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THE ROLE OF POWDER USED IN THE CONTINUOUS MOLDING OF ALLOYS

Florin Marian TOMA [1], Elena Valentina STOIAN [2], Nicolae ANGELESCU [2], Dan Nicolae UNGUREANU [2]

[1] Erdemir Romania SRL, 18, Soseaua Gaesti, Targoviste 130087 Dîmbovita
[2] Valahia University of Târgoviste, Faculty of Materials Engineering and Mechanics,13 Sinaia Alley, 130004,Tirgoviște, România

E-mail: elenastoian22@gmail.com

Abstract: *In this paper, a technology for obtaining powdery materials with special characteristics, in the metallurgical field, is presented. The compositions of these powders are from the calcium oxide - alumina - silica system, by adding CaF2, Na2O and C. The choice of oxide compositions will be made according to a series of parameters: the composition of the cast steel, the casting speed, the viscosity or the surface tension of molten steel.*

Keywords: *slag film, liquid steel, continuous casting, crystallizer, tundish*

1. INTRODUCTION

By comparison with the classic casting, by continuous casting, the improvement of some yields, the obtaining of some products of superior quality, increased productivity, the increase of the cost efficiency, etc. are achieved [1].

The main gains of continuous casting of steel compared to conventional casting are the following: high coefficient of metal extraction (93-97%), high quality of steel, lower energy consumption in the production process, a much higher need low labor force (with an effect on productivity growth), as well as reduced means of transportation and work space. All this determining the increase of the share of continuous casting, both worldwide and in our country; the importance of continuous casting in total world steel production, increasing from year to year [2]. At present, continuous casting of steel is used for about 55% of world production of liquid steel.

The application of continuous casting, which involves advanced technical technologies, subjects the related refractory materials, including the powders used in the crystallizer of the casting installations, to very severe operating conditions. For this reason, the research, production and operation personnel in this field of activity - mainly from the industrially developed countries, paid special attention to obtaining casting powders that would successfully meet the imposed operating conditions.

2. BASIC THEORY

Continuous casting of the steel was first applied to obtain stainless steels and tool steels. These types of steels could be continuously cast in various commercial forms by lubricating the walls of the crystallizer with propane oilseed rape, injected on the liquid surface of the steel. Its role is to form a continuous film of oxides on the surface of liquid steel [3-6].

As for continuous casting powders, they were first used in Japan in 1965 and are applied in order to obtain a semi-finished product without surface defects and without inclusions. These have been called powder casting and have since been used in casting any type of steel. The process of casting steel by using casting powders can be termed as casting under molten slag.
The casting techniques from the early years of the use of powders lacked a fundamental theory, absolutely necessary to solve the technological problems in the steelworks. The choice of the type of powder that determines the chemical composition or the physical characteristics of the molten slag must be made by selection, after taking into account the properties of the powder and the conditions of continuous casting of the steel.

The properties of the powder must not be determined solely by the chemical composition of the molten slag. In their selection, the technological factors of the behavior of the powder in the thermotechnological aggregate must be taken into account, such as: the control of the melting speed, the covering capacity of the liquid steel surface, the stability and the effective thermal insulation due to the powder coating.

Figure 1 shows the sketch of a continuous steel casting plant, which shows the place of application of the powder in the distributor and crystallizer [4].

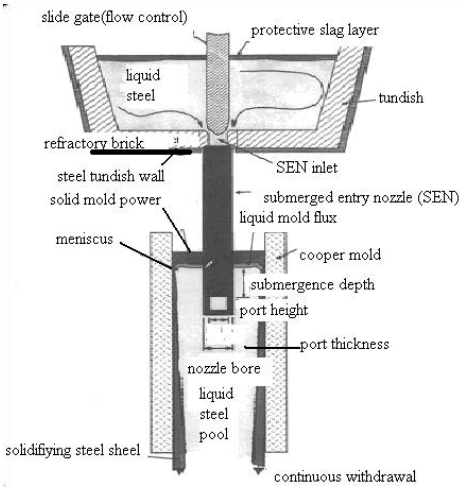


Figure 1. Section of a steel continuous casting plant

The main role of the tundish is that it is a liquid steel tank between the landle and the crystallizer. The tundish has a special importance during the replacement of the landles at the continuous casting installation and in the supply of the crystallizer with liquid steel [3]. Besides the fact that it is a liquid steel tank, the tundish is increasingly used as a machine for carrying out metallurgical processes related to the control of purity, temperature and composition of steel.

