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COMPUTER MODELLING OF OPERATION OF THE CONDUCTIVE MHD CENTRIFUGAL PUMP

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The mathematical model of the MHD centrifugal conductive pump (CCP) was proposed in [1] and is based on the experimental results obtained for the CCP working model [2]. The MHD- cell scheme shown in fig.1. Voltage U is applied to the electrodes from an external current source; the magnetic field *B* normal to the disk plane is generated by an external magnetic system.

The initial system of equations that describe the flow of a viscous electroconducting fluid in external electromagnetic fields is the known system of equations of magnetic hydrodynamics with consider possible simplifications.

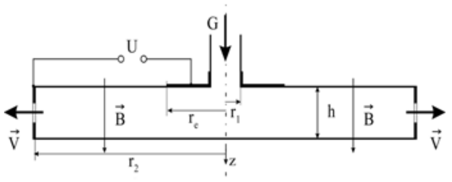

Fig.1. Scheme of the MHD cell

1. Calculation of the magnetic field. The parameter $\Lambda = b_* / B_0 \sim \mu_0 I_* r_* / S_* B_0 = 2\cdot 10^{-7} I_* / hB_0$ r characterizing the normalized induced field is ,where B_0 is the external magnetic field, b_* is the induced field, I_* is the characteristic total current; r_* and $S_* = 2\pi r_* h$ are the characteristic radius and cross section at the current observation point. For typical parameters of the experimental CCP: $I \approx 10^3 A$; $B = 0,4T$; $h = 10^{-2} m$ and the values of the parameters predicted by the estimates for a full-scale CCP: $I \approx 5\cdot 10^3 A$; $B = 2T$; $h = 2\cdot 10^{-2}$ м we have $\Lambda << 1$. Thus, we can neglect the induced field in both cases and consider the flow of an electroconducting fluid in a given magnetic field, which is further assumed to be uniform along the channel.

2. **Calculation of the friction force in the channel.** In engineering calculations of steady viscous layered flows (with one component of the velocity), the friction force is taken in the form [2] $f = \lambda \rho \bar{\upsilon}^2 / 2\ell$, where λ is the dimensionless drag coefficient, ρ is the density, $\bar{\upsilon}$ is the average velocity, and ℓ is the characteristic size normal to the flow velocity direction. For turbulent flows, the proposed definition of the friction force is eventually an empirical presentation of the experimentally obtained quadratic law for the friction force, where the parameter λ is not constant; it depends on the channel geometry and flow regime and is determined on the basis of experimental results. In the case of plane turbulent flow in a

channel the friction force (1) is defined as $\vec{f} = \lambda\rho V^2 / 2\ell \cdot \vec{V} / |V| \equiv \lambda\rho V\vec{V} / 2\ell$.

3. The initial system of equations is presentation in the coordinate vectors $\vec{V}(u,v,0);\ \vec{B} = (0,0,B);\ \vec{j}(j_r, j_\theta, 0)$.

4. The dimensionless turbulent drag coefficient is determined from comparisons of the calculated pressure with the experimental value $p_{\exp}(IB,G) = P_{calc}(IB,G,\lambda)$,

The calculations were performed for the Wood's alloy with ρ = 9430 kg/m^3 and σ = 10^6 S/m. To determine the turbulent drag coefficient λ regime with a non-zero flow rate, a series of calculations with different values of the parameter λ was performed (Fig. 2). The experimental pressure value corresponds to the $\lambda = 0.0181$. The resulting value λ was used in the calculations presented in Fig. 3. The calculated and experimental results on pressure are compared in Fig. 4 and Fig. 5

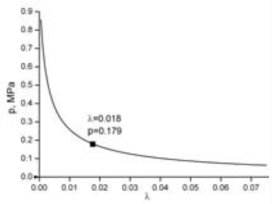

Fig. 2. Pressure versus the turbulent drag coefficient

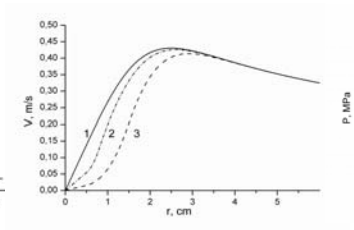

Fig.3. Distribution of the azimuthal velocity along the channel for re = 0.5 (1), 0.8 (2), and 1.5 cm

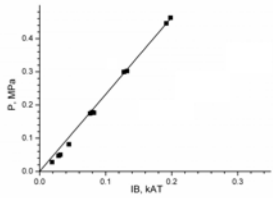

Fig.4 Pressure versus the parameter IB in the regime with a zero flow rate. The symbols are the experimental points for r_e = 0.8.

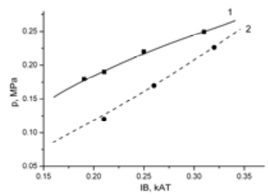

Fig. 5. Comparative characteristics of the calculated and experimental data at r_e = 1.5 cm, G = 0.15 (1) and 0.4 kg/s (2).

Verification of the mathematical model was based on the experimental results presented in the [3], where it was determined the dependence of the pressure at the pump outlet on the parameter IB, flow rate, melt density and geometry MHD- cell. From a comparison of the calculated and experimental values obtained pressure dependence of the drag coefficient on the above parameters. The dependences obtained are presented in the form of splines.

Conclusion. A simple mathematical model is developed, which ensures an adequate description of operation of an MHD centrifugal conductive pump as a function of the set of the governing parameters. The implementation of this model in a computer code can be used to design pumps of this type and to control their operation in the technological process.

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