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THE BEHAVIOUR OF ACID SLAG IN THE TUNDISH

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ABSTRACT

In the tundish, purification of steel is given by the use of an oxide powder on the steel surface. This powder perform several important functions, such as thermal insulation, protection against liquid steel surface oxidation and capturing inclusions from the bath. This paper presents an experiment carried out with an acid powder based on thermal power plant ash to the casting of steel with carbon content from 0.30 to 0.33% and 1.00 - 1.15% manganese. Powder behavior during casting can be summarized as follows: rapid spreading of liquid steel surface, good thermal insulation, revealed by the gradient temperature from the slag. The average specific consumption recorded was very low, 0.4 kg / t liquid steel. It has been analyzed the chemical composition of the slag from the tundish during casting, to prelevate 6 consecutive samples taken during casting. The compositions of these slags were compared to the oxide powder composition initially given on the liquid steel. There was a good absorption of inclusions, as evidenced by the last composition of the analyzed slag sample. There was a strong increase of MnO content and changes in values of the other oxide compounds, such as SiO2.

The paper highlights the experimental slag capacity, a hard acid slag based on thermal power plant ash, to capture the MnO type inclusions, up to 38%. This process can be interpreted as negative, meaning that the acid slag is absorbed from the steel alloying element, manganese.

KEYWORDS: fly ash, covering powder, acid slag, tundish, casting steel

1. Introduction

Many aspects of performing metallurgy require an upgraded role of the tundish, not only as a tundish of the liquid steel, but also this aggregate must be like an active reactor. In this sense, an ideal tundish should have a best mixing of the liquid steel [1], with a view to optimizing the flow conditions, the stability of refractory lining. In the first area, the steel jet flows, while in the following areas reactions to reach completion and for emergence of the inclusions take place. The tundish powder has an important role in the steel cleaning by the catch and the absorption of the inclusions in the liquid slag layer. The tundish powder was an acide powder based on fly ash. The experimentations took place at the Continuous Casting Sector, Steel Plant no. 2, Mechel, Targoviste.

The experimental conditions were the following:

- tundish with attached cover, on the four strand (Ø13 mm) continuous casting machine, the cover with two orifices, gunited with magnesia mixes mass, 5 tones operative capacity;
- bloom size: (80x80) ÷(140x140)mm;
- casting speed: 1.4–1.6m/min; medium casting time: 80 minutes/batch;
- steel temperature in the tundish: 1555-1545^{0}C;
- the quality of continuous casting steel: carbon steel for constructions;
- casting series of minimum 2 batches, maximum 4 batches;
- casting without protection stream.

The results of the tundish powder industrial tests, and the conclusions, were presented in the following part of the work.

2. Experimental research

The powder characteristics are shown in table 1, it was used in fourteen casting sequences, each included minimum two batches. The tested powder was administrated through the orifices in the cover of the tundish, 2 bags of 5kg, through each hole.

Table 1. *The main characteristics of experimental tundish powder*

Physical characteristics			
Bulk density	**Humidity**	**Spreading surface**	**Melting temperature**
[g/cm^3]	[%]	[cm^2/220g]	[^{0}C]
0.48-0.56	0.53-max0.6	780-830	1300-1320

Chemical characteristics, %								
SiO_2	**Al_2O_3**	**CaO**	**MgO**	**Na_2O K_2O**	**Fe_2O_3**	**TiO_2**	**MnO**	**I.L***
50-53	15-18	3-4	3.5-4.5	0.7-0.9 2.0-2.5	5.5 -6.5	0.4-0.6	< 0.1	min.15

* ignition lost

Table 2. *Steel quality casting in experiment*

Steel quality	**Chemical composition,** % (main elements)			
	C	**Mn**	**Si**	**Cr**
“60 Grade”	0.30-0.33	1.00-1.15	0.27-0.30	0.19-0.33
	For any steel: max. 0,17 % S; max. 0,03 % P			

In table 2, the compositions of different steel qualities used in the experiments are shown.

When the continuous casting takes place in a covered tundish, the melted powder forms a slag layer that is maintained during the whole series and ensures an optimal thermal isolation of the steel surface. The powder addition at the second batch casting is not necessary, and does not improve the thermal isolation. Hence, at continuous casting series, tundish powder is added only at the beginning of the first batch then the tundish is covered.

The used experimental powder quantity was 20-30kg per batch. It was analyzed the evolution of the slag composition in the tundish during two batches casting in series.

The sampling slag from the tundish, during the continuous casting batches took place as follows:

- the first sample, (P1), was taken after about 15 minutes from the beginning of the casting;
- the second sample, (P2), was taken after casting half of the first batch, at 40 minutes from the beginning of the casting;
- the third sample, (P3), was taken with 3-5 minutes before finishing the casting of the first batch;
- the forth sample, (P4), was taken at the second batch at the beginning of the casting;
- the fifth sample, (P5), was taken after casting half of the second batch, at 120minutes from the beginning of the casting;
- the sixth sample was taken at the ending of the second batch casting.

