EXPERIMENTAL INVESTIGATION OF THE FLOW RATE OF HEAVY LIQUID-METAL COOLANT

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The purpose of the present work was to investigate experimentally the flow velocity of lead–bismuth eutectic in a channel whose cross section is circular and where the oxygen content is monitored and regulated [1].

The high-temperature liquid-metal stand FT1 was developed to perform these investigations. The stand contains an experimental section with a sensor for measuring the local velocity in the cross section of the channel (Fig. 1). The experimental section consists of a tube (tube material – 08Kh18N10T austenitic steel) with inner diameter 26 mm and wall thickness 3 mm. The velocity was measured in the lead–bismuth coolant flow.

The sensor permits measuring the potential \( H_{\text{pot}} \) and total \( H_{\text{tot}} \) heads of the liquid metal flow. The local velocity at a given point of the flow is calculated according to the difference of the total and potential heads. The total head was measured with a capillary (tube with inner diameter 1 mm and wall thickness 0.25 mm); the free end of the tube is directed toward the flow of the lead–bismuth eutectic and the other end is embedded in the flow deflector on the probe (Fig. 2). The alloy flows through the capillary and system of pipes into a tank for measuring the total head of the flow. The potential head was measured through an opening in the wall of the experimental section. The free end of the capillary and the opening for measuring the potential head are located in the same pipe segment in the experimental section. The eutectic flows through the opening for measuring the potential head and then through a system of pipes into a tank for measuring the potential head.

The capillary can be moved in a radial direction along the section of the channel by moving a spacer plate by means of a nut. The spacer plate is connected to the tube; a probe with the capillary is secured at the opposite end of the tube.

The tanks for measuring the total and potential heads are vertical and made from identical tube sections with inner diameter 25 mm, wall thickness 3.5 mm, and length 500 mm. A corresponding line for measuring the head (total or potential) is connected to the bottom of each tank; the seal of a movable electric-contact rod is placed in the cover.

**Experimental Procedure.** The experiments were performed with lead–bismuth eutectic temperature 400–420°C, thermodynamic activity of oxygen \( a = 10^{-4} \)–\( 10^{-6} \), coolant flow through the experimental section 1.8–3 m\(^3\)/h, average velocity 1–1.7 m/sec, and Reynolds number \( (1.6–3) \times 10^5 \). A magnetic flow meter was used to determine the flow rate in real-time; the meter was calibrated at least once per day by the volume method. The oxygen content in the liquid-metal coolant was measured by feeding oxygen into the stand’s gas system in a mixture with atmospheric air or hydrogen.

The experimental program consisted of several stages. At each one, a definite thermodynamic activity of oxygen was attained and maintained in the lead–bismuth eutectic and loop, after which the velocity was measured. Measurements in the steady-state regime were performed for three values of the coolant flow rate through the experimental section. The local velocity was measured at six points (0.75, 1.75, 3.75, 6.75, 9.75, and 13 mm) over the cross section of the channel for each established and maintained flow rate. At \( r = 0.75 \) mm, the capillary touches the inner surface of the channel in the experimental section, and at \( r = 13 \) mm the axis of the capillary coincides with the axis of the channel.

The local velocity was calculated from the Bernoulli equation

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V = (2gH_d)^{1/2},
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where \( g = 9.81 \text{ m/sec}^2 \) is the acceleration of gravity; \( H_d = H_{\text{tot}} - H_{\text{pot}} \) is the dynamic head, m; and \( H_{\text{tot}} \) and \( H_{\text{pot}} \) are the total and potential heads, respectively.

The difference between the total and potential heads during the course of an experiment was measured as follows. The tanks for measuring the total and potential heads communicated with one another by means of gas. Thus a pressure arose in the tanks and a corresponding level of the heavy liquid-meal coolant was established in them. Next, the electric contact rods were moved until they touched the free level of the liquid metal in the inner cavity of a tank. This generated a light signal and the position of the electric-contact rods was recorded. The difference of the column heights of the liquid metal coolant measured according to the position of the electric contact rods was the dynamic head at the running point.

The experimentally obtained velocity of the lead-bismuth eutectic in a circular channel can be represented in the form of plots of the function \( V/V_{\text{av}} = f(r/r_0) \), where \( r \) is the running value of the radius, \( r_0 = 13 \text{ mm} \) is the radius of the tube in the experimental section, and \( V_{\text{av}} \) is the average velocity calculated as the arithmetic-mean value of the measured local velocity over the cross section of the channel with different values of the thermodynamic activity of oxygen and Reynolds number (Fig. 3).