ISSN PRINT 2319 1775 Online 2320 7876

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DESIGN AND ANALYSIS ON PORO FLUID DYNAMICS WITH MAGNETIC FLUID

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ABSTRACT

Traditional sealing technologies, such as packing seals, have limitations, such as excessive wear and heat generation from friction, which limit their usefulness in an age where increasingly complex machinery need a more robust sealing effect. Based on a theoretical analysis of the instability at the liquid-liquid interface and the pressure resistance of the seal structure, while also factoring in the angular velocity of the shaft, this study reconstructs the formula for estimating the pressure resistance value of the seal structure. The magnetic fluid seal's design is based on the high horizontal shaft diameter while submerged in liquid. We can calculate the strength of the magnetic field within the magnetic fluid seal and how it varies with the size of the permanent magnet and the width of the pole teeth using the Maxwell magnetic field analysis programme. The ring seal test apparatus was used to conduct a pressure test on the seal structure of the horizontal big shaft diameter at different rotational speeds to determine the structure's efficacy. The findings are both theoretically and practically significant for the development and implementation of magnetic fluid seal structures.

Keywords: Magnetic fluid; Sealing; Large shaft diameter; Magnetic field; Pressure test.

1. INTRODUCTION

One of the basic problems in fluid mechanics is maintaining the stability of pressure-driven fluid flows in a channel, and the book by Drazin and Reid [1] gives a good overview of the relevant literature. Because transport processes through porous media play an important role in many different fields, including the petroleum industry, thermal insulation, chemical catalytic reactor design, and the design of solid-matrix heat exchangers [2, 3, 4, 5, 6], the counterpart in a fluid-saturated porous channel has been studied.

Due to its importance in a variety of astrophysical settings, research into the stability of Poiseuille flow in a horizontal channel under the influence of a magnetic field has also garnered considerable attention. Stuart [7] looked at the stability of plane Poiseuille flow under a parallel magnetic field, whereas Hains [8] studied the stability of conducting fluids flowing between coplanar planes. Increases in the magnetic Prandtl number are associated with more stable fluid flow, as discussed by Potter and Kutchey [9]. Takashima [11] reevaluated the problem of Potter and Kutchey in light of suitable boundary conditions on disturbances in the magnetic field. Magnetohydrodynamic (MHD) Jeffery-Hamel flows at very tiny magnetic Reynolds number have been studied by Makinde and Mhone [12], while the stability of Poiseuille flow in the presence of a longitudinal magnetic field has been analysed by Proskurin and Sagalakov [13].

Moreover, when conducting fluids travel across porous media, MHD effects become significant. Some nuclear power plants employ MHD pumps to move electrically conductive fluids, and MHD pumps are also used in the petroleum industry. Electronic packages and microelectronic devices also face this issue during operation [14], [15], [16], [17] since fluid flow can be controlled by electromagnetic fields. To better understand the effects of a magnetic field on tiny disturbances in a channel filled with a saturated porous material, Makinde and Mhone [18] performed a numerical research. Recent research conducted by Shankar et al. [19] looked on the MHD stability of spontaneous convection in a vertical porous slab.

Hyper porous materials, typically created by stretching several thin metal wires, are being utilised in many technical applications of practical value. There may be significant anisotropy in the permeability of the solid substance encasing the fluid. Therefore, while considering the consistency of fluid flow across porous media, it is crucial to account for anisotropy in the permeability. Nield and Bejan's book [20] provides an in-depth examination of this issue. In addition, Givler and Altobelli [21] showed experimentally that for a highly permeable porous material, the Brinkman or effective viscosity is roughly 10 times the fluid viscosity. It makes sense, then, to consider the difference between the two viscosities to be a separate factor.

