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The influence of solid particles density on parameters of multijet insert

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Abstract

Some dependences between solid particles density, chosen geometry and exploitation parameters of multijet inserts and development of laminar motion in continuous multijet sedimentation process, are presented in this paper. Results are obtained from the analysis of the multijet sedimentation model considering development of laminar motion of the suspension in the multijet insert conduit of the settling tank. The range of the researches covered, in particular, quantities necessary for designing inserts of multijet settling tanks finding application in purifying suspended solids in casting processes. Discussed problem has practical and cognitive meanings and is a base for more efficient designing multijet settling tanks inserts applied in iron and steel industry. Application of most efficient construction and exploitation parameters allows designing devices of lower dimensions what is especially advantageous in casting works.

Keywords: Foundry; Settling tank; Sedimentation

1. Introduction

An assumption that process proceeding in single and particular conduits are the same is a fundamental and main problem discussed in almost all theoretical researches considering multijet sedimentation modeling [1, 2, 3, 4, 5, 6, 7, 8].

Moreover it is supposed overtly that the source of the suspension is of inlet shape, flux of constant volume and uniform surface density and is constant with time. The constant with time of the density and viscosity of the liquid in the space of sedimentation is also supposed, as well as constant of grain composition with time and concentration of the suspension [6].

The influence of the density of solid particles on the process of multijet sedimentation taking into consideration the development of laminar motion of suspension is presented in this paper. The influence of solid particles density on the concentration of suspension at outlet section and on the jet efficiency of the settling tank, are discussed in details.

The performance of the construction of multijet conduit insert in dependence of solid particles density is also discussed.

2. Velocity field of the liquid in conduit of multijet insert

The phenomenon of velocity filed development has a great meaning in process of multijet sedimentation, especially in conduits of small depth allowing significant increment in particles concentration in the middle part of the flux.

The analysis of the liquid motion in the initial part of the conduit based on the model of boundary layer development was presented elsewhere [1,2,3].

Targa equation, modified by author of this paper, in which quantity Ck- determined experimentally for middle section, is used has form [2]:

$$U_y(x,y)=\frac{3}{2}\cdot\left(1-\frac{16\cdot x^2}{d_{hp}^2}\right)\cdot V_p+ \\ -2\cdot V_p\cdot\sum_{n=1}^{\infty}\frac{1}{\gamma_n^2}\cdot\left[1-\frac{\cos\left(\gamma_n\cdot\frac{4\cdot x}{d_{hp}}\right)}{\cos(\gamma_n)}\right]\cdot\exp\left(-\frac{16\cdot\gamma_n^2\cdot\nu\cdot C_p}{V_p\cdot d_{hk}^2\cdot C_k}\cdot y\right) \qquad (1)$$

and for middle component:

$$U_x(x,y)=-\frac{32\cdot\nu\cdot C_p}{C_k\cdot d_{hk}^2}\cdot\sum_{n=1}^{\infty}\left[x-\frac{d_{hp}\cdot\sin\left(\gamma_n\cdot\frac{4\cdot x}{d_{hp}}\right)}{4\cdot\gamma_n\cdot\cos(\gamma_n)}\right]\cdot\exp\left(-\frac{16\cdot\gamma_n^2\cdot\nu\cdot C_p}{V_p\cdot d_{hk}^2\cdot C_k}\cdot y\right) \qquad (2)$$

where: $d_{hk}=\frac{2\cdot x_o\cdot z_o}{x_o+z_o}$, $d_{hp}=2\cdot x_o$

C_p – quantity determined for plate conduit
V_p – average velocity of liquid flow
γ_n – successive radicals of equation: $tg(\gamma)=\gamma$

Above equations found theirs application for determining the trajectory of boundary particle, concentration of the suspension at the outlet and jet efficiency of the settling tank.

3. Suspension concentration and efficiency of the settling tank

The determination of the size of boundary particle for given inflow depth, placed in co-ordinate system 0xyz of origin placed at axis of symmetry of the inlet section profile in its upper part, was based on the formulated condition of ending the motion in area ($yo\pm\Delta y$, $xo-\Delta x$), it means that particle reaches the depth of the conduit or outlet section or the next position is closer inlet section in this area.

