INFLUENCE OF MHD-PROCESSES IN WORKING AREA OF MAGNETODYNAMIC INSTALLATIONS FOR ALUMINIUM ALLOYS ON THEIR OPERATING CHARACTERISTICS

DUBODELOV[1] V.I., SLAZHNIEV[1] M.A., MOYSEEV[1] Yu.V., BOGDAN[1] K.S., PODOLTSEV[2] A.D., GORYUK[1] M.S.
[1] Physico-Technological Institute of Metals and Alloys NAS of Ukraine, Kyiv, Ukraine, Vernadsky Ave. 34/1, Kyiv-142, MSP, 03680, Ukraine
[2] Institute of Electrodynamics NAS of Ukraine, Kyiv, Ukraine, Peremogy Ave. 56, Kyiv-57, MSP, 03680, Ukraine
E-mail: mgd@ptima.kiev.ua , slazhnev@ptima.kiev.ua

Abstract: There are determined the factors, which affecting the work efficiency of casting magnetodynamic installations (MDI) for aluminium alloys. It is shown, that basic reserve for rise of technical parameters of MDI is related with reduction of magnetic fields dispersion and raises its concentration in T-shaped working area (WA) of MDI, and also with the decreasing of negative influence of vortex structures on borders of working area. It is developed the (3D) measuring method of magnetic fields distribution. It is defined the ways for optimization of systems for generating of electromagnetic fields and its superposition in working area of MDI.

1. Introduction

The magnetodynamic installation for aluminium alloys a long time and successfully is used in foundry for alloys treatment and making of castings. Presently for used in casting technologies melting-dosaging equipment the requirements about providing of energy-saving (according to useful mass on an aluminium no more than 0.08 kW*h/kg) and rising of range of technical descriptions became tougher. Its related to development of technologies and expansion of nomenclature of products on the brands of alloys, size of casting, its weights and geometry, for example, for the processes of casting under pressure, semicontinuous and continuous pouring. In particular, its necessary to provide more wide possibilities of magnetodynamic equipment on the value of the created pressure (from 30 kPa to 50 kPa), realization of the modes of the intensive heating (from 3°C/min to 10°C/min) and stirring of melt (with speed from 1 to 10 m/sec), and also expansion of range of realized at pouring mass flow rate – both toward the increase (from 3 kg/sec to 10 kg/sec), and reductions (from 0.3 to 0.05 kg/sec).

Analysis of results of performed before researches of MHD-processes on boards and in the working area MDI, and also estimation of factors lowering efficiency of work of MDI for aluminium alloys [1] showed that basic reserve of the pressure rise and expense descriptions are related to reduction of dispersion and concentration rise in working area (WA) lines of magnetic field created by an electromagnet, by the decline of the negative influencing of vortical structures, appearing on the boards of WA as a result of slump of the magnetic field, and also neutralization of effect of intaking of liquid metal in WA, the conditioned by co-interaction of magnetic field of current in a liquid-metal explorer with the magnetic field of electromagnet.

2. Presentation of the problem

For expansion of views of machineries of origin of magnetohydrodynamic effects in channels and working area MDI, which negatively affecting on hydraulic and operating descriptions of such installation, electromagnetic processes in T-shaped WA were researched at different working modes of MDI.

On the first stage of researches studied influencing of construction elements (metallic casing of channel) MDI (fig.1) on distributing (distortion, dispersion, absorption) of the magnetic field created by the external electromagnet. On the second stage the features of distributing of the magnetic fields in T-shaped WA were researched, at imitation of presence metal by location on the horizontal cavity of the W-shaped channel aluminium plate (fig 1), which are repeating rounding the environs T-shaped WA, at the passing of alternating currents was provided by the own electromagnetic systems (inductors). For systematization of experimental data of distributing of magnetic induction and construction of its topographies a vertical coordinate matrix is used a point measuring of induction of the magnetic field in T-shaped WA of MDI (fig 1).

