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The Use of Briquettes in Steel Production. Teeming

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The techniques of using briquettes during teeming boiling and killed steel are analyzed.

Keywords: STEELMAKING, TEEMING, BRIQUETTES

Introduction

The history of the use of briquettes for steel teeming began much later than for smelting.

Results and Discussion

1. Rimming steel

Teeming spans of domestic steelworks during steel teeming into ingots were always limiting production sector and in the 1970s this problem was solved by increasing the rate of filling the molds up to 3-5 m/min. The rapid increase in pressure of the liquid metal column and decrease the duration of the rimming causes a decrease in the thickness of a dense crust of δ. The problem is solved by mold additive boil intensifiers based on oxygen and gas-forming materials. First, in the form of powders, and later – in briquettes to avoid environmental pollution and over-rapid rimming of the metal.

In [1] the dependence of the specific consumption of intensifiers m, g/t on the carbon content is shown. Since the value of δ depends on the casting speed V, cm/s, it is advisable to establish a comprehensive environment impact of the intensification of the boil.

The published data were analyzed, in which the effect of powder intensifiers during steel teeming weighing 11-21 tons of sheet and high-grade 8-8.5 t were investigated that filled with velocity 1,4-13,8 cm / s an article 08кп and 3кп with unit costs intensifiers 0 - 1200 g / t containing fraction ($Д_о$) 0-0,92 oxidizer and the proportion of ($Д_г$), 0-1.0% blowing component, in which were the information about the obtained thickness of the crust in this case without ($δ_о$) and with (δ) using intensifiers and their relationship was represented. Intensifier was characterized by complexes $Ф_о$ = $mД_о/v$ and $Ф_г = mД_г/v$.

According to the statistical processing of the data set it was found that for steel 08кп

$$\bar{\delta} = 2{,}1 + 0{,}010\Phi_o - 1{,}45 \cdot 10^{-5}\Phi_o^2, \quad (1)$$

$$\bar{\delta} = 4{,}6 - 0{,}020\Phi_г + 5{,}00 \cdot 10^{-4}\Phi_г^2, \quad (2)$$

for steel 3кп

$$\bar{\delta} = 2{,}7 + 0{,}044\Phi_o - 3{,}26 \cdot 10^{-4}\Phi_o^2, \quad (3)$$

$$\bar{\delta} = 2{,}9 - 0{,}014\Phi_г + 5{,}70 \cdot 10^{-6}\Phi_г^2. \quad (4)$$

The value $\bar{\delta}$ is maximized for the steel 08кп with $Ф_о$ = 340, and 3кп with $Ф_о$ = 68, since an increase in the carbon content the selection pressure of carbon monoxide required for a sufficiently long boiling and thick crust, is achieved at a lower concentration of oxygen. For specific consumption of steel intensifiers more optimal overoxidates and gaseous tubules are formed in the crust, which in [2] due to the overoxidation of smelted converter steel made not only to abandon intensifiers, but add to the mold a mixture of iron shavings and coke for the removal of excess oxygen. With the increase in $Ф_г$ value $\bar{\delta}$ decreases and, obviously, gas-forming component of the intensifier is ineffective.

For the cases of intensifiers boiling in briquetted form [3-6] by expressions (1) - (4) was calculated quantity $\bar{\delta}_p$ which could be obtained if the spray intensifier, and found the ratio of actual value $\bar{\delta}_ф$ to the calculated $\bar{\bar{\delta}} = \bar{\delta}_ф / \bar{\delta}_p$ for the oxidation δ_o and gaseous $\bar{\bar{\delta}}_г$ components. Analysis of the data (**Table 1**) shows that the use of briquettes in most cases is better than powdered intensifiers. In addition, they reduce dust emissions in 5-9 times, which is important in conditions of continuous tightening of emission standards for hazardous substances.

Since the continuous casting of rimming steel is not used around the world, the enterprises that produce rimmsteel, it is advisable for them to use briquetted boiling intensifiers during high-speed casting.

