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EVALUATION OF FACTORS AFFECTING THE UNSTABILIZED FLOW OF ELECTRICALLY CONDUCTIVE LIQUIDS

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ABSTRACT

This article is dedicated to influence of a transverse magnetic field is determined by the action of the so-called ponderomotive forces, which has magnetic nature. Such an impact makes it possible to evaluate the characteristics of the flow in the hydrodynamic initial section, pressure losses and determine the length of the initial section itself. It is shown that in some cases the action of a magnetic field leads to a change in the rheological properties of a viscous liquid. The article presents the processing of experimental data, thanks to the planning of experimental data carried out according to the appropriate methodology. The presented form, the characteristics of the velocity field were obtained for various values of the Reynolds number and the Hartmann number. It is also shown that in the case under consideration, the length of the hydrodynamic initial section is a function of the Reynolds number and the Hartmann number.

1. INTRODUCTION

As known, the influence of a transverse magnetic field is determined by the action of the so-called ponderomotive forces, which has magnetic nature. Thus, when studying this kind of flow, it becomes necessary to assess the impact on the flow of inertia forces from convective acceleration, on one hand, and ponderomotive forces contributing to flow deceleration, on the other hand. The interaction in the fluid flow between these forces determines the nature of the degree of flow destabilization in the flow of an electrically conductive fluid.

2. EXPOSITION

In this regard, to evaluation of such effect of the flow's nature has great practical interest, which explains the appearance of a number of works devoted to this problem. Among them should be noted Regirer S. A. [1], Genin L. G. [2], Shercliff J. [3], Povkh I. L. [4], Dukure R. K. [5], Zhilin V. G. [6] and others. Such flows are characterized by the fact that effect of forces from convective acceleration, the velocity field is deformed in the hydrodynamic initial section, on the one hand, and the action of the magnetic field (ponderomotive forces), on the other hand. Studies show that the manifestation of ponderomotive forces is characterized by flow deceleration, which also affects the distribution of velocities. Thus, when analyzing this kind of flow, it is necessary to assess the degree of action on the flow of both inertia forces and ponderomotive forces. Such an impact makes it possible to evaluate the characteristics of the flow in the hydrodynamic initial section, pressure losses and determine the length of the initial section itself. Among the factors influencing this process, one can single out the effect of a magnetic field on the rheological characteristics of an electrically conductive liquid. This issue was studied by a number of authors, including Pallabazer [7]. It is shown that in some cases the action of a magnetic field leads to a change in the rheological properties of a viscous liquid, in particular, to the manifestation of viscous plasticity. Taking into account the proposed mechanisms of viscosity change, studies were carried out using electrically conductive non-Newtonian fluids with polymer additives. Polymer detergents (of the Gala type) were used as non-Newtonian liquids. The rheological curve of dependences $\tau = f(\dot{\gamma})$ and tabular data of liquids are shown in Table 1 and Fig. 1.

Table 1 *Rheological studies of liquid Gala diluted for reotest 2M in a magnetic field*

On the wall, B=94 mTl						
With magnet	**Position**	**g, 1/s**	**a**	**t, Pa**	**M, Pa.s**	**n**
1	5a	27,0	3	1,00	0,037	35,30534
2	6a	48,6	5	1,67	0,034	32,69013

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3	7a	81,0	8,0	2,66	0,033	31,38253
4	8a	145,8	9,5	3,16	0,022	20,70375
5	10b	218,7	12,0	4,00	0,018	17,43474
6	9a	243,0	13,0	4,33	0,018	16,99887
7	11b	364,5	17,5	5,83	0,016	15,25540
8	10a	437,4	19,5	6,49	0,015	14,16572
9	12b	656,0	26,5	8,82	0,013	12,83586
10	11a	729,0	29,0	9,66	0,013	12,64018
11	12a	1312,0	47,0	15,65	0,012	11,38274

