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STUDY OF A MODEL OF THE SPIRAL WINDING-FREE MHD PUMP

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This paper presents a design of the spiral winding-free MHD pump engineered to transport liquid metals and alloys. A distinctive feature of this pump is that it has a spiral channel. By changing the number of turns in the channel and by modifying the channel cross-section, the pressure drop–flow characteristics can be varied over a wide range. To generate an induction magnetic field, several "electrical loop" arrangements have been considered. The pressure drop–flow characteristics of the pump have been determined in experiments with a gallium circuit.

Introduction. The pumping effect in the channel of an MHD pump is caused by the interaction of the electric current passing through the liquid metal in the channel with its own magnetic field. MHD pumps based on this concept are sometimes called winding-free, so empasizing the lack of coils generating a magnetic field. These pumps have ferromagnetic cores, amplifying and distributing in a certain way the magnetic field generated by the electrical current in the channel. The interaction of the electric current and its own magnetic field produces an electromagnetic force, which pumps the liquid metal through the channel.

The winding-free "pull-push" MHD pump is currently in service at Berezniki JSC AVISMA Ltd. Company and at Solikamsk Magnesium Plant (Russia), where it is used to supply liquid magnesium to a foundry conveyer [1]. The pump has a simple design, which allows the pump channels to be manufactured at the plant, where the pump is employed, and offers no problems with replacing the old channel with a new one. The pump can be easily operated and maintained. The pilot model of the pump was tested in gallium experiments performed at the facilities of the Institute of Continuous Media Mechanics, UB RAS (Perm, Russia). These experiments yielded the following characteristics: at an electric current of 3000 A in the channel, the pump created a pressure of 27 kPa under shutdown conditions, and a pressure of 23 kPa at a flow rate of 176 ml/s.

Magnetohydrodynamic (MHD) pumps are widely used in modern industries, which place heavy demands to their design and operation characteristics. Such systems should be reliable, safe, lightweight, small in size, simple in design, etc. The spiral winding-free MHD pump considered in this paper has been designed for the transportation of low-melting metals and alloys.

There is a conduction spiral MHD pump, which is able to create high pressures up to 1 thousand atmospheres [2]. This pump has a channel made from a stainless steel tube of Archimedean coil configuration (adjacent turns are connected to each other electrically). The channel is placed in a steady magnetic field directed normal to the plane of this channel (Fig. 1). The radial electrical current interacts with the magnetic field, which causes the motion of liquid metal in the channel.

However, this pump suffers from some disadvantages. Its magnetic system consists of an armoured magnetic core with a magnetizing coil and a DC power

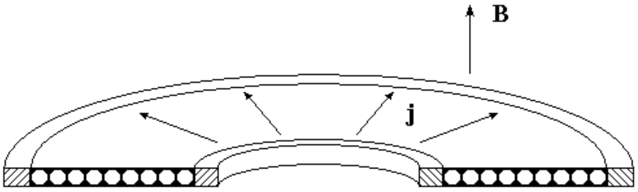

Fig. 1. Diagram of the channel of the spiral MHD-pump in section.

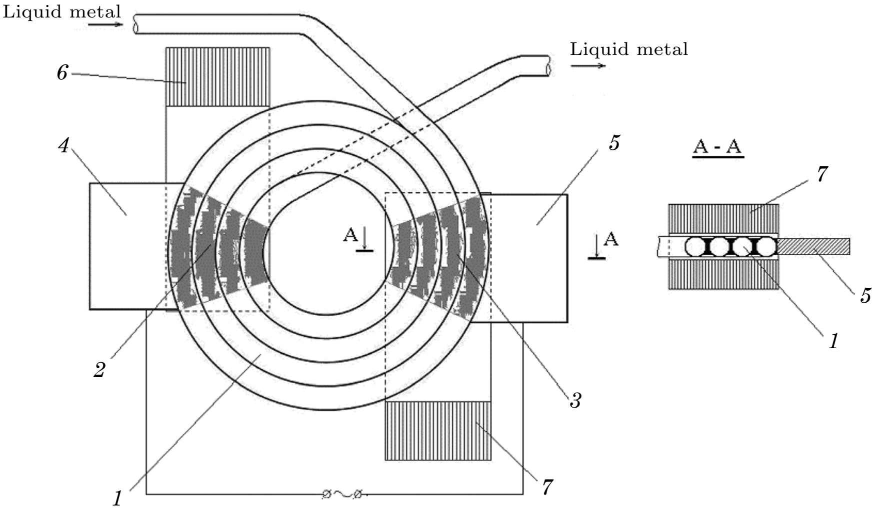

Fig. 2. Schematic view of the spiral winding-free MHD pump.