Table 1. Comparison of the effectiveness of boiling intensifiers in briquetted and powdered form (numerator - the range, the denominator - average)

№	Steel	Мсл, т	До	Дг	$\overline{\overline{\delta}}_о$	$\overline{\overline{\delta}}_г$	Source
1	3кп	7-9	0,6-0,8 0,75	0,1-0,2 0,14	0,8-1,5 1,25	1,1-2,1 1,50	[3]
2	3кп	16-21	0,8	0,2	0,6-1,7 1,14	0,7-2,2 1,37	[4]
3	08кп	14-81	1,0	0	0,7-1,7 1,14	1,0-1,3 1,15	[5]
4	08кп	7,8	0,75	0,25	1,0	0,5	[6]

2. Warming of the ingot

65 years ago, crystallizer Z. Junghans (Germany) came into effect, the principle of operation is preserved to this day, and it became clear that the future of continuous casting, since the metal yield was at least 10% higher than the casting of killed steel into molds.

In 1957 in the world every year 343 million tons of steel were smelted, including 15% in our country, most of which is poured into ingots. This led to the desire of enterprises to improve competitiveness of existing production, reducing head trimmings.

In 1959, the Central Research Institute of Ferrous Metallurgy hosted a conference with the participation of 22 plants and 12 research institutes and universities, and by 1981 22% of killed steel was poured into the country using different methods of warming the head of the ingot.

2.1. Heat producing elements (HPE)

In the group of methods, which used HPE it is possible to allocate those that had a significant exothermic effect and low exothermic.

Foreign development of trade names Kellog, Feedex, Ferrux used for casting alloy steel, allowed to reduce profit by 7-9% (Czechoslovakia, Germany, 1960), 6-8.5% (Sweden, USA, 1957), 6% (USA, 1960), 8-12% of the company Böhler (Austria, 1961).

At the domestic plants HPE based on aluminum and silicocalcium, oxides of sodium nitrate and manganese ore were used (1964-1974) that increased yield of suitable alloy steels up to 10% for ingots weighing up to 3 m and 6.5% for large sheet ingots. The approximate ratio of the reduction of the output of suitable Δ,% to the content in the HPE (Al+SiCa), % ($Ф_{ТЭ} \equiv$ Δ/(Al+SiCa)) decreases with increasing mass of the ingot $М_{сл}$, m, depending on the

$$Ф_{ТЭ} = 0,63 M_{сл}^{-1/2}. \quad (5)$$

Today in Ukraine there are mini- and microplants manufacturing, among others minor forging ingots, which, at the time was focused use of exothermic HPE.

Low exothermic HPE on the basis of carbonaceous materials with the company name Vallak (Sweden, 1957) are widely used in Italy, Germany, Austria, Holland, Great Britain, the casting of ingots weighing up to 20 tons, saving 6-8.5% of suitable. Tests liners Vallak, who conducted by the IFM to CherMZ showed savings of 6%. The so-called combustible plates provided Δ,%, to 8.5% (U.S., 1957), 4% (UK, 1957), 3-4 (up to 6,5%) (Böhler, Austria, 1961).

The use of slabs from low exothermic HPE, stacked on a metal mirror in the profits, is also known (Czechoslovakia, 1971).

2.2. Isolation elements (IE)

For mass production of steel took the path of use IE in the form of insulating refractories (IO), liners and inserts of liquid selfhardening mixtures (LSM). This was preceded by a study of the thermal balance of profit of the ingot, in particular, the share of heat,% passing through the refractory $Д_1$, $Д_2$ accumulated in it, leaving a metal mirror in the profits of $Д_3$ and $Д_4$ for the chamotte ingot (C) IO and IE (**Table 2**).

The most complete this issue has been analyzed in the IFM and PSTU [7].

In all cases, the bulk of the metal heat profit is accumulated in dense refractories, and so when you use IO or IE, having a lower density, the value of $Д_2$ is reduced and, importantly, several times could increase the proportion of heat supplied to the ingot $Д_4$ during solidification.

