Conclusion

Nitrogen is currently a quite normal alloying element together with C, Cr, Mn, Ni, etc. It provides unique combination of strength, plasticity and corrosion resistance for steels. Industry uses a lot of nitrogen-alloyed steels of various structure classes — austenitic, ferrite, martensite and two-phased. In future these steels are quite possible to replace light and non-ferrous metals' alloys. Alloying steels with nitrogen is very promising to give then special functional properties for example corrosion resistance in bioactive environments, bactericidal activity or disinfecting ability, high resistance to special impacts, lightweight steels with lower density and high strength and plasticity.

References

1. Svyazhin A. G. Hutnik-Wiadomosci Hutnicze. 1996. P. 264.
2. Kaputkina L. M., Svyazhin A. G., Siwka J., Prokoshkina V. G. Hutnik-Wiadomosci Hutnicze. 2007. P. 357.
3. Svyazhin A. G., Kaputkina L. M. *Izvestiya VUZov — Chernaya Metallurgiya* = Bulletin of High Schools — Ferrous Metallurgy. 2005. No. 10. P. 36.
4. Rashev Ts., Andreev Ch., Jekova L. et al, HNS 2009, Proceedings of the 10th Int. Conf. on High Nitrogen Steels, Moscow, 6-8 July 2009. 2009. P. 7.
5. Speidel M. HNS 2009, Proceedings of the 10th Int. Conf. on High Nitrogen Steels, Moscow, 6-8 July 2009. 2009. P. 121.
6. Chai G., Kivisakk U., Ronneteg S. HNS 2009, Proceedings of the 10th Int. Conf. on High Nitrogen Steels, Moscow, 6-8 July 2009. 2009. P. 67.
7. Han Dong, Yuping Lang, Fan Rong, Jie Su. HNS 2009, Proceedings of the 10th Int. Conf. on High Nitrogen Steels, Moscow, 6-8 July 2009. 2009. P. 21.
8. Bannych O. HNS 2009, Proceedings of the 10th Int. Conf. on High Nitrogen Steels, Moscow, 6–8 July 2009. 2009. P. 24.
9. Berns H., Riedner S., Gabriljuk V. HNS 2009, Proceedings of the 10th Int. Conf. on High Nitrogen Steels, Moscow, 6-8 July 2009. 2009. P. 129.
10. Gavriljuk V., Shanina B., Tyschenko A. et.al. HNS 2009, Proceedings of the 10th Int. Conf. on High Nitrogen Steels, Moscow, 6-8 July 2009. 2009. P. 140.
11. Nizhegorodov C. Yu., Voloskov S. A., Trusov V. A., Kaputkina L. M. *Metallovedenie i Termicheskaya Obrabotka Metallov* = Metal Science and Heat Treatment of Metals. 2008. P. 44.
12. Kaputkina L. M. , Prokoshkina V. G., Svyazhin A.G. Advanced in Science and Technology. Trans. Tech. Publication. Switzerland. 2010. 76. P. 72.
13. Kaputkina L. M., Prokoshkina V. G., Svyazhin A. G., Romanovich D. A., Kremyanskii D. V., Medvedev M. G., Nikiforenko S. V. *Metallovedenie i Termicheskaya Obrabotka Metallov* = Metal Science and Heat Treatment of Metals. 2009. Nos. 5 – 6. P. 286.
14. Kaputkina L. M., Prokoshkina V. G., Svyazhin A. G., Kremyanskii D. V., Medvedev M. G., Khadeev G. E. *Metallovedenie i Termicheskaya Obrabotka Metallov* = Metal Science and Heat Treatment of Metals. 2011. Nos. 5 – 6. P. 274.
15. Bronz A. V., Kaputkina L. M., Kindop V. E., Svyazhin A. G., Prokoshkina V. G., *Problemy Chernoi Metallurgii i Materialovedenia* = Problems of Ferrous Metallurgy and Material Science. 2012. No. 3. P. 57.

The work was performed with financial support of the Ministry of Education and Science of the Russian Federation within competitive part of applied scientific researches.

