CALCULATION OF THE FORCE ACTING ON NONMAGNETIC BODY IN MAGNETIC LIQUID IN THE PRESENCE OF INHOMOGENEOUS MAGNETIC FIELD

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Abstract **Research of influence of form and size of particles on pushing out ability of magnetic fluid separator**

Keywords **Magnetic fluid, Magnetic fluid separator, Magnetic force**

In magnetic fluid (MF) situated in inhomogeneous magnetic field phisical effect of pushing out nonmagnetic bodies into the area where the field is weaker takes place. This effect is utilized in hydrostatic magnetic fluid separators (MFS) [1]-[3]. In the operating gap of MFS (fig. 1) inhomogeneous magnetic field throughout the height of a gap (in the direction of axis Y) is formed using the shape of polar tips. MF with density ρ and magnetization M is put between the polar tips. Pressure of MF near points 1 and 2 is equal to external pressure

$$p_1 = p_0 , \quad p_2 = p_0 . \qquad (1)$$

Pressure variation in MF relative to external pressure is defined by evaluation

$$p = p_0 + \Delta p_G + \Delta p_M , \qquad (2)$$

$$\Delta p_G = \rho \cdot g \cdot (y_2 - y) , \qquad \Delta p_M = u_M - u_{M2} ,$$

where Δp_G and Δp_M - pressure incrementation at the expense of gravitational and magnetic force respectively. From the direction of MF a force is acting on non-magnetic body with exterior surface σ and volume V submerged in it in the direction of axis Y

$$F_y = -\oint_\sigma p \; \bar{e}_y \cdot \overline{d\sigma} = F_A + F_{My} , \qquad (3)$$

$$F_A = \rho \cdot g \cdot V , \qquad F_{My} = -\oint_\sigma u_M \; \bar{e}_y \cdot \overline{d\sigma} .$$

It consists of two parts: the first - force of Archimedes F_A, the second – magnetic force F_{My}, which depends upon distribution of specific magnetic energy of MF u_M on the surface of a particle. In its turn

$$u_M = \mu_0 \int_0^H M dH \qquad (4)$$

depends upon the distribution of intensity H in the volume of MF.

By variating of the current in energizing winding of electromagnet it is possible to regulate the value of magnetic force F_{My}. Obviously, a particle with density ρ_p is affected by gravitation force $\bar{F}_G = -\rho_p \cdot g \cdot V \cdot \bar{e}_y$. In MFS for lighter non-magnetic particles with dencity ρ_l a condition for their floating-up should be met, and for heavier particles with dencity ρ_h - a condition for their floating down.

$$\rho_l \cdot g \cdot V < (F_{My} + F_A) , \; \rho_h \cdot g \cdot V > (F_{My} + F_A) . \qquad (5)$$

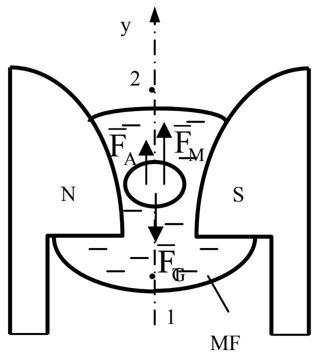

Fig .1. Operating gap of hydrostatic MFS

In order to guarantee high precision of separation shape of polar tips of MFS should be chosen based on the condition $F_{My} = \text{const}$. Magnetic force depends upon distribution of intensity H in the volume of MF. Magnetic conductivity of non-magnetic particles equals to magnetic conductivity of vacuum μ_0, which is lower then magnetic conductivity of MF $\mu_Ж$. This leads to change in distribution pattern of intensity H and specific magnetic energy u_M near non-magnetic particle. As a result a mechanism of volume value V and shape of non-magnetic body affection on the value of F_M takes place. Expression for F_M in (3) cosiders all these factors and is, apparently, the most precise. Relation [1]-[3] is often used for calculation of F_M

$$\bar{F}_M = \bar{f}_M \cdot V, \quad \bar{f}_M = \mu_0 \cdot M \cdot \nabla H , \qquad (6)$$

where magnetization M of MF and intencity gradient ∇H are taken in the position of center of non-magnetic body upon condition of its absence in MF. It is fair if presence of non-magnetic body does not change distribution pattern of intensity H in operating gap of MFS.

In order to compare formulas (3) and (6) calculational research was conducted. On the ground of finite-element analisys of plane-parallel field in operating gap of MFS filled with MF with M_S=17 kA/m specific force f_M for a rectangular cross-section body with width b, height h and unit length situated on symmetry line was defined.

TABLE I
DEPENDANCE OF RELATIVE MAGNETIC FORCE ACTING ON NON-MAGNETIC BODY ON ITS VOLUME

h, mm	3	4	5	6	7	8	10
b, mm	4	6	8	10	12	14	19
V, mm^3	12	24	40	60	84	112	190
f_M, kN/m^3	76,78	76,67	78,54	81,27	84,27	88,21	102,77

TABLE II
DEPENDANCE OF RELATIVE MAGNETIC FORCE ACTING ON NON-MAGNETIC BODY ON ITS VOLUME WITH ALTERATION OF ITS VERTICAL DIMENSION ALONE

h, mm	4	5	6	7	8	9
b, mm	6	6	6	6	6	6
V, mm^3	24	30	36	42	48	54
f_M, kN/m^3	76,67	75,19	74,06	72,74	70,88	68,59

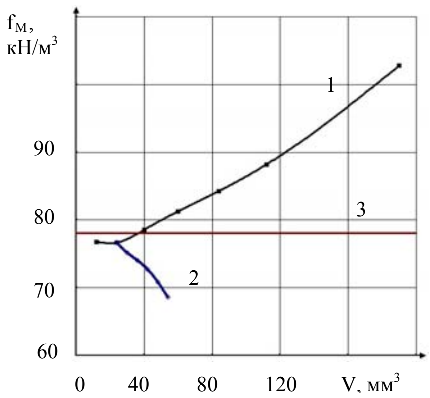

Fig. 2. Figures of dependensies of relative magnetic force on the size of non-magnetic body: 1 - size is changed along both directions, 2 - size is changed along direction of axis Y, 3 – calculated using (6).

Results of calculations show explicit dependence of f_M on the shape on size of the body. Ambiguousness of dependency is explained by type of pressure distribution in MF. In horisontal direction p increases from symmetry line to poles. Therefore force increases with the increase of dimension b (table 1, curve 1 on fig. 2). When b=const force decreases with the increase of height of the body (table 2, curve 2 on fig. 2). Results aquired using both formulas (3) and (6) coincide when body size is small and it affects distribution pattern of intensity H in MF weakly.

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