EFFECT OF THE CONDUCTIVITY OF THE END WALLS ON THE CHARACTERISTICS OF AN MHD CENTRIFUGAL CONDUCTION PUMP. I. EXPERIMENT

V. A. Gorbunov, A. A. Klyukin,
Yu. B. Kolesnikov, and V. E. Kolokolov

UDC 537.84: 621.313.532

The working volume of an MHD centrigal conduction pump [1] consists of a cylindrical enclosure filled with a liquid metal. A radial electric field, which guarantees that an electric current flows fromthe center to the side wall, is created inside the volume. When a constant uniform magnetic field is switched on parallel to the axis, the Lorentz force causes the liquid metal to rotate. The radial pressure drop created by the rotation ensures that metal flows into the output pipe, situated on the lateral wall.

The p(Q) characteristics of a model of such an MHD centrifugal conduction pump, measured on the horizontal mercury loop at the Institute of Physics of the Academy of Sciences of the Latvian SSR, are presented in [2]. It was found that the flow rate and, especially, the pressure developed by the pump in the cuttoff mode depend strongly on the conductivity of the end walls of the working zone. The purpose of this study is to investigate in detail the dependence of the pump characteristics on the conductivity of the end walls. This is important, because inthe commercial variant of the pump, in order to pump lead the working channel is made out of stainless steel.

The setup and a model of the pump are described in [2]. The pressure developed by the pump and the distribution of the gradient of the electrical potential as a function of the conductivity of the end walls, working current, and magnetic field were measured. The measurements were performed in a regime without flow through. The pressure developed by the pump was measured by indicating and mercury manometers, while the gradient of the electrical potential was measured with the help of conduction probes, consisting of a pair of thin copper wires (d = 0.3 mm), separated by a distance of 2 mm. The lateral surface of the wires was coated by electrically insulating lacquer and the ends were sharpened and amalgamated. The probes were distributed vertically in the central plane along the radius of the working zone with a step of 15 mm. The potential difference induced by the motion of the metal between the electrodes of the probes was measured by a V2-15 microvoltmeter.

The potential difference $\Delta\varphi$ measured by the probe can be expressed with the help of Ohm's law for a slowly moving medium in the form

$$\Delta\varphi = \left(-\frac{j}{\sigma} + vB\right)\Delta r, \tag{1}$$

where Δr is the distance between the electrodes of the probe; j, current density; σ, conductivity of the medium; v, azimuthal flow velocity of the metal; and B, magnetic induction.

To calculate the velocity from Eq. (1), it is necessary to know the current distribution in the working volume, which, generally speaking, is unknown, so that the current can be redistributed vertically over the working zone and be forced out onto the conducting end walls. For this reason, if we are talking about the velocity, then additional assumptions concerning the current distribution are required. We shall talk about the distribution of the gradient of the potential, making the assumption that qualitatively the radial distribution of the azimuthal velocity and the radial gradient of the potential repeat one another and their current and field dependences coincide. The conclusions drawn based on this assumption concerning the character of the change in the pressure with increasing current and field do not contradict the results obtained from the pressure measurements.

Figure 1 shows the indications of the conduction probes in the working volume of the pump with nonconducting walls. The diameter of the working zone was equal to 150 mm and its height was equal to 15 mm. The measurements were performed for values of the magnetic induction B = 0.5 and 0.8 T and for a current of

---

Translated from Magnitnaya Gidrodinamika, No. 4, pp. 105-108, October-December, 1984. Original article submitted June 5, 1984.