Simulation of hydrodynamics and heat transfer in implemention of hard particles in metal melt

I. Yachikov[1], K. Vdovin[1], K. Danilyuk[1], N. Feoktistov[1]

[1] Magnitogorsk State Technical University (Magnitogorsk, Russia)

E-mail: kn.vdovin@gmail.com

The mathematical models for the introduction of a one-dimensional refractory spherical particles in the liquid metal and its thermal state are proposed. The simulation of the heating of silicon carbide particles at their introduction into the steel melt at different fineness of the powder has been conducted.

Using computer modeling the dependences of the maximum depth of penetration of the powder of silicon carbide in the melt and the kinetics of its heating from the particles diameter have been found. The computer program "Hydrodynamics and HMTE of introducing solid particles into the melt" in the Mathcad 14 environment, allowing to conduct computer simulation of introducing of the refractory particles in the melt and their thermal state with regard to freezing and melting of a solid crust on their surface, have been created. It is seen that the diameter of the particles and their *initial velocity have significant affect on the hydrodynamic and thermal characteristics. Thus, the mathematical model and the computer program, which allows to determine the important parameters of the process of introduction and dispersion of dispersed and fine-dispersed refractory powders in the molten metal melt for engineering practice have been developed.*

Keywords: *mathematical model, refractory particles, molten metal, the system of differential equations, heat flow, solid metal shell.*

Dispersion-hardened steels can serve as an alternative to the use of expensive alloying elements and technological treatments, and that are steels, containing solid refractory fine-dispersed particles of carbides, oxides, nitrides, and hard alloys. These steels are characterized by increased values of wear resistance, tensile strength, elasticity modulus and heat resistance, low tendency to cracking compared with the steels of the same chemical composition, not having dispersed particles.

The dispersion-strengthened steels production is based on introduction of solid dispersed particles in the melt at the casting stage. However, due to the fact, that the introduced particles and the hardened steel have different density, in practice, we get the introduced particles distribution by volume, which is nonuniform, unpredictable and uncontrollable. This is largely due to the lack of reliable, adequate mathematical models for determination of process technological parameters in the course of introduction of dispersed and fine-dispersed refractory powders to the melt.

The purpose of this study is to create a simple mathematical model, which considers main factors, influencing the process of particles introduction in the liquid steel.

When modeling the particle motion hydrodynamics several assumptions have been made.

1. The kinetic energy of the particle does not transfer into heat energy, but is used to set the melt in motion.

2. The particle has a spherical shape, the molten metal surface is directed normally to the direction of particles motion.

3. There is no chemical interaction between the reagent and the melt.

4. The molten metal and the reagent deformation process is not accompanied by changes in their densities.

5. The particle motion in the melt is one-dimensional.

We will examine the mathematical model of the solid particle introduction into the melt, and in the case, when the particle density is lower than the melt density – its flowing-up to the surface. The particle motion equation in the melt along the x-axis (**Fig. 1**).

$$m_ч \frac{d^2x}{d\tau^2} = -F_н - F_{тр} - F_{ар} + F_т - F_{ин}, \tag{1}$$

where $m_ч$ — the particle mass; $F_н$ — surface tension force of the metal melt; $F_{тр}$ — friction force (front resistance); $F_{ар}$ — the Archimedes force; $F_т$ — gravity force; $F_{ин}$ — inertia force.

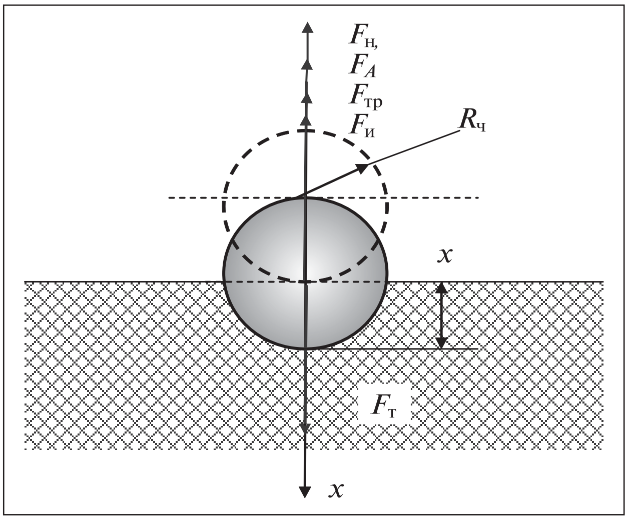

Figure 1. Forces, acting to a solid particle in the melt

The surface tension force is determined as

$$F_н = \sigma_м \frac{dS}{dx}, \tag{2}$$

where $\sigma_м$ — coefficient of surface tension of the metal melt; S — reactant metal area of contact.