It is considered that obtaining a good quality semi-finished steel is determined by the way in which the casting powders fulfill the following roles:
- ensuring a good thermal insulation at the surface of the steel in the crystallizer, in order to avoid its solidification [6];
- avoiding the oxidation of the steel in the crystallizer;
- lubricating the contact surface between the molten steel and the crystallizer wall by maintaining a layer of liquid slag at the junction of the two metals as suggested in figure 2 [7-15];
- achieving a homogeneous transport from a thermal point of view, in accordance with the technological conditions and parameters, such as: casting speed, crystallizer size, steel mark, etc .;
- avoiding the incorporation of separate allogeneic materials in the steel crust by entraining them by the liquid slag.

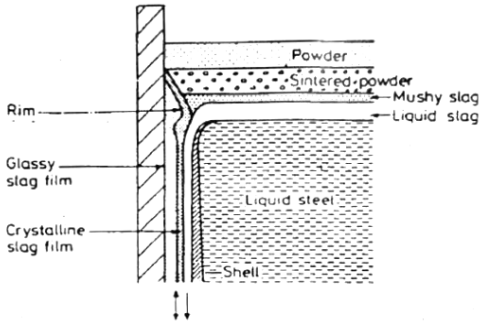


Figure 2. Representation of the continuous steel casting mold (the copper mold)

The behavior of the powders, during the technological service in the crystallizer, depends on several factors, such as: factors related to the particular characteristics of the pouring powders (in powdery and molten state); factors related to the processes and restrictions that occur at the molten steel interface - slag; factors depending on the technological parameters of the casting installation, as well as on the brands of cast steel.

The properties that give the powders a proper behavior during steel casting and that guarantee a satisfactory response to the various conditions required by the continuous casting process are the following: the thermal characteristics of the powders in powdery and molten state; melting temperature, as well as melting and solidification rate; the viscosity and surface and interfacial tension of the slag resulting from the melting of the powder.

3. THE EXPERIMENTAL PART

The experimental works considered the preparation of two casting powders, corresponding to the compositional masses designed in the CaO - Al_2O_3 - SiO_2 system, with the addition of free CaF_2, Na_2O and C, in order to follow their behavior when used.
When selecting compositions, it is necessary to take into account the brand of steel being poured, the casting speed (at low casting speeds, the powder is in long contact with the steel, and at high casting speeds, the powder has a very short interval of the formation of the homogeneous liquid phase), of the proportion of the inclusions that decant and of the properties of the steel melt (viscosity, surface tension) that strongly influence the slag behavior on the metal surface.

Therefore, considering the above, the following compositions were selected:
- for low casting speeds: E4a, B42-3, B22-3, B32-4, C13, C22 (table 1);
- for medium casting speeds: B52-3, B62-5, C43, C53, C62 (table 2).

Table 1*) Low speed continuous casting powders
***) (T_S) = Sintering temperature; (T_T) = Melting temperature; (T_C) = Flow temperature; Ƞ = Viscosity at temperatures in the range 1200°C -1500^{0}C**

Physical characteristics		Powder					
		E4a	B42-3	B22-3	B32-4	C13	C22
Ts, °C		1250	1050	1050	1020	1050	1060
T_T, °C		1360	1150	1140	1130	1150	1130
Tc, °C		1380	1165	1160	1140	1160	1150
T_T - Ts , °C		110	100	90	110	100	70
Tc – T_T, °C		20	15	20	10	10	20
$Ƞ_{1500°C}$, Poise		1,0879	0,1208	0,2090	0,1576	0,1410	0,1788
$Ƞ_{1400°C}$, Poise		2,1907	0,2175	0,3814	0,2892	0,2518	0,3248
$Ƞ_{1300°C}$, Poise		4,8404	0,4225	0,7884	0,5755	0,4857	0,6384
$Ƞ_{1200°C}$, Poise		11,9617	0,9037	1,7622	1,2628	1,0288	1,3816
Surface tension, mJ/m² at 1450^{0}C		438,2	406	-	-	-	-
Compositional structure, %	Diatomite Patarlagele		24,20	30,14	24,63	33,50	32,00
	Portland cement(CEM I – OPC SR EN 197-1)		45,50	39,50	39,50	36,50	41,00
	Calcium fluoride		11,14	11,14	10,40	18,00	10,0
	Sodium calcined		12,00	12,07	12,13	12,00	17,00
	Cryptocrystalline graphite		7,15	7,15	13,40		
	Calcite (calcium carbonate)	73					
	Quartzite	24					
	Alumina	5					
Ratio CaO/SiO_2		0,8	0,9	0,9	0,8	0,6	0,7
Degree of fineness		max. 86% under 0,06 mm					