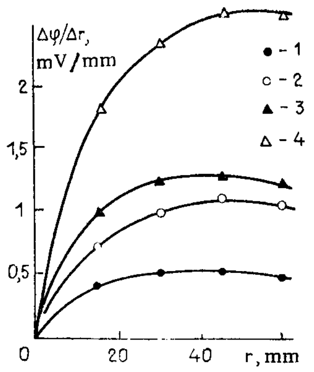

Fig. 1

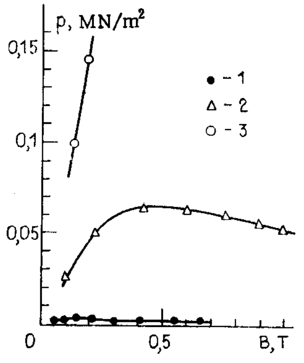

Fig. 2

Fig. 1. Radial distribution of the gradient of the potential in the working volume of the model of the pump with nonconducting end walls. I (kA) and B (T): 0.1 and 0.5 (1); 0.1 and 0.8 (2); 0.5 and 0.5 (3); 0.5 and 0.8 (4).

Fig. 2. Pressure developed in the model of the pump for different thicknesses of the conducting end walls. Δh (mm): 1 (1) and 0.1 (2). The curve 3 corresponds to the case of nonconducting end walls [2]. $I = 1$ kA.

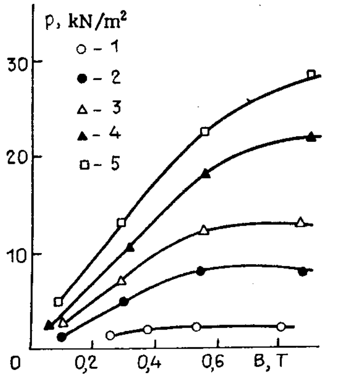

Fig. 3

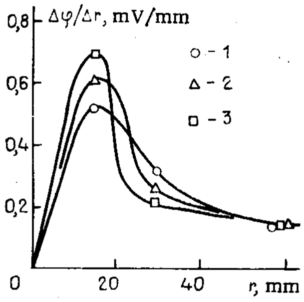

Fig. 4

Fig. 3. Field dependence of the pressure for low values of the working current in a model with nonconducting end walls. The current I (A): 1) 10; 2) 20; 3) 30; 4) 40; 5) 50.

Fig. 4. Radial distribution of the gradient of the potential for the case of conducting end walls with a thickness of $\Delta h = 1$ mm, $I = 2$ kA; B (T): 1) 0.2; 2) 0.5; 3) 0.7.

$I = 0.1$ and 0.5 kA. As is evident from the figure, the potential difference and, under the assumption adopted, also the rate of rotation of the metal in the working zone of the pump increase up to a radius of 45 mm and thereafter remain virtually constant. This radial distribution of the gradient of the potential, as shown in [3], differs substantially from the distribution calculated for the laminar regime. Evidently, in the range of currents studied, the regime of motion in the working volume of the model of the pump was no longer laminar. This is indicated by both the irregular pulsations of the gradients of the potential measured by the probes and the linear current and field dependences of the pressure obtained experimentally in [2] (Fig. 2), which also differ from the dependences computed for laminar motion [3]. More detailed measurements showed that as the working currents are decreased to 10-50 A, the growth in the pressure with increasing fields slows down (Fig. 3). This dependence agrees better with the computed dependence [3]. Apparently, in this case, a regime of motion which is intermediate between laminar and developed turbulence occurs.

Figure 4 shows the indications of the conduction probes in the working zone of the pump with conducting end walls. As in [2], the walls consisted of copper disks 1 mm thick. In this case, the conductivity of the end walls exceeded by a factor of 9 the conductivity of the mercury in the working zone. The measurements were

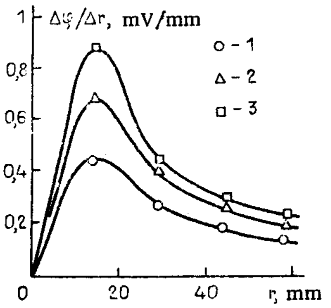

Fig. 5

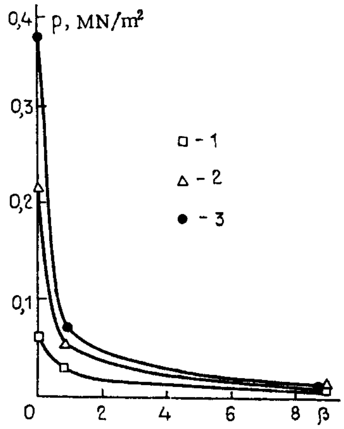

Fig. 6

Fig. 5. Distribution of the gradient of the potential for the case of conducting end walls of thickness $\Delta h = 0.1$ mm. $I = 1$ kA; B (T): 1) 0.2; 2) 0.5; 3) 0.8.

