THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 4 - 2022, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2022.4.07

THE INFLUENCE OF THE WEAR OF THE REFRACTORY LINING, OF THE TUNDISH, ON THE QUALITY OF THE STEEL

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ABSTRACT

The quality of steel and continuously cast semi-finished products largely depend on the degree and control of the interaction between slag, gas, and refractories, with the steel melt. In this work, through the analysis of some samples from a used refractory lining of a tundish, with the help of optical microscopy, the wear of the refractory layer was highlighted, due to the erosion and infiltration of steel microparticles into the pores of the lining. The examination of the samples was carried out in the interface area, metal-shotcrete, shotcrete-concrete, and the area with refractory concrete.

KEYWORDS: tundish, erosion, infiltration, refractory lining

1. Introduction

The tundish represents the link between the steel production, in the converter and its continuous casting process. The quality of steel and continuously cast semi-finished products largely depend on the degree and control of the interaction between slag, gas, and refractories, with the steel melt.

The elimination of impurity of the steel, with the atmosphere, or with particles from the refractory lining, as well as the technologies for making the refractory lining of the distributor, have led to an increase in the resistance of the refractory lining, at the number of castings, and an increase in the purity of the steel, from the point of view of the inclusions [1, 3].

In the last decade, alumina-graphite (ALG) refractories have emerged as a standard solution, for operations from the tundish. Alumina-graphite refractories offer good resistance to thermal shock and increased resistance to contact with metal and slag.

To prevent melt suction through the pores of the tundish walls, a good thickness and density of the refractory, as well as a low permeability, are required. Oxidation is controlled by applying glazes to the interior and exterior surfaces. The tundish lining is important in the technological process. The lining should be inert and not contribute to the growth of exogenous inclusions in the steel [2, 8].

2. The refractory lining of the tundish

The refractory materials used to line the tundish are often overlooked, in the importance of the technological flow. The realization of the refractory lining must take into account the following considerations:

- refractory materials are materials that wear out, and the user must take into account all the factors that influence the quality of the refractory material, in order to increase their lifespan, and the impact on costs;
- the chemical composition of the refractory material can be variable, because it is composed of multicomponent raw materials, therefore it should be tested;
- the quality of the refractory lining is of particular importance and is also influenced by the fixing method and the additives used;
- the temperature variation causes cracks for the refractory material too, lose its resistance, break and thus contribute to shortening the life of the tundish;
- failures of the refractory lining must be evaluated, taking into account all the data related to materials, operations, maintenance and the use of consumables, such as fluxes and alloys, to determine the true cause, which leads to the appearance of the defect.

Typically, the tundish liner is composed of three layers. The working liner is made of high MgO

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material and is exposed to direct contact with the steel [4, 7].

The emergence of the technology of applying the refractory lining, by spraying, led to an increase in the life of the tundish. The thickness of the layer of sprayed material is 40-50 mm, but an additional 10-15 mm can be applied to the area of contact with the slag. (Fig. 1).

Areas subject to a strong erosive flow require refractories based on magnesite.

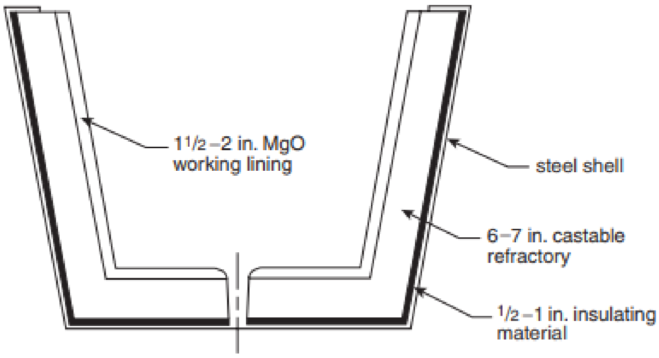

Fig. 1. *Cross-sectional view of a tundish liner*

At the distributor from the continuous casting machine, the refractory lining is made of shotcrete TUNDEX, with the following physical and chemical characteristics: - 50-75 % magnesium oxide; - 1-5% glass, oxide and chemicals.

Table 1. *Physical and chemical properties of the refractory lining*

Physical state	Color	Odor	pH	Density	Solubility
solid (powder)	grey	odorless	alkaline	1.5 - 1.8 g/cm³ [20 °C]	partially soluble in the following materials: cold water and warm water

Table 2. *Standard values of the TUNDEX 175 CS layer composition*

MgO%	SiO_2%	CaO%	Fe_2O_3%	Al_2O_3%	C%	Bulk density g/cm³
73-78	15-20	1-2	0.6-1.2	<1	2-4	1.5-1.7

3. Optical microscopy of the samples, from the tundish lining

Optical microscopy, is a method of analysing the quality of concrete samples, the purpose of the control being the determination of the existence of degradation due to corrosion.

