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EXPERIMENTAL STUDY FOR VERIFICATION COMPUTATIONAL MODELING OF OPERATION OF THE CONDUCTIVE MHD CENTRIFUGAL PUMP

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Abstract. Results obtained for a CCP model operating with a low-temperature working fluid with the main physical parameters close to those of non-ferrous metal melts are reported in this paper. The study was aimed at validating the operability of this scheme in various regimes and obtaining experimental data necessary for testing and verification of mathematical model of the CCP [1].

1 INTRODUCTION

The casting process in metallurgy consists of numerous stages, including metal melting, its transportation, processing (degassing, alloying with various dopes, including nanodisperse inoculators, etc.), and finally pouring. In turn, each stage is a rather labor-consuming process with its own complicated technological chain. A common adverse factor, however, is the contact between the melt and the atmosphere. The problem could be solved by organizing a closed cycle. It should also be noted that organization of such a cycle would make this production more environmentally friendly. An important element of the cycle is the system of liquid metal supply, which should be sufficiently universal for the entire chain of out-of-furnace processing. In particular, it could include the possibility of inserting alloying dopes and nanodisperse inoculators directly into the flow with casting under a controlled pressure, which would allow obtaining cast product of an almost arbitrary degree of complexity and high quality. It is commonly accepted that a magneto hydrodynamic (MHD) system can serve as such a device [2-4]. An analysis shows that the most promising design among all possible conductive MHD pumps is the disk scheme of the centrifugal conductive pump (CCP), which has currents 1.5-2 times lower than linear schemes and allows current-carrying electrode units to be taken out from the working area.

Two views (along of magnetic field direction – a, across one - b) of a possible scheme of such a pump are shown in Figure 1. An integral MHD cell 1 of the pump is made, as usual, of heat-resistant ceramics and is placed into a cooled pump casing built into the magnetic conductor of the setup. The melt enters the cell center through channel 2 and leaves the cell through channel 3. A current source is connected outside the cell through terminals indicated by plus and minus.

The CCP operation principle is based on using rotational motion of the medium for generating a centrifugal force and, correspondingly, increasing the pressure at the pump output. Rotation of the liquid metal is provided by the Lorentz force F induced by interaction of the radial flowing current *I* with the normal magnetic field *B*. When the rotating fluid interacts with the magnetic field, an electromotive force arises in the fluid, which prevents the current flow. As the velocity at the end faces of the channel is smaller because of viscous effects, more favorable conditions for the current flow are formed there, which results in current redistribution toward the walls (Hartmann effect). In this case, losses are drastically enhanced, and the pump efficiency decreases. The adverse influence of the Hartmann effect can be alleviated by providing a turbulent flow regime where the velocity profile is more filled and uniform and the boundary layer is thinner. It is this regime that is realized in disk CCP schemes.

