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Current Distribution on Electrodes in MHD Generator Channels

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Introduction

THE current distribution curves on the electrodes in MHD generator channels are skewed, pointing upstream at the anode and downstream at the cathode because of Hall effects. Consequently, erosion on the electrodes is localized and the durability of MHD generator channel worsens. It is therefore desirable to eliminate the Hall component of the current on the electrodes and make the current distribution on the electrodes uniform.

In order to solve this problem, such methods as resistive electrodes[1] or connecting the proper resistances[2] with the segmented electrodes have been suggested and tested.

A new method, which is described in this Note, is to control the current distributions on the electrodes, not by means of using the resistive materials directly or outer resistance as aforementioned, but instead by varying the surface temperature distribution of the electrodes and as a result, the interelectrode resistances. This method was studied experimentally on an ETL Mark V MHD generator,[3] and it was found to be effective in improving the current distribution at the anode.

Experimental Results and Discussion

To obtain the current distribuiton on the electrodes, one electrode was divided into four elements in the direction of combustion gas flow, which were insulated from one another by 0.2-mm-thick wafers of mica as shown in Fig. 1.

Figure 1 shows the dimensions and constitution of one electrode and its elements. The power lines and cooling-water pipes were individually led out of each element, and then the power lines were short-circuited at the terminals of the shunts connected to each element to measure its share of the current. Each element was constructed with a base electrode and a brazed material. All of the base electrodes were made of copper and were water-cooled, but the brazed materials were made of AISI 304 for the anode and AISI 304 and Cu-W alloy for the cathode; their thicknesses were varied as the surface temperature of each element reached the expected level.

Fifty pairs of electrodes were mounted in the Mark V MHD channel, of which four were used as measuring electrodes for current distribution to check the usefulness of this method. The other experimental conditions were as follows;

1) the mass flux in the vicinity of the measuring electrodes was about 15 g/sec cm^2 at the rated mass flow of 3 kg/sec.

2) the magnetic field strength was 42 kG, and

3) the channel was of the cold-wall type with Faraday-type segmented electrodes.

Number 18 and No. 22 electrodes consisted of brazed elements of the same materials and of the same thickness to compare their current distributions with that of No. 19 and No. 21 electrodes, where the brazed materials and their thicknesses were varied to control the surface temperatures.

Figure 2 shows the surface temperature distribution on the anode without current flow. The horizontal axis shows the number of elements that were arranged in order from the upstream end of the electrode. The surface temperatures of elements for No. 18 and No. 22 electrodes varied only a little, but for No. 19 and No. 21 electrodes, they varied nearly linearly between No. 1 and No. 4 elements as predicted. Of course, in the latter case, they were determined in order to show the opposite tendency to the concentrating pattern of current, that is, at the edge of the electrode where the current was most concentrated, the surface temperature was selected to be the lowest because the low surface temperature results in thick boundary layers and also a thick deposited seed layer, which in turn generate locally high interresistances in the boundary layer. The interelectrode resistances between electrodes in the Faraday direction, consequently, varied partially on one electrode for No. 19 and No. 21 electrodes.

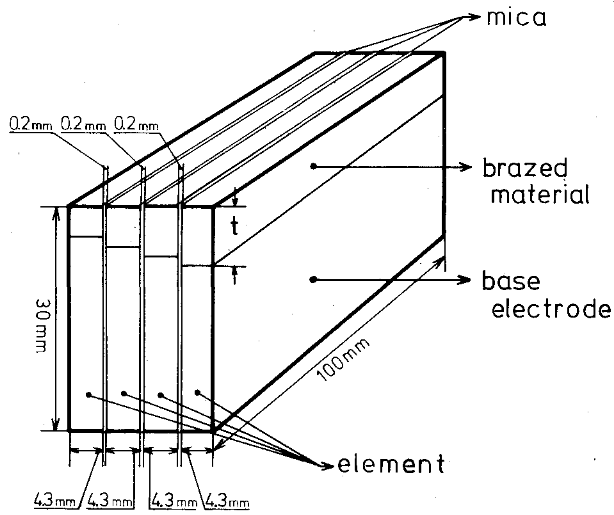

Fig. 1 The dimensions and constitution of one electrode and its elements.

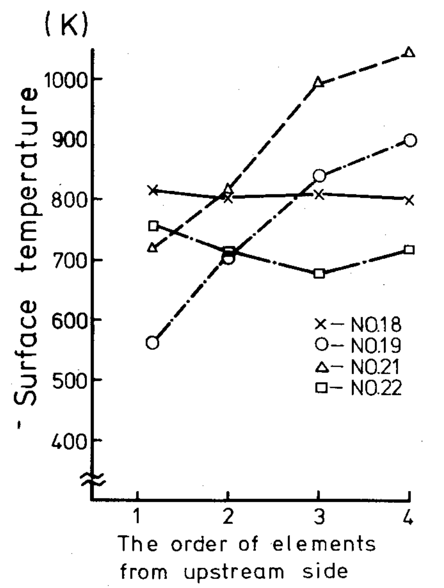

Fig. 2 The surface temperature distribution on the anode without current flow.