Friction force (resistance force) $F_{тр} = \frac{k\rho_м S_ч}{2}\left(\frac{dx}{d\tau}\right)^2$,

where $S_ч$ — area of the maximum cross-section of the reactant metal contact surface, $\rho_м$ — metal density. In the works [1, 2], the front resistance coefficient is taken equal to $k = 1{,}3$. The spherical particle is the poor streamlined body, the resistance coefficient is the function of the Reynolds number $\mathrm{Re} = 2R_ч \cdot V_ч / V_м$ [3, 4]

$$k = \frac{a}{\mathrm{Re}^m},$$

where $a = 24$, $m = 1$, for $0 \le \mathrm{Re} \le 1$;
$a = 25$, $m = 0{,}75$, for $1 \le \mathrm{Re} \le 50$;
$a = 4$, $m = 0{,}3$, for $50 \le \mathrm{Re} \le 10^3$;
$a = 0{,}45$, $m = 0$, for $10^3 \le \mathrm{Re} \le 2\cdot10^5$.

In case of the particle flowing-up the resistance force is opposite to the Archimedes force (directed along the Ox axis), this leads to setting of the uniform floating-up velocity. In general case, friction force is written as

$$F_{тр} = \mathrm{sign}\left(\frac{dx}{d\tau}\right)\frac{k\rho_м S_ч}{2}\left(\frac{dx}{d\tau}\right)^2. \tag{3}$$

The Archimedes force

$$F_{ар} = g \cdot m_м, \tag{4}$$

where $m_м$ — mass of metal, the volume of which is equal to the volume of the recessed portion of the particle, g — free fall acceleration.

Gravity force $F_т = m_ч g$. Inertia force

$$F_{ин} = m_м \frac{d^2x}{d\tau^2}. \tag{5}$$

We shall write down specific values of the listed forces depending on the coordinates in the melt. The mass of the spherical shape particle of the radius

$R_ч$ — $m_ч = 4/3(\pi R_ч^3 \rho_ч)$, reactant metal area of contact $S = \pi x(4R_ч - x)$, $\frac{dS}{dx} = 2\pi(2R_ч - x)$. Surface tension force $F_н = 2\pi(2R_ч - x)\sigma_м$.

The specific surface tension force when $x \le 2R_ч$, $F_н/m_ч = c_0(2R_ч - x)$; when $x > 2R_ч$, $F_н/m_ч = 0$, where

$$c_0 = \frac{3\sigma_м}{2\rho_ч R^3_ч}.$$

Let us introduce the function $\zeta(x, x_0) = \begin{cases} x, \text{ at } x \le x_0 \\ x_0, \text{ at } x > x_0 \end{cases}$, then

$$F_н/m_ч = c_0(2R_ч - \zeta(x, 2R_ч)). \quad (6)$$

The area of the maximum cross-section of the reagent-metal contact surface $S_ч = \pi x(2R_ч - x)$, from here the function for the friction force

when $x \le R_ч$ $F_{тр} = sign\left(\frac{dx}{d\tau}\right)\frac{k\rho_м \pi x}{2}(2R_ч - x)\left(\frac{dx}{d\tau}\right)^2$;

when $x > R_ч$ $F_{тр} = sign\left(\frac{dx}{d\tau}\right)\frac{k\rho_м \pi R_ч^2}{2}\left(\frac{dx}{d\tau}\right)^2$.

