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Effect of magnetophoresis and Brownian diffusion on thermomechanical processes in magnetic fluids

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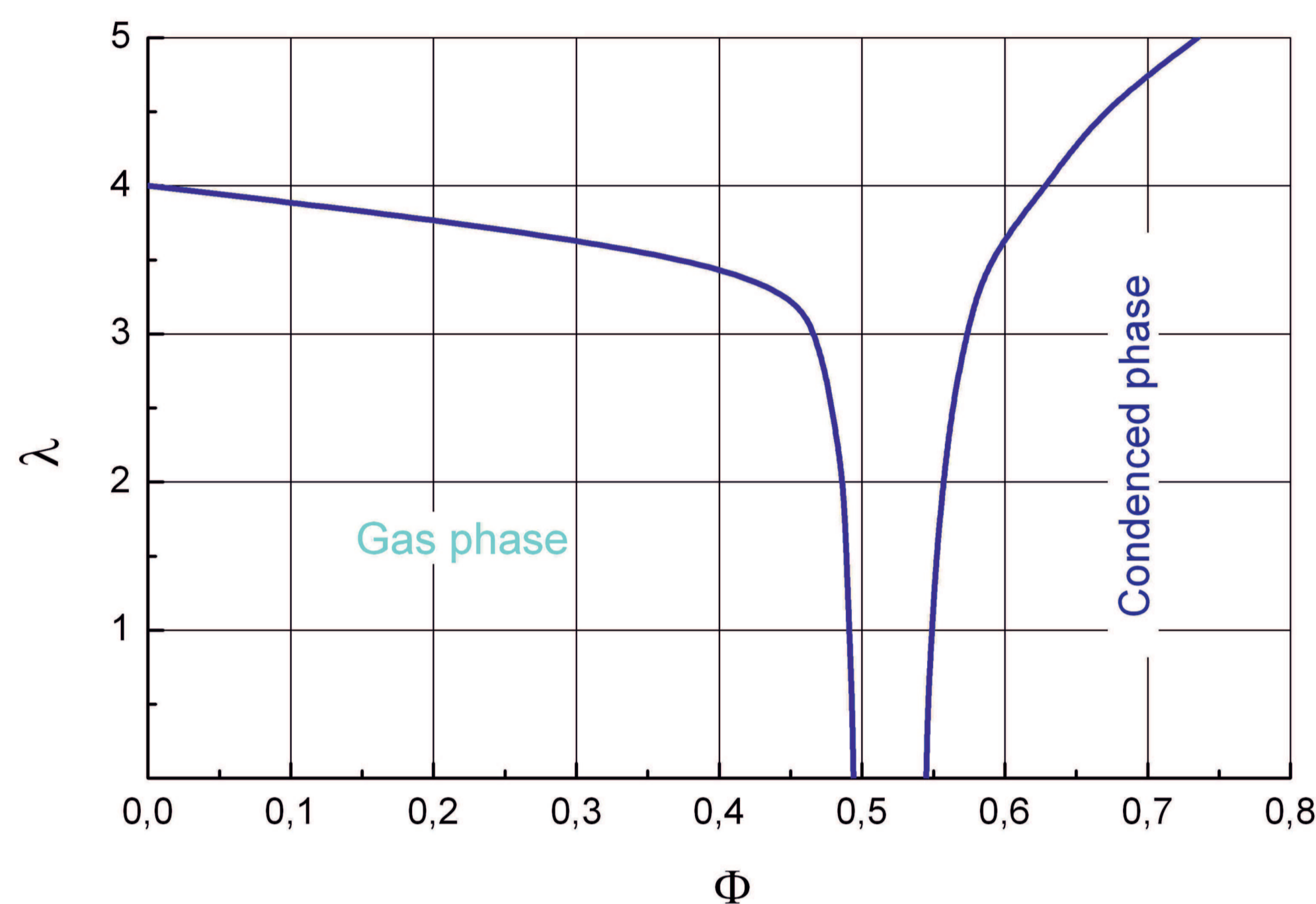
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As a result of magnetophoresis and Brownian diffusion in magnetic fluid the nonuniformity of magnetic particles concentration Φ appears. The magnetic and thermophysical properties of the magnetic fluid depend on the concentration of particles, such that the following phenomena can appear:

