Modeling and Simulation of Pressure Seals

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

Seals leak primarily at the interface between seal and cavity (Figure 1). At a microscopic level, the interface between the seal and cavity consists of regions of contact between the two elements, and voids. The voids are connected to each other, forming a microscopic system of caverns through which the leaking fluid flows (Figure 2). In two previous papers, we investigated the microgeometry of such caverns, the effect of fluid flow on it and the effect of the microgeometry on the fluid flow. This investigation gave rise to a homogenized PDE for fluid flow across pressure seals. In this paper, we simulate the PDE in COMSOL Multiphysics®, first to characterize the seal and then to validate it against laboratory data of real world seal performance.
The characterization methodology comprises: (a) laboratory experiments to generate leakage rate vs. pressure data, (b) modeling the laboratory experiment in COMSOL Multiphysics® using the proposed PDE to get the sealing characteristic (out flux vs. pressure data), (c) finding a resistivity characteristic for a given surface pair, such that the above two data match each other.
The validation methodology comprises: (a) modeling real world seals in COMSOL Multiphysics® using the proposed PDE and resistivity characteristic, to get the sealing characteristic, (b) validating the sealing characteristic against real world experiments.

The central piece of both the above methodologies is the simulation of the proposed seal leakage PDE in COMSOL®. The seal mechanics is modeled using the Structural Mechanics Module and the Nonlinear Structural Materials Module. It is then coupled with the PDE Interface to model the homogenized PDE for fluid flow across pressure seals. The solution of the PDE gives pressure profile over the seal-cavity interface. The seal performance (sealing characteristic) can be evaluated by post processing.

Resistivity characteristics of surface pairs created using the methodology described above are presented. The resistivity characteristic, together with the homogenized PDE, forms the mathematical model of seal performance proposed in this paper. Simulations based on this mathematical model are presented, and validated against real world experiments.

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. Taken together with two previous studies, we create a homogenized PDE for fluid flow across pressure seals and validate it against laboratory data of seal performance. 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).

2. R.P. Ruby, et al, Fluid leakage across a pressure seal, COMSOL Conference, Boston (2014).

Figures used in the abstract

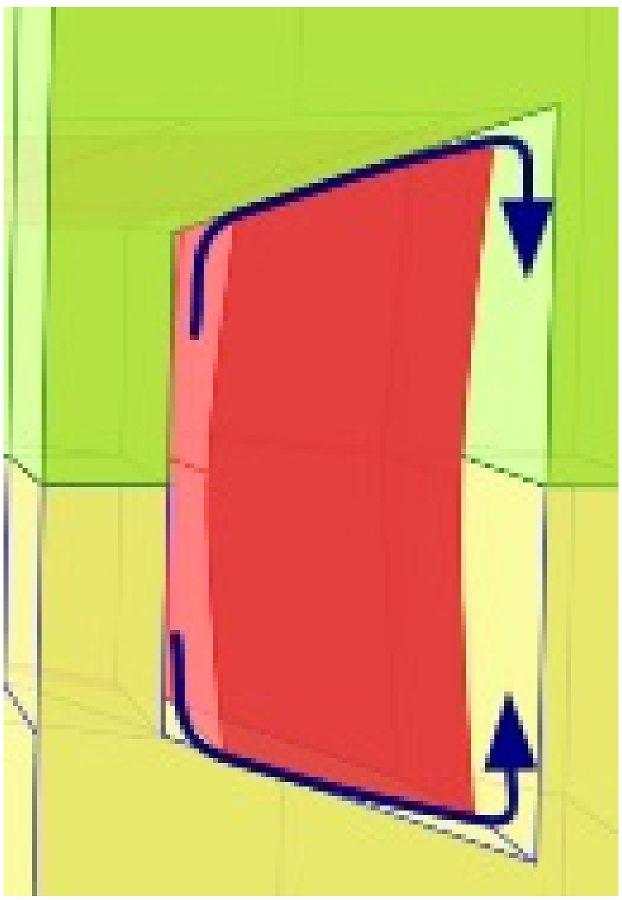

Figure 1: Seals leak primarily at the interface between seal and cavity.

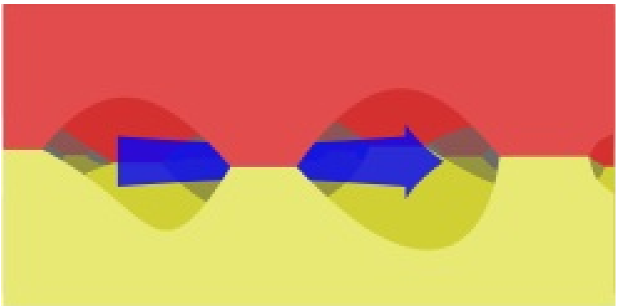

Figure 2: Microscopic system of caverns through which the leaking fluid flows.