Specific friction force (resistance)

when $x \le R_ч$ $\frac{F_{тр}}{m_ч} = sign\left(\frac{dx}{d\tau}\right)\frac{3k\rho_м x(2R_ч - x)}{8R_ч^3\rho_ч}\left(\frac{dx}{d\tau}\right)^2 =$

$= sign\left(\frac{dx}{d\tau}\right) b_0 x(2R_ч - x)\left(\frac{dx}{d\tau}\right)^2$;

when $x > R_ч$ $\frac{F_{тр}}{m_ч} = sign\left(\frac{dx}{d\tau}\right) b_0 R_ч^2 \left(\frac{dx}{d\tau}\right)^2$.

where $b_0 = \frac{3k\rho_м}{8R_ч^3\rho_ч}$. This can be written as

$$\frac{F_{тр}}{m_ч} = sign\left(\frac{dx}{d\tau}\right) b_0 \zeta(x, R_ч)(2R_ч - \zeta(x, R_ч))\left(\frac{dx}{d\tau}\right)^2. \quad (7)$$

Volume of the recessed particle portion $V_м = 1/3\pi x2(3R_ч - x)$, from here $m_м = 1/3\pi x2(3R_ч - x)\rho_м$. Specific Archimedes force

when $x \le 2R_ч$ $\frac{F_{ар}}{m_ч} = g\left(\frac{m_м}{m_ч}\right) = g\left(\frac{x^2(3R_ч - x)\rho_м}{4R_ч^3\rho_ч}\right) =$

$= a_0 x^2(3R_ч - x)$,

when $x > 2R_ч$ $\frac{F_{ар}}{m_ч} = g\left(\frac{\rho_м}{\rho_ч}\right)$, where $a_0 = g\left(\frac{\rho_м}{4R_ч^3\rho_ч}\right)$.

This function can be written as

$$\frac{F_{ар}}{m_ч} = a_0 \zeta(x, 2R_ч)^2(3R_ч - \zeta(x, 2R_ч)). \quad (8)$$

Specific gravity force

$$\frac{F_т}{m_ч} = g. \quad (9)$$

Specific inertia force

when $x \le R_ч$ $\frac{F_{ин}}{m_ч} = \frac{1}{4R_ч^3\rho_ч} x^2(3R_ч - x)\rho_м \frac{d^2x}{d\tau^2} =$

$= d_0 x^2(3R_ч - x)\frac{d^2x}{d\tau^2}$,

when $x > R_ч$ $\frac{F_{ин}}{m_ч} = 2d_0 R_ч^3 \frac{d^2x}{d\tau^2}$,

when $d_0 = \frac{\rho_м}{4R_ч^3\rho_ч}$, from here

$$\frac{F_{ин}}{m_ч} = d_0 \zeta(x, R_ч)^2(3R_ч - \zeta(x, R_ч))\frac{d^2x}{d\tau^2}. \quad (10)$$

Solving equations (1), (6)–(10) jointly and considering the fact, that when $x<0$, $dV_ч/d\tau = g$, we get the system of differential equations with initial conditions, describing the hydrodynamics of the reagent solid particle introduction into the metal melt

$$\frac{dV_ч}{d\tau} = -[c_0(2R_ч - \zeta(x, 2R_ч)) + sign(V_ч) b_0 \zeta(x, R_ч)(2R_ч - \zeta(x, R_ч))V_ч^2 + a_0 \zeta(x, 2R_ч)^2(3R_ч - \zeta(x, 2R_ч)) - g] / (1 + d_0 \zeta(x, R_ч)^2(3R_ч - \zeta(x, R_ч))); \quad (11)$$

$$\frac{dx}{d\tau} = V_ч; \quad (12)$$

$$V_ч(0) = V_{0ч}; \quad x(0) = 0, \quad (13)$$

where $V_{0ч}$ — initial velocity of the particle.

Next, we consider the mathematical model of the refractory particle thermal state of the $r_ч$ radius in its introduction into the melt with initial temperature T_0. When modeling the reagent particle heat transfer, in addition to the previously discussed limitations, several assumptions are accepted complementary.

1. The metal melt temperature is constant and equal to $T_м$.

2. The effect of the solid metal rupture on the particle surface under the action of internal pressure is absent.

3. The particle temperature $T_ч$ in all its points is the same and varies only over time.

4. There is the smooth boundary of solid and liquid phases of metal separation (Stefan problem), defined by crystallization temperature $T_к < T_м$ and having X coordinate.

