EXPERIMENTAL INVESTIGATION OF A LIQUID-METAL INDUCTION-TYPE MACHINE UNDER PUMPING CONDITIONS

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An investigation was made of a liquid-metal magnetohydrodynamic machine with a helical channel. The efficiency of the machine was verified at temperatures up to 550°C. An efficiency of 31 % was obtained at a potassium temperature of 300°C, a voltage of 145 V, a pressure head of 20.5 kg/cm^2, and a mass flow rate of 0.64 liter/sec. The maximal pressure drop was 41 kg/cm^2, at a mass flow of 0.2 liter/sec and the same values of the temperature and the voltage.

In 1971 an experimental investigation was made of a high-temperature induction-type magnetohydrodynamic machine with a helical channel, under pumping conditions; construction-wise, the machine was similar to the machines described in [1, 2].

The difference in the example under consideration consists in the use of a loop-type three-plane winding of the drum type, instead of an annular winding, encompassing the back of the magnetic conductor. The winding was made of Brand POZh wire, which permitted carrying out experiments without forced cooling at temperatures of the working body (potassium) up to 550°C.

To determine the magnetic flux the machine was equipped with measuring coils at the base and at the back of a magnetic conductor, as well as with the necessary number of thermocouples.

The channel of the machine was installed in the gap between axisymmetric external and internal magnetic conductors; the internal magnetic conductor was made without grooves, while the external magnetic conductor was provided with closed grooves.

The main structural data of the machine were: number of poles, $2p = 2$; polar scale division $\tau = 10$ cm; mean diameter of winding of channel, $D = 63.8$ mm; number of turns of helical line, $n = 8$; internal cross section of channel $a \times b = 25.6 \times 4$ (mm); thickness of channel wall, $\Delta_w = 0.25$ mm; material of channel, steel Kh18N10T; number of grooves per pole and phase, $q = 1$; number of turns in a phase, $w_{ph} = 56$.

The investigations were made in a potassium loop with a working pressure up to 65 kg/cm^2 and a working temperature up to 600°C. The mass flow rate of the liquid potassium was measured using two conduction-type flowmeters, with subsequent monitoring of the result obtained from the conditions for the coincidence of the velocity of the metal in the channel of the machine being investigated, v_M, and the velocity of the rotating field, v_s, at a working frequency of 50 Hz. To obtain the conditions for a synchronous velocity, an electromagnetic pump was used as an accelerating device. The mass flow rate and the pressure were measured by regulation of the feed voltage of the machine and by a regulating valve. The error in measurement of the electrical quantities was less than ±1 %, of the mass flow rate ±5 %, and of the pressure ±1 %.

Experimental Data

Before the experiments, the characteristics of no-load operation were recorded. Figure 1 gives the

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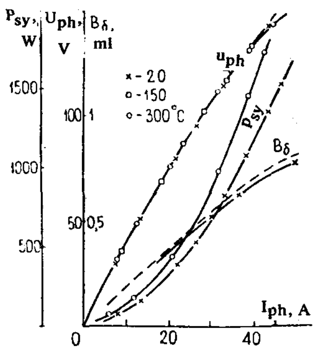

Fig. 1

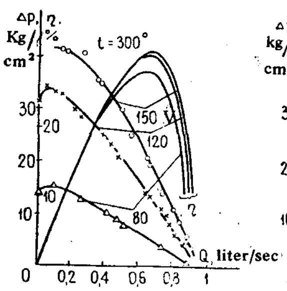

Fig. 2

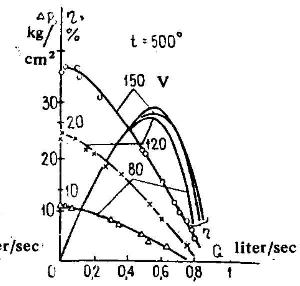

Fig. 3

dependence of the required power, the voltage, and the induction, as a function of the mean value of the phase current. The induction was measured using measuring pickup loops in the gap between the magnetic conductors, during the fabrication of a machine without a helical channel.

To check the accuracy of the calculations, an experimental determination was made of the losses in the copper winding, in the steel, and in the walls of the channel, and of the values of the magnetic fluxes in the front parts of the winding, in a tooth, and in a yoke of a magnetic conductor.