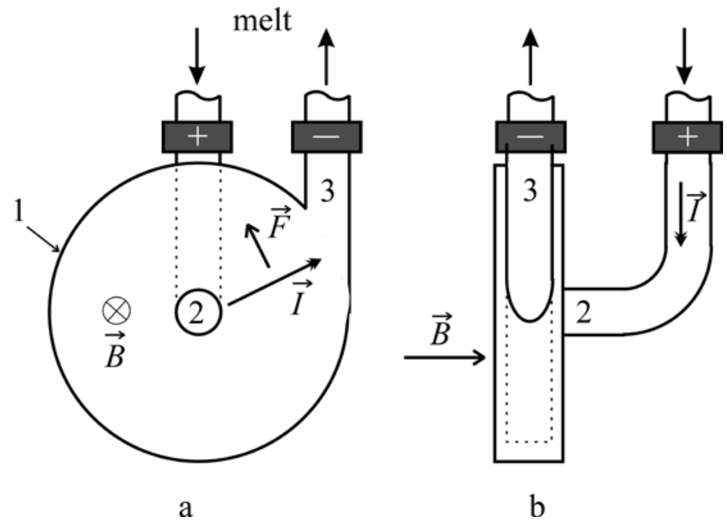

Figure 1: Principial scheme of the centrifugal conductive MHD pump

2 EXPERIMENTAL SETUP AND METHODS

The Figure 2 schematically shows an axial sectional view of an experimental model of a centrifugal pump. The pump consists of a housing 1, cover 2 with the melt reservoir 3. Surfaces covered with the insulating cover layer. The reservoir is separated from the metal insert of the pump diameter of 18 mm (6). The hole diameter in the center rates of 8 mm. The experiments were conducted with three inserts. Inserting one surface coated with an insulating layer except the opening. The other bottom surface of the insert partially covered insulator, so that electrical contact with the melt has a diameter of 12 mm. The lower surface of the third insert is not insulated , so that the contact area is equal to the diameter of 18 mm. The center electrode 4 is the tank .Distancing ring 5 sets the width of the pump channel. Material derived from the pump through the duct 7and tube 8 as the arrow shows. The internal disc cavity of the pump S may be electrically insulated from the pumped metal. Channels 10 are used for connection of pressure sensors for registering the distribution of static pressure in the duct of the pump. The pump is placed in a magnetic field **B** normal to the plane of the disk channel. Current source (lead accumulator), fed the pump, connected to the central electrode and the housing as shown. The pump had an ohmic heater (not shown in the diagram), allows you to set the temperature of the melt.

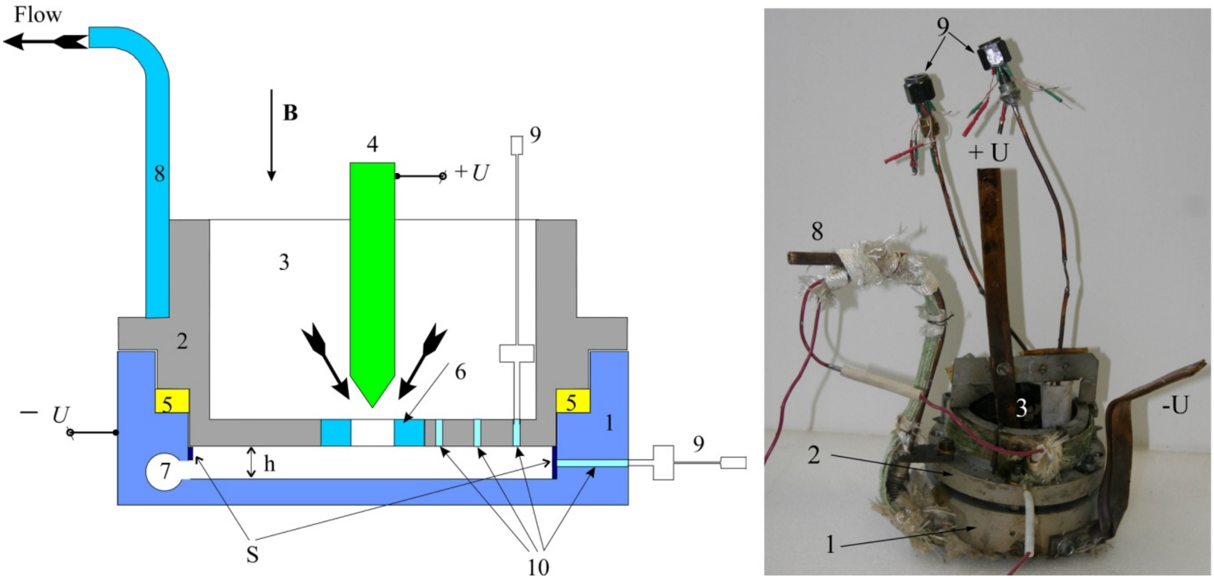

Figure 2: Scheme of the experimental pump cell and it's photography

Figure 3a shows the scheme for measuring pressure, allowed to separate the hot melt from strain gage must remains at room temperature. Figure 3b shows the calibration curve of the measuring system. The measured pressure is transmitted to the sensor *1* (KPY44A type) via a tube filled with molten metal *2* and the tube *3* is filled with mineral oil. Tubes are separated by soft rolling diaphragm annealed nickel foil *4*. Tube *3* is of sufficient length that ensures that the room temperature sensor. Calibration of the sensors was performed at an operating temperature of the pump, filled with the melt. Reference pressure was applied through the outlet tube *8* (Figure 2) at the muffled inlet *6* (Figure 2). The calibration dependence is linear with a high accuracy. On the graph shows the corresponding analytical expression. Small dc offset signal is usually for strain gages.

Mass flow rate was measured using strain-gauge balance. Scales recorded the time dependence of the melt mass ejected from the outlet tube 8. Outlet diameter varied from 1.5 to 2.3 mm and wondered installed at the outlet flow washer 8.