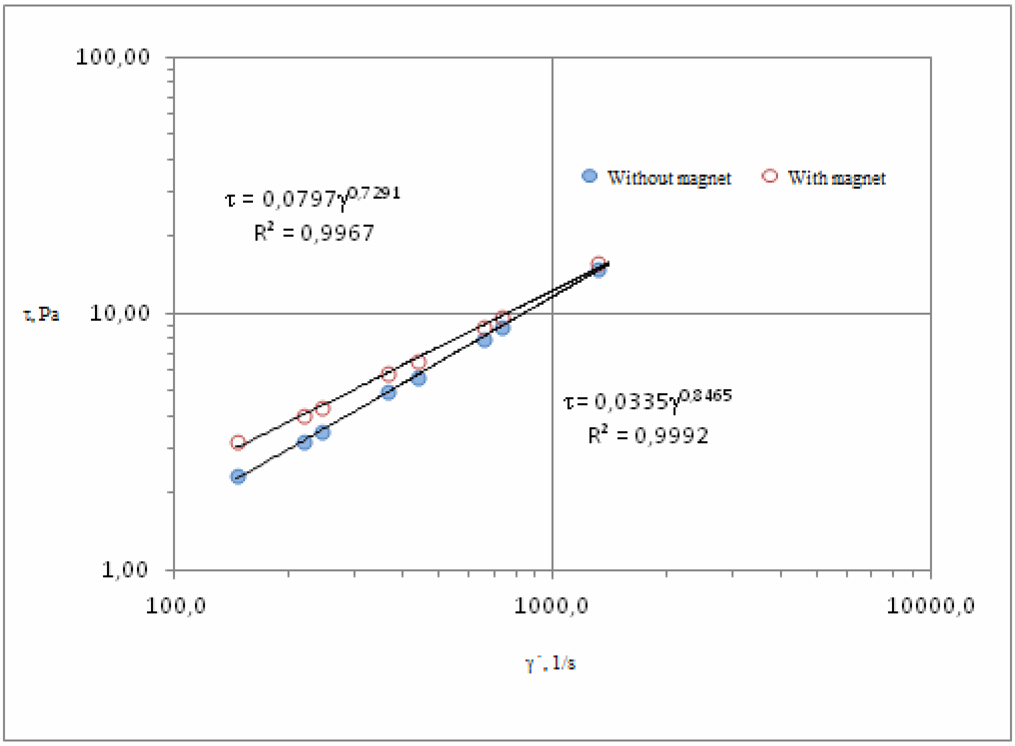

Fig. 1. Dependency graph $\tau = f(\dot{\gamma})$

The deceleration of the flow due to the magnetic field can be illustrated using a graphical dependence of the form Fig. 2. The studies were carried out on the basis of the experimental stand shown in Fig. 3.