In [8] first observed the reverse of heat transfer in the system profit-ingot when the first 17 min of

Table 2. The balance of heat profit of the ingot, %

№	Country, organization	Year	$M_{сл}$, т	insulant	$Д_1$	$Д_2$	$Д_3$	$Д_4$
1	2	3	4	5	6	7	8	9
1	USA	1950	5,4	C	15	60	25	-
2	Great Britain	1951	-	tamping	-	70-90	-	-
3	Great Britain	1952	1,8	C	15	85	-	-
1	2	3	4	5	6	7	8	9
4	Great Britain, BISRA	1957	0,25	C IE	12 13	74 55	6 11	8 21
5	DonSRIFM	1966	3,0	C	29	63	8	-
6	ChelSRIM	1967	1,2	C	9	87	4	-
7	IFM, PSTU	1974	3,6 8,1	C C	58 78		27 8	15 14
8	IFM	1974	10,6 3,4 7,95 9,9	C IE IE IE	64 37 29 28		20 23 28 29	16 40 43 43

solidification 3 tonnes ingot cast by siphon, heat is transferred to profit from the ingot, and then - out of profits in the ingot. In [9] in the ingot cast 0.25 t from the top, the reverse occurred for 4 min. Analysis of these data allows us to determine the regularity, the reverse happens - approximately 0.2 length of ingot solidification, regardless of the teeming type.

The most important components of heat transfer profit-ingot are $Д_2$ and $Д_4$.

Heat transfer in the wall of the profit goes based on the laws of heat transfer in a semi-infinite space with a specific intensity $q = b/(\pi\tau)^{1/2}$, where $b = (\lambda p c)^{1/2}$ - coefficient of thermal activity of the wall material; λ, ρ, s - its coefficient of thermal conductivity, density and specific heat; τ - time. The value of λ, kcal/m^2 · h · grad, depends on ρ and processing of published data found that at $\rho \le 1{,}4$ g/cm^3

$$\lambda = 0{,}4\ \rho^{0{,}4}, \quad (6)$$

and at ρ > 1,4 g/cm^3

$$\lambda = 0{,}18\ \rho^{2{,}8}. \quad (7)$$

For the time dτ through the wall surface F the warm $dH_2 = qFt_{ст}d\tau$ will be accumulated, where $t_{ст}$ - wall temperature, and for the time τ

$$\Delta H_2 = 2Fb\tau^{1/2}t_{ст}/\pi^{1/2}. \quad (8)$$

Heat transfer within the profit is with the coefficient $\alpha_1 = (\lambda_1 p_1 c_1/\tau)^{1/2}$ [10] and for the time dτ heat $dH_1 = \alpha_1 F(t_1 - t_{ст})d\tau$ will go to the wall, where λ1, ρ1, c1, t1 – thermal conductivity, density, specific heat and the temperature of the metal, and for the time τ

$$\Delta H_1 = 2Fb_1(\tau_1 - t_{ст})\tau^{1/2}. \quad (9)$$

Proportion of profit of heat accumulated by lining

$$Д_2 \equiv \Delta H_2/\Delta H_1 \approx 4bt_л/\pi^{1/2}\rho_1\Delta H_{пл}k_\delta \approx 0{,}0155bt_л \quad (10)$$

where $t_л$ – liquidus temperature of the metal; $\Delta H_{пл}$ - its heat of fusion: $k\delta = 2{,}5cm/c^{1/2}$.

In the expression (10) determining the value of $Д_2$ is b_3 which makes in the CGS

	C	tamping	LSM	isol. C	IFM	wool	Vallak
b	0.047	0.028	0.021	0.019	0.017	0.0091	0.0054
$Д_2$	1.02	0.62	0.48	0.44	0.9	0.21	0.13

and the main task in selecting the IE is to provide sufficient structural strength of the material. Given the assumptions made, calculation of derived values of $Д_2$ are responsible trends of the results in **Table 2** (**Figure 1**).