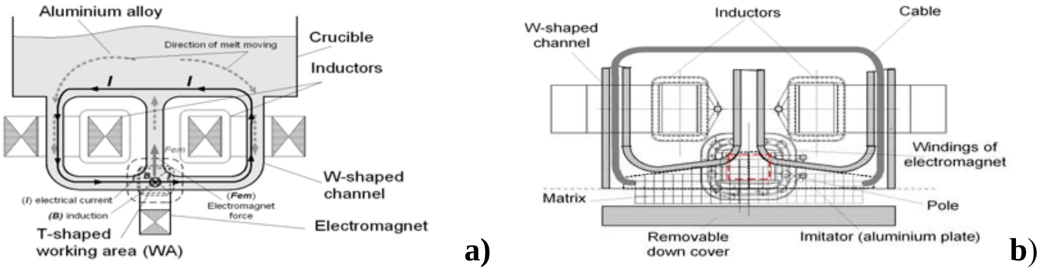
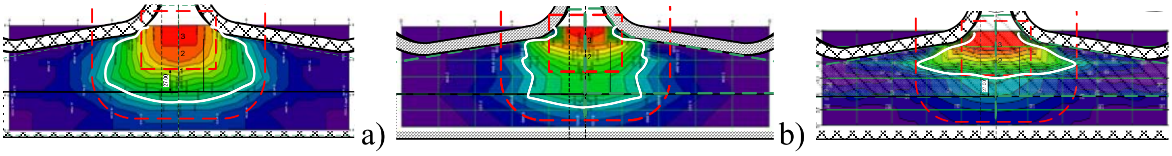


Figure 1: Scheme of MDI (a) and W-shaped channel of MDI (b) and method of magnetic induction distributing researching in the imitation mode.

With the purpose of the detailed study of the «spatial distributing» of the magnetic field (induction is to 1.0 T) in T-shaped WA of MDI and record of instantaneous values of the vectoral component of magnetic induction by 3D-sensor allowing to realize the continuous measuring of normal (Z) and two tangential components (X, Y) of induction was developed. The dispersions of fields (distributing of normal and tangential components of magnetic field) not far from T-shaped WA was determined by apparatus, which providing the simultaneous three-vectoral measuring of parameters of the magnetic field in the set point of space. 3D induction sensor consists of six sensors of Hall, mounted as a cube with a rib 6 mm, three output signals (U_x, U_y, U_z) giving out, variable voltage on which proportionally intensity of the magnetic field in the three mutually perpendicular directions in the point of sensor location.

Researches of distributing of magnetic induction, dispersions and influencing of elements of construction of channel in WA and systems of electric currents inductions and its intercommunication, was produced in three stages: at the switched electromagnet MDI; at the switched electromagnet and set in a channel aluminium plate; at the switched electromagnet, set in a channel to the aluminium plate with passing the electric current, inducted by the inductors. The results of experimental researches showed that in areas (fig. 2a) proper 1 and 2 of plane in relation to the pole of electromagnet, there is distortion of distributing of lines of the magnetic field as a result of interaction with material of channel casing. The area of maximal normal values of magnetic induction is found in neighbouring of projection of pole of electromagnet, and in relation to the plane T-shaped WA of MDI closeness of induction (by the value not below 0.05 T), is distributed on 35÷40% to its area, where and electromagnetic pressure is created. The maximal value of magnetic induction corresponds to the center of pole of electromagnet.

The analysis of the distribution of the magnetic induction topographies at presence of «imitator» (fig. 2b) (imitator – aluminium the plate from the aluminium alloy with thickness 8 mm, the form of which corresponded to geometry of horizontal area of the W-shaped channel of MDI) showed characteristic for the mode of imitation «deflection» of normal component of magnetic induction for vertical lines and narrowing on a horizontal line (a white line corresponds to the size equal 20% from the basic value of magnetic induction). This phenomenon is caused by the interaction of the external magnetic field with appearing in current conductive aluminium the vortical electrical currents and its contours, which raise the reactive resistance to magnetic field.



a) b) c)

Figure 2: Distributing of normal components of induction in T-shaped WA MDI in the imitation mode: a) at the electromagnet switched (***B* ≠ *0; I* = *0***); b) with "imitator" (***B* ≠ *0; I* = *0***); c) at placed on the horizontal area T-shaped WA "imitator" with the current (***B* ≠ *0; I* ≠ *0***).

At research of influencing of MHD-processes in the working area MDI on operating descriptions in the imitation mode at passing through the aluminium plate the inducted current and superposition of the external magnetic field, was it is shown, that concentration of normal component of magnetic induction in area of the discharge to pipe of WA to increases on 25%, and in down part of WA to decrease on 15% (fig. 2c). Thus the effective square of WA, where are the electromagnetic forces are created, makes no more than 60% its actual value.

The graphic image of algebraic difference of redistribution of the normal component magnetic induction, conditioned by influencing of the magnetic field of current, passed on a metallic conductor in WA, is shown in fig. 3.

