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Fluid Level Change at the Bottom Blowing by not Assimilated Gas

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Mathematical model of bubbled fluid level change during not assimilated gas blowing was made. The model includes criteria equations by Reynolds, Archimed and Weber considering consumption and density of gas, initial level of fluid and its capillary tension. Fluid level change under its neutral gas blowing was investigated on the basis of developed technology.

Keywords: BLOWING, NEUTRAL GAS, HYDRODYNAMICS, RISE RATE, BATH LEVEL, NOT ASSIMILATED GAS, GAS CAVITY

Introduction

It is necessary to learn motion of not assimilated gas bubbles in molten metal in order to solve a problem of metal purification from nonmetallic inclusions and dissolved gases. This interaction of phases is featured for processes of melt argon treatment at gas feeding through the special devices in the bottom of steel-teeming ladle.

Possibility of creation of physical model and technology corresponding to the natural sample is connected with considerable difficulties, many of which seem to be insoluble now. Nevertheless, considering the practical importance of this problem - essential improvement of metal products quality - cold simulation of specified processes is of interest from the point of view of obtaining qualitative dependences of blowing parameters.

Results and Discussion

We will define the values to describe given physical model, and blown fluid level (H) will be a target value. This value depends on depth of flat bath (H_0) and its diameter (d_b), gas rate (V_g), gas and liquid density (ρ_g, ρ_l), surface tension (σ) and kinematic viscosity of liquid (v), diameter of nozzles (d_n):

$$H = f(H_0, V_g, d_b, \rho_g, \rho_l, \sigma, \nu, d_n) \qquad \text{(Eq. 1)}$$

To investigate speed of gas bubbles we will use similarity criteria by Archimedes, Weber and analogue of Reynolds` number [1]

$$Ar = j^2 \cdot \rho_2/(g \cdot H_0 \cdot \rho_l), \qquad \text{(Eq. 2)}$$

$$We = \sigma/[g \cdot H_o^2(\rho_l - \rho_g)], \qquad \text{(Eq. 3)}$$

$$Re = u \cdot H_o/\nu, \qquad \text{(Eq. 4)}$$

where *j* - specific intensity of blowing equal to $j = V_g/S$, $m^3/(m^2 \cdot s)$, *S* - cross-section area of column, m^2, *u* - average speed of gas bubble, km/s.

Laboratory research was carried out on a cold model of direct- and counterflow reactor equipped with gas rate measurement system (rotameter), compressor and receiver with pressure-measuring instruments for gas pressure measuring. The reactor consisted of cylindrical acrylic plastic clear container 1000 mm high and with diameter d_b = 0.132 and 0.230 m. Gas pressure was 4-5 atm. The rotameter measured gas rate in the range of $0.1\text{-}2.2 \cdot 10^{-3}$ m^3/s. The central hole in the air box is closed by plug valve and liquid does not leak out when parallel-current flow blowing. The imitating medium were air, distilled water (ρ_w = 1000 kg/m^3, σ = 0.073 kgf/m) and 26 % water solution NaCl (ρ = 1.197 kg/m, σ = 0.083 kgf/m). Blowing was carried out at H_0 = 0.10; 0.20; 0.30; 0.40; 0.50 and 0.60 m.

Change of blown fluid level was recorded by high-speed filming; fluid level fluctuation was minor at small gas rates, which allowed precise definition $\Delta H = H - H_0$. The amount of gas bubbles in the fluid N, frequency of their detachment from nozzle *v* (1/s) and speed of bubble floating-up were defined by expression:

$$\upsilon = H \cdot v/N \qquad \text{(Eq. 5)}$$

If gas rate exceeded 50 mkm^3/s, the average speed value was defined on the basis of mentioned below equations. When blowing by not assimilated gas, raise of fluid level will be [2, 3]:

$$\Delta H = H - H_0 = V_t\tau_{bl}/S, \qquad \text{(Eq. 6)}$$

where V_t - total amount of gas bubbles in the fluid, m^3/s. As:

$$\upsilon = (H_0 + \Delta H) / \tau_{bl},\ \tau_{bl} = \Delta H/j, \qquad \text{(Eq. 7)}$$

the average speed of bubble floating-up is:

$$\upsilon = (1 + \Delta H/H_0)\ j / (\Delta H/H_0) \qquad \text{(Eq. 8)}$$

Reynolds criterion is usually used for estimation of motion pattern of bubbles in the liquid under various conditions of gas blow-down. It is necessary to know diameter of floating bubbles to define Reynolds criterion.