5. Results regarding the tundish powder behaviour

The powder was easily spread, maintaining the dark grey colour on the steel bath, for about 15 minutes, then the melting process takes place, the dark red slag layer is formed, and this protected the steel, surface. In the tundish liquid steel three temperatures on each batch were measured: the first, at the beginning of the casting, the second at the middle and the last at the end.

The heat losses were very low, the difference between the second temperature registered in the tundish, 1555-1550^{0}C, and the third of about 1550-1545^{0}C, at the end of the continuous casting, was of maximum 5^{0}C. On the other hand, it is known that the covered tundish ensures its own thermal isolation.

The maximum consumption powder to the first casting batch was of 30kg/71 tone, with medium specific consumption 0.42kg/t liquid steel, and minimum quantity of powder used, was 20kg/71 tone, with medium specific consumption of 0.28kg/t steel.

If this powder quantity is reported to the entire series, because at the second batch, another powder quantity is not used, and the medium specific consumption is very low. The tundish slag entrapment capacity of steel inclusions was pointed out through the chemical analysis of the samples.

The classical X-ray diffraction on the melted powder showed amorphous structure mass. At the same time, a few samples from the slags were investigated by scanning analysis, EDS.

A few of these analyses are shown in Figures 3 and 4.

6. Discussions

It is known that the tundish powders based on fly ash form silicate acid slag with high viscosity comparatively to the basic powders and during the melting process thus give amorphous or semi-amorphous slags.

The molten powder composition, table 3, over 60% SiO_2, about 20% Al_2O_3 and very low level of MnO, provides a high absorption capacity of basic oxides.

Table 3. *The main oxide compounds of a molten powder sample*

Chemical analysis, %						
SiO_2	Al_2O_3	CaO	MgO	MnO	Fe_2O_3	I.L.
62.01	19.87	4.97	5.51	0.08	7.60	0.16

Table 4. *The level of chemical analysis of the tundish slag*

Batch-sample	SiO_2	Al_2O_3	MnO
	[%]		
I - P1	51.25	19.27	2.22
I - P2	48.22	17.60	11.22
I - P3	40.58	12.82	32.50
II- P4	38.33	9.70	31.06
II- P5	33.84	7.51	34.88
II- P6	24.30	7.20	38.83

At the same time, the slags that have below 20% Al2O3 content, can very well catch Al2O3 inclusions, when the tundish powder is used to casting aluminium deoxidized steel.

The results of chemical analyses values of the main oxydics compounds in the slag, during the continuous casting of two batches, are shown in table 4 and the graphs, Figures 1 and 2.

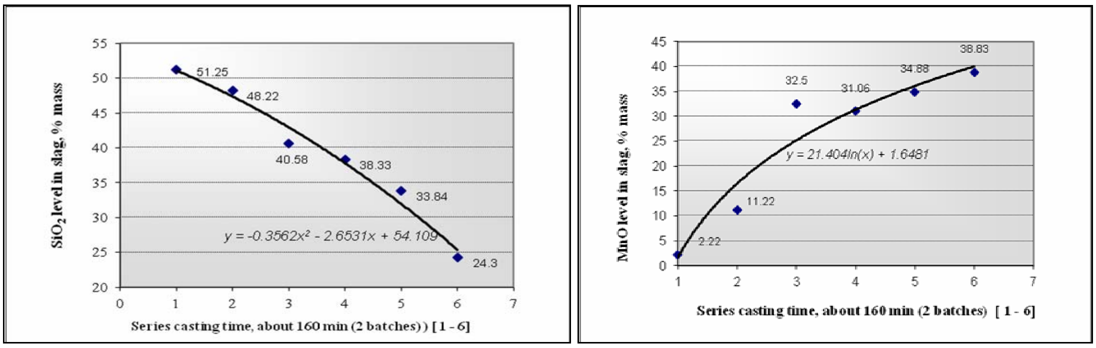

Fig. 1. *The level of SiO_2 and MnO from tundish slag samples during continuous casting*