In optical microscopy, non-oxidized steel strongly reflects light, and corrosion products, reflect the light more attenuated, than steel, with a stronger intensity, than aggregates and cement stone.

Steel and corrosion products are opaque in light transmission. Aggregates are generally transparent in light transmission.

The aggregate particle, in the upper and middle portion of the image is subject to the chemical reactions and thermal shocks that occur. The aggregate particle is more porous inside, and denser at the contact surface with the cement stone.

Alternating layers of ceramic material, silica gel and corrosion products, deposited on the side faces of the crack, can be seen in the images below (Fig. 2-5).

The examination of the samples was done with an Olympus BX51M optical microscope, the samples being taken from the used refractory lining, of a distributor from the continuous casting machine.

Through microscopy, the wear of the layer due to the erosion and infiltration of steel microparticles into the pores of the lining was highlighted.

The impact zone of the melt with the blasted surface of the distributor was highlighted, at 100X magnification.

Examined:
- the area from interface 1, respectively shotcrete - metal;
- the area at interface 2, respectively shotcrete-concrete;
- the area with refractory concrete.

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It can be observed a surface wear, highlighted by the roughness of the contact surface. Also, the steel particles penetrated the capillaries of the shotcrete layer (Fig. 3).

It can be noted that both the shotcrete layer and a good part of the concrete layer have been damaged. The liquid alloy particles penetrated the capillaries, due to the porosity of the material, as well as due to the microcracks, which appear due to the temperature gradient, and the pressure exerted on the walls of the distributor.

Analysing the multitude of causes that lead to the deterioration of concrete elements, it is noted that most of them evolve, depending on a very important characteristic of hardened concrete – permeability (STAS 3518-89).

Permeability can be defined as the property (of a material with a porous structure), which quantitatively characterizes the ease with which a fluid or vapor passes through it, under the action of a pressure difference.

For concrete constructions, which are located in environments exposed to wear, and in areas of intense exploitation, obtaining concretes with a low degree of permeability is essential.

Fig. 2. *The appearance of the sample, in the area at the shotcrete -metal interface*

Fig. 3. *Penetration of the liquid alloy into the capillaries of the ceramic material*

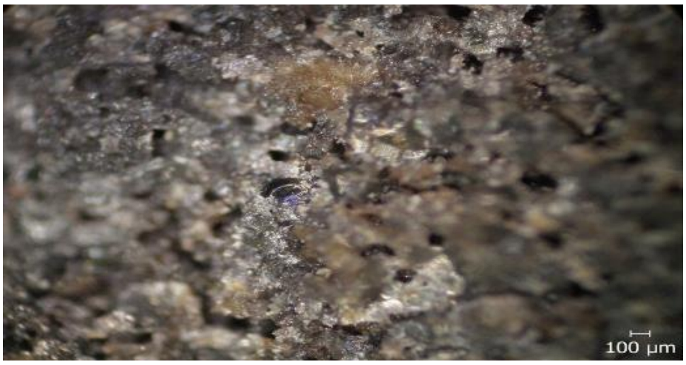

Fig. 4. *The appearance of the sample, in the area at the shotcrete-refractory concrete interface*

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Fig. 5. *The appearance of the sample, in the area of the refractory concrete wall*

4. Phenomenon of pores production

Pores represent any space in the concrete structure (spherical or cylindrical), which is filled with air or water, and which can have a winding route, through the section of the concrete element.

In order to understand the complexity of the concrete formation mechanism, as compact as possible, it should be remembered that each of its components (binder and aggregate) has its own permeability, and that the products obtained as a result of the reactions between them will influence, in a certain way measure, the general permeability of the mass [5, 6].

The dehydration of the hardened binder gels, and its weak adhesion to the aggregate granules, makes the concrete always represent a microporous, with a microcracked system - gel pores. Thus, it can be found that the permeability of the cement paste varies over time, depending on the progress of the cement hydration process.

Spherical pores appear due to the resettlement of cement granules, according to their weight, immediately after the preparation, transport, and placing of the concrete. The excess water is collected on top, from which the air included in the mixing is separated in bubbles. The pores under the aggregates (spheres), are finer than those created by the inclusion of mixing air, and are not visible to the naked eye [7].

Capillary pores in concrete appear due to the loss of excess water through evaporation (Fig. 6).

Fig. 6. *The image obtained by optical microscopy of a pore that appeared in the lay of ceramic material*

Analysing the aspects presented, we can highlight several factors that influence the permeability of concrete of the tundish following corrosion:

- fineness of cement grinding (the finer the cement, the lower the permeability);
- cement dosage (increasing the cement dosage reduces permeability);
- the type of cement (cements with additions, require a larger amount of water, which can increase permeability);
- concrete treatment after putting into work (keeping fresh concrete in a humid environment for as long as possible, it decreases permeability);
- the use of additives in concrete compositions (use correctly, they considerably reduce permeability);

- the existence of tensile stresses and compressive stresses above the cracking limit (increase permeability).

