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A 2D Hydrodynamic Solver of the Reynolds Equation for the Piston Ring-Liner Conjunction

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It is essential for the automotive industry to improve efficiency and mitigate frictional losses. About 20-25% of frictional losses arise in the piston ring pack-liner assembly. As a result, reduction of piston ring friction has the potential of improving efficiency, fuel consumption and emissions.

1. Introduction

The overall aim is to create a 2-dimensional numerical model comprising hydrodynamic and mixed regimes of lubrication. This paper presents the methodology developed to predict the generated pressures through solution of Reynolds equation through Finite Difference Method.

2. Methodology

There are many methods of discretisation of Reynolds equation. The central difference discretisation is used with the advantage of improved accuracy for the second order Poiseuille flow terms [1]. The 2D Reynolds equation is [2]:

$$\frac{\partial}{\partial x} \left[\frac{\rho h^3}{6\eta} \left(\frac{\partial p}{\partial x} \right) - \rho h U \right] + \frac{\partial}{\partial y} \left[\frac{\rho h^3}{6\eta} \left(\frac{\partial p}{\partial y} \right) - \rho h V \right] = 2 \frac{\partial(\rho h)}{\partial t}$$

This form of the equation includes the flow in the direction of entraining motion, x as well as side-leakage from the contact, y . It also includes the effect of squeeze film action (the term on the right-hand side of the equation). Solution of the equation requires the film shape, h , lubricant rheological state equations for viscosity and density variation with pressure under assumed isothermal conditions. Boundary conditions are necessary for solution of Reynolds equation. For outlet boundary conditions Swift Stieber [3,4] (or Reynolds) conditions are used as they take into account the continuity of flow at the lubricant film rupture point, thus for the piston ring conjunction [1]. The inlet boundary under fully flooded conditions becomes:

$$p_{x=-b/2} = P_a$$

and at the rupture point:

$$p_{x=c} = P_c$$

and:

$$\left. \frac{\partial p}{\partial x} \right|_{x=c} = 0$$

In the application of ring, P_a is the pressure at the ring inlet which depending on the direction of the motion of the ring, thus it can be the combustion chamber pressure or the crankcase (or inter-ring) pressures. P_c is the cavitation pressure which is normally considered to be the same as the atmospheric pressure. In this representation, $x=c$ is the position of lubricant film rupture.

3. Validation

The model has been validated against existing works as shown in Figures 1 (Morris et al [1]) and Figure 2 (against multi-phase flow, using Navier-Stokes equation [5]). The convergence is obtained significantly quicker than previous models. Results here are for a representative snapshot of a typical engine cycle. The code will be further developed to take into account a full engine cycle.

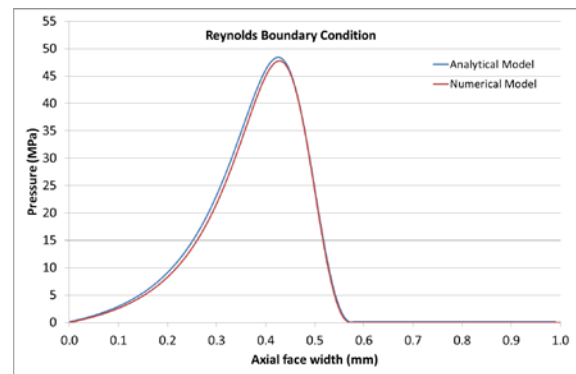


Figure 1: Pressure distribution (compared with [1])

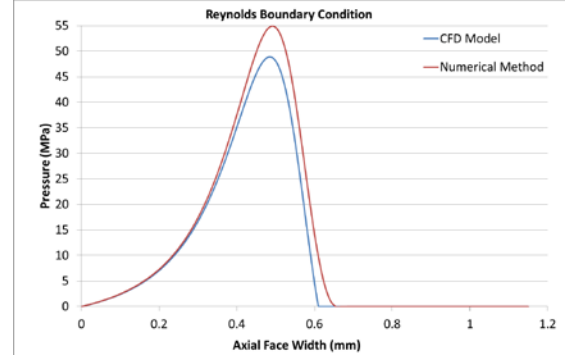


Figure 2: Pressure Distribution (compared with [5])

4. Acknowledgement

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5. References

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