INVESTIGATION OF MHD PROCESSES IN ALUMINIUM REDUCTION CELLS

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Summary The MHD processes in high-power industrial aluminium reduction cells are investigated. The mathematical models of MHD processes in reduction cells are developed. The effective numerical methods for calculations of the electric and magnetic fields, steady flows of the melt and wave processes are proposed. The computer program is developed to simulate MHD processes. The experimental investigation of MHD processes in the case of physical models has been carried out.

INTRODUCTION

MHD processes in high-power industrial aluminium reduction cells is one of the most essential factors which influence the technological process of electrolysis. Intensive vortex motions of the melt, deformation of the metal-electrolyte interface and the oscillations of this interface caused by electromagnetic forces lead to the notable decreasing of the current efficiency and increasing of the specific expenditures of energy during aluminium production. Neutralizing the negative influence of MHD processes is of great importance to develop of new cells and to improve of existing ones. For last 30 years the MHD problem of aluminium reduction cells attracts attention of investigators [1]–[7]. In this work the results of numerical research of steady flows of the melt and wave processes in aluminium reduction cells are presented. Also the results of experimental research of MHD processes in electrolytic cells containing immiscible, current-carring fluids interacting with the background magnetic field are discussed.

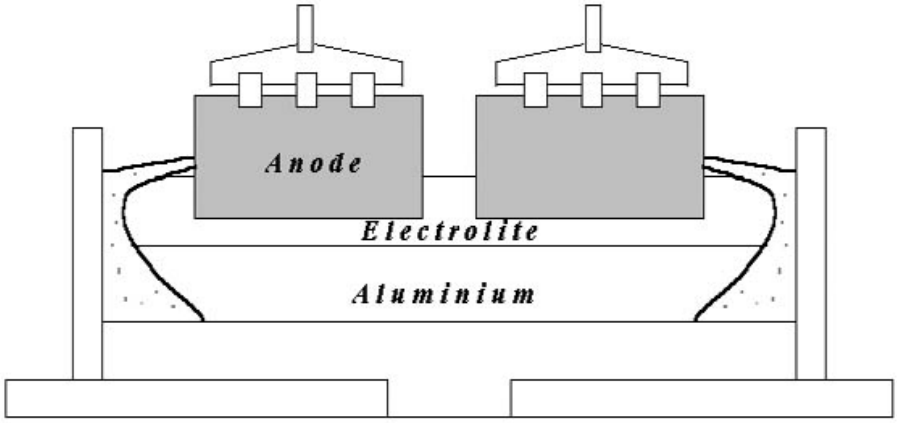

Fig. 1. Scheme of aluminium reduction cell

STEADY FLOWS OF THE MELT

On the basis of semiempirical models of a turbulence the numerical modelling of steady flows of the melt is made. The iterative procedure for solving of governing equations is proposed that allows to specify by steps the distribution of the electric current and magnetic field induction, fields of velocities and pressure in the melt as well as steady shapes of the metal - electrolyte interface. Effective calculation methods for the electric and magnetic fields are developed. Calculations of the magnetic field were carried out with the ferromagnetic details of the reduction cells taken into account. The electric field in the cell was determined including the preceding and following cells into calculation scheme. In the steady flow calculations two parameter differential turbulence models ($k-\varepsilon, k-\omega$) are used. The computer program (Alpha) is developed to simulate influence of design and technological parameters of reduction cell on basic characteristics of the melt flow.

WAVE PROCESSES

With increasing a current intensity and/or with decreasing an anode-cathode distance the steady flow is replaced by a wave regime of a melt motion. The problem of wave excitation conditions is reduced to research of a steady flow stability of a melt with respect to small perturbations described by linearized equations of magnetic hydrodynamics. The evolutionary problem on small perturbations which is time-dependent according to exponential law, can be reduced to a spectral boundary problem. Using Galerkin method the spectral boundary is reduced to an algebraic eigenvalue problem. Electrolyte and molten aluminium at electrolysis temperature have a low viscosity that makes possible to use the boundary layer method in the construction of Galerkin basis. The methods of determination of the boundary of a stability region in space of design and technological parameters of a reduction cell are proposed. The induction currents in the molten

aluminium and magnetic field perturbations induced by oscillations of metal - electrolyte interface are taking into account in wave processes investigation . For industrial reduction cells of different types the calculations of critical values of current intensity in dependence on the anode-cathode distance, aluminium layer depth and other parameters have been carried out. This calculations allowed to reveal many interesting features of wave process accuring in the melt: MHD - interaction of different modes with close natural frequencies that can give rise to a rotating wave, changing oscillations form attending with drestic changing of their periods under changes of cell parameters. Mathematical models of nonlinear oscillations of metal-electrolyte interface are proposed. Method of calculations of amplitudes and frequencies for the nonlinear periodic oscillations is developed.

EXPERIMENTAL RESEARCH OF MHD PROCESSES.

The experimental researches of MHD processes in a two-layer system of immiscible current-carring fluids (electrolytes) with weakly distinguishing densities and strongly distinguishing conductivities are carried out. The fluids fill a cylindrical vessel with a rectangular cross-section located in an interpolar gap of DC-electromagnet.

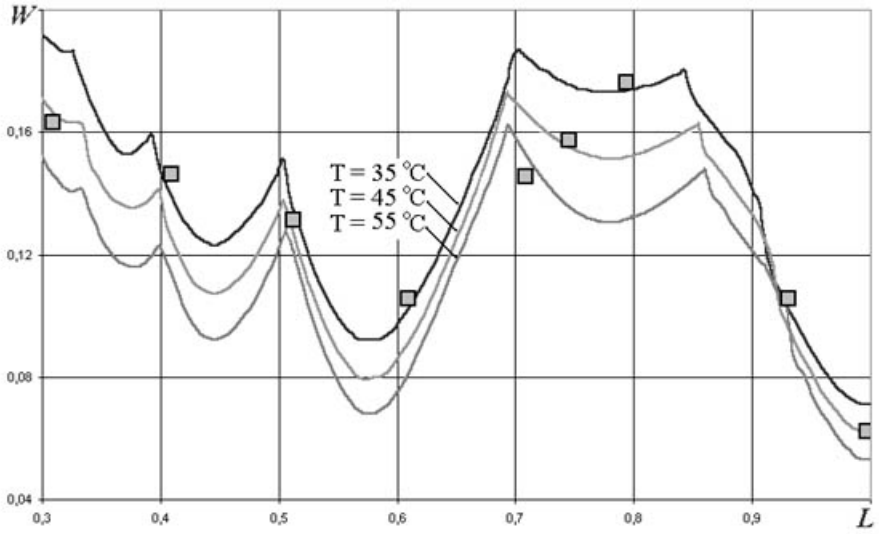

Fig. 2. Boundary of stability region

The results of these experiments confirmed theoretical conclusions about strong dependence of the critical value of the current intensity J on aspect ratio $L = L_x/L_y$ of liquid layers and their depth, and also about influence of the vertical B_z and horizontal components B_x, B_y of the magnetic field induction on a stability of interface. The figure shows theoretical and experimental (averaged over several experiments) dependencies critical values of the dimensionless parameter $W = JB_z/(\Delta\rho g L_x L_y)$ that characterize ratio of the Lorence force to gravitational force, on the parameter L in the case of the uniform background field. Here g is the acceleration of gravitational force and $\Delta\rho$ is the difference of densities. Curves on the figure correspond to the temperature range $35^0C \leq T \leq 55^0C$ that was observed in the experiments.

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