Fluid Film Formation and Cavitation in Parallel Sliding Contacts – Simulations and Experimental Investigations

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The paper investigates film formation in parallel sliding contacts, experimentally and numerically by focusing on the relationship between cavitation and film formation. For this reason, film thickness measurements are applied on a rectangular face seal with a textured axial contact. Selected texture allows to realize direct observation of concentrated cavitation within texture at the seal interface. Thus, validation of numerical results is possible in terms of cavitation form and size in addition to film thickness. While film formation is modelled based on cavitation, texture, surface irregularities, roughness and cavitation pressure effects are investigated as well.

Keywords: parallel sliding contact, cavitation, film formation, face seal

1. Introduction

Parallel sliding contacts are common for face seals, lip seals and thrust bearings. The sliding surfaces may be macroscopically plain with a random micro geometry (roughness, pores) or structured in a deterministic manner in order to improve film formation either by liquid media or by liquid lubricants. In both cases it is possible to observe a Stribeck type transition from boundary to mixed lubrication and eventually to full film lubrication. The existence of local films and a net lifting force coincides with local cavitation on a microscopic respectively macroscopic scale. In this work film formation mechanism in parallel sliding contacts is investigated via textured rectangular face seals experimentally and numerically by focusing on the relationship between cavitation and film formation. Besides, showing relationship between cavitation and film formation, the work also shows effect of texturing, surface irregularities, roughness on film build up and cavitation as well.

2. Methods

An optical test rig was built to observe cavitation formation at the face seal interface. Friction torque and lubricant film thickness measurements based on fluorescence method was made. The relationship between film formation and cavitation was investigated. In order to analyze hydrodynamic flow at the contact of the seal numerically, the Reynolds equation was solved with a mass conserving JFO cavitation model using Fischer – Burmeister - Newton - Schur (FBNS) algorithm via finite element method using ELMER solver. For simulation one section of the seal ring is modelled in three different ways. First, an ideal structured surface without irregularities and roughness was modelled. Second model was a structured surface with macro irregularities and in the third model, roughness was taken into account. To model the surface with roughness, seal section was scanned via a laser microscope. Later on scanned seal section data was prepared to be meshed in MATLAB. The aim of creating three different models was to investigate whether structures are capable to generate hydrodynamic lift without roughness and to see the influence of macro irregularities on lubricant film formation. In addition, three different cavitation pressures were selected to investigate the effect of cavitation pressure as well.

2.1. Results

Concentrated cavitation within divergent part of the structure at the seal interface was observed. The implemented numerical model successfully shows cavitation formation and pressure build up. The results are compared with experimental results in terms of cavitation area ratio and film thickness. The effect of texture, roughness and macro irregularities are shown. An ideal geometry without any irregularities may generate hydrodynamic lift. However, macro irregularities change the film formation behavior of the seal.

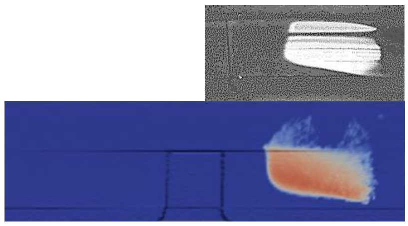

Figure 1: Top: observed cavitation area on the seal interface. Bottom: A simulated seal section (with macro irregularities and without roughness) with cavitation area. Flow direction is from right to left.

3. Discussion

The work allows an understanding of film formation by focusing on cavitation occurrence in axial contacts and shows consideration of cavitation is an important parameter to model film formation. Besides, it contributes to surface texturing field. Many researchers showed that structures alone do not generate hydrodynamic lift. However, many of these works were done for dimple type structures. The current work focuses on relatively large structure form which is a “t shape”. Numerical implementations supported by experiments give an opportunity to better understanding of film formation in axial contacts in general. It could be shown that macro irregularities change film formation noticeably by influencing pressure build up and cavitation formation. Because many simulations focus on idealized geometries the influence of macro deviations needs to be considered. Furthermore, the influence of roughness during film build up was investigated.