Fig. 6. Dependence of the pressure developed in the model on the relative conductivity of the end walls $\beta = 2\Delta h\sigma_1/h\sigma$ (h is the height of the working volume, σ_1 is the specific electrical conductivity of the wall). $I = 0.5$ kA; B (T): 1) 0.1; 2) 0.5; 3) 0.8.

performed for magnetic inductions of $B = 0.2$, 0.5, and 0.7 T; the working current was equal to $I = 2$ kA. As is evident from the graphs, the distributions of the gradient of the potential in the case of nonconducting (Fig. 1) and conducting (Fig. 4) end walls differ considerably from one another. The previously measured potential differences increased with the radius, whereas now significant potential differences are observed only in the region near the axis and they decrease markedly as the distance from the axis increases. This fact is explained by the displacement of the working current out of the working zone onto the conducting end walls. As the magnetic field is increased, the current displacement is manifested increasingly more strongly. It was noted in [2] that in the range $B = 0.3$-0.6 T, the pressure developed by the pump drops as the field is increased. Taking into account what was said above regarding the relationship between the gradient of the potential and the velocity, this fact qualitatively agrees with the results illustrated in Fig. 4.

In the case when the end walls of the pump consisted of copper disks 1 mm thick, the ratio of the conductivity of the end walls of the pump to the conductivity of the metal in the working zone was higher than in the commercial variant of the stainless steel pump for pumping fused lead. Figure 5 shows the results of the conduction measurements for the case corresponding to the real situation when the conductivity of the end walls is approximately equal to the conductivity of the volume of working liquid. In this case, in the model of the pump, the copper disks were replaced by foil-covered textolite with a copper coating 0.1 mm thick.

A comparison of Figs. 4 and 5 shows that the distributions of the gradient of the potential for thick and thin conducting end walls of the pump qualitatively coincide. There is, however, a quantitative difference in the values of the potential gradients measured by the probes. A comparison of the results obtained leads to the conclusion that the effect of displacement of the working current onto the conducting foundations, in the case of thin foundations, is not manifested as strongly. Most of the current in this case flows along the liquid, and the rate of rotation of the liquid increases. This increases the pressure developed by the pump over the case of thick end walls. Figure 2 shows the dependence of the pressure developed by the pump in the locked mode on the magnetic field for different wall thicknesses. The data presented permit constructing the dependence of the pressure developed by the pump on the conductivity of the end walls for different values of the magnetic induction (Fig. 6). They can be used to estimate the efficiency of the pump in pumping different media.

LITERATURE CITED

1. D. G. Bykhovskii, Yu. A. Krylov, V. I. Platonov, and A. N. Panov, "Magnetohydrodynamic pumps for melts of nonferrous metals," in: Abstracts of Reports at the Second All-Union Conference on the Application of Magnetohydrodynamics in Metallurgy and Casting, Institute of Applied Casting, Academy of Sciences of the Ukrainian SSR, Kiev (1981), Pt. 2, pp. 170-171.
2. V. A. Gorbunov, Yu. B. Kolesnikov, V. E. Kolokolov, N. N. Polyakov, and V. V. Frolov, "Experimental study of the characteristics of a model of a centrifugal conduction MHD pump," Magn. Gidrodin., No. 1, 134-137 (1984).

3. V. A. Gorbunov, and V. E. Kolokolov, "Effect of the conductivity of the end walls on the characteristics of a centrifugal conduction MHD pump. II. Theory," Magn. Gidrodin. (to be published).