec{V}}{Dt}=-\nabla p+\nabla.(\bar{\tau}_{ij})+\vec{F} \tag{2}$$

where D/Dt is the covariant derivative operator, ρ is the lubricant density, p is the pressure, $\bar{\tau}_{ij}$ is the viscous stress tensor and $\vec{F}$ is the body force field vector. In addition, $\vec{V}=U\hat{i}+V\hat{j}+W\hat{k}$ is the velocity vector in which U is the component of velocity in the direction of axial lubricant flow entrainment, V is that in the side-leakage direction and W is the squeeze film velocity, $\partial h/\partial t$. The viscous stress tensor is:

$$\bar{\tau}_{ij}=\eta\left(\frac{\partial U_i}{\partial x_j}+\frac{\partial Uj}{\partial x_i}-\delta_{ij}\frac{2}{3}\nabla.\vec{V}\right) \tag{3}$$

where η is the effective lubricant dynamic viscosity, δ_{ij} is the Kronecker delta and it is defined as:

$$\delta_{ij}=\begin{cases}0 & \text{if } i\neq j\\ 1 & \text{if } i=j\end{cases} \tag{4}$$

To better understand the flow behaviour through the connection rod bearing, a detailed CFD based simulation of the two-phase flow for the 3D geometry is performed, using the commercial CFD software ANSYS Fluent.

3. Results

The pressure profile through the circumferential centre line is illustrated in figure 3. The positions of high pressure and cavitation zones as well as lubricant film rupture and film reformation points can be seen in figure 3.

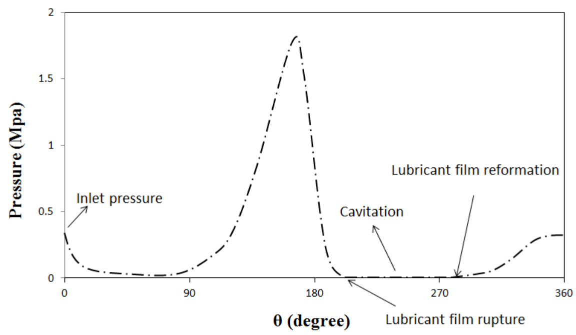

Figure 3. Pressure distribution in the centre plane at crank angle 180°

References

[1] Richardson, D.E., 2000, Review of power cylinder friction for diesel engines, Journal of Engineering for Gas Turbines and Power, Transactions of the ASME, Vol. 122, pp. 506-519