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Magnetic fluid brake

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Abstract

The paper presents a series of theoretical and experimental results concerning the influence of an exterior magnetic field of various configurations and intensities over a power dissipated by a disk brake in magnetic liquid. The formula of the dissipated power and the influence of magnetic field over this for regimes of laminar and turbulent flow of the liquid has been determined. The conclusions resulted from the interpretation of the experimental results confirm the theoretical aspects explained in the paper. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Disk brake; Magnetic liquids

1. Introduction

The main engineering applications of the magnetic fluids rely on keeping them in a magnetic field, on the effect of levitation and on other specific physical properties. The magnetorheologic effects which manifest in the magnetic fluids can be used for accomplishing new types of dampers, shock absorbers and actuators [1]. The friction force between two surfaces, one mobile and the other fixed, with a magnetic fluid between them, is determined both by the magnetic fluid and the action of the external magnetic that can have field, diverse configurations and intensities. The paper points out a series of theoretical and experimental results concerning the influence of the magnetic field versus the power dissipated by a disk brake in magnetic fluid for various speed conditions.

2. The principle of the method

The schematic diagram of the experimental stand is shown in Fig. 1. The disk made of ferromagnetic material, ground on both sides is placed into an enclosure filled with magnetic fluid. The used magnetic fluid is a kerosene based one. It has the following characteristics: $\rho = 1168$ kg/m^3, $\eta = 3.5 \times 10^{-3}$ N s/m^2, $\varepsilon = 0.085$, $M_S = 18.3 \times 10^3$ A/m.

The disk is rotated by a balanced motor that allows the determination of the brake force and the adjusting of the speed. The eight electromagnets placed on the external parts of the carcass can produce a magnetic field transversal on the flow direction of the working fluid. The intensity of the magnetic field is modified by adjusting the intensity of the electric current used to supply the electromagnets.

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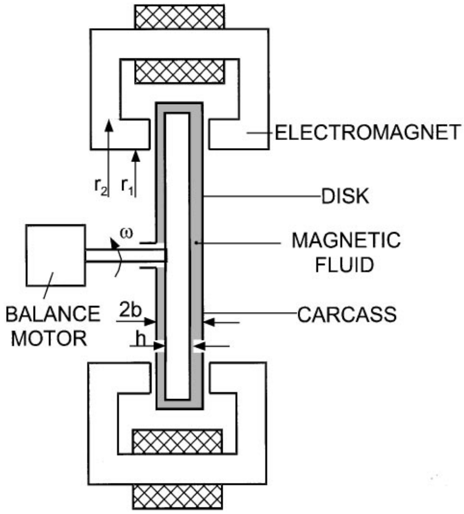

Fig. 1. Schematic diagram of the experimental equipment.

3. Theory

It is known that an r_2 radius disk that rotates with an angular velocity ω in a carcass of $2b$ in length, filled with a liquid of a dynamic viscosity η and a density ρ, determines friction forces, because of the unitary shear stresses. In conditions of laminar flow, the shear stress at a distance r on the disc, is given by Newton's law:

$$\tau(r) = \eta \frac{\omega r}{b}\,. \quad (1)$$

In a unitary magnetic field, the viscosity tends not to be Newtonian, depending, for a constant temperature, on the intensity of the magnetic field $\eta = \eta(H)$ and on the direction of this in comparison with the flow way of the liquid. If the viscosity is modified by applying a magnetic field, the power P_{LH} dissipated by the brake rises proportional to the viscosity. In conditions of turbulent flow, it is taken into consideration a distribution of velocities u_r, given by the exponential law $u_r = u(r/r_2)^{1/7}$ in which $u = \omega \times r_2$ is the peripheral velocity.

The apparent friction effort is given by Prandtl relation $\tau = \rho(l\,du_r/dr)^2$ in which $l = kr$ is the mixture length and k is the Karman constant. The power dissipated due to friction on the two lateral interior surfaces of the carcass is

$$P_T = \frac{4\pi}{161}\rho k^2 \omega^3 r_2^5\,. \quad (2)$$

In a regime of turbulent flow the power dissipated by the brake does not depend on the viscosity. The rotation of the magnetic fluid created by the disk (when a magnetic field operates) determines each particular floating particle to rotate at the moment it passes around the magnetic field. The rotation takes place both due to the action of the magnetic torque of the particle and the external magnetic field and reduces the gap angle φ between the two directions.