supply, and hence is rather massive. The spiral channel of the pump has quite a lot of turns (about 50). This pump creates a pressure of hundreds of atmospheres, but has a relatively low flowrate. The model of such a pump was tested in a series of gallium alloy experiments. The pump channel was made from a tube with an internal diameter of 4 mm and a wall thickness of 1 mm and had 44 turns. With a magnetic field of 1.63 T and a current of 5220 A, the model created a pressure drop of 89.2 MPa at zero flowrate and a flow rate of 25 ml/sec at zero pressure drop.

However, for pumping liquid metals under actual operation conditions, it is necessary that the device provides a pressure drop of about 3–7 atmospheres and a flow rate of about 100–200 ml/sec. For this purpose, we have developed a small compact pump, in which electromagnetic forces are caused by the interaction of the current in the channel with its own magnetic field.

Fig. 2 shows the scheme of the pump in section. Channel *1* is designed as an Archimedean spiral of several turns, which are electrically connected (by welding or brazing) to each other in two areas *2* and *3*. Electrodes *4* and *5* are connected to the outer turn of the channel. Ferromagnetic cores *6* and *7* embrace the electrically connected channel parts so that the pressures arising on these channel sections can be summarized.

To test the efficiency of the pump proposed in this study, an experimental model was manufactured. The channel of the model was made from a stainless steel tube with an outer diameter of 12 mm and a wall thickness of 1 mm. The

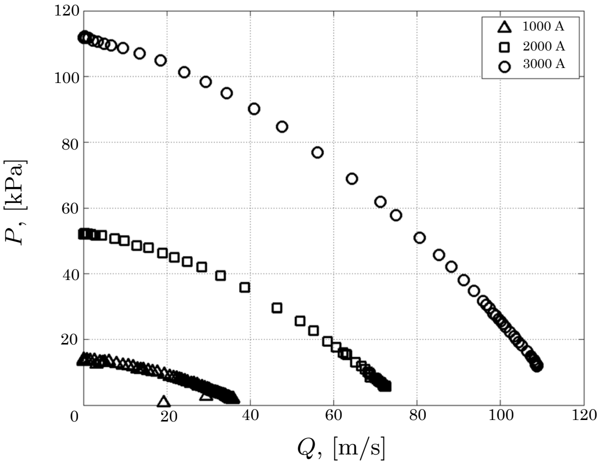

Fig. 3. Pressure drop–flow rate characteristics of the spiral winding-free MHD pump.

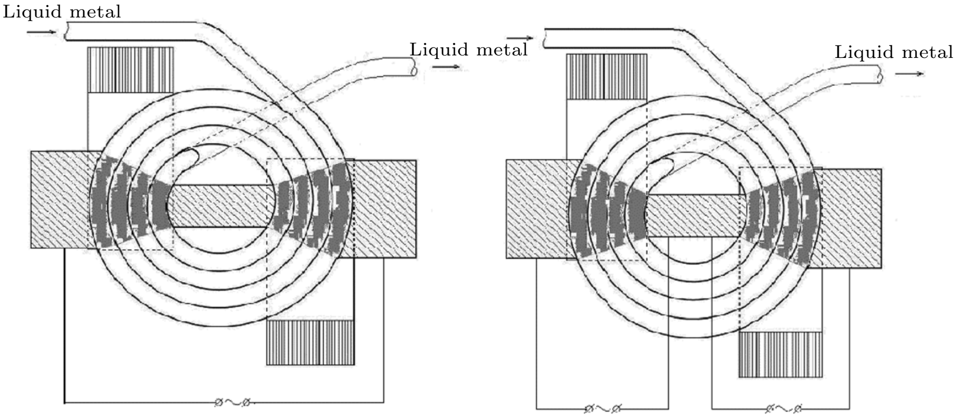

Fig. 4. Connection diagram of the spiral winding-free MHD pump having (left) a channel supplied with an additional electrode (maximum pressure 160 kPa, maximum flowrate 123 ml/s), and (right) a channel supplied with an additional electrode and an additional power supply (maximum pressure 190 kPa and maximum flowrate 152 ml/s.