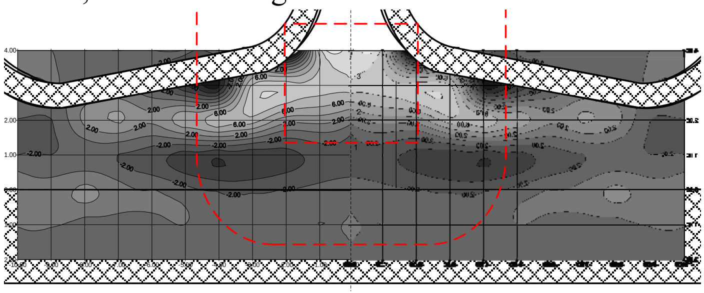


Figure 3: Topography of redistribution of normal component of induction of the magnetic field in T-shaped WA of MDI in the imitation mode.

Determinate MHD-effect (fig. 2c and fig. 3) is classified as a reaction of "anchor" in WA of MDI [3], as a result of interaction between the external alternating magnetic field, generated by an electromagnet and alternating magnetic field, created in liquid-metal conductor by the horizontal area of the W-shaped channel, which having meeting direction in relation to the external magnetic field in lower part of WA and accordant direction in overhead part.
Influencing of «anchor» reaction increases with the increase of current density ***j*** in WA and stipulates the unevenness of distributing of induction, that results to decline of electromagnetic interaction efficiency and appearing the areas of the differentiated distributing, both by a electromagnetic forces ***Fem*** and electromagnetic pressure ***Pem***.

In the applied sense, at the analysis of the pressure descriptions MDI, in depending from parameters of inductors work and electromagnet [4, 5] (fig. 4a), its shown, that with the increase of the voltage on inductors, the angle of slope of pressure descriptions decreasing and dependence of coefficient of pressure loses linear.

By other important aspect, which determining influence of MHD-processes on operating descriptions of the MDI, there is influencing of electromagnetic processes of co-operation of the magnetic fields of currents in a liquid-metal conductor in channel with the core (yoke) of electromagnet. This influence is characterized by the appearing of «involvement» effect as a result of negative vector of electromagnetic pressure in WA, the size of which makes 20÷25% from pressure descriptions MDI (fig. 4b). Thus, the electromagnetic pressure created in MDU, corresponds 30÷35 kPa, and the loss of pressure due to inducing in the disconnected coils of electromagnet makes from 6.0 to 8.75 kPa.

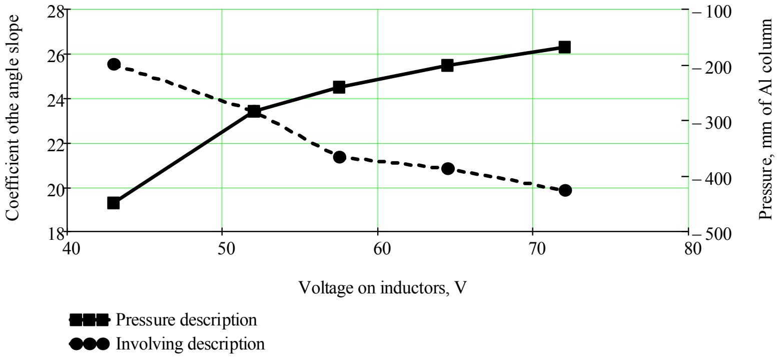


Figure 4: Dependence pressure descriptions and negative component of the electromagnetic force from voltage on inductors.

Along with this, research tangential component induction in this case (fig. 1) on the Y-axis corresponding to the component of the magnetic field induced in a T-shaped WA by alternating current, which passing through the aluminum plate has demonstrated the existence density of the maximum concentration induction in the lower parts of WA (fig. 4), and presence of the phase angle between alternating magnetic fields from 23º÷43º (0.18π÷0.28π), which reduces the electromagnetic pressure on 1.5÷4.5 kPa (70÷180 mm pressure by liquid aluminum alloy column).

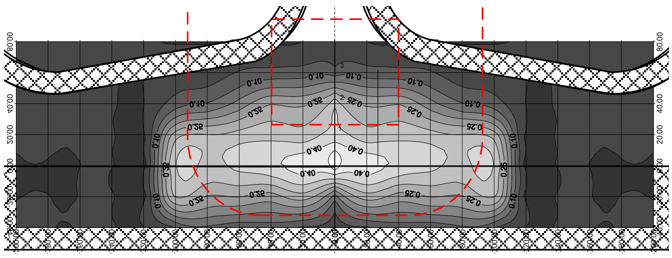


Figure 5: Frontal topography and distribution graph of the tangential (axial) component of the magnetic field induced in the T-shaped WA by AC passing through the aluminum plate.

