Modeling of Inclusion Motion Across Steel-Slag Interface

Wei Liu1, Shufeng Yang1*, Jingshe Li1,2*, Feng Wang2

1School of Metallurgical and Ecological Engineering, University of Science and Technology Beijing
No.30 Xueyuan Road, Haidian District, Beijing, China, 100083
Phone: +86-1062334277
Email: youiithe@foxmail.com (W.L.)

2Engineering Research Institute, University of Science and Technology Beijing
No.30 Xueyuan Road, Haidian District, Beijing, China, 100083
Phone: +86-1062333241
Email: b20150439@xs.ustb.edu.cn (F.W.)

*Corresponding Author: yangshufeng@ustb.edu.cn (S.Y.); lijingshe@ustb.edu.cn (J.L.)

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INTRODUCTION

Cleanliness has been a primary and vital demand for producing high-performance steel products. Clean steel requires removing harmful inclusions as many as possible. For decades, a lot of effort has been put on the chemical reaction related to inclusions, such as generating [1, 2] and modifying reaction [3, 4]. Most of the inclusions are removed by slag absorption, which contains floating in the liquid steel, transferring across the interface and dissolving in the molten slag. Among the three steps for inclusions' removing, the interaction of inclusion with the interface is the essential process because it decides whether the inclusion can be separated from the steel [5-7]. The whole removing process of inclusion from the steel is high-temperature transient micro-phenomenon that is difficult to catch and describe. It is a process that contains chemical and physical phenomena. Some researchers have tried the way of theoretical analysis [8-10] and computational fluid dynamic (CFD) simulation [13] to improve the removing efficiency of inclusions. The CFD models usually use a Lagrange method to track the motion of inclusions in steel, and this method neglects the volume of inclusion and only focuses on the motion and effect of inclusion on the surrounding fluid(s). This macro model considers flow and motion in a large scale and shows little accuracy for the micro-process of inclusions' removal. The other way is to simulate the micro-flow around an inclusion, which for now cannot deal with the interface problem. However, it is the interaction of inclusion with the steel-slag interface should be paid more attention to and thus find out the critical condition for inclusion removal.

In this study, the micro-phenomenon of a rigid sphere inclusion's moving and interacting with steel, slag and their interface are modeled with complex transient force analysis. The model is validated with a water-model experiment. The critical condition for inclusions' transferring the interface and removal are obtained and which step of the whole process is vital for the steel cleanliness is discussed.

MODELING

The three steps mentioned above are all considered in this model. For the motion model, a complex force analysis was performed on the process of inclusion’s moving statement in the steel, and all the forces acting on inclusion are considered to be dynamic. For the reaction model, the dissolution of inclusion when it is in contact with the slag phase is considered. The motion and dissolution models are coupled with a consideration that they influence each other, especially the size change by dissolution will change the motion status. To simplify the calculation, some assumptions are made.