V.V. Kovarda

EXPERIMENTAL INVESTIGATION OF ATTENUATION OF VIBRATIONS OF MAGNETIC FLUID COLUMN

Kursk State Technical University
Russia, 305040, Kursk, ul. 50 Let Oktyabrya, 94
Tel: +7(4712) 51-65-64; E-mail: polunin-vm1@yandex.ru

The results of experimental investigation of vibrating system with magnetic-fluid column, filling glass tube, are given in this work. There have been carried out comparison of the experiment results with deductions of classic theory and evaluation of contribution into dissipation of elastic energy of mechanisms of viscous friction and heat losses.

Technique of experimental investigation and experimental plant allowing to carry out measurements of attenuation of the vibrations of the system β, being studied, with variations of the area of heat transfer surface and also with the possibility of magnetic fluid magnetization in magnetic field, being transverse to hydrodynamic flou, are described in this work [1].

Main characteristics of investigated samples of magnetite magnetic fluid on the basis of kerosine and siloxane, measured according to traditional procedures at the temperature of 20°C, are given in Table 1.

Table 1

Sample	**Fluid-carrier**	**ρ, kg/m^3**	**M$_s$, kA/m**	**χ**	**φ, %**	**η$_s$,Pa·s**
MF-1	Kerosine	1345	-	-	8,8	$3{,}1\cdot10^{-3}$
MF-2	Kerosine	1294	52	6,3	7,3	$3{,}9\cdot10^{-3}$
MF-3	Kerosine	1294	52	6,3	7,3	$3{,}5\cdot10^{-3}$
MF-4	Kerosine	1499	60	7,5	10,2	$8{,}1\cdot10^{-3}$
MF-5	Kerosine	1500	60	-	10,2	$12\cdot10^{-3}$
MF-6	Siloxane PES-V-2	1400	40	-	-	$500\cdot10^{-3}$

In Table 1: ρ – density of magnetic colloid, M_s – magnetization of saturation, χ – initial magnetic susceptibility, η_s – statical viscosity, φ – volumetric concentration of solid phase.

Owing to very fast attenuation of system vibration while using MF-6 sample we could obtain only roughly evaluating meaning of the attenuation coefficient 45-50 (s^{-1}) at frequency of 28 Hz.

Results of measurements of attenuation coefficient, obtained at stabilization of equilibrium position by different methods and at two different methods of positioning induction circuit in the limits of measurement errors of 7-10%, agree with each other.

Dependence of the coefficient of vibration β attention on the magnetic field H strength, during MF column suspension between electromagnet poles, is given in Fig .1. Dependence of β(H) for less concentrated colloids is characterized by positive derivative.

Approximated line of experimental dependence β for MF-3, obtained at stabilization of equilibrium position of MF column by ring magnet, is given in Fig.2.

Results of β measurements at the frequency of 32 Hz, obtained for MF-3 by two different methods of stabilization (Fig.1 and 2), coincide in the limits of measurement errors, that proves truth of measurement results.

Approximate value of the contribution into the coefficient of attenuation of the mechanism of interphasic heat exchange has been carried out according to the formula of I.A.Chaban for dimensionless coefficient of attenuation of vibrations δ of spherical gas space in the fluid [2]:

$$\delta = \frac{3(\gamma_1 - 1)\sqrt{2\psi_1}}{4\sqrt{\omega}R_0} \tag{1}$$

where $\gamma_1 = C_{p1}/C_{v1}$ - heat capacity ratio at constant pressure and constant gas volume, ψ_1 - coefficient of gas thermal diffusivity, ω -angular frequency, R_0 -radius of gas bubble in the fluid.

Calculated value of the coefficient of attenuation β_T is 0, 38 s^{-1} , that is less in the order than experimental value and is in the limits of measurements errors.

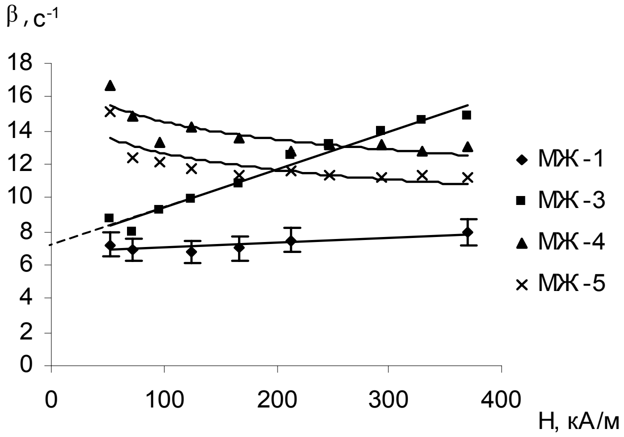

Fig.1. β (H) dependence

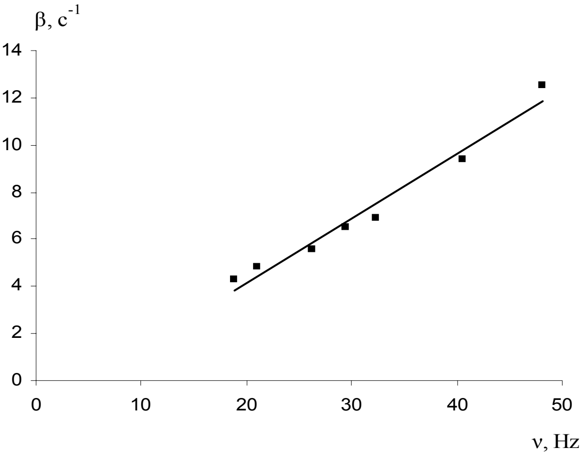

Fig.2. Dependence of β (ν) for MF-3

Special experiment, using methods for extending interphasic surface and for complete exclusion of the given mechanism, has been carried out for more reliable evaluation of the contribution into dissipation of elastic energy of interphasic heat exchange mechanism. Experimental data, obtained from the experimental with MF-3 at different area of interphasic heat exchange are given in Table 2.

