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PHYSICAL MODELING OF HYDRODYNAMICS PROCESSES IN LADLES OF SMALL CAPACITY AT THE COMBINED METHOD OF HASHING STEEL

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(Report 1)

Results of physical modeling for hydrodynamics of metal in a casting ladles at electromagnetic hashing are brought. There are found regressive dependences of speed for metal streams in the volume of casting ladle.
Key words: casting ladle, modeling, hydrodynamics, electromagnetic mixing, statistics, optimization

For more effective application of casting ladles as metallurgical aggregates which allow to improve quality liquid metal, it follows, coming from their specific, additionally to use the forced hashing. One of the most modern methods of the fusion forced hashing in a ladle there is the use of the electromagnetic field [1]. Advantage of such method before other methods consists in absence of baring for metal mirror and, thus, to absence of the contact of metal with an atmosphere. Except for that, during imposition of the electromagnetic field on fusion wide possibilities appear in relation to adjusting of power for hashing, and also change direction of motion for metal streams.

During research of hydrodynamics of metal in the process of his electromagnetic hashing in casting ladles used the methods of physical modeling. In particular, a liquid metal was replaced by water, slag – by organic oil, and device of electromagnetic hashing – by the special setting which recreated the characteristic for electromagnetic hashing contour of hydrodynamic streams.

Obviously, that a designing environment is monophase and that is why implementations of model carried out on terms the comforts of design [2] but a model scale did not matter in this case.

For the physical modeling of hydrodynamics of metal in casting ladles used the transparent experimental setting as reverse truncated cone. In obedience to positions of similarity theory such model allows to get quantitative descriptions of liquid streams for the real ladles indepehdently of their capacity.

The forced moving of liquid in the model of ladle was provided due to the use of the special device, that set in the set place of ladle the cavities by means of the worked out mechanical fastening in obedience to tasks of the experiment. A device is constructed so that allows to change direction of liquid streams. The power of electric motor of device executed by means of direct-current which is regulated.

Visualization of liquid flow in a model was executed by means of styrene marbles (tracer) with diameter a 1.0-1.5 mm which have a zero buoyancy (method of «tracks»). During determination of quantitative values for speeds of liquid streams an equipment «light knife» is used what clears up axial plane of model of ladle. Researches carry out in a black-out apartment by fixing of hydrodynamic picture on digital phto- and video cameras. The quantitative values of speeds of liquid streams determined by means of calculations the relation of length of tracks for tracers трасерів, measured on phtoprints, to time displays taking into account the coefficients of down-scaling. Receipt of value for speeds and time of homogenization of liquid transferred on the real sample.

Change of area position of imposition of identical forces for the forced hashing allowed to set that the best results in relation to decrease of homogenization time are observed at time location of it at the distance a 0.4-0.6 radius of ladle. Therefore further researches executed for the noted conditions.

In all investigational cases during hashing of liquid bath there was a considerable circulation area, directed in the volume of ladle along the speed vector of liquid streams, which was divided into a few (4-6) whirlwinds with sizes which depend on speed of liquid, and, thus, and from dissipation of energy of whirlwinds.

As a result of treatment of phto- and video data is showen, that speeds for metal streams at different power of hashing are within the limits of a 0.018-0.240 m/s (a place of appendix of electromagnetic action is 0.25 heights of ladle), 0.029-0.256 m/s place of appendix of electromagnetic action is 0.50 heights of ladle) and 0.026-0.218 m/s (a place of appendix of electromagnetic action is 0.75 heights of ladle). Thus, an appendix of forces of external action on the distance 0.4-0.6 radius of ladle and to the half of height of fill to it of metal is most rational.

Obviously, that introduction of additional reagents to the volume of liquid metal it follows to execute in places with most absolute speeds of metal streams, which are necessarily pointed down. Indisputably, an area, located symmetric to the area of imposition of electromagnetic forces is answered to such criteria.

On results statistical calculations (confidence interval of authenticity for all calculations is 95 %) regressive dependence of speeds of metal streams (*W*, m/s) in inplane, which passes through the axis of ladle in area, which is free from imposition of forces of electromagnetic hashing, from position of area for imposition of influence on the height of aggregate and place of location of control points in a ladle is found. Here and farther the parameters of equation are located in order of decrease for gravimetric criteria:

$$W = 0{,}102 - 0{,}520H^2 + 0{,}378H^3 + 0{,}169H + 0{,}110P^2 - 0{,}002r\,; \qquad (4)$$

$$R = 0{,}46\,;\quad R^2 = 0{,}21;\quad F(6{,}183) = 8{,}22\,;\quad \Delta = 0{,}025\ ,$$

where r is distance from the axis of ladle, unit; H is distance from the bottom of ladle, unit; P is part from the level of metallic bath, unit; R it is a coefficient of quantitative correlation; R^2 is a coefficient of determination; F is a Fisher criterion; Δ is an error of determination.

Obviously, the height of location of control points has a most influence on the function of review. The least speed is observed on the half of height for ladle at practical absence of dependence on the radius of ladle. Will mark that, on the average, absolute speed streams near the bottom of aggregate a few higher than near-by the surface of metal. The same tendency is observed in relation to position in the aggregate of area for imposition of electromagnetic influence.

The decision of task for search of global extremum for many extreme functions (1) allowed to define, that maximum speed is arrived at on axis of aggregate near-by the meniscus of metal during the location of the affected zone near the fettling bottom of ladle which is not acceptable from the position of technologicalness and can result in the rapid wear of refractory materials.

More acceptable, at our view, location of such area approximately on 0.5 heights of metal fill in a ladle. Analysis of the got corresponding regressive dependence which looks like

$$W = -0{,}241 - 3{,}251H^2 + 1{,}886H + 1{,}772H^3 + 0{,}169H + 0{,}338r^2 - 0{,}316r\,; \qquad (2)$$

$$R = 0{,}65\,;\quad R^2 = 0{,}42\,;\quad F(6{,}140) = 1{,}683\,;\quad \Delta = 0{,}022\ ,$$

showed that after such location of the affected zone metal of streams speed is higher near it surface, than near a bottom, but is some less in a middle. But, as well as it followed to expect of metal streams speed of on the half of radius was more than on axis and near the walls of ladle.

The decision of task for optimization of many extreme function (2) allowed to define, that a most value (0.16 m/s) absolute metal of streams speed has on axis of ladle near it surface. Also certainly, that reagents unreasonable to enter on the depth of bath a 0.25 height of metal and in the distance 0.37 from the axis of ladle.

Conclusions. The executed researches allowed to define quantitative descriptions of conduct of metal in the volume of casting ladle at operating on it of the electromagnetic field, location of active and stagnant areas, its geometrical parameters depending from intensity of hashing and location of place of appendix of electromagnetic action, desirable and undesirable places of introduction of additional reagents.

LIST OF LITERATURE

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