THE INFLUENCE OF THE EXTERIOR MAGNETIC FIELD ON THE LAMINAR ENERGY OF THE MAGNETIC FIELDS

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INTRODUCTION

Ferrofluids are dispersions of magnetic microparticles in a basic fluid.

Ferrofluids are perfectly soft, from the mangnetic point of view and nonmagnetic in the absence of a magnetic field. Sensational fluido-mechanic phenomena were revealed, leading to new solutions for the scientific and technological problems.

Ferrofluids answer almost instantaneously to the application of a magnetic field through repositioning, flowing and changes in the internal pressure distribution.

The viscuosity of the magnetic fluids in the absence of the magnetic field has an ideal Newtonian behavior, without being dependent on the speed gradient. In an uniform magnetic field the viscuosity tends to be non-Newtonian. So, the viscuosity owing to the applied field rises at the trust four times.

This phenomenon appears only in very powerful magnetic fields or at slow speed gradients.

The specific characteristics of the magnetic fluids extend the area of their utilization

The magnetic fluids apply in some domains In wich the conventional techical solutions are over passed.

The main methods to obtain ferro-fluids are:

a) the mechanical dispersion (Stephen Papell)
b) the electro-condensation method
c) the electro precipitation depositting method
d) the chemical precipitation method

The magnetic licuids keep the specific characteristics of the base liquids being influenced by the viscous α thermic proprieties of these.

The viscuosity of collidal suspension of solid particles, in a liquid, depends on the base liquid viscuosity the form of the partcles the volume of the dispersed phase and the dissolving grade.

The magnetic viscuosity, pointed out by R.E.Rosensweig in1968, was analysed both theoretically and experimantally, in a large number of papers.

1. PROBLEM FORMULATION

The classic nozzle-flopper mechano-hydraulic amplifier (figure 1) is replaced with a new type of magnetic ferrofluidic amplifier (figure 2). The nozzle-flopper amplifier provide the setting of pressure p from chamber (2) by modifying the distance x between the nozzle and the flopper. The setting of pressure p in the magnetic ferrofluidic amplifier is made by the influence of the exterior magnetic field produced by the electromagnet that is crossed by the current I.

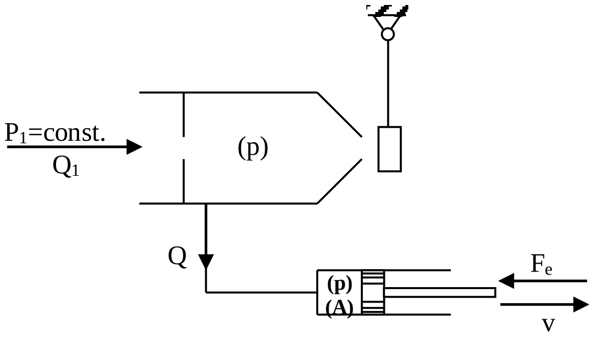

Figure 1.

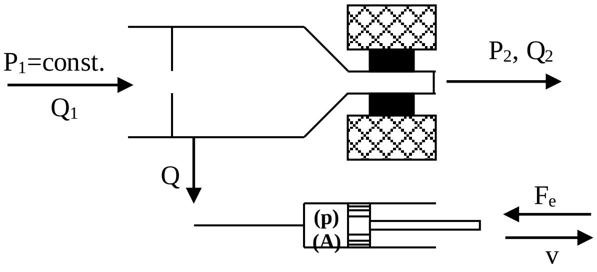

Figure 2.

2.THE CALCULATION OF THE PRESSURE

The equilibrium equation of the outputs is :

$$Q_1 = Q + Q_2 \qquad (1)$$

where :

Q_1 is the output through the constant section A_{dr};

Q is the alimentation output of the execution element;

$$Q_1 = C_1 A_{dr} \sqrt{\frac{2}{\rho}(p_1 - p)} \qquad (2)$$

$$Q = A\frac{dx}{dt} \qquad (3)$$

In the relation 3 the friction and elastic forces were neglected.

