

Mathematical modeling of the crystallization process to obtain a fine fraction aluminates

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Abstract. Considered process of melt crystallization of the material in a twin-roll mold. Resolved an important problem of heat conduction through the wall of variable thickness, using the Fourier method and theorem Duhamel. Obtain theoretical dependence of the thickness of a frozen layer on the physical parameters of the melt and technological parameters of the crystallization process.

1. The first section in your paper

Development and implementation of technologies for the processing of low-grade ores of nonferrous metals and extraction of precious metals from scrap and waste around the world is becoming an important area of activity of metallurgical companies. In connection with the above, an urgent task becomes optimizing production to reduce the cost of deeper extraction of precious metals from ores and waste.

In order to exclude the long-term operation of cooling and energy-consuming step of crushing pigs, proposed to use modified twin roll crystallizer. For easy clarifying character of crystallization process, two-roll scheme during molding considered on example of the right roll (Figure 1). Second roll will be same in operating.

Full rotational cycle may be divided into four zones marked as I, II, III and IV.[1]

First zone - crystallization time t_1 layer thickness δ_1 , that is the contact time of roller surface element with a liquid melt, which is located in a container-crystallizer.

Second area - further crystallization time t_2 , during it imposition of liquid film thickness δ_2 is completely solid.

Third zone - cooling time of "rolls wall - hard layer" system till full crystallized layer at which the destruction of the material under a permanent load by shear knives 8. This zone is limited to the area of passage crystallized surface layer element by the moment of complete solidification imposition films to chopping knives.

In the fourth zone only wall of the roll is cooled till come to entrance of container-crystallizer zone.



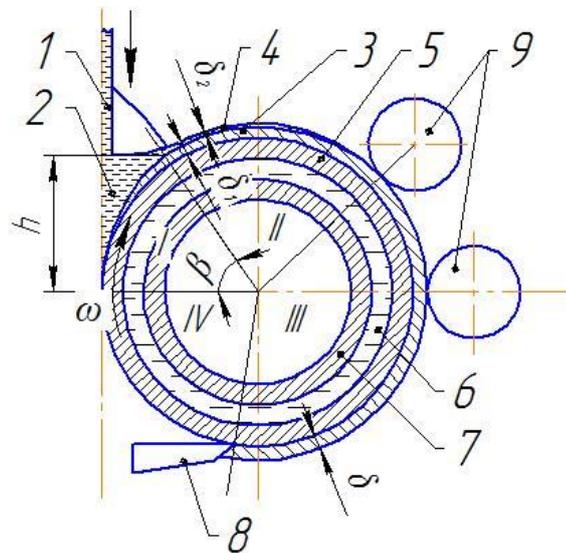


Figure 1. Scheme of continuous operation roll crystallizer.

1 - melt filing; 2 - container-crystallizer; 3 - crystallized layer; 4 - film liquid melt; 5 - drum, 6 - coolant, 7 - internal drum 8 - blade, I - first cooling zone, II - second cooling zone, III - third cooling zone IV - cooling zone of the roll, δ_1 - thickness of crystallized layer at the outlet of the first zone, δ_2 - layer thickness of liquid melt at the outlet from the first zone, δ - thickness cooled melt, ω - angular rotation velocity of the rolls, β - angle of the first zone, h - the depth of container - crystallizer

2. Heat transfer in thin-layer crystallization on the rolls.

Considered adjoin problem of heat conduction through variable thickness of wall "rolls wall - hard layer" with a convective heat exchange from two sides [2], solid layer with release heat of phase transition.

Heat transfer problem for the drum wall comes to the solution of the heat equation [3]:

$$\frac{\partial T_C}{\partial t} = \alpha_{CT} \frac{\partial^2 T_C}{\partial x^2}, \quad 0 \leq x \leq l;$$

where T_C - layer temperature, α_{CT} - heat transfer coefficient from freezing layer to the rolls wall, x - coordinate of the rolls wall layer beginning from inside of rolls wall, washed by coolant, l - thickness of the rolls wall, t - contact time of cooled roll surface with the melt.