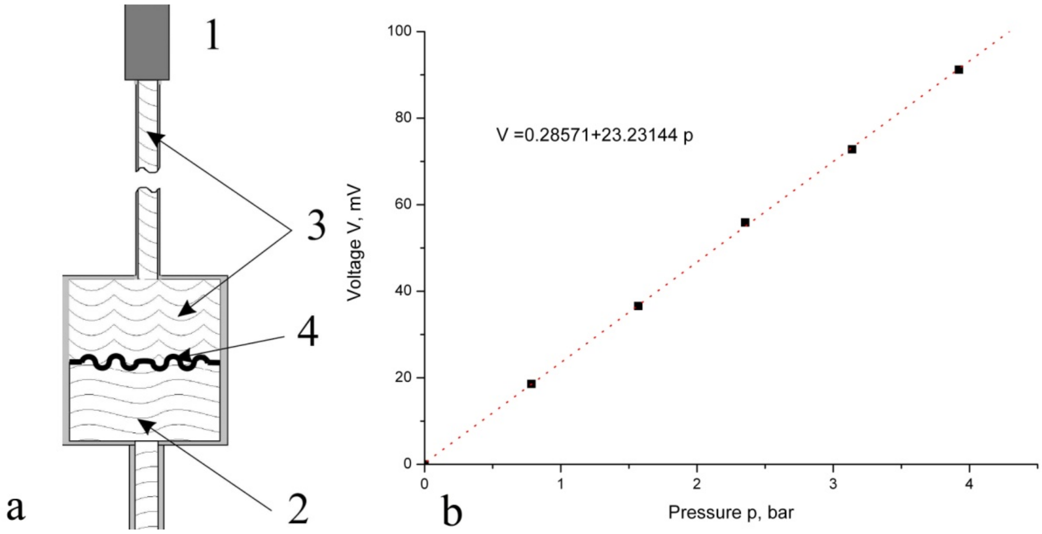

Figure 3: Scheme of the pressure measurement (a) and typically voltage-pressure dependence for him (b)

3 RESULTS

Theoretical models of CCP describe the dependence on the value of the pump performance parameter $I \cdot B$, where I - current through the pump cell , B - magnetic induction , which is placed in the pump. Therefore, the pressure developed by the pump and the flow rate measured in the experiments associated with the value of this parameter.

3.1 Mass rate *G*=0

In the graphs of Figure 4a shows the pressure dependence of the parameter values $I \cdot B$ for the different channel width h - 4, 8 and 12 mm.

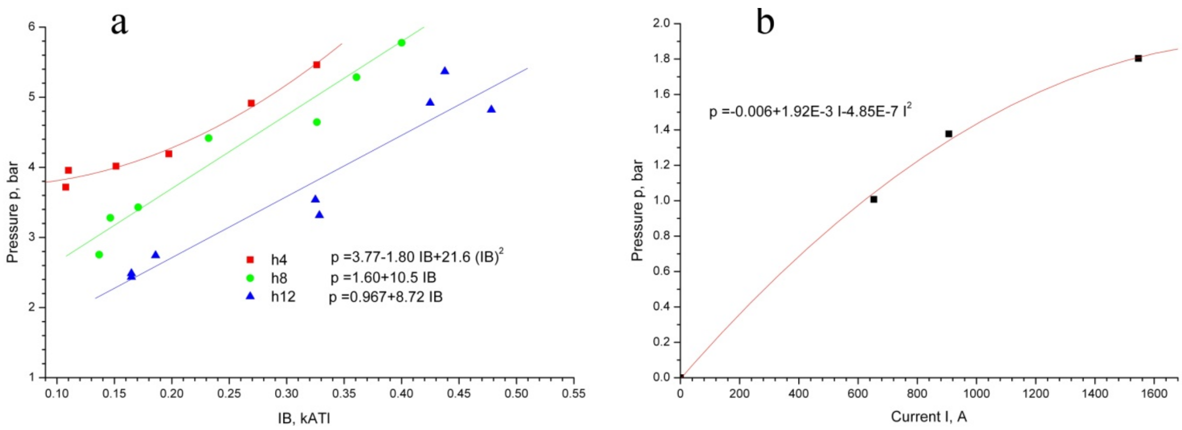

Figure 4: Page layout

Data obtained by varying the magnetic induction. The amount of current I slightly changed values near 1800 A for h = 12 mm, 1600A for h = 8 mm and 1200A for h = 4 mm. The current value decreased with the channel width, as the ohmic resistance of the cell increased.

On the graph shows the corresponding analytical curves obtained by fitting the experimental data. Fig. 4b shows the current dependence of the pressure at the outlet in zero external magnetic field.