Table 2. Powders for continuous casting at medium speed

Physical characteristics		Powder				
		B52-3	B62-5	C43	C53	C62
Ts, °C		1030	1060	1060	1060	1050
T_T, °C		1150	1130	1150	1140	1120
Tc, °C		1160	1140	1160	1180	1140
T_T - Ts , °C		130	70	90	80	70
Tc – T_T, °C		10	10	10	40	20
$Ƞ_{1500°C}$, Poise		0,0990	0,0872	0,0680	0,0548	0,0677
$Ƞ_{1400°C}$, Poise		0,1758	0,1555	0,1137	0,0923	0,1155
$Ƞ_{1300°C}$, Poise		0,3720	0,2996	0,2077	0,1664	0,2116
$Ƞ_{1200°C}$, Poise		0,7095	0,6338	0,4138	0,3274	0,4227
Surface tension, mJ/m² at 1450^{0}C		-	-	412	410	419
Compositional Participation, %	Diatomite Patarlagele	22,00	15,94	25,00	22,00	21,00
	Portland cement (CEM I – OPC SR EN 197-1)	47,71	45,00	45,00	48,00	52,00
	Calcium fluoride	11,14	9,76	18,00	18,00	10,00
	Sodium calcined	12,00	10,57	12,00	11,50	17,00
	Cryptocrystalline graphite	7,15	18,70			
Ratio CaO/SiO_2		1,0	1,1	0,9	1,0	1,1
Degree of fineness		max. 86% under 0,06 mm				

4. RESULTS AND DISCUSSIONS

From the above-mentioned masses, two powders were chosen to be tested on the continuous casting plant, namely B42-3 powder for low casting speeds and B52-3 powder for medium steel casting speeds.

The chemical analyzes performed by X-ray fluorescence spectrometry of these experimental powders allowed the identification of some chemical elements present as impurities in their composition: F, Al, Mg, Na, Fe, O, Si, Fe, Mn, Ca, K [8,15]. Examples, in this context, are given for the powder B42-3 corresponding to be used for low casting speeds - figure 3, as well as for the powder B52-3 used for medium casting speeds - in figure 4.

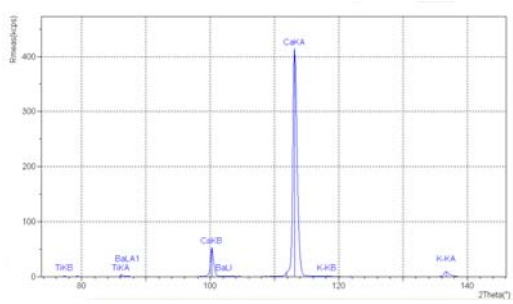


Figure 3. Highlighting the presence of K, Ca and Ba in B42-3 powder for low speed casting

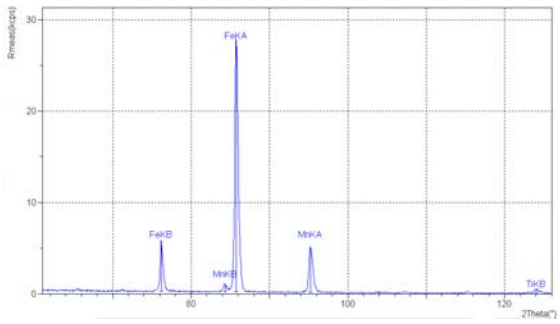


Figure 4. Highlighting the presence of Fe and Mg in powder B52-3 for medium speed casting

The morphology of these powders, highlighted by electron microscopic investigations - figure 5, highlights the presence of polyhedral crystals of vitreous appearance and white color with size ≤ 5 µm, for powder B42-3. The dark background is made up of very fine particles, some of which have a fibrous appearance. [8,12,15]

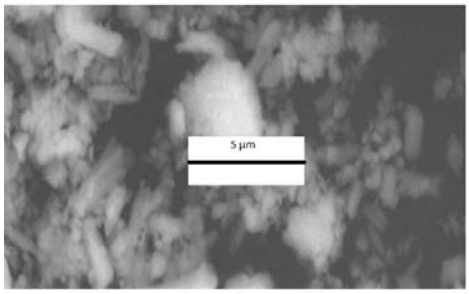


Figure 5. Morphology of B42-3 powder for low speed casting (x 3500)

The electron-microscopic image in figure 6 shows the structure of the B52-3 powder which highlights the presence of translucent particles, of various shapes (polyhedral and even spheroidal) and different sizes, with a size of ≤ 10 µm.

