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Steel refining possibilities in LF

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Abstract. This article presents the main possibilities for steel refining in Ladle Furnace (LF). These, are presented: steelmaking stages, steel refining through argon bottom stirring, online control of the bottom stirring, bottom stirring diagram during LF treatment of a heat, porous plug influence over the argon stirring, bottom stirring porous plug, analysis of porous plugs disposal on ladle bottom surface, bottom stirring simulation with ANSYS, bottom stirring simulation with Autodesk CFD.

1. Introduction

At a basic level, the refining is a purifying process of certain gaseous/solid substances. The word “refining” is commonly used in relation with raw materials. The nature and complexity of liquid steel refining depends mainly by the steel type, meaning steel chemical composition and required cleanliness [1], [2].

Refining is a stage of the secondary steel making process which is also referred as ladle metallurgy. The secondary metallurgy concept forced the reorganization of the technological flux. In this way, between primary steel making and steel casting in Continuous Casting Machine, a series of specific installations have been installed one being Ladle Furnace.

Mainly, steel refining in LF aims the following objectives [3], [4]:

- To continue steel deoxidation started during tapping;
- To complete steel desulphurization also started during tapping;
- To homogenize steel bath thermic and chemically;
- To increase steel temperature according to required values for further events;
- To adjust the Carbon content and steel alloying;
- To eliminate inclusions in flotation in order to reach desired cleanliness;
- To modify inclusions shape in order to improve casting process at CCM;

Diversification of the refining process for steel aims to ensure a way to continue the metallurgical operations from primary aggregates in secondary aggregates, the process consisting in two stages: primary steelmaking (melting) and secondary steel making, steel treatment outside the furnace [5].

In Figure 1 we present steelmaking stages.





Figure 1. Steelmaking stages

The improvements done to the refining installations lately conducted to the possibility to obtain unquestionable performances regarding the quality of liquid steel which will be studied in this paper.

2. Steel refining through argon bottom stirring

During the ladle transportation process from the Electric Arc Furnace to the Ladle Furnace on the transfer car, argon (Ar) stirring must be intense in order to facilitate thermal and chemical homogenization and to prepare the slag for steel treatment. A rigorous attention is required for the steel bath level inside the ladle in order to avoid steel splashing. This has a huge impact both on company economic indicators but also on safety.

Bottom stirring effect is very complex and if the working parameters are chosen correctly and respected, the resulted alloys are high quality products. Special alloys required for cutting edge technology sometimes treated even vacuum, are treated through this procedure which has special metallurgical benefits related mainly with homogenization and refining.

The most important effects of inert gas bottom stirring are:

- Thermal homogenization of the steel bath as a result of the agitation created by the gas;
- Chemical homogenization of the steel bath as a result of intensified mass transfer processes;
- Non-metallic inclusions refining as a result of increased vertical velocity of these particles;
- Degassing through gases diffusion from the melt into the Ar bubbles;
- Interaction of the active gases with unwanted elements from the melt and formation of solid particles which no longer have the capacity to melt in the steel bath;

Refining process – intensification of physical and chemical processes thus a reduction in required time as a consequence of increased mass transfer velocity;

Gas injection into the melt is done either using a lance, protected or not with refractory material, disposed at the end with porous refractory component or, in case of the ladles, through porous plugs disposed in the bottom. The main problems of this procedure are those related to special quality of refractory materials and advanced wear rate, to purity of the injected gas, to steel melt cooling during treatment.

Steel bottom stirring start with average to high intensity generally before first heating. This intense stirring, prior to heating last for 2-3 minutes.

The main objective is to prepare the slag for an initial heating and to start the bath homogenization. The intense stirring will also facilitate the desulphurization. During this period slag deoxidizers may be added which are called “reduction mixes”. In Figure 2 is presented the HMI for this online control system. The installation can use either argon or nitrogen. Nitrogen is used only for steels that require a high content.



Figure 2. Online control of the bottom stirring

Bottom stirring (Figure 3) is considered an important technological process for refining. This is a very important aspect because most of the products require a low Sulphur content. Thus, is fundamental to control the evolution of this process.

In order to obtain a good desulphurization, it is mandatory that the following conditions should be respected:

- Slag basicity;
- Deoxidized slag and steel bath;
- High temperature;
- Intense stirring;
- Fluid slag;

A very important aspect is that the intense stirring must be done at the beginning of the process. A strong stirring at the final moments of the process has repercussions for the steel refining (reoxidation, slag emulsification).

Also, too fluid slag may affect the steel refining (reoxidation due to the fact that the slag do not protect enough, emulsification, dissolution of the MgO from the refractory). This is the reason why it is fundamental to respect the slag desired composition.

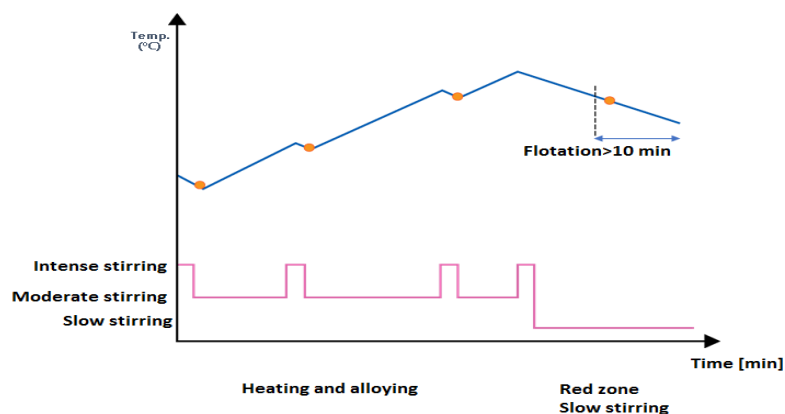


Figure 3. Bottom stirring diagram during LF treatment of a heat

The main stirring effects of the steel consist of: improving the properties through steel quality control, improving quality and productivity of continuous casting, improving overall performances of semi-products.