- 1) the dependence of the magnetic fluid magnetization on Φ leads to a change of the magnetic volume force F_m acting on volume;
- 2) the dependence of the fluid viscosity η on Φ (which can be described by the approximation of Krieger-Dougherty $\eta = \eta(\Phi=0)(1 - 1,35\Phi)^{-1,85}$) leads to a change of the forces of viscous friction F_t on the solid boundaries;
- 3) the dependence of the effective thermal conductivity of the magnetic fluid λ_c on Φ (which can be described by the Maxwell's formula $\lambda_c(\Phi) = \lambda_f[2 + \varepsilon - 2\Phi(1 - \varepsilon)] / [2 + \varepsilon + \Phi(1 - \varepsilon)]$, where ε is the ratio of thermal conductivity of a base fluid λ_f to the thermal conductivity of solid particles) leads to a change of heat fluxes Q in a non-isothermal fluid.

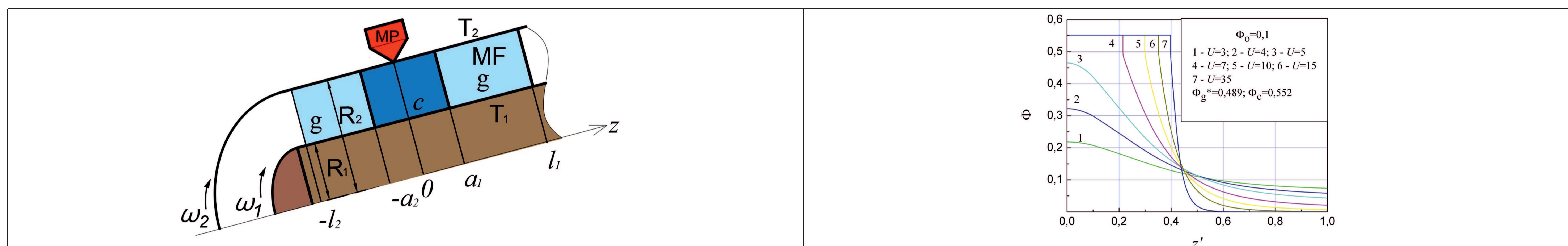
Governing equations and phase transition conditions



$$\rho \frac{\partial \Phi}{\partial t} + \text{div} \vec{i} = 0, \quad \vec{i} = -\rho D \nabla \Phi + \rho b \mu_0 m \Phi L(\xi) \nabla H$$

Fig. 1. Diagram of phase equilibrium in magnetic fluid with magnetization of saturation.

Magnetic fluid in a gap between rotating coaxial cylinders with different temperatures in a locally inhomogeneous magnetic field



$$\Phi_g = B \frac{\text{sh}[UH'(z')]}{H'(z')}, \quad \Phi_c = \text{Const}$$

U is a ratio of the magnetic energy of a particle to its thermal energy.

Fig. 2. Distribution of particle concentration Φ in magnetic fluid depending on magnetic parameter U at initial concentration $\Phi_0=0,1$, and $a_2=l_2=0$.