2. PRINCIPLE OF MAGNETIC FLUID SEAL

The use of magnetic fluid as a composite material is extremely common. It consists mostly of nanometer-sized solid magnetic particles that, under the influence of various interfacial active agents, can be uniformly dispersed in the base carrier solution to form a solid-liquid mixed colloidal solution [5]. Figure 1 [6] depicts its constituent parts. In the presence of external magnetic and gravitational forces, the colloidal solution can be maintained without precipitation [7]. Sealing applications are one of magnetic fluid's more established uses at the moment [8]. Magnetic fluid seal technology has now reached maturity after years of study, development, and implementation. The four main parts of a magnetic fluid seal are a permanent magnet, a shaft, magnetic fluid, and a pole shoe. The interior structure is depicted in Figure 2 [9]. The pole shoe is equipped with pole teeth on several levels. The permanent magnet forms a magnetic circuit with the help of the magnetic fluid, the shaft, and the pole shoe. Under the influence of the magnetic field, the magnetic fluid in the sealing gap solidifies into a liquid "O" shaped seal ring, thereby completely sealing off the gap [10, 11].

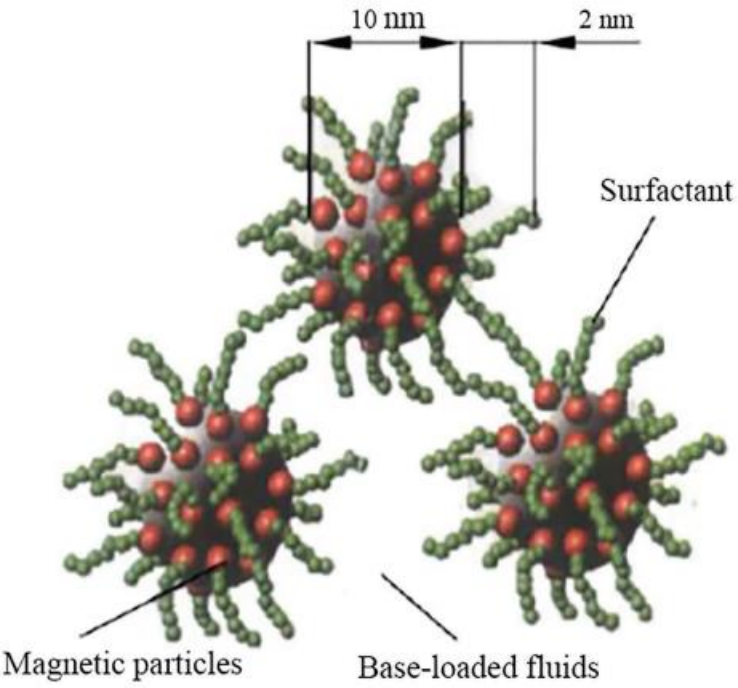

Figure 1: Composition of magnetic fluid.

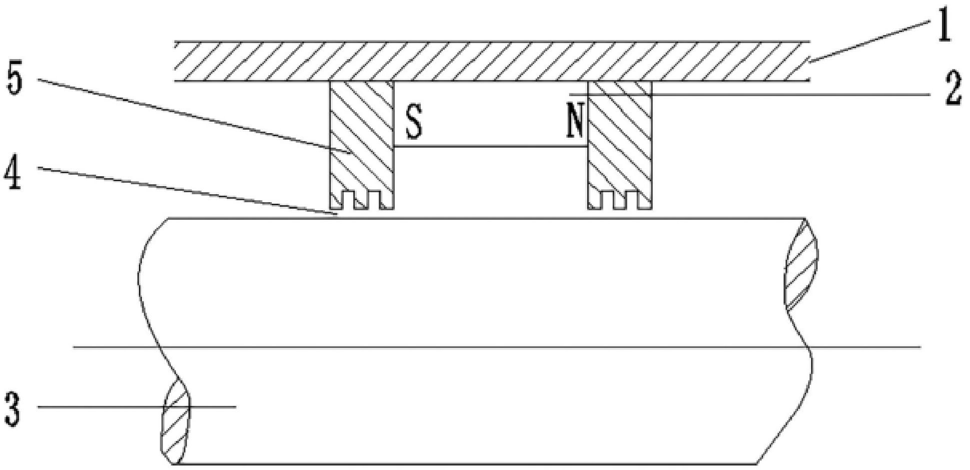

Figure 2: Structure diagram of magnetic fluid seal.