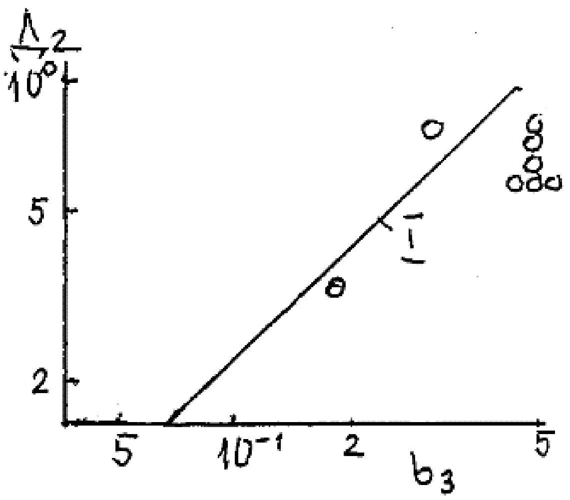

Figure 1. Proportion of profit of heat accumulated by insulation

Heat transfer in the system profit-ingot after the reverse occurs with a coefficient of $\alpha_4 = C[\Pr Ra/(0{,}952 + \Pr)]^{1/4}$, where Pr; Ra – Prandtl number and Rayleigh; C ≈ 0,43 [11], and approximately equals to (CGS) $\alpha_4 = 0{,}122 \cdot \Delta t^{1/4} / D^{1/4}$, where Δt - temperature difference between profit-ingot; D - the transverse dimension of the system. For the time dτ the amount of heat transferred from the ingot came to be $dH_4 = \alpha \Delta t F d\tau$ and its share $Д_4 = \Delta H_4 / \Delta H_1 \rho$,

$$Д_4 = 2{,}7 \cdot 10^{-4} \Delta e^{5/4} \Delta\tau / \mathrm{h}_{\text{пр}} \mathrm{D}^{1/4} \qquad (11)$$

where $h_{пр}$ – profit height.

The value of $Д_4$was determined by a numerical method for the conditions [8], where it is necessary to calculate the data, and was from the moment of reversal until the end of the solidification temperature of from 0 to 0.45-0.48, averaging 0.23 for the time of solidification, which is close for the profit wall from the chamotte.

According to (11) $Д_4$ is inversely proportional to the height profit $h_{пр}$, which is associated with a decrease in ΔH_1 and consistent with the practice.

In our country the leading role played by IFM, which made a bet on sand-cellulose inserts and mastered their use in some plants. Analyzing the dynamics of the economy began based on calm head trim can set a pattern: an increase in 1968-1975 from 2-4 to 5-7%, and in 1975-1988 - decline to 1.5-2.0%, both in connection with the outflow of SRI and decreased attention to the problem of decision-makers, as well as the removal of the plant to the periphery of the savings were higher and more stable.

2.3. Insertion from the LSM

M. Tigershiold (Sweden) used (1957) liquid selfhardening mixtures for the production of profitable spots of sand and sodium silicate = 12:1 with the blowing the CO_2 under pressure 4.2 atm for 2 min. In Jimuiden (The Netherlands) instead of sand limestone was applied, at the plant St. Pitch & Tozer (UK) it eliminated welding of the insertion to the ingot. Inserts in English literature were mentioned jokingly as tiger-top.

In 1960 BiSRA held Junion Steelmaking Conference, at which papers were presented on different methods of warming the profits from floating extension C & D before exothermic inserts, including tiger-top, which was made from blast furnace slag and limestone (2:1), 6 and 7 % of water glass, blown with carbon dioxide under a pressure of 6 atm. The technology used on 12 and 15 tons of forging ingots and 32-40 and 20-25 tonnes of the metal slab with savings of 6-7%. Cracks on the ingots were eliminated, monetary and labor costs for insulation, the number of types of molds were reduced, there is no need to observe the exact weight of the ingot, mold resistance increased, the cost of crane time for broadening mold bottom reduced by 60%, residence time of the mold in the ingot and their specific consumption reduced as well.

In 1963-1969 DMetI conducted a study of options for LSM on 16.5 tons of ingots at "Zaporizhstal" and received an increase in the output of suitable 3.5-4.8%.

2.4. Inserts from kaolin wool

Despite minimal compared to other insulators value b of kaolin wool inserts when tested in the 1979's at a number of plants were given reduced head trim only to 1-2%.

They say that new is well forgotten old. Today, with nearly half of all steel in Ukraine, cast into a mold, it is advisable to analyze the possibility of increasing the yield, using proven methods of warming the head of the ingot.

Conclusions

The technologies of using briquettes during steel teeming were analyzed.

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Использование брикетов в сталеплавильном производстве. Разливка

Охотский В.Б.

Проанализированы технологии использующие брикеты, при разливке кипящей и спокойной стали.