Fluid Leakage Across a Pressure Seal

R. P. Ruby[1], G. Kulkarni[2], U. Kanade[1]

[1]Noumenon Multiphysics Pvt. Ltd., Pune, Maharashtra, India
[2]Oneirix Engineering Laboratories Pvt. Ltd., Pune, Maharashtra, India

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 (Figure 1). The voids are connected to each other, forming a microscopic system of caverns through which the leaking fluid flows. In a previous paper, we investigated the microgeometry of such caverns, and the effect of fluid flow on it. In the present paper, we investigate the effect of the microgeometry on the fluid flow.

Use of COMSOL Multiphysics® software

Various idealized microgeometries, created during the previous study are used as idealized cavern geometries in the present study. The entire cavern is taken to be a single fluid flow domain in COMSOL. The leaking fluid is assumed to be an ideal gas. The system of caverns is idealized to a lattice of caverns.

A periodic boundary condition is used to fold the lattice into a single cavern. But there is a caveat: usually a periodic boundary condition entails exact repetition of boundary fields at surfaces separated in space. In the present case, the pressure drops from one side of the cavern to the opposite side, and thus exact periodicity is not to be achieved. Yet, the situation from one cavern to the next is almost identical, and hence, a boundary condition like the periodic boundary condition - except that it creates a constant difference in pressure rather than exactly the same pressure - is useful in modeling. Since COMSOL does not have a direct implementation of such a periodic boundary condition, the answer is to modify the PDE, such that the usual periodic boundary condition in the modified PDE will equal the modified periodic boundary condition for the original (Navier-Stokes) PDE. This entails the use of the Mathematics interfaces in creating the model.

Results

A tabulation of fluid flow parameters is achieved with this simulation. The independent variables

are the microgeometry itself, and the local pressure and pressure gradient of fluid. The dependent variable is the fluid flow rate. From this data as well as the data from the previous study connecting the microgeometry to the fluid flow parameters, a homogenized fluid flow PDE can be created. It is hoped that, even though this tabulation is performed for an idealized geometry, realistic seals will behave qualitatively similarly to this idealization.

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. Taken together with a previous study, a homogenized PDE for fluid flow across pressure seals is created. The programming of this homogenized PDE in COMSOL, and the tallying against laboratory data of seal performance is the topic of a future paper. Together, the three papers develop a theory and methodology of analyzing, designing and optimizing pressure seals.

Reference

1. R. P. Ruby, et al, The microgeometry of pressure seals, COMSOL Conference, Cambridge (2014).

Figures used in the abstract

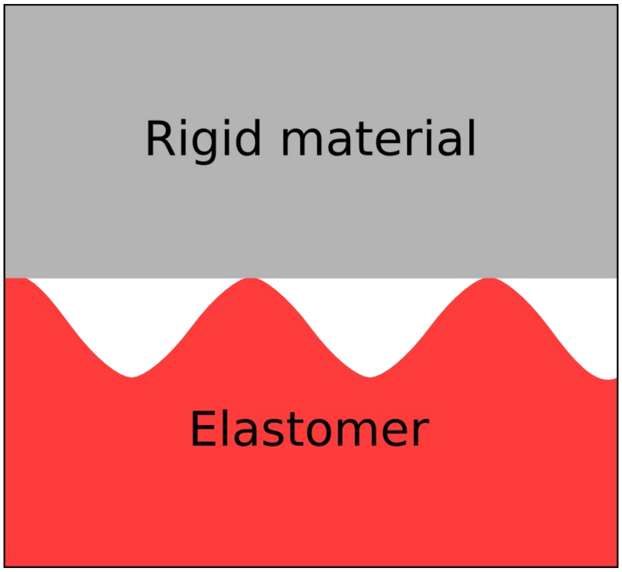

Figure 1: Idealized representation of the microgeometry of seals. Fluid creeps through the crevices between the seal and the wall.