Numerical analysis of hydrodynamic journal bearings lubricated with ferrofluid

H Montazeri
Department of Mechanical Engineering, School of Engineering, Yazd University, Yazd, Iran. email: montazeri_hamid@yahoo.com

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Abstract: The current work focuses on studying the hydrodynamic characteristics of flow in journal bearings lubricated with ferrofluid. The bearing has an infinite length and operates under incompressible laminar flow and steady conditions. Assuming linear behaviour for the magnetic material of the ferrofluid, the magnetic force was calculated. The displaced current-carrying infinitely long wire is used as a field model. This model gives a field distribution with a gradient in the circumferential and radial directions. The analysis is based on the numerical solution of the full Navier–Stokes equations using computational fluid dynamics techniques. Considering the complexity of the physical geometry, conformal mapping is used to generate an orthogonal grid and the governing equations are transformed in the computational domain. Discretized forms of the transformed equations are obtained by control volume method and solved by the SIMPLE algorithm. In the current study, cavitation effects are also considered by an appropriate cavitation model. To validate the computational results, a modified Reynolds equation has been obtained and solved by finite-difference method. The results indicated that comparing with a conventional lubricant, the ferrofluid as a lubricant improves the hydrodynamic characteristics of journal bearings and provides a higher load capacity and a reduced friction coefficient. It will be evident that the other bearing characteristics depend on the applied field model. Numerical results of this analysis can be used to investigate the oil flow pattern and the hydrodynamic characteristics of journal bearings lubricated with ferrofluid.

Keywords: ferrofluid, journal bearings, hydrodynamic analysis, infinite length, computational fluid dynamics

1 INTRODUCTION

Ferrofluids are suspensions of single domain magnetite particles with average diameters of approximately 10 nm stabilized by surfactants in carrier liquids. When a magnetic field is applied to the ferrofluid, each particle experiences a force that depends on the magnetization of the magnetic material of the particles and on the strength and position of the applied field [**1**].

It is found that ferrofluids have different applications in a variety of engineering devices and systems, such as in lubrication and sealing of bearings. Therefore, this makes it necessary to carry out more research in this field to improve the hydrodynamic characteristics of journal bearings lubricated with ferrofluid as a controllable fluid.

Several studies have been reported in the field of ferrofluid-lubricated bearings [**2**–**9**]. They found that a ferrofluid lubricant increases the pressure as well as load capacity of the bearings, improves bearing stability and stiffness, and reduces wear noise and maintenance costs.

Most of the previous studies used suppositional magnetic field distribution for calculating the magnetic force. Tipei [**3**, **4**], Sorge [**5**], Chang *et al.* [**6**], and Osman *et al.* [**7**] in their analysis to compute the magnetic force used an axial magnetic field resulting from the parabolic distribution. Tarapov [**2**], in his study, suggested the displaced infinitely