The Bernoulli equation describing the energetic equilibrium of the flow of the ideal ferrofluid is :

$$\frac{\rho v^2}{2} + p + E - \mu_0 \int_0^H M(\xi)d\xi = const. \qquad (4)$$

where :

E - any function of potential energy whose gradient is a force of volume. We consider $E = 0$.

M – the magnetization;

$\xi \in [0; H]$

dξ – the infinitesimal variation of the field intensity.

By integration we obtain :

$$\frac{\rho v^2}{2} + p - \mu(\mu_r - 1)\frac{H^2}{2} = const. \qquad (5)$$

We define $K_1 = \frac{\mu_0(\mu_r - 1)}{2}$

The magnetic retention in the field is described by the Bernouli equation :

$$\Delta p_B = p - p_2 = K_1 H^2 \qquad (6)$$

Taking into account the magnetoviscosity phenomena which is specific to the ferrofluids and using the Hagen Poiseuille relation for the lamination flow, we obtain the pressure loss Δp_V :

$$\Delta p_V = p - p_2 = \frac{8\eta(H)l}{\pi r^4} Q_2 \qquad (7)$$

Since the pressure p depends on the two physical phenomenas (equations 6 and 7), by summing the effects (for $p_2=0$) :

$$\Delta p = \Delta p_B + \Delta p_V \qquad (8)$$

For $p_2=0$, we obtain :

$$p = K_1 H^2 + \frac{8\eta(H)\cdot l}{\pi r^4} Q_2 \qquad (9)$$

Considering relations 2, 3 and 8, the equation 1 for the continuity of the output becomes

$$\begin{aligned} & C_1 A_{dr}\sqrt{\frac{2}{\rho}(p_1 - p)} = \\ & = A\frac{dx}{dt} + \frac{(p - K_1 H^2)\cdot \pi r^4}{8\eta(H)\cdot l} \end{aligned} \qquad (10)$$

In stationary regimen, $v = \frac{dx}{dt} = 0$, so we obtain :

$$C_1 A_{dr} \frac{2}{\rho}(p_1 - p) = \frac{(p - K_1 H^2)\cdot \pi r^4}{8\eta(H)\cdot l}$$

$$\frac{2C_1^2 A_{dr}^2}{\pi r^4 \rho}\cdot 8\eta(H)\cdot l\cdot(p_1 - p) = p - K_1 H^2$$

By using the notation $K_2 = \frac{2C_1^2 A_{dr}^2}{\rho}$, we obtain :

$$K_2\eta(H)(p_1 - p) = p - K_1 H^2$$

$$p[1 + K_2\eta(H)] = K_2 p_1 \eta(H) + K_1 H^2$$

By using the notation $K_3 = \left(\frac{\pi r^4}{8l}\right)^2$ and $K_4 = \frac{K_2}{K_3}$, we obtain :

$$p^2 + K_4\eta^2(H)p - K_4\eta^2(H)p_1 - K_1H^4 = 0 \qquad (11)$$

Solving the equation 11 allows us to obtain pressure p depending on the variation of the magnetic field intensity H.

We find that the pressure is square dependent on the magnetic field.

In the case of laminar flow of the ferrofluid, the viscosity variation depending on the exterior magnetic field that is applied is given by the following relation :

$$\eta(H) = \eta_0[1 + 2.5\varphi(1 + \frac{3\alpha - tg\alpha}{5\alpha + tg\alpha}\sin^2\Theta)] \qquad (12)$$

where :

$\alpha = \frac{\mu_0 \cdot V \cdot M_s \cdot H}{K \cdot T}$ - the argument of the Longevin function;

η_0 - the basic fluid viscosity;

Θ – the angle between the magnetic field direction and the direction of flowing;

Φ – the volume concentration of particles.