3. METHODS OF NUMERICAL ANALYSIS

When discretizing a system of PDEs numerically, prevalent practises include employing the finite element method (FEM), finite difference method (FDM), or finite volume technique (FVM). A computational domain is built up from a mesh of nodes and cells in order to solve the discretized equations (Peiro' and Sherwin, 2005). In order to discretize differential equations on regular grids, the FDM uses a local Taylor expansion. FE and FV approaches were created to increase the adaptability of discretisation procedures in complex geometries (Wikipedia, 2001). Integral forms of PDEs are the foundation for FE and FV approaches, whereas the differential forms are discretized with FDM. Quantity values in FVMs are cell averages, whereas in FEMs and FDMs they are localised at the mesh points, which is the major distinction between the two (Hirsch, 2007). Consequently, the following features distinguish FEMs from FVMs (Blazek, 2015):

FVMs first conceal the positions of mesh points when computing parameters like cell volume or side areas. Therefore, the physical feature is not localised to a single spot within the control volume (cell), but rather can be viewed as a volume-averaged value.

Second, FVMs imply that the average value of a physical property varies in a way proportional to the total of the fluxes transmitted between surrounding cells, whereas PDEs do not contain source terms. In other words, all physical quantities entering a cell from one side must leave the same cell by some other side, in accordance with the conservation principles underlying FVMs.

3.1 Implementation of FVMs and FEMs in structural and fluid flow analyses.

It is generally agreed that FEMs are better suited for structural analysis, while FVMs are better suited for fluid flow simulations (Hirsch, 2007). Nonetheless, that doesn't rule out FEMs as a viable tool for studying fluid dynamics. There are numerous sources that introduce finite element methods (FEMs) for fluid flow issues. We will explain why these studies show that FVMs are superior to other approaches to fluid flow problems in terms of accuracy, numerical stability, and calculation speed.

MolinaAiz et al. (2010) used FE and FV techniques to model the airflow in a greenhouse's ventilation system. Mesh generation was proven to be simpler in the FE model compared to the FV model. The FE model took twice as long to solve computationally as the FV model did. In addition, the amount of RAM needed to store the FE model was 10 times that of the FV model. As the authors point out, this is because of the dissimilar nature of the computations involved in the two methods. Researchers such as Luka'cova'- Medvid'ova' and Teschke (2006) and Jeong and Seong (2014) have underlined the rising demands of FE models in terms of processing power and memory. Jeong and Seong (2014) compared the performance of two commercial FVM-based CFD solvers and one FEM-based solution in assessing fluid flow in straight and Y-shaped pipes. ANSYS/Fluent and ANSYS/CFX were used to create the CFD models, whereas ADINA was used for the FEM solver. It was found that compared to the two FVM-based models, the FEM-based model required around five times more time to calculate for the same mesh size of the fluid domain. The FEM-based model was also shown to be more sensitive to variations in mesh type and quality than the FVM-based model. Water flow in channels of varying shapes was studied using FE and FV simulations by Luka'cova'-Medvid'ova' and Teschke (2006). The FV model was found to be faster and more efficient than the FE technique. The turbulent flow of an isothermal, incompressible, viscous fluid via pipes has recently been modelled using finite elements. The efforts required to guarantee numerical stability, accuracy, and convergence led to its classification as "challenging."

CONCLUSION

This research set out to do something no other has done before: present a complete overview of the cutting-edge numerical models powering MR fluid devices and applications. It has been shown that the usage of MR fluids in various MR applications is on the rise, necessitating a deeper insight into the flow properties. However, it's possible that the analytical approaches typically used in MR fluid research aren't robust enough to accurately forecast the properties of MR fluids. Analytical models can be used to assess the dynamic properties of certain MR fluid devices, but they may not provide light on the rheological fluid flow behaviour. Several factors, such as transient, inertial, and compressibility effects, air as a pocket or air bubbles in the fluid, possibly cavitation, and turbulence, might have an outsized impact on such behaviour, which may be ignored by analytical models.

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