Slag Foaming in the $FeO-SiO_2$ based Desiliconization Slag system

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ABSTRACT

The slag foaming of $FeO-SiO_2$ based desiliconization slags was investigated using a X-ray fluoroscopy technique. Foam generation phenomena and antifoam effects of metallic aluminum and carbon based materials were observed. As for the antifoaming capability, aluminum based agent with a proper particle size range had a significant-antifoam effect much better than the conventional carbon based ones. The major contribution of antifoaming agent may be due to an instantaneous reduction of FeO in the slag, resulting in the sudden decrease of slag viscosity. Although the carbon based agent also has the capability of lowering slag viscosity, and suspension of carbon particles tend to increase a bulk viscosity due to its relatively slow reaction with FeO slags.

1. INTRODUCTION

The foaming of slag have been considered to have a significant effect of the productivity of iron and steel process, especially in the desiliconization.[1]
The present work was accomplished primarily due to the difficulties associated with maintaining a sound operation not interfered by a slag overflow inevitably encountered at a high desiliconization ratio. Consequently a marked reduction in the productivity was obtained accompanied by a decrease in the desiliconization efficiency. The slag foaming observed in the desiliconization treatment principally comprised of evolved carbon oxide and carbon dioxide from the reaction between added agents containing oxygen content to some extent and the desolved [C] surrounded by a highly viscous $FeO-SiO_2-(CaO)$ slag system. The gas bubbles entrapped in the viscous slag has some difficulties to escape from due to an insufficient liquid drainage in themselves. Figure 1 shows the schematic diagram for the slag foaming phenomena in the desiliconization process.[2]

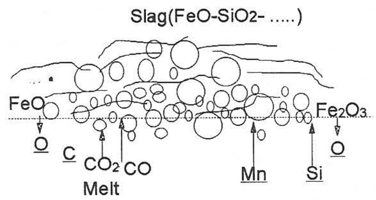

Figure 1. Schematic diagram for slag foaming

The above phenomena results in lowering a process efficiency on account of the use of a restricted unit consumption, followed by a decease of tapping productivity. Foam stabilization can be expressed by the product of the rate of gas evolution and the ability of the solution to hold the gas phase. In terms of a foam, there have been a lot of trials to investigate the properties of foaming slag, such as surface viscosity and surface tension.[3] When slag foaming increases, the slag overflows from the top of a ladle. In actual operations, the suppression of foaming is carried out either by dumping a certain amount of rice brans or temporally suspending a tapping operation until the calm down of a foam. Dumping a rice bran, however, could not continue an additional receiving of pig iron due to an excessive boiling greater than that of previous one. Previously, a number of laboratory scale trials to suppress a slag foaming used one of two approaches; changing slag properties and inducing artificially overgrown bubbles by applying gases. Higher FeO content bearing agent was used by virtue of maintaining a high surface tension. Additional refractory powders were also introduced to modify the slag composition for the benefit of lower slag viscosities and surface tensions. On the other hand, an excessive gas evolution was deliberately produced to break the foam film escaping the trapped gases from the bubbles either by burning obsolete tires or by applying flames.[4)] Their reliability, however, in accuracy and maintenance is still in question. To make a selection of appropriate materials, a goal for the minimum requirement of antifoamer. Apparently it should be helpful to instantaneous thinning of foam film followed by escaping gases from bubbles in the actual process as well as cheap enough and available around steel works. The aluminum dross was considered to be the most appropriate materials for its metallic aluminum content preferably to reduce the FeO content in the $FeO\text{-}SiO_2$ based slag system accompanying a heat of reaction. Its low melting temperature and strong reducing ability are thought to enhance the foaming slag viscosity useful to the instantaneous thinning of the foam film. The available aluminum dross contains some of alkalies known as good for the subsidiary suppressing a foam.