In boundary conditions [4, 5]:

$$\begin{aligned} \frac{\partial T_C}{\partial x} &= \frac{\alpha_2}{\lambda_{CT}} (T_{CT} - T_2), x = 0; \\ T_{CT} &= T_0(t), x = l; \\ T_C &= f(x), t = 0; \end{aligned}$$

where λ_{CT} - rolls wall heat transfer coefficient, α_2 - rolls wall heat transfer coefficient to the coolant, T_2 - coolant temperature, T_{CT} - outside rolls wall temperature.

To solve this problem of the inhomogeneous heat on roller wall used Fourier method [6] and Duhamel theorem.

The task of freezing melt layer in our formulation was solved by multivariable L.G. Loitsiansky, common to the heat conduction problem with moving boundary E.M. Smirnov [7].

After the transformation equations to new dimensionless variables and then integrate a series expansion in powers of the parameters, we obtain a system of equations for the determination of $T = T_0(t)$ and $\delta_1 = \delta(t)$, describing the process of freezing the liquid product on the surface of the roll wall.

As a result of solving the problems described above to determine the dependence of the film thickness, frozen on the surface of the roll, during his stay in container-crystallizer [8, 9].

$$\delta_1 = 6,5 \cdot 10^{-5} \frac{\left(\lambda_P \frac{T_{kp} - T_2}{c_{kp} \rho a_P} \tau \right)^{\frac{2}{3}}}{\left(\lambda_P \left(\frac{1}{\alpha_2} + \frac{\delta_{cm}}{\lambda_{CT}} \right) \right)^{\frac{1}{2}} \left(\alpha_1 \frac{T_1 - T_{kp}}{T_{kp} - T_2} \right)^{\frac{1}{6}}};$$

$$\delta_2 = 0,94 \left(\frac{\mu u}{\sigma} \right)^{\frac{1}{6}} \left(\frac{\mu u}{\rho g \sin \frac{\beta}{2}} \right)^{\frac{1}{2}} \frac{\rho}{\rho_{me}}.$$

Where: μ - dynamic viscosity of the of liquid melt, u - linear outer surface of the rotational speed of the roll, σ - the surface tension of liquid melt, ρ - melt density at a temperature close to the temperature of crystallization, g - acceleration due to gravity, β - angle of first zone, ρ_{me} - frozen melt density.

Experimental data of conducted experiments on the two-roll mold shows a good correlation for the given formula.

Calculation of twin roll crystallizer conducted to determine the required flow of coolant (water) and rotational speed of the rolls when aluminates crystallize.

As the input task of data accepted a requirement the cooling on the existing two-roll mold aluminate 0,034 m³ during 120 seconds with the ability to specify the installation location of the shearing knife. Results of calculations presented in graphical form in Figures 2.

