# Magnetic fluids in full film lubrication

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In this paper three mechanisms are identified through which the magnetic properties of magnetic fluids can be used to improve the pressure distribution in full film bearing systems, specifically, ferrofluid pressure increase, magnetorheological behavior, and controlled sedimentation of particles. In this paper, the effect of the combination of these mechanisms on the pressure increase in the lubricant film is determined using a new unified Reynolds equation.

**Keywords (from 3 to 5 max):** full film lubrication, magnetic fluid, ferrofluid, magnetorheological fluid, Reynolds equation

## 1. Introduction

Magnetic fluids consist of a carrier fluid that contains suspended magnetic particles. These fluids are used in full film bearing configurations in which a specifically designed magnetic field in the lubricant film is used to locally activate the fluid and thereby improve the pressure distribution in the film. This activation modifies the fluid flow in the film through three different mechanisms, specifically, (1) the ferrofluid pressure increase, which is a local pressure increase in the fluid as a result of the magnetic field gradient, (2) the magneto-rheological behavior, which is a change in the rheological behavior of the fluid as a result of the magnetic field strength, and (3) the local sedimentation of particles from the fluid on the bearing surface as a result of the magnetic field gradient. The relative importance of these mechanisms in a specific fluid film system mainly depends on the magnetic field and the size and concentration of the particles.

Mechanisms (1) and (2) have been the subject of numerous studies published in literature [1], however, these studies focus on the use of one of these mechanisms, not on the combination. Mechanism (3), the controlled sedimentation of magnetic particles has been introduced recently by the authors. In this paper, for the first time, the combination of all mechanisms in one system will be studied.

## 2. Method

To this end a new unified magnetic Reynolds equation is introduced that is used to determine the pressure field $p$ in a lubrication film in which all three magnetic fluid mechanisms may interact.

Mechanism (2), the magnetorheological behavior of the fluid can be described using a Bingham plastic fluid model. A new and efficient method to calculate the pressure increase in a Bingham plastic fluid lubricated bearing was introduced in [2]. This method forms the basis for the new magnetic Reynolds equation,

$$\nabla\left(-\frac{1}{\eta}\left(F_2-\frac{F_1^2}{F_0}\right)\nabla\left(p-p_f\right)+\left(\frac{h}{2}-\frac{F_1}{F_0}\right)U\right)=0 \quad (1)$$

where $F_0, F_1$ and $F_2$ are viscosity integrals specified in [2], $h$ is the local film height, and $U$ is the surface velocity. In this equation mechanism (1), the ferrofluid pressure increase, is introduced as a magnetic field dependent correction $p_f$ on the fluid pressure. Finally, mechanism (3), the sedimentation of particles, is taken into account through a local modification of the fly height $h$ equal to the sedimentation height.

This equation is studied using a 2D FEM simulation using a commercial simulation software package [3]. The calculation of the magnetic field in the bearing is performed using a 3D FEM calculation. The coupling between the magnetic field and the fluid behavior is introduced using three additional equations, one for each of the mechanisms, presented in the full paper.

## 3. Results

A typical result that can be obtained with this equation is presented in Figure 1, showing the pressure distribution in a herringbone journal bearing [3]. In this example only mechanism (2) has been used, in the final paper other examples will be added.

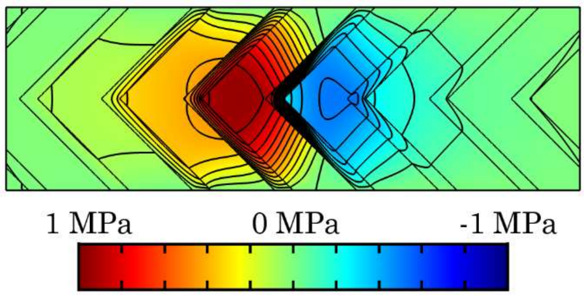


Figure 1: Pressure distribution in a magnetically textured, MR-lubricated herringbone bearing.

## 4. References

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