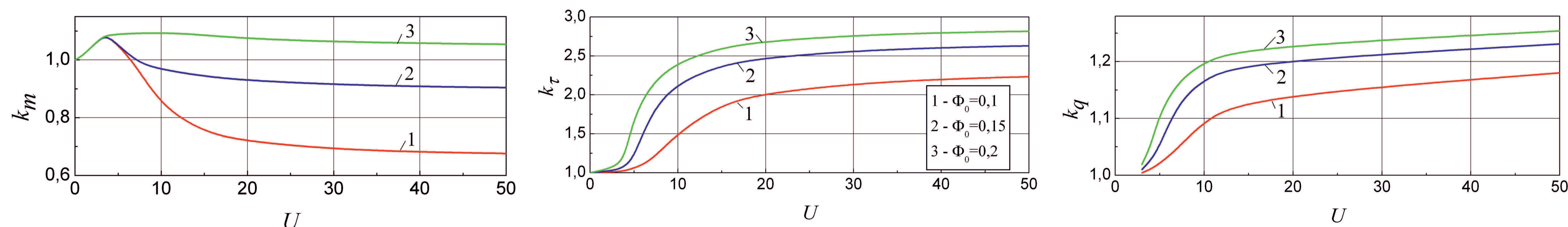
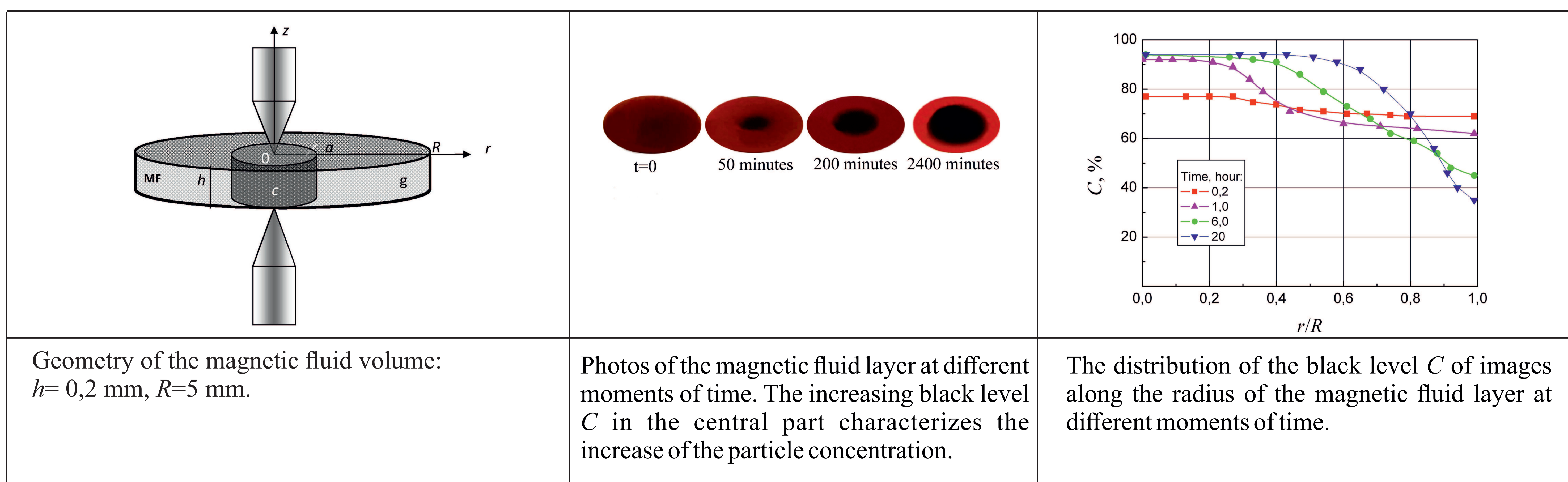


Fig.3. Effect of redistribution of particle concentration on relative magnetic volume force $k_m = F_m(\Phi)/F_m(\Phi_0)$, on relative force of viscous friction $k_\tau = F_\tau(\Phi)/F_\tau(\Phi_0)$, and on relative heat flux $k_q = Q(\Phi)/Q(\Phi_0)$.

Experiment

Magnetic fluid: kerosene, magnetite, initial concentration of particles - 0,074, magnetization of saturation - 22 kA/m, density - 1130 kg/m³. Maximal magnetic field intensity - 560 kA/m, $U=39$.



Geometry of the magnetic fluid volume:
 $h = 0,2$ mm, $R = 5$ mm.

Photos of the magnetic fluid layer at different moments of time. The increasing black level C in the central part characterizes the increase of the particle concentration.

The distribution of the black level C of images along the radius of the magnetic fluid layer at different moments of time.