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A thermo-elastohydrodynamic lubrication model for hydraulic rod O-ring seals under mixed lubrication conditions

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ABSTRACT： Because of the fluid viscous shear and the asperity contact friction, a temperature rise will occur in the sealing zone, which may cause rupturing of lubrication films or wear failure of seal rings. To investigate the influence of thermal effect on seal behavior, a thermo-elastohydrodynamic (TEHD) lubrication model for hydraulic rod O-ring seals under mixed-lubrication conditions is developed. The operation mechanism of thermal effect on seal behavior is revealed by checking the lubrication film. The TEHD characteristics of an O-ring seal under different operating conditions are analyzed and discussed. The numerical results show that the thermal effect should be taken into consideration in simulation analysis, and the generated heat tends to accumulate on the seal surface in the sealing zone.

Keywords: TEHD model; Thermal effect; Mixed lubrication; O-ring seals

1. Introduction

Since the middle of the nineteenth century, elastomeric rubber O-ring seals have been widely used in hydraulic reciprocating devices in the fields of aerospace engineering, engineering machinery, petroleum exploitation and other industrial applications, as a tool to prevent the leakage of lubricant or sealed medium and ensuring reliable operation of the hydraulic system [1]. When the rod moves, a thin lubricant film with thickness in the nanometer to micron range will exist at the rod-seal interface due to the combined effect of the fluid pressure difference and the traction force supplied by the rod, which is proved by the experimental study of Karaszkiewicz [2]. The thin fluid film can separate the seal lip from the rod outer surface and lubricate the seal, but increase the leakage. To firm understand the operation mechanism of the viscous thin film, extensive theoretical and experimental studies have been conducted, for example, by Nikas [3], Salant et al. [4], Crudu et al. [5], and Li et al. [6]. According to their results, it is interesting to note that all these problems are related to soft elastohydrodynamic lubrication problem, and the film thickness in sealing zone is very sensitive to changes in mechanical and thermal loads. Therefore, the operation mechanisms of the thin film, so as to the variation of seal behavior are also quite complex due to many factors, such as fluid properties, operating conditions, seal materials and shapes.

Benefit from the contributions of previous researchers, the influence of the factors on seal behavior has been revealed to some extent. However, very few works have been focused on the study of the thermal effect of such reciprocating hydraulic seals. According to the research results of rotary lip seals by Maoui et al. [7], Day et al. [8], and Liu et al. [9], the thermal effect would alter the viscosity of the lubricant in the sealing zone, and consequently the seal behavior. According to the experimental investigation by Pinedo et al. [10], the contact temperature rises on the rubber-steel interfaces are quite remarkable during the reciprocating operation, and would also affect the rubber's tribological performance. In addition, some of the seal failure modes, such as rubber aging and swelling, are

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