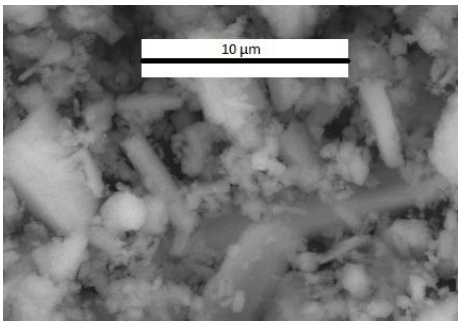


Figure 6. Morphology of B52-3 powder for medium speed casting (x 3000)

The powder was tested on two continuous casting sequences: the first sequence at low speed (0.3 m / min) and the second sequence at medium speed (0.85 m / min) on a horizontal continuous casting installation of the alloys. [10,11,14,15]

In the first sequence, at low speed, a batch of 150 Kg C 45E steel was poured continuously, and for the second sequence - with medium speed of continuous casting, a batch of 100 Kg S235JR steel was used, according to European standards.

To achieve this goal, two types of zirconium silicate rupture rings were made - $ZrSiO_4$ (ZrO_2 = 66% and SiO_2 = 32%), according to figure 7.

One of the rings with an inner diameter of 12 cm and a height of 5 cm is intended for the low speed casting sequence and the second with an inner diameter of 10 cm and a height of 3.5 cm, intended for medium speed casting.



Figure 7. Zirconium silicate rupture ring

The breaking (or pulling) ring, mounted in the crystallizer of the continuous horizontal casting plant, plays a multiple role in operation: it participates in the initiation of the continuous casting process by facilitating the process of hanging and pulling the bead. The rupture ring also gives the round shape of the bead, as well as has appropriate wetting properties in contact with liquid steel and liquid slag (to facilitate the pulling process of the blank).

The experiments were performed by continuous billet at low speed of a round steel plate brand C 45E, developed at a temperature of 1570 ° C, using as casting powder 20 Kg of B42-3 powder.
It was possible to pull a continuous semi-finished product with a length of 1.8 m, until the entire amount of liquid metal in the tundish was consumed (150 kg of liquid steel prepared for this purpose).

The beginning and end of the billet were not uniformly round. Only the middle part of the billet, on a length of 1.2 m, was perfect in shape and appearance.

For the experiment of B52-3 powder, at medium firing speed, the steel mark S235JR was considered, elaborated at a temperature of 1595 °.

Except for the first 15 cm of the size, it was possible to draw a semi-finished product (completely round billet) with Φ = 10 cm on a length of approximately 75 cm.

Then the wire broke because the solidified steel crust formed near the wall of the crystallizer did not have the capacity to support the mass of liquid steel inside the semi-finished product; the liquid steel mass depreciated the crust and then flowed. This impediment seems to have had two causes. One of the causes was the high firing speed which did not allow enough time for the formation of a suitable crust with a constant thickness, which could support the mass of liquid steel inside the semi-finished product.

In the same sense, the ceramic firing ring (the second possible cause) that had a shorter length (3.5 cm compared to 5 cm than the ring used in the low speed casting sequence) probably did not contributed accordingly to the formation of a sufficiently strong surface layer of the crust when the billet exits the continuous casting plant.

5. CONCLUSIONS

The experimental work has resulted in several composite masses of powder that meet the quality requirements to be used as powders for continuous casting of steel, at low or medium speed.

A powder was selected from the two categories of compositions, namely, the symbolized composition B42-3 indicated to be used as a lubricating powder for continuous low speed casting of steel and, respectively, the composition B52-3 as a lubricating powder for continuous casting with medium speed.

Pilot batches were prepared for each of the two powders selected.

The two pilot batches of powders (B42-3 and B52-3) were applied experimentally on a continuous horizontal casting of steel with a single-wire adapter.

Two types of zirconium silicate rupture rings were made which were mounted in the crystallizer. One of the two types, with an inner diameter of 12 cm and a height of 5 cm, was intended for continuous casting sequences with low speed, and the second type - for average

casting speeds, had an inner diameter of 10 cm. and a height of 3.5 cm.

Two sequences of continuous casting of the steel were performed. The first sequence was performed with low pouring speed when the B42-3 powder was used and when a semi-finished product was obtained that was perfect in shape and appearance (round billet) with a length of 1.2 m and Φ = 12 cm. The second sequence was performed at medium speed using the experimental powder B52-3 when a perfectly round billet was drawn with Φ = 10 cm and a length of 75 cm.

The absolute use in Romania of zirconium silicate in the production of breaking rings necessary to be mounted in crystallizer representing a national priority in our country of the use of these lubricating powders on a continuous horizontal steel casting plant.

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