

берілген разрядтар саны 100-ден 200-ге дейін жоғарлағанда судағы көрінетін жарықтың жұтылу көрсеткіші 0,0693-тен 0,0136-ға дейін төмендегенін байқауға болады.

Қазіргі күнге дейінгі белгілі болған суды тазалау және оның физика-химиялық сипаттамаларын жақсарту әдіснамаларына талдау жүргізілді. Судың элементтік құрамында каттылықтың азайғандығын және судың жұмсарғандығын байқауға болады. Бұл графиктерден біз электр разрядтың су каттылығын төмендетуге оң әсер еткендігін көреміз.

Су қоймаларынан алынған су үлгілеріне, жарық сәулерінің жұтылу дәрежесінің өзгерісіне электроимпульстік разрядтар санының әсерін зерттеу нәтижелерін ауыл шаруашылығын және өнеркәсіптерді таза сумен қамтамасыз ету мәселелерін шешуде қолдануға болады.

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### Copper melt’s flow numerical modeling into account design of liquid metals

Computer simulation of melts’ motion, which are widely used in metallurgy in the production of ferrous and non-ferrous metals, is impossible without considering mathematical aspects of solving the hydrodynamics’ equations [1-6]. In order to describe a melts’ motion in given book the continuity equation and the Navier-Stokes equations are considered, which are a consequence of applying conservation of mass and momentum to the elementary volume of liquid. Only way to check what Navier-Stokes equations actually provide for describing melt motions is, first of all, to conduct a rigorous mathematical analysis of the boundary value problems’ solvability posed for them in hydrodynamics. Now consider melt’s flow in an inclined chute. Equations general view is given in work [1]. For a particular design, you can interpret and write them as follows. Direct axis  $Oz$  by chute axis, assuming that chute’s design is infinitely, and the melt’s flow is directed along chute’s axis so that three velocity components  $u, v, w$ , is left only one  $w$ , therefore  $u = 0$ ,  $v = 0$ . Let melt’s flow be isothermal, then density  $\rho$  and viscosity coefficient  $\mu = const$ .

Hence, the Navier – Stokes equations are written in the form:

$$\begin{aligned}
-\frac{1}{\rho} \frac{\partial p}{\partial x} &= 0, \\
-\frac{1}{\rho} \frac{\partial p}{\partial y} &= 0, \\
w \frac{\partial w}{\partial z} &= -\frac{1}{\rho} \frac{\partial p}{\partial z} + \gamma \left( \frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2} \right),
\end{aligned} \tag{1}$$

$$\frac{\partial w}{\partial z} = 0.$$

Thus, as can be seen from the system of equations (1), velocity  $w$ , represents a function of only coordinates  $x, y$ , besides that, pressure function  $p$  is a function of  $z$ . In other words, if we conduct normal to the axis of the chute section, then the velocity in all such distributions sections are same. The pressure changes only from section to section, keeping the same value in this section. Such movements are called established.

Based on (1) we obtain equation:

$$\frac{dp}{dz} = \mu \left( \frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} \right). \quad (2)$$

The right side of (2) represents a function of  $x, y$ , then the left side is a function  $z$ . When coordinates are independent of each other, this can be observed only in the case when the left and right sides of the equation are constant separately. From the hydrodynamics main provisions follows:

$$\frac{dp}{dz} = -\frac{\Delta p}{\ell},$$

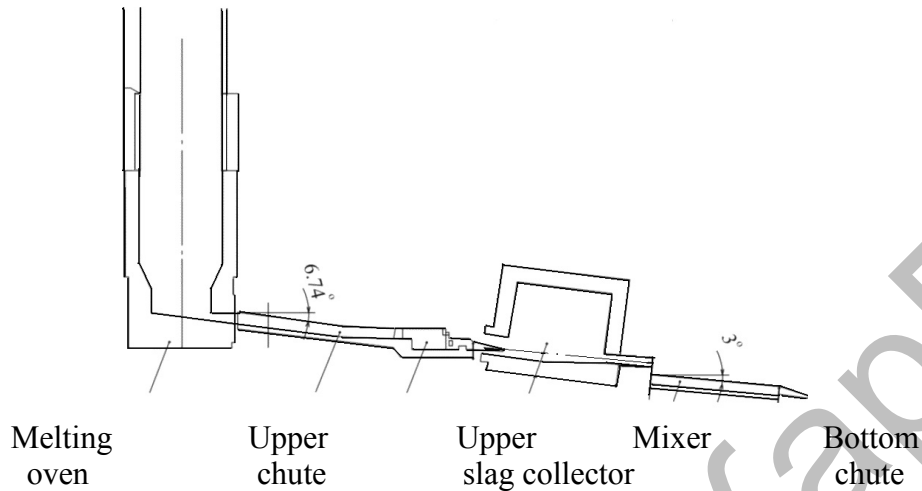
where  $\Delta p$  – pressure dropping in an arbitrarily selected area,  $\ell$  – chute's length. Besides that due to the melt's free surface presence in the chute, pressure is equal to atmospheric. Since chute is inclined to the horizon at a certain angle  $\alpha$ , then a volume force arises, a projection of which onto the axis  $Oz$  is equal to  $F_z = g \sin \alpha = \frac{\Delta p}{\ell}$ . Then the motion equation (2) in the direction  $Oz$  takes the form:

$$\mu \left( \frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} \right) + \rho g \sin \alpha = 0. \quad (3)$$

To solve obtained equation, boundary conditions are necessary. These conditions will be determined by melt's sticking to the chute's bottom and the friction's absence on the melt's free surface. Let us denote the flow's depth through  $h_1$ , and the width through  $h_2$ . Then the problem's boundary conditions are written as follows:

$$\begin{aligned} w &= 0 & \text{at } y &= 0, \\ \frac{\partial w}{\partial y} &= 0 & \text{at } y &= h_1, \\ \frac{\partial w}{\partial x} &= 0 & \text{at } x &= h_2. \end{aligned} \quad (4)$$

Thus, the equation 3) with boundary conditions (4) will describe a melt’s flow process in concrete designs of chute’s type. This model is built for melting equipment of the SCR – 2000 line, sketch of which is presented in correspondence with Picture 1.



