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Computational Modeling Study of Few Novel Oxygen Steelmaking Processes

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***Abstract*- Emulsification of slag and metal is very important for removal of carbon from liquid steel melt. The volume of fluid method (VOF) has been used to see the interaction of oxygen slag and metal in oxygen steelmaking process. Simultaneously discrete phase model (DPM) was used to judge the effect of iron ore addition during steelmaking process. The effect of both bottom purging as well as without bottom purging condition was judged through computational fluid dynamics model. Lastly a novel metallurgical reactor was developed which will be highly potential to create rapid mixing of melt, slag, lime, scrap and oxygen.**

Key words - Oxygen steelmaking, Novel Process, Iron Oxide, Induction Stirring, Emulsification

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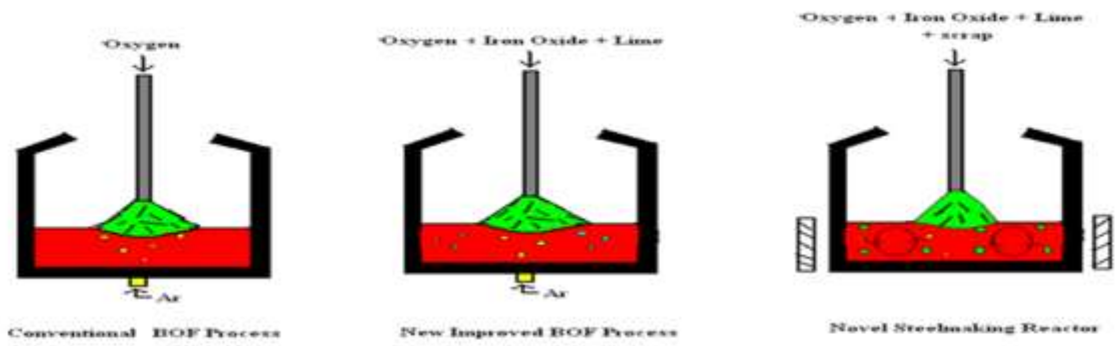
I. Introduction

Oxygen steelmaking is currently the dominant technology for producing steel from pig iron. The process is complex since it involves simultaneous multi-phase interactions, chemical reactions, heat transfer and complex flow patterns at high temperatures. The transient nature of the process also adds more complexities. The severe operating conditions make it difficult to take measurements and directly observe the process. Furthermore, experimental results are not always adequate in providing an evaluation of important parameters of the system. Mathematical modeling has been widely used to describe the complicated nature of the process; improve understanding of the system and optimize the process control [1].

Many metallurgical processes involve supersonic gas jets impinging on liquid metal as a method of purifying the molten metal by oxidation reactions. The most prominent application is the top and inclined jetting in Basic Oxygen Furnace (BOF) and Electric Arc Furnace (EAF) steelmaking respectively. The jets play significant role in bath mixing, chemical reactions, bath recirculation and formation of droplets [2].The reactions between metal bath and oxidizing gasses are of particular interest, as a significant proportion of carbon removal in oxygen steelmaking occurs in the impact zone in the reactor. It is known, as oxygen from a top blown lance reaches the surface of the liquid bath, it reacts with carbon dissolved in the metal at the impact zone and forms a mixture of CO and CO_2 gases. Subsequently, dissolved carbon also reacts with CO_2 simultaneously at this region [3]. Oxygen steelmaking processes involving an oxygen-jet impinging onto a steel bath surface, a good understanding of the underlying fluid dynamics is desirable in order to optimize the involved kinetics such as decarburization. Important parameters are the penetration depth and the shape and magnitude of the velocity field [4]. An enduring problem in process metallurgy is the mathematical description of impinging gas jets on liquid surfaces. The most prominent application is the top lancing of oxygen in the basic oxygen steelmaking process. The momentum of the oxygen jet destabilizes the slag and metal phases to create what is known as the slag–metal emulsion. At the same time, the oxygen reacts with the slag and the metal at extremely high rates and generates a large amount of heat [5]. Therefore, a complex interplay takes place between fluid flow, heat transfer, and mass transfer that has not been captured in a detailed mathematical model of the process. The present work is a contribution to the fluid mechanical aspects of the impinging jet with liquid surfaces, focusing on aspects of surface instability and droplet formation.