During the course of the measurements, the pressure head-mass flow rate characteristics were obtained at temperatures of 300-500°C and feed voltages up to 150 V. The following quantities were measured: the pressure at the inlet and the outlet of the machine; the mass flow rate; the phase voltages; the currents and the powers; the electromotive force of the measuring coils; the temperature of the metal and of the winding. Figures 2 and 3 give the dependences of the pressure head and the efficiency on the mass flow rate of the metal at potassium temperatures of 300 and 500°C.

At small mass flow rates (less than 0.2 liter/sec) there is noted a certain nonlinearity with a marked maximum of the pressure, due mainly, in our opinion, to an increase of the temperature of the metal in the channel. Maxima of the efficiency occur at mass flow rates of 0.5-0.63 liter/sec.

Figure 4 gives the dependences of the electromagnetic power N_e on the mass flow rate, as a measure of which there was adopted the reading of the flowmeters, in millivolts. The power was determined as the difference between the power required from the circuit and the losses in the copper, the walls of the channel, and the steel of the machine at corresponding voltages and temperatures. It is evident from the curves that these characteristics intersect, with a certain scatter, at a single point on the axis of abscissas. The value of this point corresponds to a synchronous mass flow rate of the potassium.

The results of the experiment were used to plot the dependence of the dimensionless criterion $P = \Delta p v_s l_c / \sigma_M U_{ph}^2$ as a function of the relative mass flow rate Q/Q_{sy} for all the investigated operating conditions of the machine. Here Δp is the pressure drop developed; v_s is the velocity of the running field of the machine; l_c is the length of the working part of the channel; σ_M is the conductivity of potassium; U_{ph} is the phase voltage; Q is the mass flow rate of the potassium; Q_{sy} is the synchronous mass flow rate of potassium. Figure 5 shows the independence of the criterion of the temperature and the voltage.

Principal Results

1. Experiments under pumping conditions verified the efficiency of the machine with normal current loads and temperatures up to 550°C.

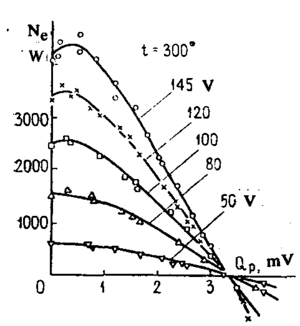

Fig. 4

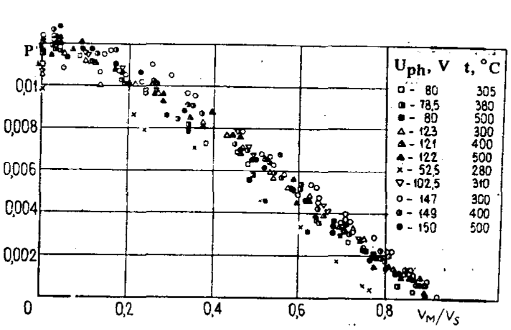

Fig. 5

2. A maximal efficiency, equal to 31%, was obtained at a potassium temperature of 300°C, a voltage of 145 V, a pressure head of 41 kg/cm^2, and a mass flow rate of 0.64 liter/sec.

3. A maximal pressure drop, equal to 41 kg/cm^2, was obtained at a mass flow rate of 0.2 liter/sec, a potassium temperature of 300°C, and a voltage of 145 V.

4. A rise in the working temperature up to 500°C led to a lowering of the maximal pressure drop down to 37 kg/cm^2 at a voltage of 150 V, and of the efficiency down to 22% at a voltage of 120 V.

5. With an increase in the temperature, along with the decrease of the maximal efficiency, its maximal value is shifted toward the side of lower voltages.

6. Reduction of the pressure head-mass flow rate characteristics to dimensionless form showed that, for the machine being tested, there is a single universal characteristic which does not depend on the voltage or the temperature.

7. The total operating time of the machine during the course of the tests was 120 h. A verification of the condition of the machine, made after the end of the tests, showed that it was in good working order.

8. The pressure head and efficiency indices achieved, obtained with temperatures of 300-500°C, are at the present time substantially higher than the indices of machines of a similar class, known from the literature.

LITERATURE CITED

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