Modeling of Piston Ring Assembly and Connecting Rod Bearing Lubrication and Tribological Performance

Abstract

Due to strict environmental legislation and the fact that internal combustion engines (ICEs) are recognized as majority of energy sources in transportation, car manufacturers are motivated to improve ICEs efficiency. Mechanical power loss of lubricated and bearing surfaces serves as an attractive domain to study and research as way to take step to increase ICEs productivity regarding to fuel and oil consumption. Friction reduction at lubricated and bearing surface is one of the most cost-effective tool to reduce gas emission and improve ICEs efficiency. The majority of the mechanical power loss in an engine can be attributed to the main tribological components of an engine, piston-cylinder system (PCS), connecting rod big-end and crankshaft main bearings.

The objective of this dissertation is to develop a complete mathematical and numerical model, firstly to evaluate the piston-cylinder system lubrication mechanisms in terms of design parameters and lubricant rheology. PCS enjoys different lubrication regimes during engine strokes including hydrodynamic, mixed and boundary lubrication. To simplify modeling, most of early studies usually considered full film hydrodynamic lubrication using lubrication theory governed by Reynolds equation. This study makes effort to evaluate piston ring pack lubrication taking into account different operating circumstance and corresponding lubricant film shape at rings and cylinder junction. Oil is treated as viscous and iso-viscous fluid to consider the role of lubricant viscosity dependence on temperature. To simplify the problem rings and liner are treated as iso-thermal bodies.

Secondary motion of piston is analyzed considering hydrodynamic lubrication at bearing surfaces interface. The effect of piston ring pack tribology on piston dynamics has been considered to gain insight into skirt lubrication mechanism. Numerical scheme is introduced to calculate power loss contributed by viscous shear stress.

An analytical model is introduced to evaluate connecting rod big-end and crankshaft main bearings. Besides, Mobility method as well-known approach to evaluate dynamically loaded journal bearings lubrication has been applied to validate analytical model.

The current study tends to evaluate the effects of different boundary condition and oil film shape at ring and liner interface. Full Sommerfeld, oil separation, and Reynolds cavitation and reformation as boundary conditions are applied and their influences have been examined. Design of experiment and ANOVA are used to study the effect of ring profile geometry on oil film thickness and power loss at bearing surfaces interface. In contrary to maturity of conducted investigations, the effect of piston ring pack lubrication on piston secondary motion and tribological performance. General formulation have been developed to evaluate hydrodynamic journal bearing. The analytical model is applied to study connecting rod big-end tribology.