II. Present Study

In the Present study three different oxygen steelmaking processes was studied shown in figure 1. The first one is conventional oxygen steelmaking process where oxygen is blown from top and simultaneously argon is purging from bottom. The second new improved process consists of same process like conventional process except along with oxygen iron oxide particles are blown from top. As oxygen has low density its penetration is less to liquid melt. But the new process will apparently increase the oxygen density which will help to get more penetration of oxygen and highly reactive oxygen particles. It is anticipated that the new process will increase the oxidation reaction and will expedite the process effectively. The last novel process is injection of oxygen, lime scrap fines, iron oxide within the induction stirred melt. In the conventional oxygen steelmaking process reaction takes place at top surface. So all impinging oxygen doesn't take place in reaction. But the novelty of the last process is that slag metal oxygen reaction will take place effectively which will produce rapid refining without the loss of metal and damage of equipment from slopping.

III. Results & Discussion

Metal droplets are ejected from the jet impact area in top blown oxygen steelmaking

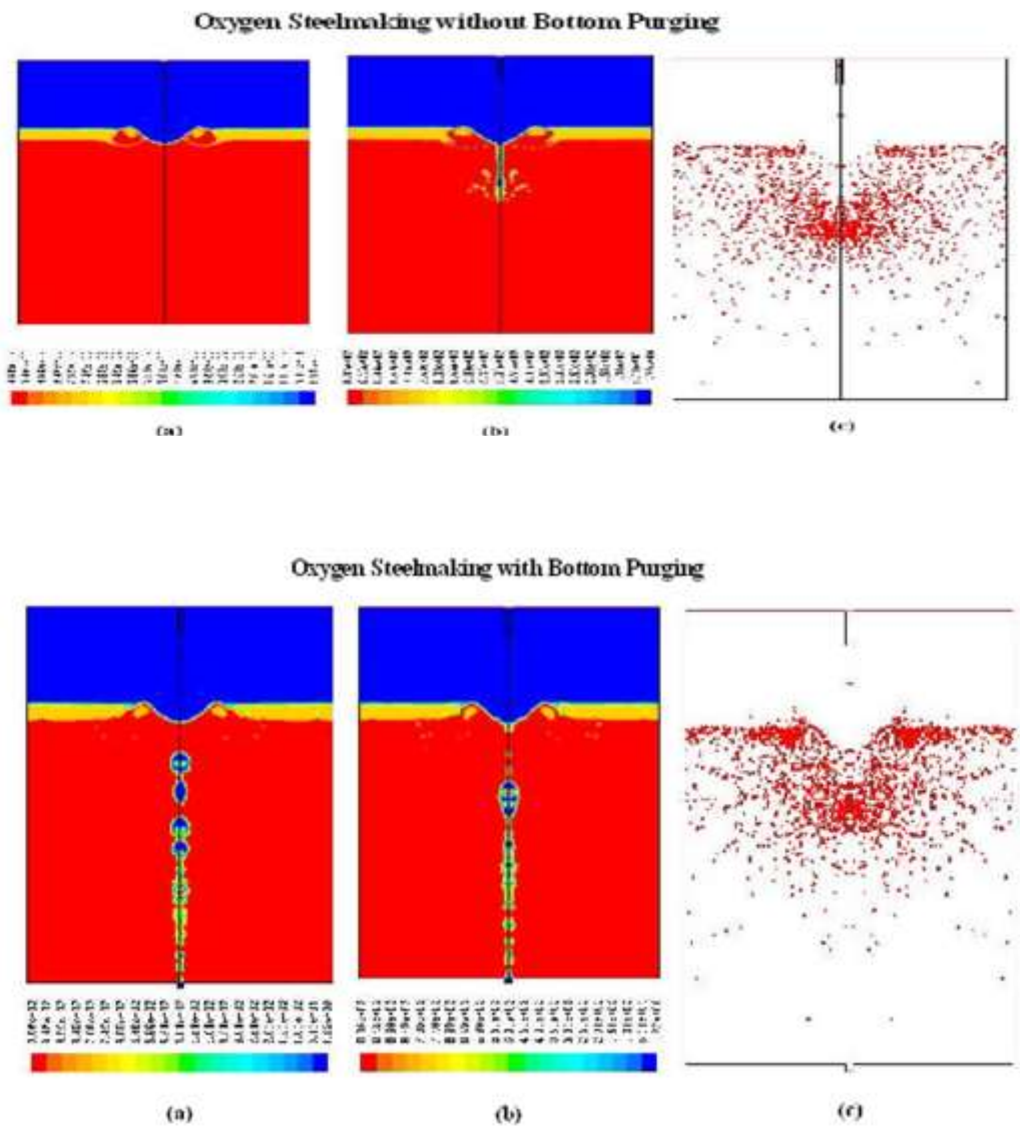


Fig. 3 Multiphase Plot (a) Conventional (b) New Oxygen Steelmaking Process (c) Discrete phase plot of New Oxygen steelmaking Process with bottom purging

converters. A large fraction of these droplets fall through the surrounding slag-gas mixture while some of the may escape through the mouth of the converter or deposit as skull at the mouth of the converter. Simultaneous to the production of droplets, gas bubbles, primarily of CO are produced by decarburization reaction

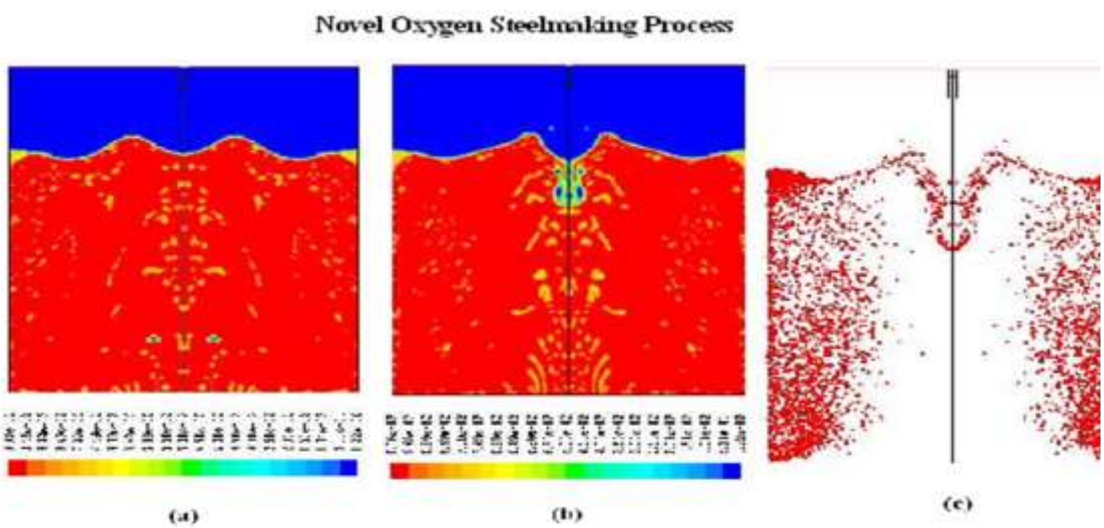


Fig.4 Multiphase Plot Novel Oxygen steelmaking Process at (a) Conventional with stirring (b

in the jet impingement zone as well as by decarburization reaction at the interfaces of metal droplets and slag, and bulk metal and slag. The falling metal droplets and rising gas bubbles have finite residence times in slag [6]. The two phase mixture of slag, metal is referred to in this work as emulsion.