It is possible to assume that size of floating bubbles is approximately equal to diameter at the moment of detachment from a nozzle (d_{det}) depending on gas rate and nozzle diameter; diameter of detached bubble grows with increase of gas rate [4]. Dependence of relative build-up of fluid on gas rate when bath blowing (column diameter 0.132 m) with nozzle diameter 9.6 and 12.0 mm and various level of flat liquid: H_0 = 0.10; 0.20; 0.30 and 0.40 m was obtained experimentally and on the base of experimental data processing. These data show that level of gas-liquid mixture grows with increase of gas loading; $\Delta H/H_0$ grows with decrease of flat bath level H_0 growth.

In actual practice, melt blowing in steel-teeming ladle for the purpose of degasification is carried out at much lower rate of inert gas (specific intensity of blowing), therefore a series of tests at reduced gas rates were accomplished on a column with diameter 0.23 m; dependence of relative increase of bath level on a specific air-flow rate at various levels of flat fluid is presented in **Figure 1**.

Relationship between increase of fluid level and values of Archimedes and Weber`s numbers at various levels of flat fluid is shown in **Figure 2.**

Relative increase of bubbled fluid level from specific intensity of bath blowing by air, numbers Ar/We at H_0 = 0.4 and 0.6 m (H_0/d_K = 1.74 and 2.61) are presented in **Figure 3**.

Summarized data show that liquid density does not have a considerable effect on $\Delta H/H_0$, which occurs at H_0 = 0.4 and 0.6 m. Some differences in curve run can be caused by inaccurate measuring of bubbled liquid level. Analysis of complex numbers Ar/We also shows that effect of ρ_l on $\Delta H/H_0$ is not observed. Criteria equation $\Delta H/H_0 = 0.56\ (Ar/We)^{1/3}$ was obtained as a result of electronic data processing. Calculation is close to industrial data according to which metal level in 160-ton steel-teeming ladle increased by 10 - 12 cm at blowing.

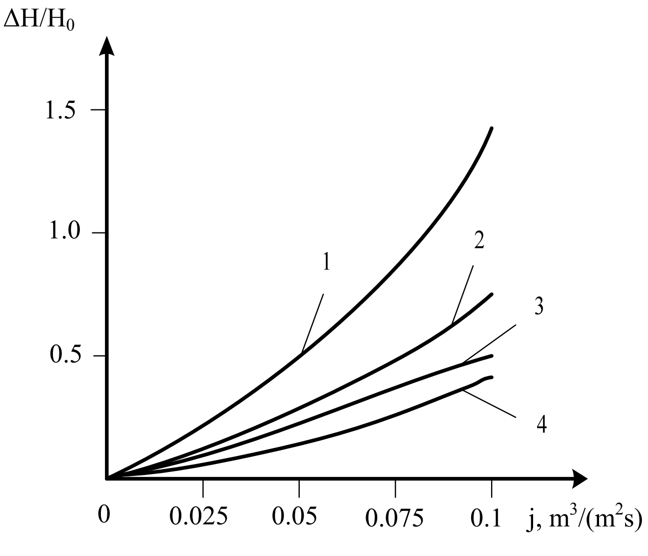

Figure 1. Dependence of relative bath level on specific not assimilated gas rate H_0**,** m**:** *1* – 0.1; *2* – 0.3; *3* – 0.4; *4* – 0.5