The dimension of boundary particle $d_{gr}(x_i)$ was determined on the base of algorithmic analysis of the trajectory of the particles starting movement from particular depths of the section.

Average velocity of the space connected with particles flowing through infinitesimal surface $dx\cdot dz$ placed on depth x in layer z was determined by:

$$V_{pcr}=V_p-V_{0d_{gr}} \qquad (3)$$

where: $V_{0d_{gr}}=\frac{1}{d_{gr}}\cdot\int_0^{d_{gr}}w(d)\cdot dd$

$w(d)$ is a component in direction $0y$ of the velocity of the free settling

For finite element of the surface of defined position the mass flow of the particles moving through it for elements in the middle layer of inlet section is equal:

$$m_r=V_{pcr}\cdot\Delta x\cdot\Delta z\cdot u[d_{gr}(x_i)]\cdot Z_{dx} \qquad (4)$$

where: $u[d_{gr}(x_i)]$ is a function tabulating the features of particle dimensions distribution and expresses the mass fraction of the particles smaller than $d_{gr}(x_i)$ in the whole mass of particles in the suspension.

Therefore mass flux of the particles inflowing by inlet section of the layer is equal:

$$M_r=\sum_{i=1}^{w-1}m_r(i) \qquad (5)$$

Thus the concentration of the suspension leaving the outlet section of the middle layer of the conduit is given by:

$$Z_{oze}=\frac{M_r}{V_p\cdot x_o\cdot\Delta z} \qquad (6)$$

The concentration of the suspension leaving the whole outlet section is in dependence with concentration Z_{oze} and coefficient of concentration leveling s being the function of relative width of the conduit z_0/x_0 and velocity V_p:

$$Z_{oce}=\frac{Z_{oze}}{s[(z_o/x_o),V_p]} \qquad (7)$$

Jet efficiency of the decanter for whole section of the conduit considering also laminar motion development is equal:

$$\eta_{ceo}=1-\frac{Z_{oce}}{Z_d} \qquad (8)$$

Defined characteristic quantities were used for determination and analysis some of the dependences in process of multijet sedimentation.

4. The influence of solid particle density on suspension concentration in the outlet and sedimentation efficiency

The solid particles of densities from the range: $\rho=1,1\cdot 10^3\div 4,5\cdot 10^3$ kg/m^3 present in casting processes were analyzed. The dependence between suspension concentration in the outlet of conduit Z_{oce} and the density of solid particles ρ for different velocities of liquid flow $V_p(V_p=2,5\cdot 10^{-3}\div 20\cdot 10^{-3}\ m/s)$ are presented in figure 1.

Presented dependences show that for conduits of low depths $xo=0,011m$, the influence of the density of solid particles ρ on the suspension concentration in the outlet Z_{oce} decreases with increment of the density and decrement of the average liquid flow velocity V_p. The biggest intensity of the solid particles density ρ on the suspension concentration Z_{oce} is visible for the density up to $2,0 \cdot 10^3$ kg/m^3.

The dependence between the jet efficiency of the settling tank for whole section η_{ceo} of the conduit and ρ for different liquid flow velocities V_p is presented in figure 2. Analysis of the plot allows to observe the maximum intensity of the efficiency increment for $V_p=20 \cdot 10^{-3}$ m/s and for density of solid particles lower then $2,0 \cdot 10^3$ kg/m^3.

Presented dependences $Z(\rho)$ and $\eta(\rho)$ allow to analyze of values of discussed quantities. These dependences are presented in figures 3 and 4 respectively, refer to conduit of depth $x_o=0,050m$.

Total analysis of dependences $Z_{oce}(\rho)$ and $\eta_{ceo}(\rho)$ shown in figures 1 and 2 respectively referring to conduit depth $x_o=0,011m$ and in figures 3 and 4 referring to conduit depth $x_o=0,050m$ allow to observe more dense placement of the curves for particular velocities V_p referring to conduit of lower depth, considering of the same range of ordinates, what testifies, among other things, the higher exploitation elasticity of such conduit.