A prototype cylindrical model of height 1.35 meter and diameter 1 meter was used to simulate the oxygen steelmaking process. The height of the liquid bath was 1 meter. The distance between exit oxygen nozzle and liquid bath was 250 mm. The slag height was 50 mm. As the kinematic viscosity of water and steel are same. So the simulating fluid was water in place of steel and oil was used in place of slag. The exit oxygen nozzle diameter was 20 mm. The oxygen velocity was 100 m/sec used. The turbulence kinetic energy was 1500000 m^2/s^2 and dissipation energy was 5 m^2/s^3. Volume of fluid model was used for simulation. Due to supersonic impinging of oxygen jet on the water surface a penetration was observed shown in figure 2 and 3. Simultaneously a small circulating flow was observed on the water surface at the position of impinging jet.

In the case where fine particles of iron oxide (here wood particles) was used with supersonic oxygen a deep penetration was observed at the center of shallow penetration. It is increasing the oxygen metal interaction in the steelmaking process. The particle concentration at the impinging position was high. It is then diffused to the upward lateral surface. The oxygen impinging with bottom argon purging was similar profile except the depth of penetration for new oxygen steelmaking was lower. The novel oxygen steelmaking reactor comprises of emulsion due to induction stirring shown in figure 4. Around 100 revolutions per minute stirring were used. Due to formation of emulsion the reaction rate will be high. Instead of concentrating at the impinging area of iron oxide particles it was dissipated throughout the liquid in the vessel which ultimately cause high rate of refining. From the multiphase flow analysis it is seen that there is no high viscous slag phase at the top surface of the liquid. So whatever the co/co$_2$ gas evolved will have less chance to foam the slag and slopping can be avoided. Not only that as the iron oxide particles, lime or slag flow was taking place along the periphery of the converter so lining life will be improved. It will indirectly improve the productivity of the process.

Mixing Time

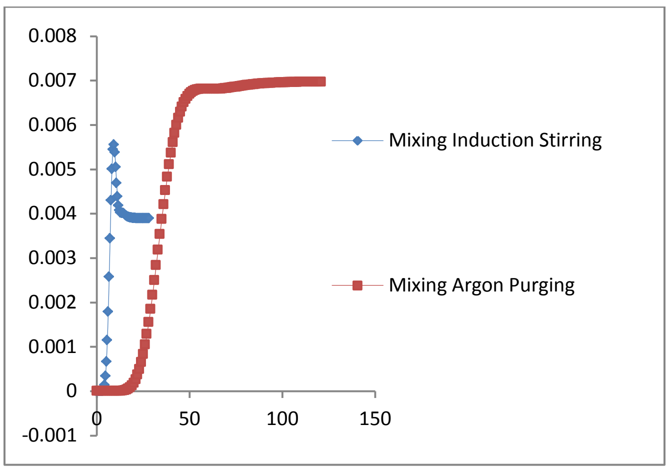


Fig. 5 Mixing time comparison of argon stirred melt with induction stirred melt.

Mixing time of argon purging and induction stirring process was compared by applying species transport model. It is shown in figure 5. The mixing time of induction stirred melt rotating at the speed of approximately 100 revolutions per minute was 20 sec where as the argon purging stirred converter it was approximately 60 sec with reasonable purging rate.

Conclusions

The following conclusions can be drawn from the above research

- The novel steelmaking reactor will be much more efficient in terms of refining reaction from the conventional process of oxygen steelmaking due to generation of emulsion within the melt.
- The slopping can be avoided in this metallurgical reactor by removing high viscous slag from the top surface of the melt.
- Due to formation of thin slag layer at the side wall of the converter the lining life of the new reactor will be high.
- As the mixing time is much less than the argon purging stirred converter the productivity will be high of this novel reactor as compared to the conventional steelmaking process.
- The novel oxygen steelmaking reactor will be much versatile as compared to conventional process in terms of raw material feeding.
- End point prediction will be much easier for this process.

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