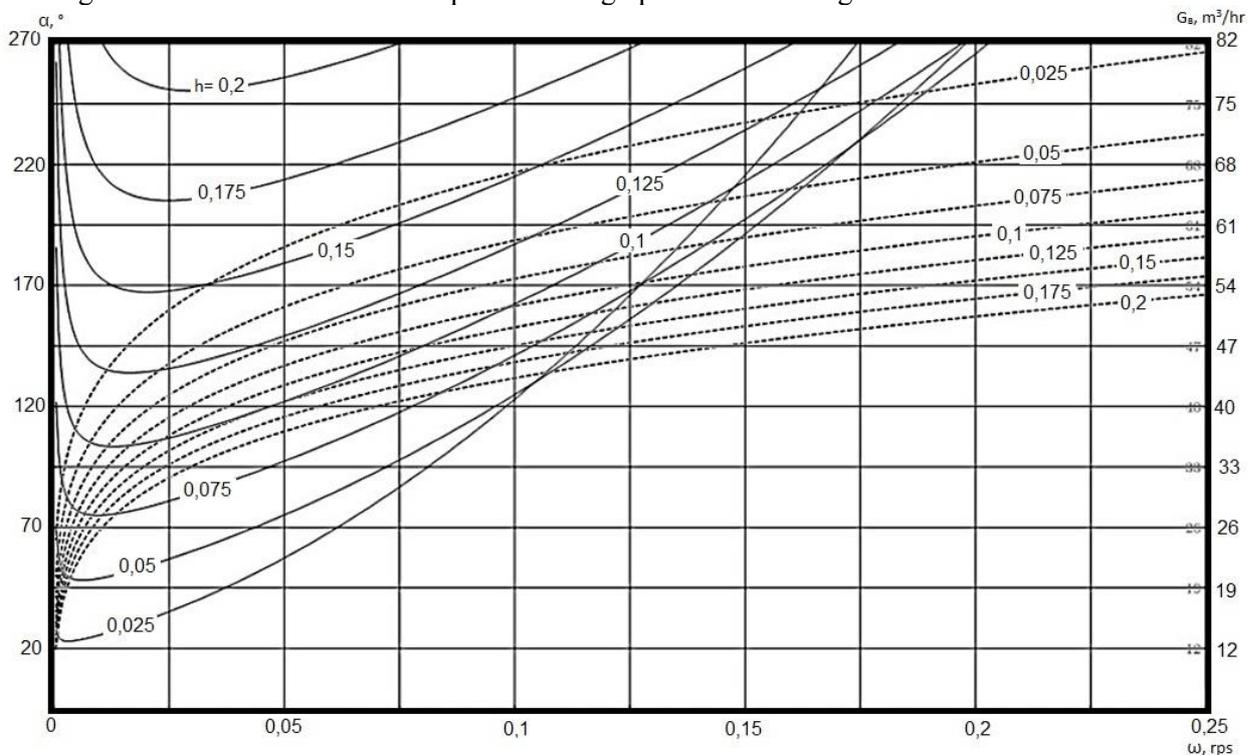


Figure 2. The nomogram for determining the parameters crystallizer work.

- The installation angle of the blades, α° ; ---- Coolant flow in m³/h; h - depth container-crystallizer, m.

The result of this work is a method of calculating the two-roll crystallizer, allowing to select appropriate modes of operation depending on the crystallizing melt. All this allows choosing the optimal operating conditions crystallizer work mode for the specific requirements of the final product.

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References

- [1] Kravchenko V M 1950 Triple system benzene-toluene-naphthalene *Journal. nat. chemistry* **24** pp 1033-1056
- [2] Anosov V J, Pogodin S A 1947 *The basic principles of physical and chemical analysis*. (Publishing AN USSR, Moscow) p 228
- [3] Wang H 1979 *Basic formulas and data on heat transfer for Engineers. Directory*. (Atomizdat, Moscow) p 216
- [4] Israphilov I H, Israphilov D I, Bashmakov D A, Galiakbarov A T, Samigullin A D 2015 Calculation of thermal processes in bottom electrode *Contemporary Engineering Sciences* Vol 8 no 1 pp 13 – 20
- [5] Israphilov I H, Israphilov D I, Bashmakov D A, Galiakbarov A T, Samigullin A D 2014 Numerical analysis of temperature distribution in bottom electrode of DC arc furnace in process *Contemporary Engineering Sciences* Vol 7 no 26 pp 1483 – 1491
- [6] Timmermans J 1959 *The physicochemical constants of binary systems in concentrated solutions*. (Interscience Publishers Inc., N.Y.) V 1
- [7] Gelperin N I & Nosov G A 1975 *Basic techniques of melt crystallization* (Chemistry, Moscow) p 182
- [8] Kuzmenko Yu P, Kasymbekov B A & Myasnikov S K 1984 *Phase equilibrium liquid - solid body in the system n-hexadecane - n-octadecane*, Dep. In TSSNF TSNIITENEFTEHIM, IGIC them. NS Kurnakova USSR, Moscow, USSR
- [9] Israphilov I H, Galiakbarov A T & Israphilov D I 2014 *The bottom electrode for metal smelting* RU Patent 142995 FSAEI HPE KFU, Russian Federation 25 Feb 2014 2014107020/07