channel consisted of four turns. The mean value of the inner diameter of the channel spiral was 85 mm. The electrodes were made of copper. The non-magnetic gap of cores was 15 mm, and the width of the cores was 48 mm. The gallium alloy (liquid at room temperature, $T_{\mathrm{m}} = 17°\mathrm{C}$) was used as a working environment. The alloy conductivity is $\sigma = 3.56 \times 10^6$ S. A controlled single-phase transformer with the secondary winding connected to the electrodes of the model was used as a power supply. The error of experimental measurements is 5% [3].

The pressure P is plotted versus the flow rate Q for three values of the current in the channel: 1000 A, 2000 A, and 3000 A (Fig. 3). The maximum pressure is 112 kPa, and the maximum flow rate is 110 ml/sec.

Even slight modifications made to the pump design (an electrode was inserted into the inner turn of the spiral channel to connect channel parts 2 and 3 (Fig. 4, right)) have changed for the better the pressure drop–flowrate characteristics of the model, with the same current values in the channel (Fig. 5, left). The maximum pressure was 160 kPa, and the maximum flowrate was 123 ml/s.

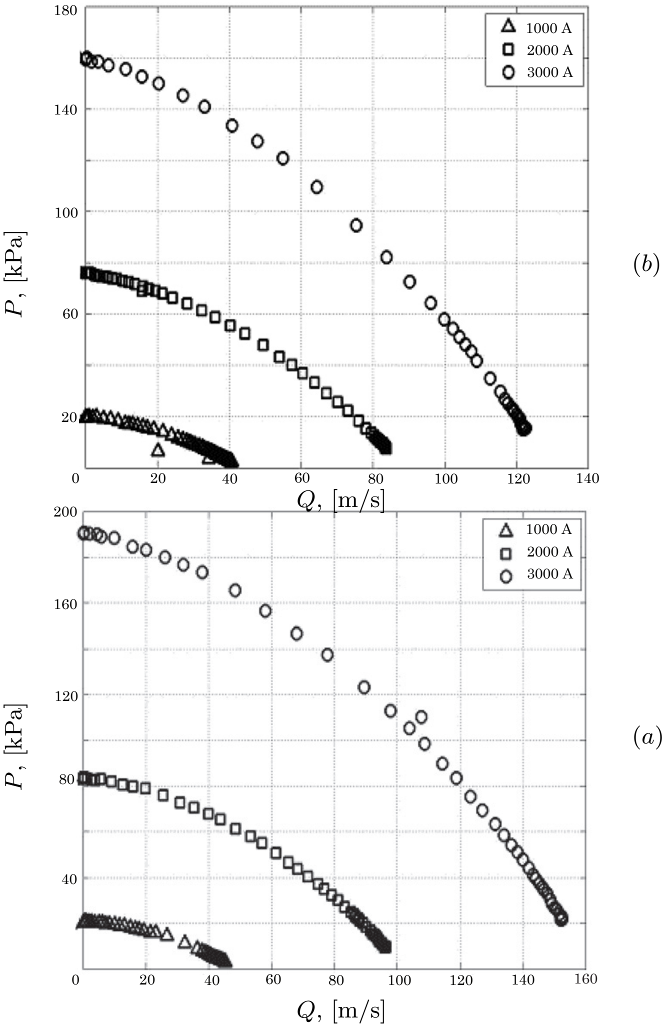

Fig. 5. Pressure drop–flow rate characteristics of the spiral winding-free MHD pump with (a) a channel suppliedd with an additional electrode, and (b) a channel supplied with an additional electrode and an additional power supply.

The change in the connecting diagram of the channel - each section, consisting of electrically connected turns, was attached to an individual power supply (Fig. 4, right) – improved further the pressure drop–flowrate characteristics of the model (Fig. 5, right).

Conclusions. So, by selecting the tube diameter, the number of turns of the channel, the type of the diagram for connecting the channel with a power supply, and the value of the current in the channel, one can change the pump design to obtain the required pressure drop–flow rate characteristics.

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