In this paper we used the following notations :

$\overline{B} = \mu_0(\overline{H} + \overline{M})$ - the magnetic induction in the interior of a magnetized body;

$M = \chi H$ and $B = \mu_0(1+\chi)H = \mu H$ for the ferromagnetic bodies;

$\mu = \frac{\overline{B}}{\overline{H}}$ - the magnetic permeability;

$\chi = \frac{M}{H}$ - the magnetic susceptibility;

μ_0 – the magnetic permeability of the void;

$\mu_r = \frac{\mu}{\mu_0} = 1 + \chi$ - the relative permeability of the medium.

3. EXPERIMENTAL RESULTS

We established the characteristic ***p=f(H)*** (figure 3) for a ferrofluid with a mineral oil base, conceived by the laboratory of Fluid Mechanics, Engines and Hydraulic Systems Iasi, We can notice the square dependence of the pressure on the applied exterior magnetic field. This result confines the mathematical model presented above.

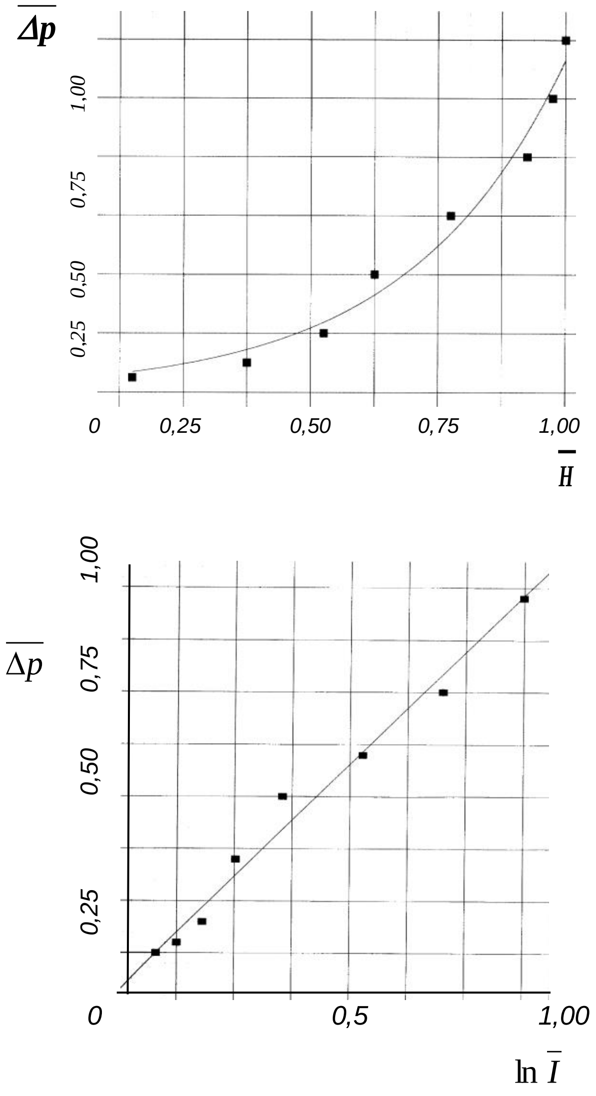

Figure 3.

4. CONCLUSIONS

The viscuosity of the magnetic fluids in the absence of the magnetic field has an ideal Newtonian behavior, without being dependent on the speed gradient. In an uniform magnetic field the viscuosity tends to be non-Newtonian. So, the viscuosity owing to the applied field rises at the trust four times.

The viscuosity of collidal suspension of solid particles, in a liquid, depends on the base liquid viscuosity the form of the partcles the volume of the dispersed phase and the dissolving grade.

Solving this problem is difficult because of the complexity of the phenomenon that requests a multidisciplinary approach.

Making of the ferrofluid, determining its features and building the experimental installations, these are delicate problems, whose solving requests profound knowledge in the domanis of physics, chemistry, fluids mechanics, hydraulics, mechanics, etc.

The theoretical and experimental results that we obtained lead us up to a new field of practical applications, namely the magnetoferrofluidic command systems.

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