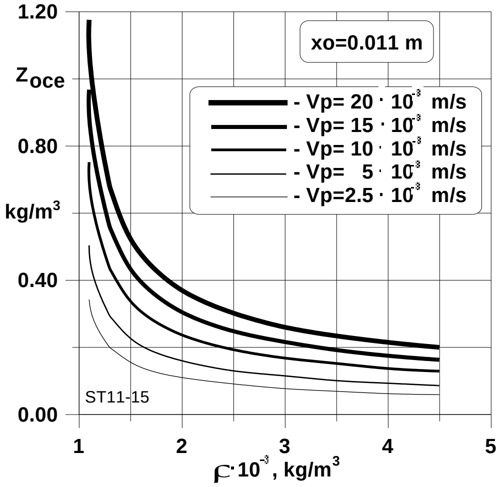

Fig. 1. Dependence $Z_{oce}(\rho)$

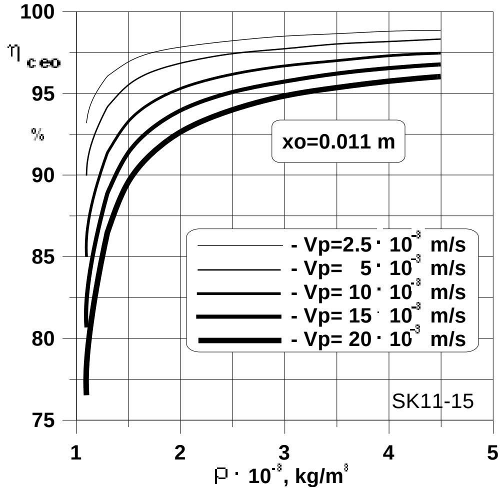

Fig. 2. Dependence $\eta_{ceo}(\rho)$

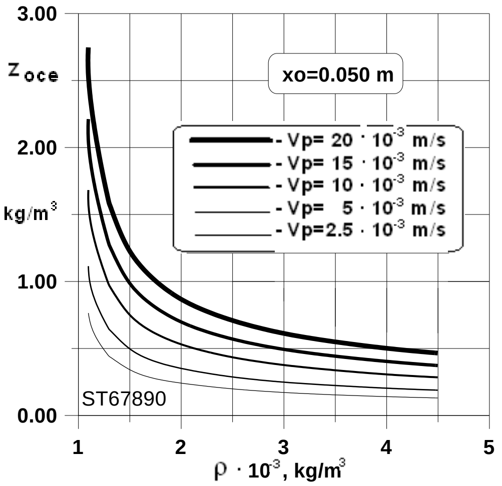

Fig. 3. Dependence $Z_{oce}(\rho)$

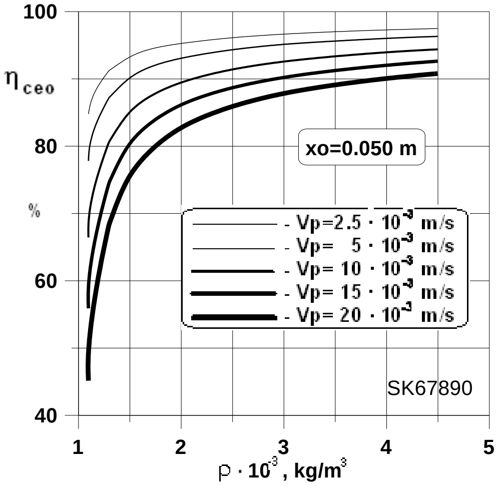

Fig. 4. Dependence $\eta_{ceo}(\rho)$

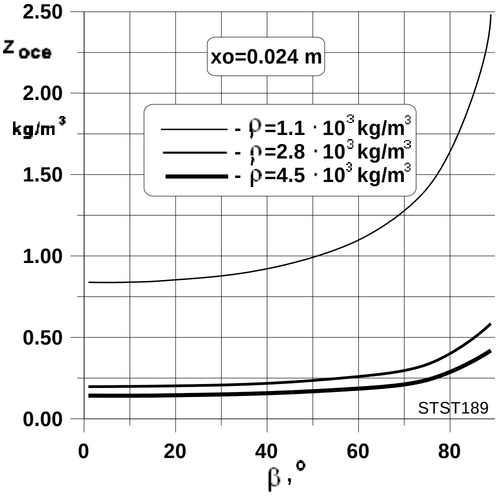

Fig. 5. Dependence $Z_{oce}(\beta)$

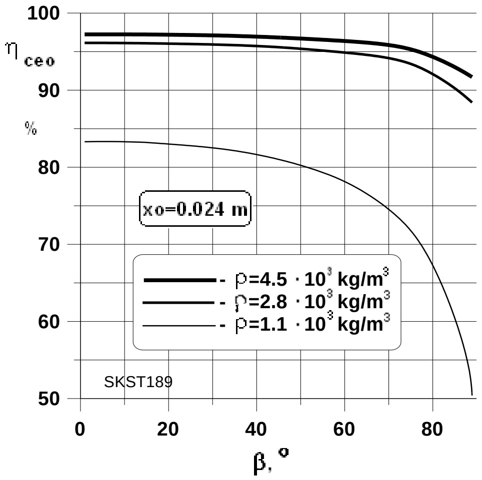

Fig. 6. Dependence $\eta_{ceo}(\beta)$

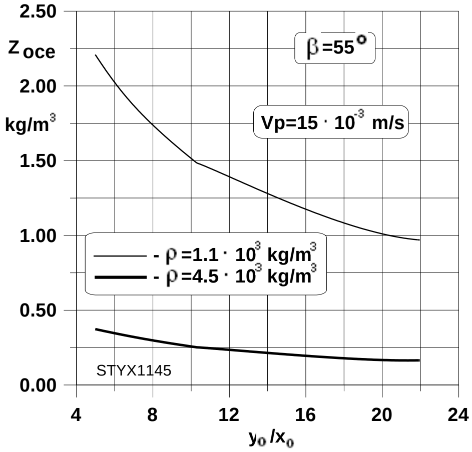

Fig. 7. Dependence $Z_{oce}(y_o/x_o)$

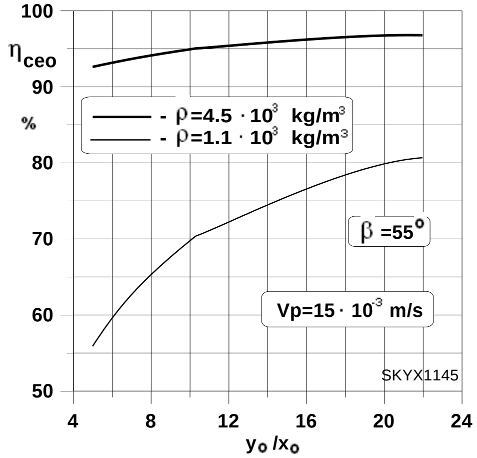

Fig. 8. Dependence $\eta_{ceo}(y_o/x_o)$

The analysis of $Z_{oce}(\beta)$ and $\eta_{ceo}(\beta)$ shown in figures 5 and 6 respectively (conduit of depth $x_o=0{,}024m$, average liquid flow velocity $V_p=10{,}0\cdot10^{-3}m/s$) determined for solid particles densities $\rho=1{,}1\cdot10^3;\ 2{,}8\cdot10^3$ and $4{,}5\cdot10^3\ kg/m^3$ shows that curves relating to densities $2{,}8\cdot10^3$ and $4{,}5\cdot10^3\ kg/m^3$ are placed close together in the range of high value of efficiency what testifies about lower influence of solid particles density in this range of values on the concentration of the suspension and jet efficiency of the settling tank.

The influence of relative conduit length y_o/x_o comes from the analysis of the dependence $Z_{oce}(y_o/x_o)$ and $\eta_{ceo}(y_o/x_o)$ shown in figures 7 and 8 respectively.

The higher value of relative length x_o/y_o the higher efficiency of process sedimentation. The stability of jet efficiency of the settling tank also increases for for higher relative length y_o/x_o and higher density of solid particles material ρ.

5. Conclusions

Presented and discussed dependences between the suspension concentration in the outlet and settling tank efficiency in the process of continuous multijet sedimentation with consideration of laminar flow development depict advantageous features of conduits of low depth for higher values of density of solid particles material.

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