2.EXPERIMENTS

In this work some experiments were carried out to study the slag foaming phenomena of the actual desiliconization slag using a X-ray fluoroscopy technique. The reduction of FeO content in the slag and their effect on slag viscosity were observed. Foam suppression by aluminum based antifoamer and carbon based one was also compared at the same experimental condition. Simultaneously, actual trials on suppressing the foaming slag were also performed at the blast furnace cast house by the practical modification involving the form of antifoamer and timings for the best application.

Experiments were conducted in four phases.

First, the suppressing fashion of the foaming slag in a magnesia crucible were observed. Next, to get a grasp of effect of the containers differing from a magnesia, same kinds of work were carried out at a graphite crucible. And then powdered carbon based antifoamer was also tested to compare with the aluminum based one. Finally, actual trials with the antifoamer which were determined by the lab scale experiments were also applied for some heats. A schematic drawing of the experimental apparatus is shown in figure 2. The X-ray fluoroscopy is composed of an X-ray tube(120kVA/400mA maximum intensity), and image intensifier, a TV camera and a video tape recorder. The X-ray fluoroscopy can be continuously run for about 30 minutes at an intensity of 90kVA and 0.8 mA. Carbon saturated iron was melted at 1400 °C in a graphite and magnesia crucibles of O.D. 50mm, I.D.40mm and L 200mm size.

Sinter dusts were added at the experimental temperature to induce slag and CO bubbles at the slag metal interface. Figure 3 shows the X-ray fluoroscopic image of a typical foaming slag overflown at ten times as big as the original slag height in a magnesia crucible. As the sinter dusts

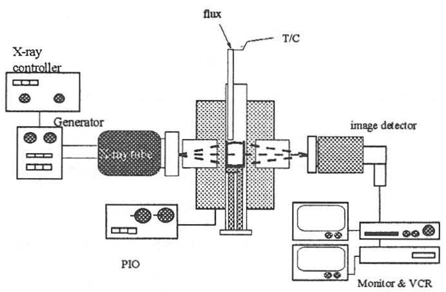

Figure 2. Apparatus for X-Ray fluoroscopy and radiography

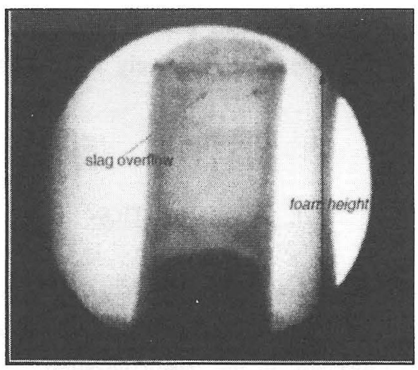

Figure 3. X-ray fluoroscopic image of slag foaming without antifoamer

dissolves in slag, the CO bubbles were generated at the slag/metal interface and rapidly rose through the slag layer. The formation and growth of CO bubbles happens as the solid sinter dusts completely melt down, which remains until the gas bubbles are no longer supplied by carbon oxidation.

3. RESULTS AND DISCUSSIONS

3.1 Suppression of foaming slag in a magnesia crucible

The foaming slag reached at the summit of the crucible by virtue of the crucible wall, which might be served as sites for stabilizing the foam resulted from the interaction between generated bubbles and the crucible wall, as illustrated in Figure 4-(a). By analogy with the role of surface active species in the Marangonian model, the crucible wall seemed to behave a surface active element to reduce the drainage rate by increasing the viscosity of the surface relative to the bulk. Figure 4-(b) shows the X-ray fluoroscopic image of foaming slag just after adding the antifoamer into the foam. A convex form of foaming slag top was converted to a flat one by spreading a rigid foam structure. The added aluminum dross reacted with the foam causing a local thinning of foam owing to the FeO reduction and with some heat of reaction. Accordingly, the gas hold-up escaped from the bubbles instantaneously leading a disintegration of the apparent foam structure. Finally, resultant volume of slag almost disappeared by leaving some scraps of foaming slag onto the crucible wall. Figure 4-(c) explicitly illustrated the abilities of the aluminum dross based antifoamer for suppressing a foaming slag.
A marked decrease in the foam height was observed on the addition of aluminum dross based agent due to the role of metallic aluminum as previously discussed.

