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FORMATION OF REACTION ZONES IN A LIQUID BATH AT ROTATING OF SUBMERGED LANCE

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The results of studying the behavior of the gas jet effluent in liquid bath from nozzle of immersion tuyere and features for formation of reaction zones, depending on the speed of the revolving tuyere. Correlations for determining the length of the sector are proposed.

Key words: immersion tuyere, dispergated magnesium, decujfurazion of cast-iron, reactionary sector

Forming expanded secondary bubble diameter of the reaction zone and increase the interfacial surface of the reaction-gas melt allows to reduce the time for processing and increase the utilization of the reagents in the melt in the refining ladle. Installations, the use of submerged lances rotating instead stationary for desulphurization as a powdery mixture of magnesium lime, calcium carbide, magnesium and magnesium dispersed without additives can arrange more dispersed input reagent, increase the degree of desulphurization of 20-30 %, reduce heat loss by 40-50 %, a tendency to wave formation and release of melt from the bucket without reducing the utilization of magnesium desulfurization while improving the stability of the lances.

The purpose was to study the peculiarities dispersion of the gas jet and the formation of reaction zones in a liquid bath by blowing gas through a nozzle positioned horizontally rotating submerged lance.

Studying the behavior of the gas jet and the formation of reaction zones in the volume of the liquid bath was carried out using a cold plexiglas simulation model 200-t ladle (in 1:13 scale). In model by fluid was water, by injected gas - air compressor. Speed tuyeres around the vertical axis varies from 0 to 240 r/min. The process of purging fixed camera at shooting (120 frames/s) and subsequent separation of the footage for the video sequence processing. To visualize the flow in the bath using the method of «tracers», as that was injected into the liquid polystyrene beads with a diameter 0.001-0.0015 m and a density of 974 kg/m^3.

Several typical reaction zones in a liquid bath may to select by blowing gas through a nozzle positioned horizontally are:

− primary, within which the introduction of the gas jet into the bath;

− secondary bubble, the bottom of which is bent upwards by the Archimedes force $F_A = \rho_{li} \cdot Q_{ga} \cdot g$ at the direction opposite to the rotational direction of the lance nozzle under force resistance $F_{F.r} = 0.5 k_1 \cdot S_1 \cdot \rho_{li} \cdot U^2$ of the gas stream is broken into bubbles, and within which the latter to float bath surface; here Q_{ga} is gas expense, m^3/s; $\rho_{ж}$ - closeness of liquid, kg/m^3; g is acceleration of gravity, m/s^2; U is speed of moving of stream

outflowing from a nozzle at the rotation of lance around to the vertical axis, m/s; S_1 is area of longitudinal section of gas stream, m^2; k_1 is coefficient, taking into account the construction of lance (quantity, the angle of slope nozzles). At the rotation of lance about vertical axis section of stream S_1 (having a form of cone with foundation a radius r, m, by the corner of opening of stream α and in high L, m) it is possible to present as a triangle with a height to equal length of continuous area streams $S_1 = L^2 \cdot \mathrm{tg}(\alpha/2) \cdot$. Speed of moving of stream is determined as $U_{mid} = \pi \cdot n \cdot d_{la}$, where n is number of turns of lance about vertical axis, s^{-1}; d_{la} is diameter of lance, m.

When rotating around the vertical axis of the tuyere section of the jet can be presented in the form of a triangle with a height equal to the length of the continuous stream portion:

– circulation zone outside the bubbling;

– txit zone to the bath surface gas volume.

Gas flow through the nozzle of tip a fixed (stationary) form is accompanied by the formation of the lance, and floating down the barrel lance bubbles, with a local swelling surface of the bath relative to the initial level and the development of wave and splashing with increasing intensity of blowing. Bubbling by bath bubbles causes the formation of the circulation zone. Throughout the range studied speed gas flow through the nozzle remained the same as when stationary lance. By rotating the lance at a rate of up to 10 r/min of gas bubbles wave formation character and direction of the hydrodynamic flows do not differ significantly from established for stationary lance. At the same time, the size of the area due to the occurrence of bubbling at the periphery of small bubbles increases. In the bath surface formed several zones exit gas volume of reduced diameter in the direction of rotation moving the lance. With increasing rotational speed of the lance 30 r/min size pop bubbles decreases, zone extends observed forming a circulation zones. The speed of floating bubbles decreases in proportion to increase in the speed of rotation of the lance (with a decrease in the size of bubbles). On the surface of the bath is formed by gas-liquid form layer with a decrease of wave through the gas outlet dispersal zone. Increasing the speed of rotation of the lance to 50 r/min leads by a further reduction in size of bubbles with extension zone, by development flows directed from the periphery to the end of the lance, by increases the level of the gas-liquid layer on the surface of the bath and suppression of wave. Floating bubbles to the surface of the bath decreases. In the investigated range of exhaust velocities gas stream flowing out of the nozzle stationary lance, had a pulsating character. Length of the jet phase 1 does not exceed the radius coming off the bubble. It should be noted that at a constant flow rate of gas through the nozzle with the start of rotation of the jet lance length portion 1 is reduced proportional to the speed of rotation. By rotating the lance near the nozzle is always a small area of the jet area. Evidently, the rotation of the hole of the lance nozzle is increased flow resistance, which ensures a constant flow of gas there through. The energy of the injected fluid in the gas jet, besides overcoming the Archimedes force is expended in overcoming the resistance of the liquid jet implement.