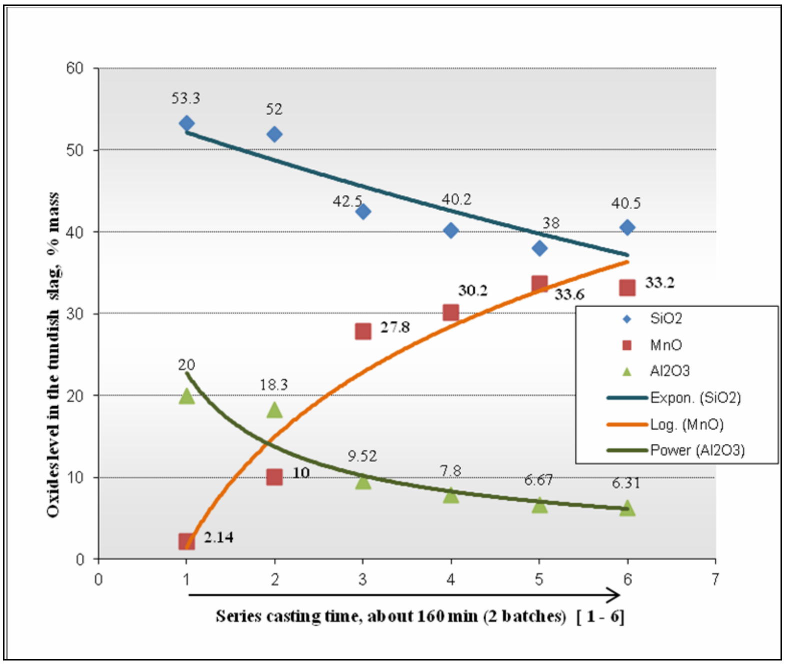

Fig. 2. *The values of main compounds from tundish slag during the experiment*

One of the spot compositions EDAX analysed, on a sample of slag, is shown in Figure 3.

The analysis of the experimental slag inclusions is presented in Figure 4.