3.2 Suppression of foaming slag in a graphite crucible

Contrary to the formerly visualized results, a mushroom shaped foam was produced with a relatively lower volume of foaming slag, not climbing the top any more. Figure 5-(a) shows the maximum foam height of the typical foam occurred at a graphite crucible. The contact angle became sharp more than that in a magnesia crucible, which means a weaker wettability between graphite and foaming slag. Figure 5-(b) illustrates the X-ray image of foaming slag just after adding the antifoamer into the foam layer. The excessively

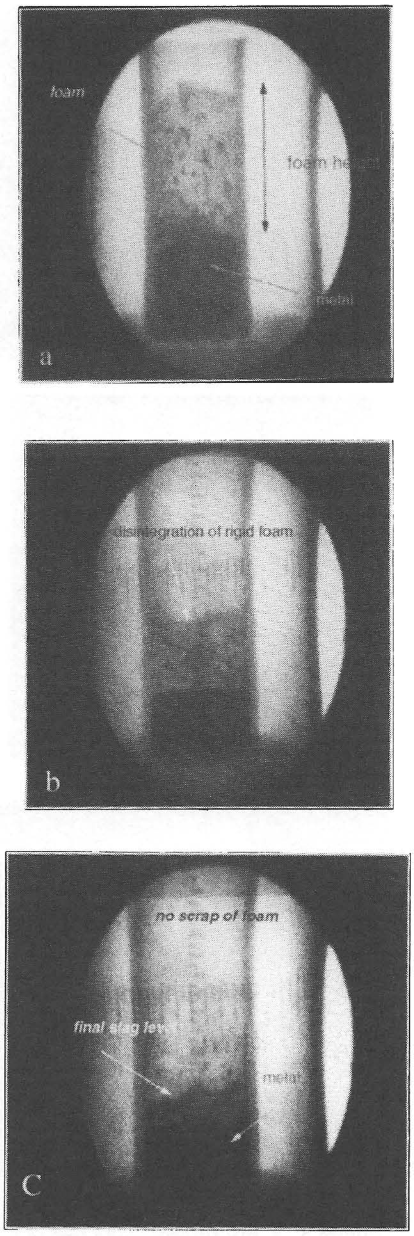

Figure 4. X-ray fluoroscopic image in a magnesia crucible
a) fully foamed state
b) just after addition of antifoamer
c) resultant volume of slag

convex contour of the foam top changed into a concave shape implying a disintegration of a rigid foam. The suppressing fashion is somewhat different from the previous one. Figure 5-(c) represents the resultant view of the foaming slag after suppression ends.

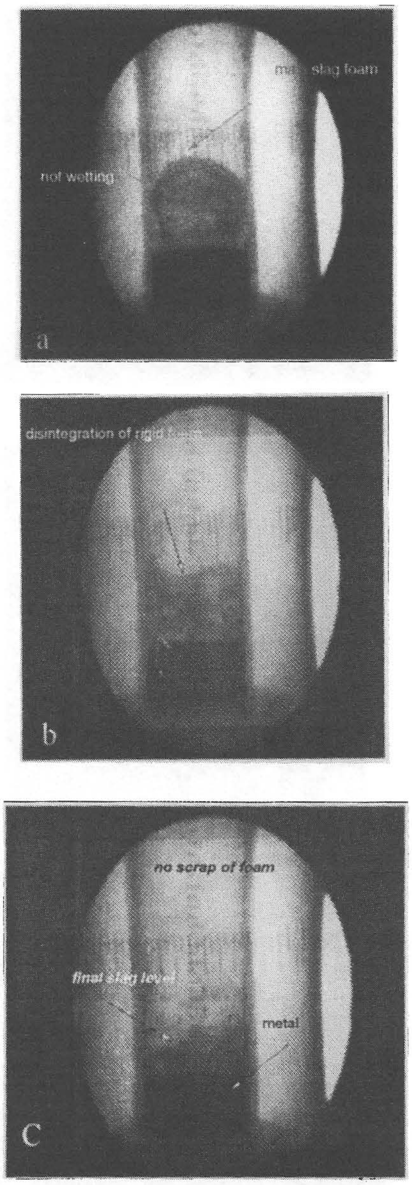

Figure 5. X-ray fluoroscopic image in a graphite crucible
a) fully foamed state
b) just after addition of antifoamer
c) resultant volume of slag