3.2 Mass rate $G \neq 0$

Depending on mass rates of the pressure developed by the pump, for various values parameter *IB* is given in Figure 5. These curves were obtained by processing the experimentally obtained dependences *p (IB)* and *G (IB)* for various flow sections diaphragms fitted at the outlet tube 8 (Fig. 1). Taken into account part of the mass rate gives by the interaction of the current with only the external magnetic field. The figure shows the approximate linear dependences of *p (G)* for the parameter values *IB*: 0.45 kATl, 0.35 kATl, 0.25 kATl and 0.15 kATl.

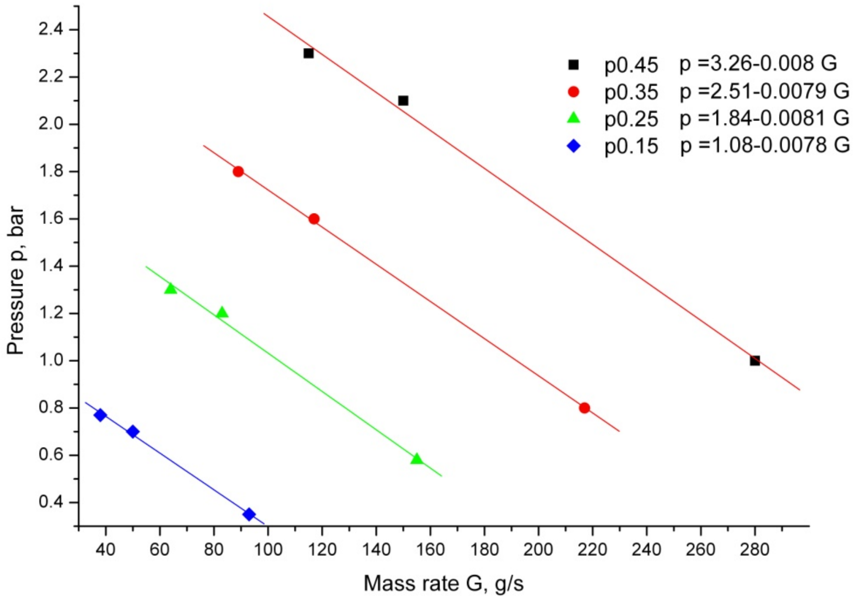

Figure 5: Pressure vs mass rate for differ *IB* values

4 RESULTS DISCUSSION

Figure 6 helps to explain present of the azimuthally flow and non zero pressure in zero external magnetic field. In the figure labeled: *1* - the outer cylindrical wall of the pump casing, *2* - central inlet and electrode *4* (Figure 1), *3* - melt channel pump. The current **I**, is connected to the pump housing, creates a magnetic field **B** within the channel. The radial component of the current flowing through the channel interacts with the magnetic field. The resultant force **F** gives rise to an azimuthally flow melt. If the current direction of the force of interaction with the external magnetic field coincides with the direction of the force F, the pressure developed by the pump is increased. The plots in Figure 4a indicate that. Thus, the pump can operate without an external magnetic system. With a narrow channel (h = 4 mm) current density in the channel is high and is associated with this quadratic dependence of the pressure on the parameter *IB*. With wider channel linear dependence. If we subtract a constant offset pressure, then the remaining part describes the case of a symmetric connection of the pump housing to the source. These adjusted data were used to verify the mathematical model of the pump.

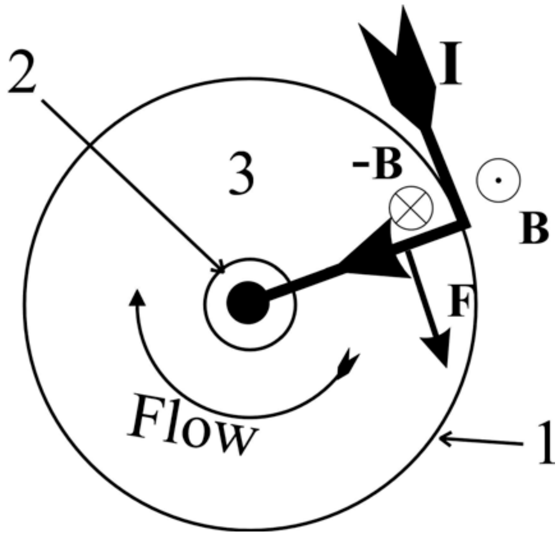

Figure 6: To the explanation of the azimuthally flow in zero external magnetic field

5 CONCLUSIONS

- Obtained experimental data on the pressure developed by the pump and the flow rate for different values.
- Determine the empirical formula for the dependence of the pressure and flow parameter t needed to verify the mathematical model of the pump.

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