3. Porous plug influence over the argon stirring

A porous plug consists of: plates, refractory concrete and metallic cover. In figure 4 are presented images of a porous plug.



Figure 4. Bottom stirring porous plug

4. Analysis of porous plugs disposal on ladle bottom surface

Actual tendency:

- In line displacement of the plugs on the same side of the ladle;
- Diagonally displacement of the plugs;

4.1. In line displacement of the plugs on the same side of the ladle

This displacement method was initially designed to create a bath agitation having a circular motion from left to right (from one side to another), but on the top of the ladle in the right side (opposite side of the plugs) unassimilated ferroalloys may be observed, theory confirmed by the simulation illustrated in Figure 5. In order for the ferroalloys to be assimilated, a more dynamic stirring is required (bypass=maximum line pressure) leading to an increased argon consumption and a longer treatment time. For the plugs displaced in line, it has been observed that on the plugs side, refractory layer presented an increased wear, not uniform on the entire surface.



Figure 5. Bottom stirring simulation with ANSYS

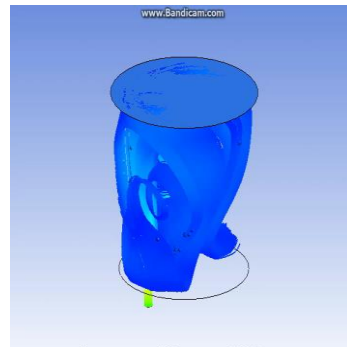


Figure 6. Bottom stirring simulation with Autodesk CFD

4.2. Diametrically porous plugs displacement

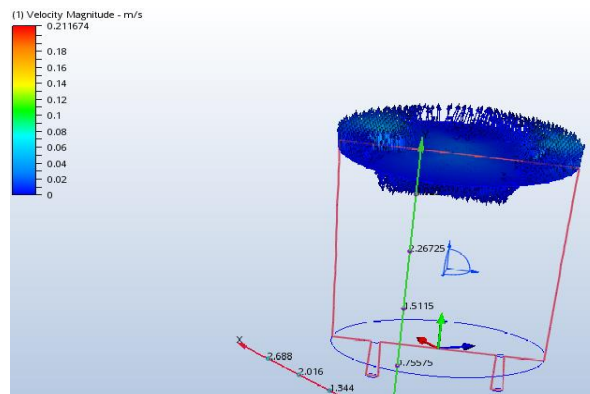


Figure 7. Bottom stirring simulation with Autodesk CFD

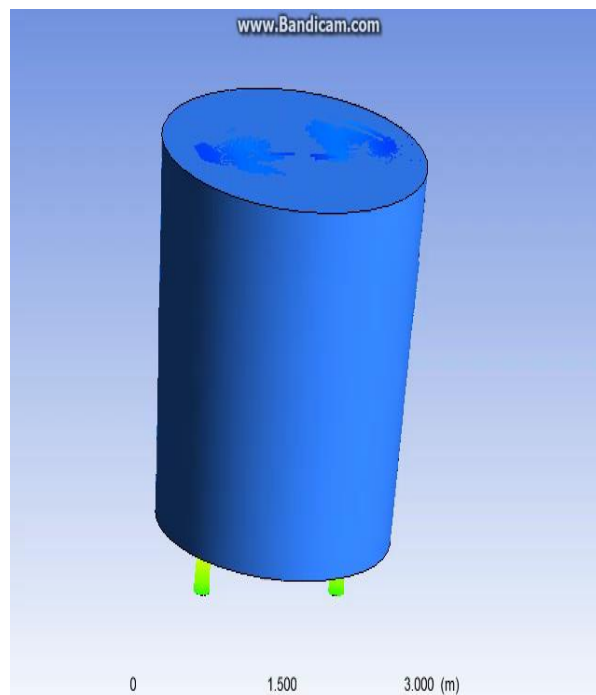


Figure 8. Bottom stirring simulation with ANSYS

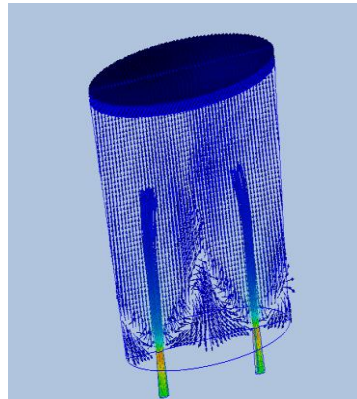


Figure 9. Bottom stirring simulation with Autodesk CFD

5. Conclusions

As a result of the simulations presented above and physical experiments in the steel shop, it has been observed that diametrically plugs displacement provides better results for the process than in line plugs displacement regarding steel homogenization, ferroalloys assimilation and refractory layer uniform wear. Plugs displacement on the same side of the ladle leads to an increased argon consumption and a larger stirring time with increased temperature loss, therefore a larger amount of electrical energy is required to homogenize the steel melt both thermally and chemically.

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