3.3 Suppression of foaming slag by carbon based antifoamer

In order to compare the suppression ability between aluminum dross and carbon based antifoamers, a similar slag was fully foamed as shown in figure 6-(a). Figure 6-(b) shows the X-ray fluoroscopic image of foaming slag just after adding a carbon based antifoamer. As illustrated in the figure, a vivid suppressing line was formed in a concave shaped contour after a short period of adding. Obviously it can be inferred that the carboneous material reduce the iron oxide in the slag as the metallic aluminum as does in the aluminum dross. Yet a sudden increase of foam height was observed after a few seconds, recovering its initial height. Figure 6-(c) represents the recovery of foam. It was assumed that the unreacted carboneous material served as suspensions despite of its foam suppressing abilities. In other words, the suspended materials resulted from slower reaction with FeO slags tend to increase the apparent viscosity of the slag rather than the liquid phase viscosity.

3.4 Actual trials with aluminum dross based antifoamer

To obtain an optimum feature of antifoamer for the plant scale application, actual trials were conducted in the blast furnace cast house. The aim of each experiment is how many tons of pig iron can be received by adding an antifoamer without any break or slag overflow. Accordingly sets of conditions were varied to set up proper limits including both antifoamer itself and subsidiary condition related with tapping operation.

First a typical form of antifoamer composed by 30 percents metallic aluminum containing and fine powder was applied to the violent foaming slag. As soon as pouring an antifoamer of 0.8kg/T-pig in the course of tapping, a simultaneous calm down of foam was observed to be enough to continue a receiving of pig iron up to 270ton.

In a second trial, a minor change in the aluminum content of the antifoamer was conducted to check up the role of metallic aluminum relative to the suppressing function. Half of the previous antifoamer was replaced by 25 percents metallic aluminum containing dross, resulting in several times delay to calm down the foaming slag with big fumes. However, a continuous receiving of pig iron was possible up to the upper limit. Particularly, a pellet type antifoamer of the same feature as that of the first trial was added to the foaming slag. Unfortunately no antifoam effect was observed. A very similar result was also found in the case which higher aluminum bearing dross was used in a considerably large amount of a remaining melt containing ladle. Consequently powdered aluminium dross based foam was selected for making best of it especially in a relatively clean ladle. Through the application of this kinds of antifoamers, more than 260 ton of pig iron could be received even in the higher desiliconization flux consumption, which had not been possible in the normal operations. Figure 7 shows the effect of antifoamer on the tapping productivity in actual trials. Surprisingly, a certain amount of sulfur pick ups were observed in every aluminum based antifoamer applications. As figure 8 indicated, some amounts of sulfur was inversely transferred to the melt. The sulfur pickup into the iron melt can be explained by the oxygen potential diagram proposed by Rosequvist et. al.[5]. Even though no lime was included in the treatment, the final basicities after treatment usually reached to 1.5 or 2.0. Clearly, no torpedo cars carrying pig iron from blast furnace go to the converters without passing through lime-based desulfurization treatment.