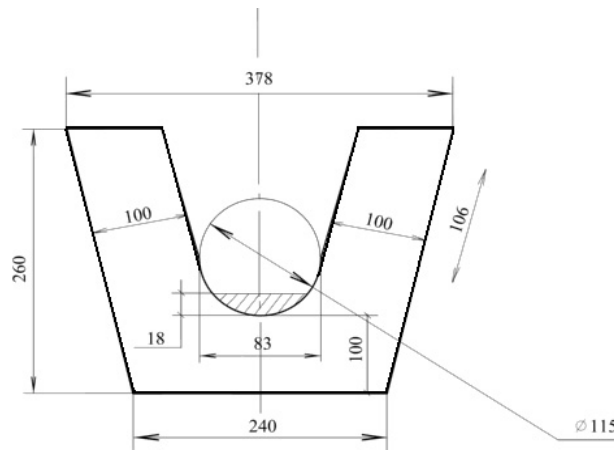
Picture 1 - Sketch of the melting equipment SCR – 2000 line’s location

Calculations are made for the lower chute with an inclination angle of 3°. Cross section of the lower chute is presented in correspondence with Picture 2 and shows the melt’s level in it.

Numerical parameters are determined by following calculations: the segment’s area is  $S = \frac{[lr - a(r - h)]}{2}$ , where  $l$  – arc length,  $a$  – chord,  $h$  – segment arrow:  $a = 83 \text{ mm}$ ,  $h = 18 \text{ mm}$ ,  $l \approx \sqrt{a^2 + (16h^2 / 3)} = \sqrt{83^2 + (16 \cdot 18^2 / 3)} = 92,8 \text{ mm}$ .

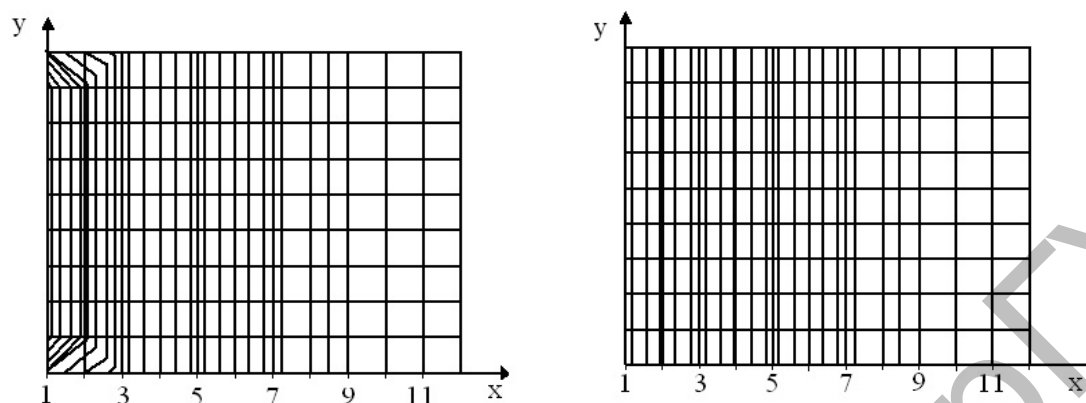
$$\text{Hence } S = \frac{\left[ 92,8 \cdot \frac{115}{2} - 83 \left( \frac{115}{2} - 18 \right) \right]}{2} = 1029 \text{ mm}^2.$$

Then second melt’s flow velocity is  $Q = 3,61 \frac{\text{kg}}{\text{c}}$ . With this taken into account it is possible to determine average melt’s flow velocity, which is equal to  $v_{cp} = 0,45 \frac{\text{M}}{\text{c}}$ . Constant step sizes  $\Delta x = \Delta y = 0,02$ . were used in the calculations. Time step in the calculations was chosen to be equal to  $\Delta t = 0,001$ .



Picture 2 - Section of lower chute

Established results for the velocities profiles  $v$  and  $u$  melt's flow profiles in the flat channel are presented in correspondence with Picture 3.



a) b)  
Picture 3 - Profiles a) - transverse  $v$  and b) longitudinal  $u$  velocities

Established flow attainment required 3000 steps. Analysis of obtained results shows following facts regarding accuracy of applied numerical calculations. Firstly, when calculating the flow in input cell of lattice, calculation error leads to a mass loss of 8-9%. As soon as we reduce cell size by 10 times, the mass loss is reduced to 4-6%. When calculating with great accuracy taking into account boundary conditions peculiarities, it was necessary to use a special numerical scheme. Secondly, the maximum velocity on the current's centerline is equal to  $0,63 \frac{M}{c}$ . Which is approximately on 15% higher than experimental value. Obtained results show that proposed computational scheme is quite economical and without special problems it can be used for calculating the flow at sufficiently small Reynolds numbers.

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