Distribution represented by the magnetic field created by the alternating electric current (fig.5) obtained experimentally in simulated work MDI mostly its mode "pump", the picture quality predetermines the redistribution component of the current density ***j*** in the WA and its surroundings as a result of interaction with an external magnetic field of the electromagnet and is characterized by displacement (pushing) the flow lines in the area remote from the projection of the poles of an electromagnet. A characteristic feature of the effect on the performance of education MDI is significant differential values of the normal component of the magnetic induction in the WA, resulting in the formation of pressure fluctuations and the magnitude of the electromagnetic volume electromagnetic forces therein. Analysis of topography (fig. 3c) shows that at a distance of 50-60 mm from the edge of the vertical projection on the horizontal pole of the electromagnet takes place decrease the absolute value of the normal component of the magnetic induction of up to 50%, and up to 80 mm - 80%. Recession induction vertically in WA from bottom edge electromagnet pole distance of 50 mm is over 85%. The result of this differential induction in two-dimensional plane WA determines the difference value and the volume of the electromagnetic forces of the electromagnetic pressure in T-shaped WA, in which there is rotate on 90º the melt flow and dynamic vortex structures formation.

These vortex structures have a wide range of impacts on the hydraulic characteristics of the MDI and hydrodynamic processes in channels and the working area installation, and at speeds of melt channels MDI (up to 1 m/sec) and high current densities in the channels has been increasing dynamic pressure oscillations and electromagnetic pressure (10÷20% from its nominal value at a frequency from 1 Hz up to 3Hz), and at the transition to the metal with medium speeds (over 1 m/sec) at high current densities , due to the turbulence of flow in WA and the output therefrom is stabilized oscillation pressure characteristics, which do not to exceed 10-15 %. However, the oscillation frequency becomes one or two additional (2nd and 3rd) harmonics - 0.4÷0.8 Hz, 2.5÷3 Hz, 3.4÷4 Hz [6].

Among the most promising areas for further research is to optimize the processes of redistribution of the normal component of the magnetic induction in the WA and its surroundings, with a view to a more rational use of working volume WA to create volumetric electromagnetic forces, optimization of magnetohydrodynamic processes in it, stabilize and improve the operational and technical characteristics of magnetohydrodynamic systems.

To eliminate the harmful influence of the "anchor effect" pole electromagnet geometry and its projection on the working area can be transformed from a parallelepiped with width 100% for width of WA and height 70 % from height of WA, to trapezoidal form with the width of the upper base of the trapezoid - 40÷50 %, the lower base - of 120÷200% and 90-100% about height of WA. This will ensure a forced change (rotate on 90º angle) direction of the streamlines in the flow of melt moving through T-shaped WA, reduce friction loss, prevent the formation of stable vortex structures.

Increasing pressure characteristics MDI can be achieved by increasing the depth of the base WA by 50÷60% by performing indentations in the bottom part of the W-shaped channel. Estimated growth promoted by electromagnetic pressure, while maintaining constant values of the current density and the magnetic flow is up to $\approx$ 50÷60%. To eliminate the effect of retracting melt by creating a negative vector of the electromagnetic force in the working area, a special design of the electromagnetic system MDI as two U-shaped electromagnets, not connected to a common yoke, with two windings, which is included in the counter mode. The proposed solution avoids interaction of magnetic core of an electromagnet with induced in the liquid metal coil electrical current and increase the pressure and flow characteristics by 15÷25%.

3. Conclusion

The factors that reduce the efficiency of the operating magnetohydrodynamic units (MDI) for aluminum alloys its shown, that the main reserve increased performance MDI associated with reduced dispersion and increase in the concentration of magnetic fields in T-shaped WA, as well as reducing the negative influencing of vortex structures on its borders. Experimental studies aimed at researching the magnetohydrodynamic processes in MDI allowed to specify the representation of the role of the particular geometry of WA, the location and geometry of the C-shaped poles of an electromagnet, and the redistribution component of the current density $\boldsymbol{j}$ and the normal component of the external magnetic field in the projection of T-shaped WA. An assessment of the impact of MHD-effects in T-shaped WA on efficiency, technical and operational characteristics of MDI.

4. References

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