Modeling Ferrofluid Flow in an Annular Gap Moving with Reciprocating Shaft

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Abstract

Introduction
Ferrofluids, also called magnetic fluids, are stable colloidal suspensions, of which the flow behavior and energy transport processes can be controlled by applying an external magnetic field. Ferrofluids have been successfully used in the seals for rotary shafts, but few studies focus on the reciprocating motion seals. Since the completely different operation regime compared with the rotary motion, previous experiences could not be directly applied on the cases for reciprocating shafts. Efforts are needed to explore the phenomena happened in the thin ferrofluid film confined in the seal gap.

In this paper, we present a simplified model to describe the process that a shaft reciprocally moving in a cylinder housing, which coated with a layer of ferrofluids. Transverse magnetic field formed by a permanent magnet ring, which set on the outside of the cylinder, induced magnetic force on the ferrofluids to keep them in the proper positions. Finite element method is used to solve the differential equations mathematically.

Use of COMSOL Multiphysics®
The coupling magnetic field and flow field have been derived through COMSOL Multiphysics® commercial software. We use the AC/DC Module with Magnetic fields, No currents physics interface to calculate the magnetic fields produce by the permanent magnet rings with different geometric parameters. In addition, the level set method was introduced to capture the free interface of the ferrofluid film, because the magnetic stress acting on the interface has significant effects on the air pressure difference which the seal can withstand.

The influences of the geometric parameters of the shaft and the cylinder, and the physical properties of ferrofluids on the critical pressure difference were also studied. It is shown that the external magnetic field increases the load capacity of ferrofluid seal when the frequency of shaft lower than a critical value. However, considerable inertia force due to high frequency reciprocating motion weakened the function of magnetic fore, and caused the loss of ferrofluids.

Keyword: Ferrofluids; Permanent magnet; Magnetic field; Level set