5. Temperature field $T(r)$ in a solid metal is one-dimensional (**Fig. 2**).

We believe that the processes of metal freezing on the particle surface and incrustation melting are described by conditions at the objects boundary [5]. The heat flow, transferred to the particle, is the sum of the heat flow, generated by the metal crystallization, and the heat transfer from the liquid metal

$$\lambda_т \frac{dT_ч}{dr}(\tau, x) = \frac{L}{S}\frac{dm_т}{d\tau} + q_S, \quad (14)$$

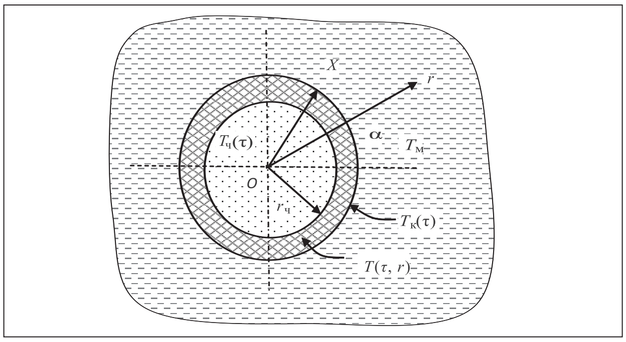

Figure 2. For calculation of the melt and particle heat transfer

where τ — is time; L — specific melting heat; $\lambda_\text{т}$ — coefficient of solid metal thermal conductivity; $S = 4\pi \cdot r_\text{ч}^2$ — heat exchange surface, q_S — heat flow to the particle from the part of the liquid metal. On the boundary between the particle and the metal

$$\lambda_\text{ч}\frac{dT_\text{ч}}{dr} = \lambda_\text{т}\frac{dT}{dr}(\tau, r_\text{ч}), \tag{15}$$

$$T_\text{ч}(\tau) = T(\tau, r_\text{ч}), \tag{16}$$

where $\lambda_\text{ч}$ — coefficient of thermal conductivity of the particle material.

It is assumed, that temperature distribution in the solid metal shell is described by the rules of stationary heat conduction through the ball wall [3]

$$T(\tau, r) = T_\text{ч} + \frac{(T_\text{к} - T_\text{ч})}{X - r_\text{ч}} X \cdot r_\text{ч}\left(\frac{1}{r_\text{ч}} - \frac{1}{r}\right). \tag{17}$$

Then temperature derivative $\frac{dT}{dr} = \frac{(T_\text{к} - T_\text{ч})}{X - r_\text{ч}} X \cdot r_\text{ч}\left(\frac{1}{r^2}\right)$

and its value at the boundaries

$$\frac{dT}{dr}(\tau, X) = \frac{(T_\text{к} - T_\text{ч})}{X - r_\text{ч}}\left(\frac{r_\text{ч}}{X}\right), \tag{18}$$

$$\frac{dT}{dr}(\tau, r_\text{ч}) = \frac{(T_\text{к} - T_\text{ч})}{X - r_\text{ч}}\left(\frac{X}{r_\text{ч}}\right). \tag{19}$$

The heat flow on the particle from the part of the liquid metal can be defined as the heat flow through the spherical wall

$$q_S = \frac{4\pi(T_\text{м} - T_\text{ч})}{\frac{1}{\alpha X^2} + \frac{1}{\lambda_\text{т}}\left(\frac{1}{r_\text{ч}} - \frac{1}{X}\right)} \cdot \frac{1}{4\pi r_\text{ч}^2} = \frac{(T_\text{м} - T_\text{ч})}{\frac{r_\text{ч}^2}{\alpha X^2} + \frac{r_\text{ч}^2}{\lambda_\text{т}}\left(\frac{1}{r_\text{ч}} - \frac{1}{X}\right)}. \tag{20}$$

Let us write down the differential of the solid metal mass shell $dm_\text{т} = 4\pi r^2 \rho_\text{т} dX$ and taking into account equations (14) and (18) we get

$$\frac{dX}{d\tau} = \frac{r_\text{ч}^2}{L\rho_\text{т} X^2} \times \left[\lambda_\text{т}\frac{(T_\text{к} - T_\text{ч})}{X - r_\text{ч}}\left(\frac{r_\text{ч}}{X}\right) - \frac{(T_\text{м} - T_\text{ч})}{\frac{r_\text{ч}^2}{\alpha X^2} + \frac{r_\text{ч}^2}{\lambda_\text{т}}\left(\frac{1}{r_\text{ч}} - \frac{1}{X}\right)}\right], \tag{21}$$

