The Microgeometry of Pressure Seals

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Abstract

Introduction

Seals leak primarily at the interface between seal and cavity. At a microscopic level, the interface between the seal and cavity consists of regions of contact between the two elements, and voids (Figure1). This is due to microscopic undulations on one or both surfaces. The voids are connected to each other, forming a microscopic system of caverns through which the leaking fluid flows. In the area of contact, the force on the two objects is primarily the mutual mechanical reaction. In the area of no contact, the force on the two objects is primarily the pressure of fluid present at that location.

Use of COMSOL Multiphysics®

In the COMSOL Multiphysics® model, the two sealing surfaces are metal and rubber. We assume the metal part to be perfectly smooth. The rubber part is assumed to be undulating. We assume the crests of the rubber to form a 3D structure with 2D periodicity, with appropriate symmetry boundary considerations. The stresses at the rubber-metal interface as the metal presses down on the rubber, are found using Structural Mechanics Module and Nonlinear Structural Mechanics Module in the first component.

Result

We explore how the geometry of the system of caverns depends on the mechanical pressure of the seal and the fluid pressure of the leaking fluid. In particular, we use COMSOL to test the hypothesis that the geometry of the voids depends to a first order of approximation on the difference between the sealing and fluid pressures.

Relevance

Sealing of containers containing fluids is an important problem to the industry. Being able to predict and optimize performance of sealing solutions is of immense importance. This study

takes one of many steps towards that goal. We make an assumption that the flow of fluid is modulated by the mechanical pressure of the seal against the sealing surface and the pressure of the fluid itself, at each point of contact between the seal and the sealing surface. In this study we test the hypothesis that the microgeometry of the seal (and hence the fluid flow parameters) depends not on the two pressures (mechanical and fluid) individually, but on the difference between the two. If proved correct, this would reduce the seal flow characterization data points required to be evaluated in the laboratory for accurate prediction of seal behavior, from a two dimensional to a one dimensional data set.

Figures used in the abstract

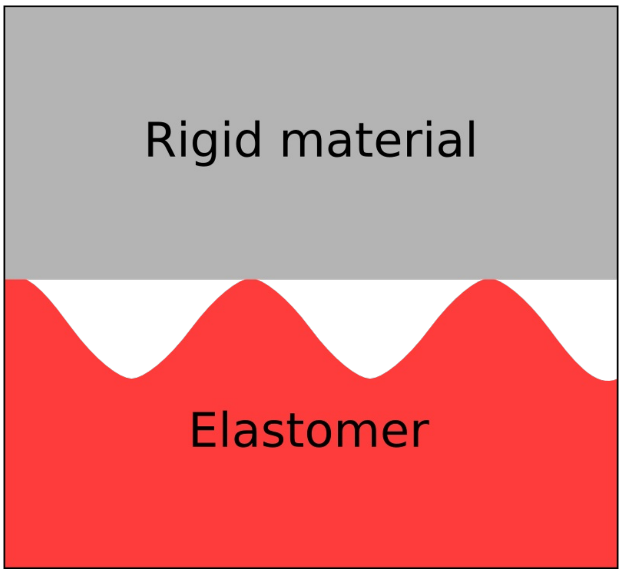

Figure 1: Idealized representation of the microgeometry of seals. Fluid is supposed to creep through the crevices between the elastomeric seal and rigid wall.