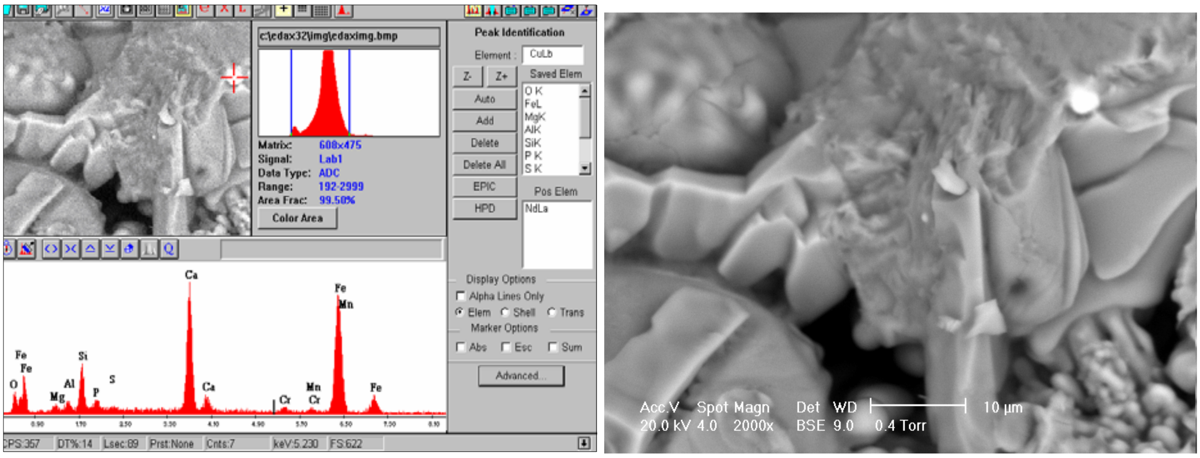

***Fig. 3.** Microscopic image of a sample of slag and the elemental composition of a zone*

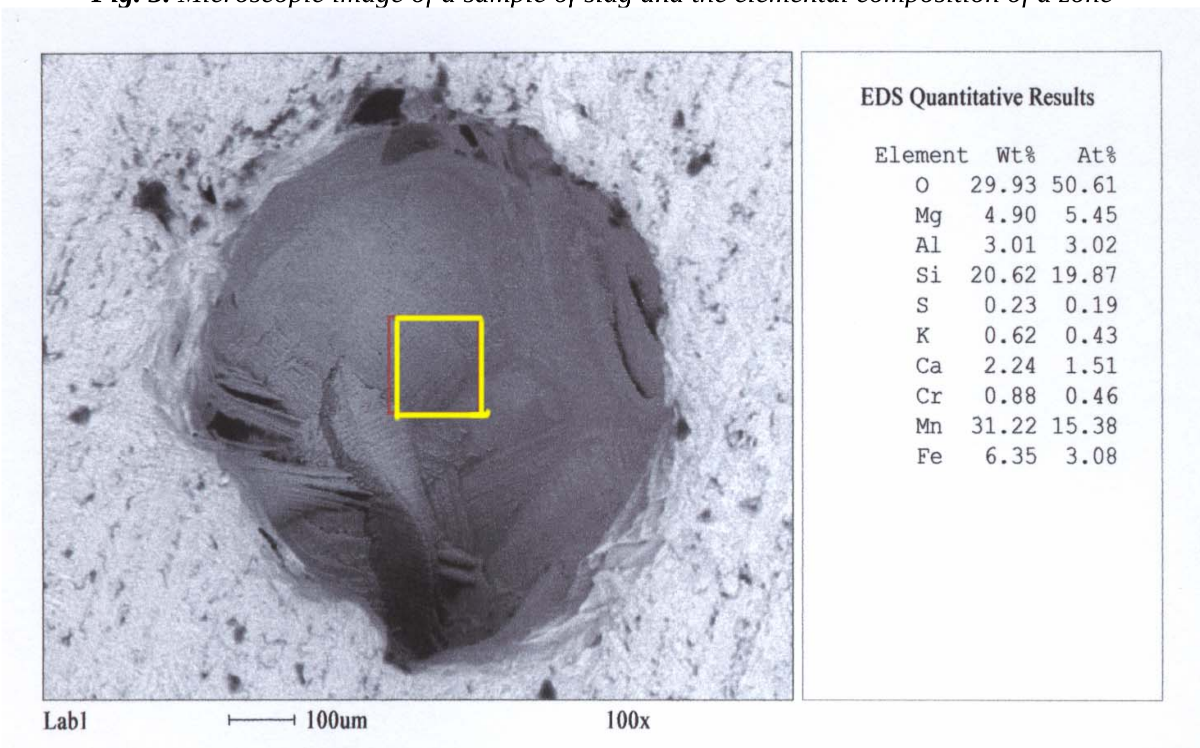

***Fig. 4.** The EDS analysis on the last sample slag P6 (an inclusion)*

The data presented in last table show that during the continuous casting of the first batch, an important increase of the MnO content took place, as well as a decrease in the content of the other oxide compounds, SiO_2, Al_2O_3, caused by dilution. For the second batch casting, these tendencies have been maintained: high increasement of MnO content, and decrease of SiO_2 and Al_2O_3 content. The microstructures aspect by EDS, showed a heterogeneous slag.

The elementary composition from the various points of the slag is different, function of the analyzed point location. If the medium composition of these points is calculated, it is observed that there is a relative concordance of the EDS results with the chemical analysis.

In the EDS analyses, many inclusions inserted manganese-silicate, probable tephroite $2MnO{\cdot}SiO_2$, or, MnO - black globular inclusions it has shown. Light globular inclusions may be magnesia-spinel, $MgO{\cdot}Al_2O_3$, or wustite FeO·MnO, or other silicates. A wide range of solid solubility exists between manganosite (MnO) and several metal oxides, Me(II)-

oxides [2], and it is very difficult to know exactly the identity of the oxide. The industrial tests of tundish powder, based on fly ash, have shown that the formed slag absorbs and partially it dissolves the metallic or nonmetallic, inclusions, especially MnO compounds witch can be dissolved in the silicate network.

The high content of MnO in slag was caused by the presumed reasons:

- the MnO inclusions passing from the casting ladle into the tundish;
- direct oxidizing of Mn in the slag, surface interactions between the slag and the liquid steel; the acid slag oxidizes manganese at the steel interface and retains it. This is a detrimental phenomenon and must be avoided by the usage of the acid powder tundish at the casting of alloyed and micro alloyed steel, with V, Al, Si. The cause of the moderate increase of MgO in the slag is the occuring of refractory inclusions, most often from the tundish lining. At the same time it was observed that the magnesia lining is quite stable, because MgO amount in the last slag is below 7% and the initial composition of powder is about 4%.

7. Conclusions

An acid tundish powder based on fly ash was tested at continuous casting carbon steel and the results of the tests were presented in this paper.

The principal aspects are presented as follows. When the continuous casting takes place in covered tundish, the melted powder forms a bath slag that overcasts the steel surface. This is maintained during the whole casting batches and ensure an optimal thermal isolation.

The evolution of tundish slag composition during casting steel of two batches in sequence has shown the process of cleaning steel. The main oxide compounds of the tundish slag composition were: MnO, SiO_2, MgO and Al_2O_3. The EDS results confirm the amount of inclusions and chemical analysis.

The powder behaviour can be resumed as follows:

1. fast spreading on the steel surface;
2. very good thermal isolation (the gradient in the tundish was about 5^0C);
3. low consumption, the specific consumption was maximum 0,42 kg/ t liquid steel;
4. very good absorption of inclusions, with prevailing MnO.

Formally, regarding the last point, it can be interpreted as it shows, the high capacity of tundish powder based on fly ash, to catch the steel inclusions, thus helping at cleaning continuous casting steel.

This process can be interpreted as negative, meaning that the acid slag is absorbed from the steel alloying element, manganese.

Although the steel quality was not affected by manganese absorption (up to 38%), the manganese colletion in the acid slag is an undesirable phenomenon.

References

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