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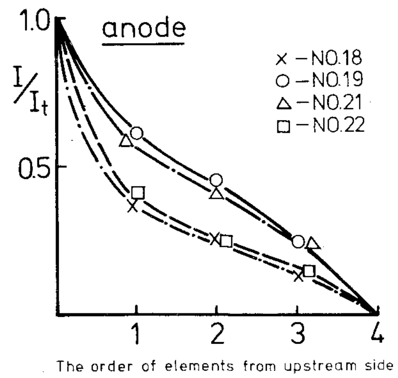

Fig. 3 The current distribution on the anode.

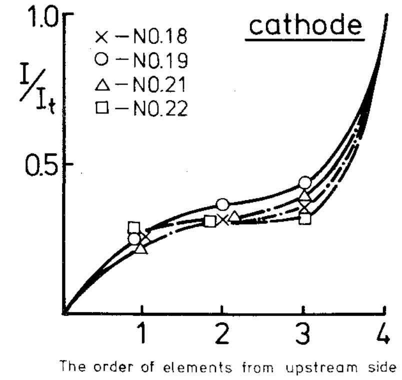

Fig. 4 The current distribution on the cathode.

Figures 3 and 4 show the experimental results of current distributions at the anode and the cathode, respectively. The vertical axis shows the ratio of current (I) accumulated from the downstream edge of the electrode at the anode, or the upstream edge of the electrode at the cathode up to one element to the total current (I_t) (the latter ranged from 12A to 56.6A on one electrode). As is shown in Fig. 3, at the anode, the share of the current of No. 1 element was about 60% for No. 18 and No. 22 electrodes but it reduced to 40% for No. 19 and No. 21 electrodes. This reduced current on No. 1 element was distributed among other elements and therefore, a more uniform current distribution was obtained by this method.

However, the current distribution on the cathode was hardly improved by this method as shown in Fig. 4. These results are caused mainly by the differences in the type of discharge in relation to generating and depositing electrons on each electrode. On the cathode, where electrons are generated, the arc discharges are usually highly concentrated, tend to fix their arc spots on the electrodes, and are affected strongly by the properties of the electrode materials,[4] but it seems that so long as water-cooled metal electrodes are used, the variation of surface temperature of the electrodes, that is, the variation of the interresistances in the boundary-layer regions that contain the liquid and solid seed layers, is not so effective in modifying the current distribution.

On the contrary, on the anode that attracts electrons, the arc discharges are hardly dependent on the properties of electrode materials, and so, in the MHD channel, they are strongly affected by the interelectrode resistances in boundary layers as mentioned in Ref. 5. Although, in this experiment, the surface temperature distributions were determined approximately using assumed values for the thickness of seed layers, the thermal and electrical conductivity of seed material, and other parameters, further study is necessary to obtain the detailed correlations between the current and surface temperature distributions and to make it possible to design in detail this type of electrode for future MHD generators.

Conclusion

A new method is described to control the current distribution on the electrodes in a MHD channel with good results in improving the current distribution on the anode, but with little change for the current distribution on the cathode.

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On Newtonian Flow Past Power-Law Bodies

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RECENTLY Hui[1] has developed an iterative method for studying the steady Newtonian flow past two-dimensional (and axisymmetric) bodies of any thickness at zero incidence. To consider the power-law body shape, the discussion is eventually restricted to slender bodies by invoking the hypersonic small-disturbance assumption. The leading terms of Hui's solution for power-law bodies are identical to those of Cole.[2] As Cole points out, these solutions have singularities such as zero density and infinite temperature at the aerofoil surface. These singularities arise because the hypersonic small-disturbance theory does not account for the region of high entropy surrounding the body. As is well-known, the effects of this entropy layer can be treated by the method of matched asymptotic expansions. Using this approach, Ryzhov and Terent'ev[3] have investigated the flow in the entropy layer enveloping bodies supporting power-law shocks, without invoking the Newtonian flow approximation.

In this note a uniformly valid solution under the Newtonian flow approximation is obtained by composition of the "outer" solution of Cole[2] and the "inner" solution of Ryzhov and Terent'ev.[3] However, as will be seen, the existing "inner" solution[3] will have to be improved in order to treat the Newtonian flow problem.

The Newtonian Approximation

Consider a two-dimensional symmetric aerofoil of unit chord length placed in a uniform hypersonic stream of perfect gas at zero incidence. Let the effects of viscosity and heat conduction be negligible. Fix a rectangular coordinate system Oxy so that the origin coincides with the nose of the body, given by $y=y_b(x)$, and the x axis lies along the direction of the freestream. Let u,v,p, and ρ be velocity components in the x and y directions, pressure, and density, respectively.

Following Cole,[2] define

$$y^* = y - y_b(x) \qquad \text{(1a)}$$

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