and when $X \le r_\text{ч}$, we have $dX/d\tau = 0$. The function $\frac{m_\text{ч} C_\text{ч}}{4\pi r_\text{ч}^2}\frac{dT_\text{ч}}{d\tau} = q_s$ can be written from the solid particle heat balance, where $m_\text{ч} = 4\pi\rho_\text{ч} r_\text{ч}^3/3$ — the particle mass; $c_\text{ч}$ — specific heat of the particle material. Considering equations (19) and (22) jointly, we get

$$\frac{dT_\text{ч}}{d\tau} = \frac{3(T_\text{м} - T_\text{ч})}{c_\text{ч}\rho_\text{ч} r_\text{ч}^3\left[\frac{1}{\alpha X^2} + \frac{1}{\lambda_\text{т}}\left(\frac{1}{r_\text{ч}} - \frac{1}{X}\right)\right]}. \tag{22}$$

For the Cauchy boundary problem formulation the differential equations (21) and (23) are supplemented with the initial conditions

$$X(0) = r_\text{ч}; \quad T_\text{ч}(0) = T_0. \tag{23}$$

The heat transfer coefficient α is determined by the empirical formula of Katsnelson B.D. and Timofeeva-Agafonova F.A., describing the heat transfer in the sphere flow, taking into account heat conduction and forced convection [3]

$Nu = 2 + 0{,}03 Pr^{0{,}33} Re^{0{,}51} + 0{,}35 Pr^{0{,}35} Re^{0{,}58}$, where $Re = 2X \cdot V_\text{ч}/\nu_\text{м}$; $Nu = 2X \cdot \alpha/\lambda_\text{м}$, $Pr = \nu_\text{м} c_\text{м} \rho_\text{м}/\lambda_\text{м}$, $\nu_\text{м}$, $c_\text{м}$, $\lambda_\text{м}$ — are kinematic viscosity, specific heat and coefficient of thermal conductivity of liquid metal, respectively.

The boundary problem (21) (23) allows to find the particles temperature change and the coordinate of the molten metal solidification front, that defines the current radius of the particle in the implantation process. The thermal interaction equations in the course of the reagent implantation in the melt are solved together with the hydrodynamics equations (11) — (13). Crystallization front $R_\text{ч} = X$ is taken for the current radius of the particle.

The computer program *"Hydrodynamics and HMTE of introducing solid particles into the melt"* in the *Mathcad* 14 environment, allowing to conduct computer simulation of introducing of the refractory particles in the melt and their thermal state with regard to freezing and melting of a solid crust on their surface, have been created.

Simulation of the silicon carbide particles implantation in the steel melt and their thermal state at $T_0 = 30\,°C$; $T_\text{м} = 1200\,°C$; $T_\text{к} = 1100\,°C$ have been conducted. Thermophysical properties of liquid steel were taken as the following: = 7000 kg/m³; $\nu_\text{м}$ = 0,7 mm²/s; $c_\text{м}$ = 840 J/(kg deg); $\lambda_\text{м}$ = 34,8 Wt/(m deg); $\sigma_\text{м}$ = 1,8 N/m; $L = 2{,}72 \cdot 10^5$ J/kg; solid steel = 7800 kg/m³; $\lambda_\text{т}$ = 40 Wt/(m deg). Thermophysical parameters of the material particles were set as medium-integral for the operating temperatures range [6]: $\rho_\text{ч}$ = 3032 kg/m³; $c_\text{ч}$ = 1146 J/(kg deg); $\lambda_\text{ч}$ = 18,52 Wt/(m deg).

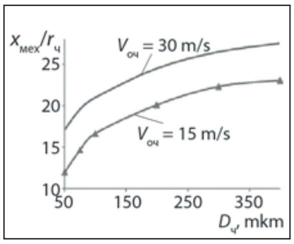

Figure 3. Dependence of the maximum depth of particle's penetration into the melt from the diameter at different initial velocities

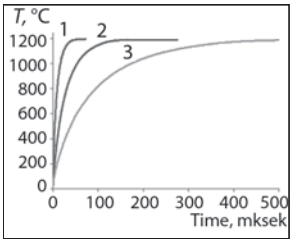

Figure 4. Dependence of the particle's temperature from the time of its being in the melt at different diameters:
1 — 50 mkm; 2 – 100 mkm; 3 – 200 mkm

Using computer modeling the dependences of the maximum depth of penetration of the powder of silicon carbide in the melt (**Fig. 3**) and the kinetics of its heating (**Fig. 4**) from the particles diameter have been found. It is seen that the diameter of the particles and their initial velocity have significant affect on the hydrodynamic and thermal characteristics.