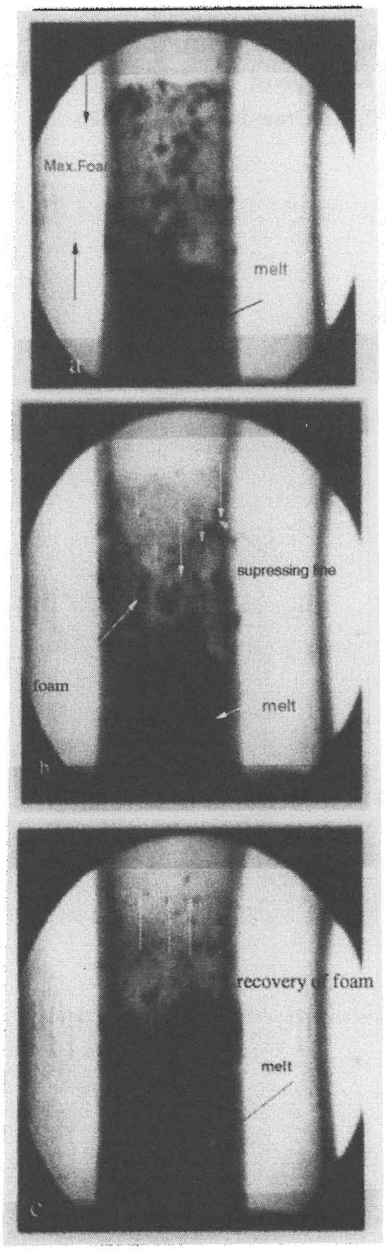

Figure 6. X-ray fluoroscopic image with carbon based materials
a) fully foamed state
b) just after addition antifoamer
c) recovery of foam shortly after

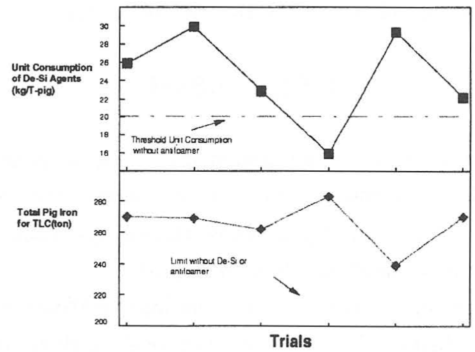

Figure 7. Effect of antifoamer on the productivity in actual trials

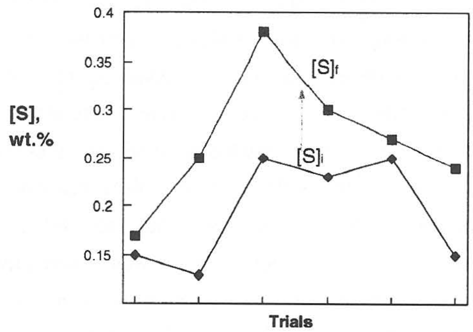

Figure 8. Sulfur pick-up during desiliconization with antifoamer

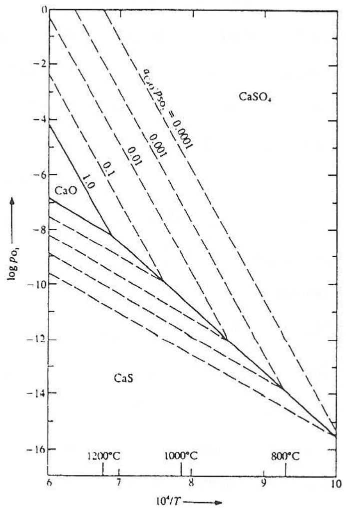

Figure 9. Oxygen potential in the Ca-S-O system after Rosenquvist[5]

Obviously it can be inferred that the remaining calcium sulfide decomposed into calcium oxide and free sulfur under the high temperature and fairly oxidizing atmosphere. As illustrated in figure 9, calcium sulfide or calcium sulphate tend to decompose if a restricted condition were to be provided.

4. CONCLUSION

In this work, foam generation and antifoam efects of metallic aluminum and carbon based one were investigated by using a X-ray fluoroscopy technique. Aluminum based agents with a proper particle size range had a significant-antifoam effect much better than the conventional carbon based ones.

The major contribution of antifoaming agent may be due to an instantaneous reduction of FeO in the slag, resulting in the sudden decrease of slag viscosity. Although the carbon based agent also has the capability of lowering slag viscosity, and suspension of carbon particles tend to increase a bulk viscosity due to its relatively slow reaction with FeO slags. Through several trials for plant scale applications, the productivity was considerably improved despite of sulfur pick-up due to the decomposition of calcium sulfide remained after desulfurization.

5.REFERENCES

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