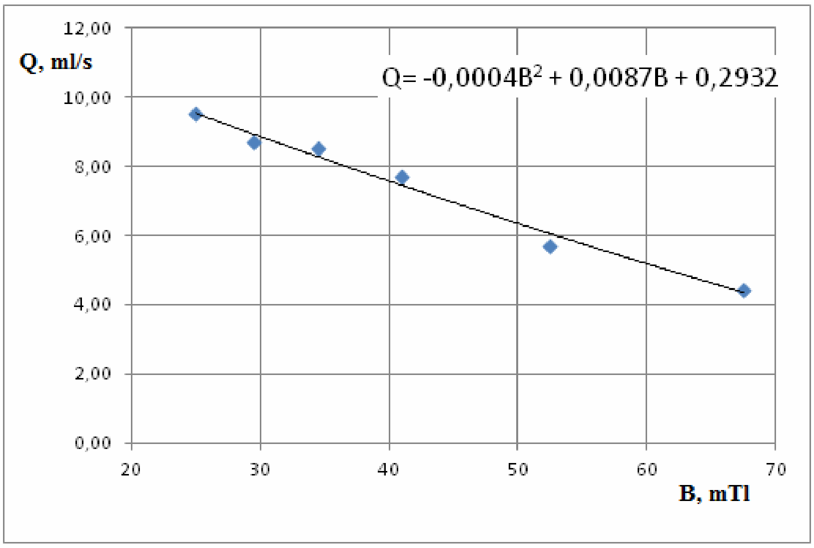

Fig. 2. Dependency graph $Q = f(B)$

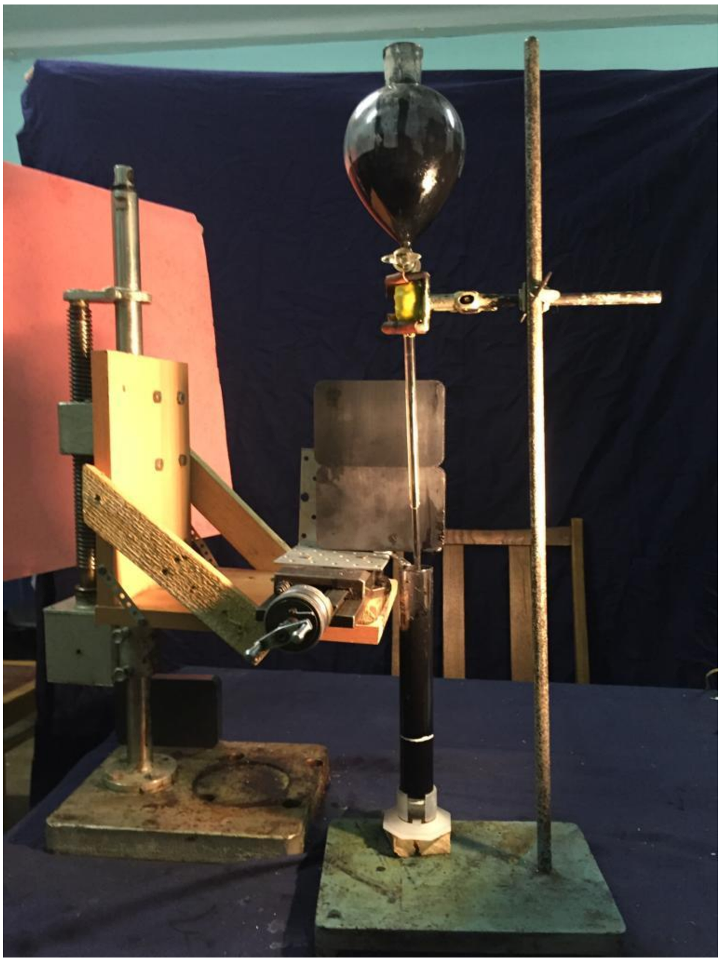

Fig. 3. Experimental stand

Processing of experimental data was carried out with the appropriate methodology for planning experimental data. The analysis of the unstabilized flow in the field of action of magnetic forces was carried out on the basis of the equations of motion:

$$\begin{cases} \rho\left(u_x \dfrac{\partial u_x}{\partial x} + u_y \dfrac{\partial u_x}{\partial y}\right) = -\dfrac{dp}{dx} + \mu \dfrac{\partial^2 u_x}{\partial y^2} - \dfrac{\sigma B_0^2}{c^2} \cdot \dfrac{\partial u_x}{\partial y} \\ \dfrac{\partial u_x}{\partial x} + \dfrac{\partial u_y}{\partial y} = 0 \end{cases} \qquad (1)$$

where u_x, u_y - velocity projections on coordinate axes;
p, ρ - fluid pressure and density;
μ - dynamic viscosity;
σ - magnetic field density;
B_0 - magnetic field induction;
c - speed of light.

In this equation, the influence of the magnetic field was characterized by the term $\dfrac{\sigma B_0^2}{c^2} \cdot \dfrac{\partial u_x}{\partial y}$. Three next cases are considered:

$$\rho\left(u_x \frac{\partial u_x}{\partial x} + u_y \frac{\partial u_x}{\partial y}\right) << \frac{\sigma B_0^2}{c^2} \cdot \frac{\partial u_x}{\partial y}; \qquad (2)$$

$$\rho\left(u_x \frac{\partial u_x}{\partial x} + u_y \frac{\partial u_x}{\partial y}\right) \approx \frac{\sigma B_0^2}{c^2} \cdot \frac{\partial u_x}{\partial y}; \qquad (3)$$

$$\rho\left(u_x \frac{\partial u_x}{\partial x} + u_y \frac{\partial u_x}{\partial y}\right) >> \frac{\sigma B_0^2}{c^2} \cdot \frac{\partial u_x}{\partial y}. \qquad (4)$$

In the case when there are no inertia forces and a magnetic field, the flow is characterized, as is known, as Stokes. For the case when ponderomotive forces act and there are no inertia forces from convective acceleration, the flow is a Hartmann flow. Both the Stokes flow and the Hartmann flow are quite fully described in [1], [3], [4], [8] and others. For the case of an unstabilized flow in the absence of a magnetic field, solutions were obtained for the initial section presented in [9], [10], [11] and others. The most difficult case is when it is necessary to evaluate the influence of both the magnetic field and inertial forces on the characteristics of the initial section.

3. CONCLUSION

Such an estimate was made in this work based on the solution of the corresponding equations of motion during linearization based on the methodology presented in [11]. Based on the solution of the problem in the presented form, the characteristics of the velocity field were obtained for various values of the Reynolds number and the Hartmann number. It is also shown that in the case under consideration, the length of the hydrodynamic initial section is a function of the Reynolds number and the Hartmann number.

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