Thus, the mathematical model and the computer program, which allows to determine the important parameters of the process of introduction and dispersion of dispersed and fine-dispersed refractory powders in the molten metal melt for engineering practice have been developed.

REFERENCES

1. Sidorenko M. F. Theory and practice of purging metal by powders. Moscow. *Metallurgiya* = Metallurgy. 1978. 232 p.
2. Gordon G. M., Peisakhov I. L. Dust collection and gas cleaning. Moscow. *Metallurgiya* = Metallurgy. 1968. 499 p.
3. Kutateladze S. S. Fundamentals of the heat transfer theory. Moscow. *Atomizdat* = Atomic Publishers. 1979. 416 p.
4. Povkh I. L. Technical hydrodynamics. Leningrad. *Mashinostroenie* = Engineering, 1976. 504 p.
5. Chumanov I. V., Yachikov I. M., Vorona E. A. Teplo- i massoperenos pri reaktsii obogashchennykh zhelezom okatyshey s rasplavom (Heat and mass transfer in the interaction of iron-rich pellets with a melt). *Izvestiya vuzov. Chernaya Metallurgiya* = Bulletin of High Schools. Ferrous metallurgy. 2010. No. 9. PP. 28-32.
6. Chirkin V. S. Teplofizicheskie svoistva materialov (Thermophysical properties of materials). Moscow. *Izdatelstvo fiziko-matematicheskoy literatury* = Publishing house of physical-mathematical literature. Moscow. 1959. 356 p.

***V. V. Reshetov*[1], *A. I. Trushin*[1], *V. S. Valavin*[2], *V. V. Bredikhin*[2]**
[1] *LLC "Spetsmash" (Moscow, Russia)*
[2] *LLC "Ferrotrade" (Beloretsk, Russia)*
E-mail: nppsm@mail.ru

Putting horizontal continuous casting machine into trial operation

In the context of the significant cost of credit resources, construction of giant plants with large metallurgical aggregates becomes quite costly event. The new principles of creation of less capital-intensive metallurgical complexes with shortened technological cycles and greater maneuverability succeed. In recent decades, a greater interest has been shown in the creation of mini steel plants with an annual production of less than 100 thousand tons, and in some cases - even at the level of 5—30 thousand tons. Currently, pilot enterprise for the production of rods with diameter 6—10 mm of high-alloy steels and special alloys is constructed at the LLC "Ferrotrade" (Beloretsk) plant. By the beginning of 2014 a steelmaking facility was built and construction of the rolling mill had begun. The main technological equipment of the steelmaking facility is represented by midrange induction melting furnace IST0.45 produced by LLC "SPE Kurai" (Ufa) with capacity of up to 0.5 tons and one-strand HCC produced by LLC "Spetsmash" (Moscow) with Ø60 mm section of the billet.

Key words: *horizontal continuous casting, rolling, high-alloyed steels, special alloys, mini-metallurgical production, tundish, withdrawal, moulds.*

In the context of the significant cost of credit resources, construction of giant plants with large metallurgical aggregates becomes quite costly event. The new principles of creation of less capital-intensive metallurgical complexes with shortened technological cycles and greater maneuverability succeed. In recent decades, a greater interest has been shown in the creation of mini steel plants with an annual production of less than 100 thousand tons, and in some cases - even at the level of 5-30 thousand tons.

Construction of a mini-metallurgical production requires addressing a number of specific issues related to the complexity of metallurgical production with the steel furnaces of small capacity, when there are no conditions for casting "ladle to ladle". Or, for example, those related to the need to use existing industrial buildings in order to reduce capital costs, which imposes restrictions on the size of the equipment. To reduce the weight and capacity of the rolling equipment, an optimization of billet section is required, that usually means the need to reduce it.

Horizontal continuous casting machine (HCC), whose characteristics are in good agreement with a small