Table 2

	Area of interphasic surface, mm^2	ν, Hz	$\overline{\beta}$, c^{-1}	Δ β	
				c^{-1}	%
Free surface of the bottom	750	26,2	5,5	-	-
Glass powder on the surface of the bottom	1550	21,3	6,0	0,5	9
Quartz sand on the surface of the bottom	1550	22,9	5,8	0,3	5,5

In the case of the tube, opened from both sides, formula for approximate theoretical evacuation of the vibrations frequency is of the following from :

$$\nu_T = \frac{1}{2\pi}\sqrt{\frac{2\mu_0 M_z \cdot G}{\rho b}},$$

where ρ – density of MF, M_z – local magnetization, G – intensity gradient of magnetic flied at upper (lower) free surface of MF-column, b – height of MF-column.

Experimental and calculated value of investigated parameters are given in Table 3, coefficients k_g and k_p have been calculated according to formulae, given in the work [3].

Experimental coefficient of elasticity was difined according to the formula

$$k_{\exp} = 4\pi^2\nu^2 m,$$

where m – mass of magnetofluid inert element.

Table 3

Volume of gas space	H, кА/м	ν, Hz	ν_T, Hz	$\overline{\beta}$, c^{-1}	β_η, c^{-1}	k_p, Н/м	k_g, Н/м	$k_{exp.}$, Н/м
Elongated by 6,5 times column of gas space (in comparison with initial height of 15 mm)	52	14,8	15	5,7	1,7	16	196	211
Tube, opened at both sides	214	7,7	8,6	4,1	1,2	72	-	57
	247	8,9	9,5	4,7	1,3	87	-	76,3
	457	12,1		6,4	1,5		-	141

On the basis of data of Table 3 one may come to a conclusion on the applicability of approximated model theory of ponderomotive elasticity. The process of interphasic heat exchange does not influence the value of the coefficient of attenuation β under conditions of the experiment; mechanism of viscous friction plays the main role in dissipation of elastic energy.

If the length of the circle, embracing side surface of fluid column, is much longer than the length of viscous wave λ ($\lambda = 2\sqrt{\pi\eta / \rho\nu}$), then attenuation coefficient is found according to the formula of Helmholtz [4]:

$$\beta_\eta = \frac{2}{d}\sqrt{\frac{\pi\eta\nu}{\rho}} \tag{2}$$

Proceeding from obtained experimental data «effective elasticity» is calculated:

$$\eta_{ef.} = \frac{\rho d^2}{4\pi\nu}\beta^2 \tag{3}$$

Coefficient of vibrations attenuation is calculated according to the formula of Poiseuille at small values of d and ν and when condition $\pi d < 2\lambda$ is fulfilled:

$$\beta_P = \frac{16\eta}{\rho d^2} \tag{4}$$

Dependence of lnβ(lnν) for MF-3 (dotted line) and MF-1 (solid line) according to the data of experiment, in which fluid column rests on air space of different height, and stabilization of equilibrium position is provided by the field of ring magnet, is given on Fig. 3. Dependence of attenuation coefficient on the frequency is close to proportional one, i.e. $\beta \sim \nu$, while according to classical theory $\beta \sim \sqrt{\nu}$, that is caused by the increase of effective viscosity with the frequency.

One may suppose that «superclassic» attenuation of vibrations in the investigated system with specific dependence on vibrations frequency (Fig. 3) and intensity of magnetic field (Fig. 1) is connected with delaying, in respect to viscous fluid-carrier, motion of aggregates from ferroparticles in the limits of the depth of viscous wave penetration h_η ($h_\eta = \lambda / 2\pi$).

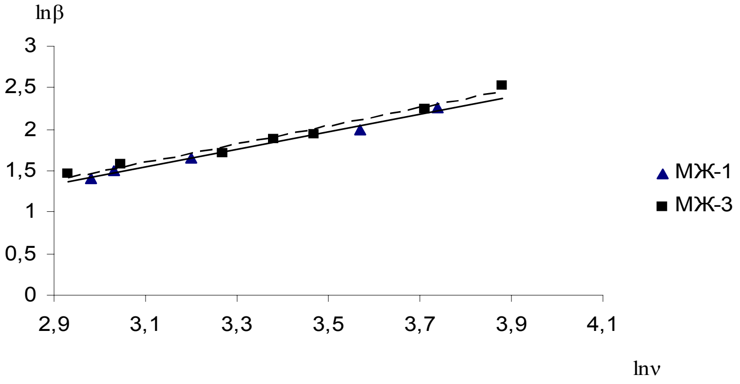

Fig. 3. Dependence of lnβ(lnν)

Effective viscosity for colloids with less concentration (MF-1 and MF-3) increases with the growth of frequency and intensity of the field.

Approximated curve of the dependence β(H) for more concentrated MF-2 is characterized by sloping fall, that is, probably, explained by competition of two possible mechanisms of elastic energy dissipation, influencing the value of effective viscosity: effect of rotating viscosity and dipole-dipole interaction of ferroparticles, making difficult liquid and solid phases motion in the limits of the depth of viscous wave penetration.

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