The magnetic fluids have the typical behaviour of the superparamagnetic materials.

Taking into consideration a concentration ε of the particles in an ideal suspension with a magnetic moment $\bar{M}_m$ and under the same angle φ in comparison with the magnetic field $\bar{H}$, the magnetisation of the liquid is $M = M_m \varepsilon V \cos\varphi$. The magnetic torque corresponding to the volume V is $M_V = (\mu_0/\chi)M^2(H)V\tan\varphi$, where μ_0 is the magnetic permeability of the vacuum, χ is the magnetic susceptibility of the magnetic fluid and $V = \pi(r_2^2 - r_1^2)(2b - h)$ is the volume of the liquid between the disk and the carcass, influenced by the magnetic field. The supplementary power dissipated by the brake due to the action of the magnetic field H for the turbulent flow is

$$P_{TH} = \frac{\mu_0 V}{\chi}\omega M^2(H)\tan\varphi\,. \quad (3)$$

4. Experimental results

The influence of the intensity and of the configuration of the magnetic field over the power dissipated by the disk brake in a magnetic field at various angular velocities has been experimentally determined (see Fig. 2).

For case A, the eight electromagnets were fed in the same manner, realising the same direction of the magnetic field. In case B, four electromagnets placed consecutively produced a N–S field and the other four produced a magnetic field in a contrary direction. In case C, the eight electromagnets are

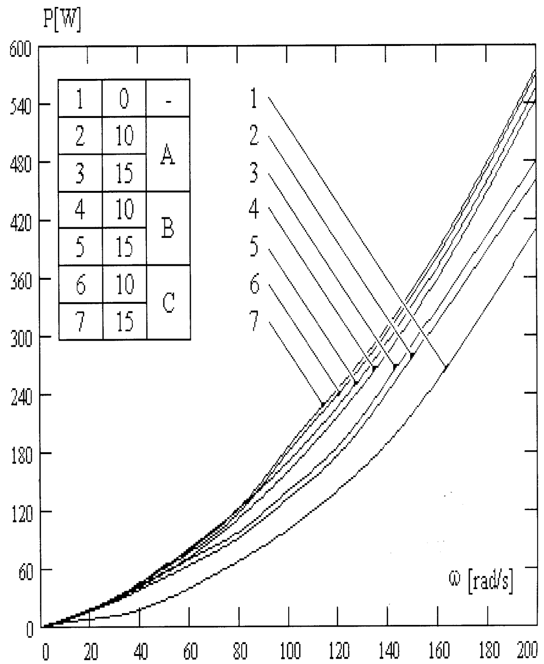

Fig. 2. Experimental results.

supplied in such a way that two consecutive ones produce magnetic fields with contrary polarities.

In every case, there have been used two intensities of the magnetic field, each of them being obtained due to specific values of the control current ($I_1 = 10$ A; $I_2 = 15$ A).

The experimental determinations were realised for the regime of the turbulent flow. They do not point out the influence of the magneto-viscosity. In conditions of turbulent flow it has been found that the dissipated power rises when we apply the magnetic field for an angular velocity. The rise of the value of the dissipated power due to the magnetic field is greater in high velocities domain. The configuration of the applied magnetic field influences the rise of the dissipated power. The rise of the alternating frequency of the field polarity has a positive influence at high velocities. The rise of the magnetic field intensity for the same fields configuration has minor results [2].

5. Conclusions

The exterior magnetic field applied to the magnetic liquid for a disk brake influences the dissipated power. For a value of the intensity of the magnetic field the dissipated power rises due to the alternative application of this. In conditions of turbulent flow the rise of the power dissipated by the brake because of the exterior magnetic field is given by the magnetic torque that acts over the dipolar torque on each monodomain of the magnetic field.

References

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