Energy of gas stream, except to overcoming force of Archimedes, is expended on overcoming resistance a liquid introduction of stream $F_B = 0.5 k_2 \cdot S_2 \cdot \rho_{li} \cdot V_{mid}^2$ and gravities $F_G = \rho_{ga} \cdot Q_{ga} \cdot g$, where k_2 is coefficient, taking into account the parameters of insufflations

of gas; ρ_{ga} is gas closeness, кg/m^3; V_{mid} is speed of gas stream on its length L, m/s. Area of foundation of stream S_2 with an account $S_2 = \pi \cdot r^2$ и $r = L \cdot tg(\alpha/2)$ determined on expression $S_2 = \pi \cdot L^2 \cdot tg^2(\alpha/2) \cdot$.

At rotating of lance around the vertical axis, the energy flowing out from nozzle jet also spent on overcoming the resistance forces of liquid to movement of a gas cavity in a circle. In this case, the zone 2 takes the form of an ellipsoid of revolution with an increase in the size proportional to the speed of rotation of the lance. In a general view equation of energy balance for gas stream can be presented expression:

$$\rho_{li} \cdot Q_{ga} \cdot \frac{V^2}{2} \frac{T \cdot \alpha}{360} = k_1 \cdot S_1 \cdot \rho_{li} \cdot \frac{U_{mid}^2}{2} \cdot l_{rot} + k_2 \cdot S_2 \cdot \rho_{li} \cdot \frac{V_{mid}^2}{2} \cdot L + \left(\rho_{ga} - \rho_{li}\right) \cdot Q_{ga} \cdot g \cdot \frac{T \cdot \alpha}{360} \cdot H, \quad (1)$$

where V is speed of expiration for stream from a nozzle, m/s, $V = 1.08\sqrt{RT}$; T is time of one turn of lance, s, ($T = 1/n$); l_{rot} is length of way of stream at a rotation in a horizontal plane, m, $l_{rot} = \pi \cdot d_{la}$; H is depth of immersion of nozzle in bath, m.

For revolved submerged lance length of stream area of gas stream can be defined on expression

$$L = \sqrt{\frac{Q \cdot \alpha \cdot \left[V^2 \cdot \rho_{ga} - 2\left(\rho_{ga} - \rho_{li}\right) \cdot g \cdot H\right]}{360\, n \cdot tg^2 \dfrac{\alpha}{2} \cdot \rho_{li} \cdot V_{mid}^2 \cdot k_2}} - \frac{\dfrac{1}{3} \cdot \left(k_1 \cdot tg \dfrac{\alpha}{2} \cdot \rho_{li} \cdot \pi^3 \cdot n^2 \cdot \dfrac{d_{la}^2}{2}\right)}{k_2 \cdot tg^2 \dfrac{\alpha}{2} \cdot \rho_{li} \cdot \dfrac{V_{mid}^2}{2}} \,. \quad (2)$$

For immobile lance length of stream area for gas stream can be defined on formula

$$0,0615\, \rho_{li} \cdot V_{mid}^2 \cdot k_2 \cdot L^2 + 20\, Q_{ga} \cdot g \cdot \left(\rho_{li} + \rho_{ga}\right) - \frac{\rho_{ga} \cdot Q \cdot V^2}{L} = 0 \,. \quad (3)$$

Conclusions. The behavior of the gas jet into the molten bath from a nozzle rotating immersion lance and forming a bubble zone in dependence on the speed of the lance. Proposed an expression for determining the length of the jet area. Reducing the size of bubbles dispersed in the stream with increased speed lance allows prolongation of floating bubbles and reduce wave formation in the bath surface.