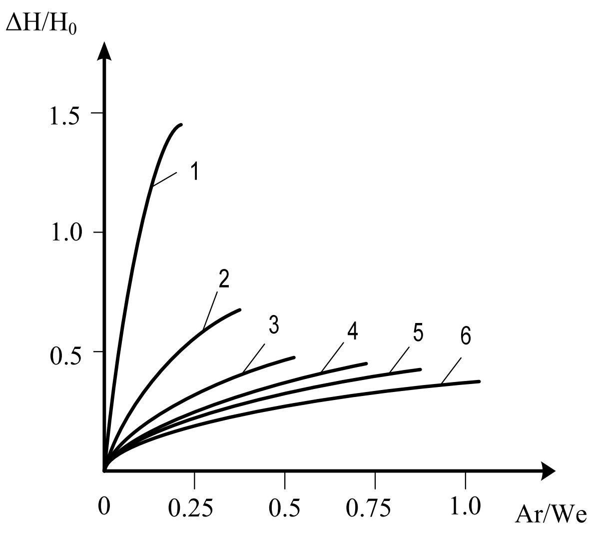

Figure 2. Effect of Ar/We on $\Delta H/H_0$: H_0/d_b = 0.43 (*1*), 0.87 (*2*); 1.3 (*3*); 1.74 (*4*); 2.17 (*5*); 2.61 (*6*)

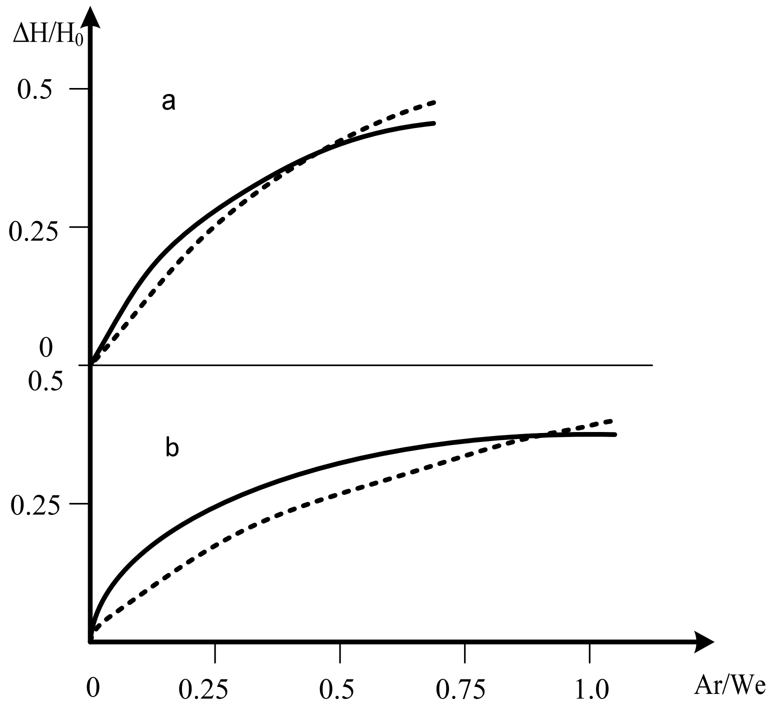

Figure 3. Dependence of relative build-up of fluid level on criterion Ar/We: H_0/d_b = 1.74 (*a*); 2.61 (*b*); — - water, ----- - water solution NaCl

Conclusions

The basic hydrodynamics regularities of bath bubbled by not assimilated gas were determined as a result of conducted research with the use of cold simulation. Obtained criteria equation covers change of hot-metal level at argon blow in steel-teeming ladle taking into account accepted assumptions.

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Изменение уровня жидкости при донной продувке неассимилируемым газом

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Составлена математическая модель изменения уровня барботируемой жидкости при продувке её неассимилируемым газом. Модель включает критериальные уравнения Рейнольдса, Архимеда, Вебера, учитывающие расход и плотность газа, начальный уровень спокойной жидкости и её поверхностное натяжение. Представлена методика и выполнено на её основе исследование изменения уровня жидкости при её продувке нейтральным газом.