Corrosion can also continue in compact and thick layers. In this case, the film of reaction products does not adhere at the metal, but detaches as it forms and falls. This detachment can occur for the following reasons:

- the volume of the formed oxide is greater than the volume of the original metal, and this increase in volume, caused by oxidation, can produce internal stresses that exceed the adhesion between the corrosion layer and the metal. These efforts are all the greater, as the ratio between the volume of the oxide, and the volume of the metal from which the oxide originates, is higher;
- the formed oxide layer has a different coefficient of thermal expansion than that of the base metal and when the temperature of the surrounding environment varies, internal stresses arise due to unequal expansions.

The porosity of the layer of ceramic material is an important factor that leads to the degradation of the refractory lining of the tundish and is influenced by a multitude of phenomena that were highlighted previously.

5. Conclusions

The quality of the refractory lining is of particular importance and is also influenced by the fixing method and the additives used.

The variation in temperature causes the refractory material to crack, lose its strength, break and thus contribute to shortening the life of the tundish.

The tundish lining is composed of three layers. The working liner is made of high MgO material and is exposed to direct contact with the steel.

Areas subject to a strong erosive flow require refractories based on magnesite. At the tundish, from the continuous casting machine, the refractory lining is made of shotcrete TUNDEX.

The samples taken from a used tundish, from the continuous steel casting machine were also examined by optical microscopy.

Optical microscopy is a method of analysing the quality of concrete samples, the purpose of the control being to determine the existence of degradations due to corrosion.

We highlighted through microscopy the wear of the layer due to the erosion and infiltration of steel microparticles into the pores of the lining.

We examined: the area at the metal-shotcrete interface, the area at the shotcrete-concrete interface, the area with refractory concrete.

Both the shotcrete layer and a good part of the concrete layer were damaged. The liquid alloy particles entered the capillaries, due to the porosity given by the material, as well as due to the microcracks that appear due to the temperature gradient, and the pressure exerted on the walls of the distributor.

Analysing the multitude of causes that lead to the deterioration of concrete elements, it is noted that most of them evolve according to a very important characteristic - permeability.

For concrete constructions that are located in harmful exposure and exploitation environments, obtaining concretes with a low degree of permeability is essential.

The durability of concrete decreases through the degradation of the intimate structure due to the phenomena of dissolution, expansion, cracking or exfoliation.

The porosity of the ceramic material layer is an important factor that leads to the degradation of the refractory lining of the tundish and is influenced by a multitude of phenomena that have been highlighted.

References

[1]. McLean A., *The Turbulent Tundish-Contaminator or Refiner*, Proc. Steelmaking Conf., Iron and Steel Society, 71, p. 3-23, 1988.
[2]. Van der Stel J., *et al.*, *Tundish Metallurgy: A Solution or a Limitation to Clean Steel*, Development in Ladle Steelmaking and Continuous Casting, edited by G.D. Lawson, Montreal: The Canadian Institute of Mining and Metallurgy, p. 218-223, 1990.
[3]. Lowry M. L., Sahai Y., *Thermal Effects on the Flow of Liquid Steel in Continuous Casting Tundishes*, Iron and Steelmaker, 19:3, p. 81-88, J. Schade. Lecture Notes, ISS Short Course on Ladle and Tundish Metallurgy for Clean Steels, 314-321, 1992.
[4]. ***, *Refractories, Manufactured Carbon and Graphite Products, Activated Carbon, and Advanced Ceramics*, Annual Book of ASTM Standards, vol. 15.01 (Index), 1998.
[5]. Daussan A., Martin J., Roziere J., *Steel Purity in Continuous Casting Tundishes*, Proc. Steelmaking Conf., 78, p. 471-477, 1995.
[6]. Melville S. D., Brinkmeyer L., *Evaluating Steelmaking and Casting Practices Which Affect Quality*, Proc. Steelmaking Conf., 78, p. 563-569, 1995.
[7]. ***, https://www.holcim.ro/sites/romania/files/documents/Manual_de_utilizare_a_betoanelor_5.pdf.
[8]. ***, https://www.creeaza.com/tehnologie/constructii/Proprietatile-betonului-intari669.php.
[9]. ***. https://materialedeconstructie.files.wordpress.com/2010/03/28246437-controlul-calitatii-betoanelor.pdf.
[10]. ***, https://www.revistaconstructiilor.eu/wpcontent/uploads/2011/09/nr_72_iulie_2011.pdf.