LUBRICATION DYNAMICS COUPLED MODELING OF A THREE-DIMENSIONAL PRCL SYSTEM WITH CONSIDERATION OF PISTON INFLUENCE

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ABSTRACT
The piston ring-cylinder liner (PRCL) is the core frictional pair in an engine, generating over 40% of the total friction loss [1-2]. In today's era of strict carbon emission regulations, research on its tribo-dynamics has become increasingly important. However, the tribological performance evaluation of PRCL systems has often been carried out with the help of a two-dimensional model for a long time. That is, a simulation model is established for the ring cross-section. Two-dimensional models play a crucial role in studying the overall tribology performance of the PRCL. Nevertheless, their capability is limited when analyzing the ring's circumferential uneven characteristics [3].

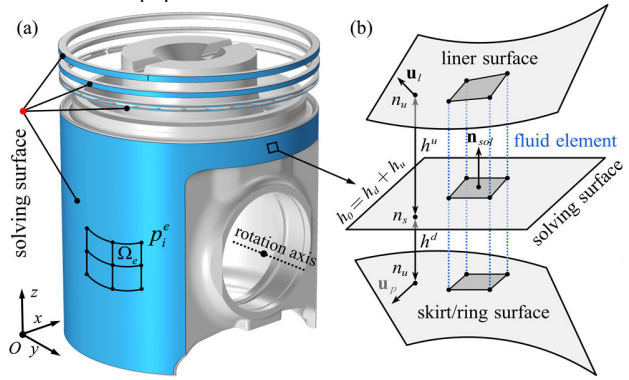

Fig.1. Global solution of the average Reynolds equation.

Therefore, a three-dimensional lubrication dynamics coupled model of the PRCL is established in this study. The dynamic equations of multibody systems are obtained based on FEM in a unified global coordinate system. The piston-liner is established as a flexible lubricated reciprocating joint to consider the influence of its secondary motions and deformation on the PRCL. The fluid lubrication characteristics between the piston-liner and ring-liner interfaces are described by the averaged Reynolds equation. The study assembles stiffness matrices for different lubrication domains and performs calculations based on a unified global coordinate system to enhance computational efficiency (as shown in Fig.1). A dedicated coupling algorithm is designed to couple the lubrication and dynamics. In addition, the comparison with existing research results demonstrates that the model exhibits good accuracy.

Utilizing the three-dimensional model facilitates the easy assessment of circumferential uneven tribological characteristics of the ring group (fig.2), revealing some novel laws. For instance, the computational results indicate that the assembly position significantly influences the circumferential distribution of lubrication dynamic parameters. A noteworthy observation is that when the peak elasticity position of the ring coincides with the thrust side or anti-thrust side, the ring lubrication performance experiences a significant deterioration. Therefore, this position should be avoided during assembly. Another intriguing phenomenon is that the unique structure of the oil ring leads to periodic wave-like disturbances in parameters such as film thickness and load along the oil scraping edge, a phenomenon rarely reported in existing studies.

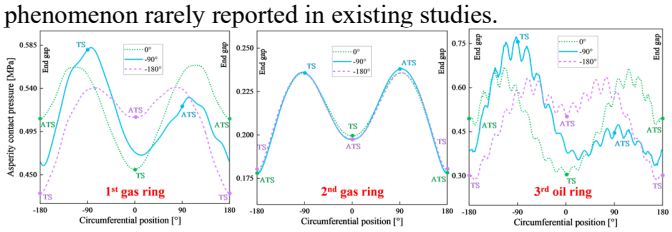

Fig.2. Circumferentially uneven tribological properties of the three-dimensional PRCL system.

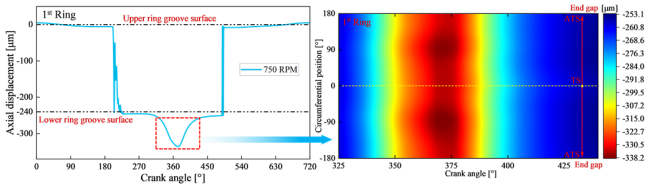

Fig.3. The influence of piston deformation on PRCL.

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