1. Introduction

Desulfurization of steel is achieved primarily by slag treatment. Most previous investigators have claimed that the vast majority of metal/slag reaction kinetics are determined by mass transport in either phase.\textsuperscript{1–15} Many researchers have employed gas stirring to enhance mass transfer in bulk phases. It was suggested that surface active elements such as oxygen and sulfur, when existing in the system, induced additional interfacial convection flow, which enhanced the mass transfer.\textsuperscript{10,16–22} Most of these studies were carried out with a system arrangement in which the molten metal was covered with molten slag. Turkdogan et al.\textsuperscript{23} carried out a laboratory study in which iron drops were allowed to fall on the molten slag pool and the resultant metal drops were then collected and analyzed. Results indicated that substantial solute transfer had occurred over a relatively short time in the order of seconds. They demonstrated that slag–metal reaction rates under dynamic conditions could substantially be different from rates in systems with static interfacial conditions. Wu et al.\textsuperscript{14} studied silicon and manganese transfer under dynamic conditions in which carbon-saturated liquid iron drops were allowed to fall through the slag layer. They found that transfer rates were two to three orders of magnitude larger than those under static metal–slag contact conditions. They attributed the enhanced rate to the combined effect of surface renewal in the slag side, enhanced circulation in the metal drops, and fragmentation and emulsification at the metal/slag interface.

The aim of the present study is to explore the possibility of enhancement of desulfurization rate of steel by employing a dynamic condition in which metal drops fall through the slag pool. The study was carried out by dispensing liquid iron droplets and allowing them to experience free fall through the slag layer. The falling velocity and the change in chemical compositions of the metal drops after falling were examined.

2. Experimental

2.1. Apparatus

The schematic diagram of the experimental apparatus employed in the present study is shown in Fig. 1. The resistance furnace (MoSi\textsubscript{2} heating elements) was designed to provide two heating zones in such a way that the upper and lower halves of the furnace were heated independently so that the temperature of the metal and slag samples could be adjusted independently. The metal and slag samples were enclosed in the furnace tube (alumina, 100x10\textsuperscript{-3} m OD, 90x10\textsuperscript{-3} m ID and 1.2 mL), which was fitted with an end cap at the upper end and with a quenching device at the bottom end. For dispensing metal drops, two different techniques were employed: (1) dispensing one drop at a time by using an alumina tube (6x10\textsuperscript{-3} m ID) with one end having a small hole (1x10\textsuperscript{-3} m diameter) and (2) dispensing multiple drops in one run by using an MgO crucible (25x10\textsuperscript{-3} m ID, 55x10\textsuperscript{-3} m H) equipped with a stopper system. The above two devices are shown schematically in Fig. 1. The slag was melted in an MgO crucible (60x10\textsuperscript{-3} m ID, 100x10\textsuperscript{-3} m OD, 80 mL), which was fitted with a stopper system.
100×10^{-3} m H), the bottom of which was tapered toward the center. A draining hole was constructed at the bottom center of the crucible, which was kept closed by a stopper. A quenching device was attached to the lower end of the furnace tube. The quenching device was a closed water container and was separated from the lower end of the furnace tube by a slide gate which was opened only when the molten samples (slag + metal) were subjected to quenching. Movement of metal drops was monitored using an X-ray fluoroscope which was installed beside the furnace. The image from the X-ray fluoroscope was recorded using a VCR.

2.2. Sample Preparation

Metal samples were prepared by melting high purity electrolytic iron (99.99 mass%) and Fe–50 atomic% S in an alumina crucible using a separate heating furnace under an inert Ar gas atmosphere which was purified by passing through a sulfuric acid aqueous solution and then through an Mg-chip column heated at 773 K. The melt was kept at 1873 K for 10 min and then withdrawn into quartz tubings (5\times10^{-3} m ID) by suction, followed by quenching into water. The metal surface was ground to remove any contamination or oxidation. The sulfur content in the alloy was analyzed using a C/S determinator (LECO, Model #: CS-200®). Metal samples of three different sulfur contents were prepared, namely, 3.49\times10^{-2} mass%, 1.47\times10^{-2} mass% and 6.2\times10^{-3} mass%.

Slag samples were prepared by melting CaCO₃, Al₂O₃ and MgO (all of reagent grade) in a graphite crucible in an induction furnace under the high purity Ar atmosphere. The melt was kept in the furnace for 30 min at 1873 K. The quenched slag was thoroughly ground and then decarburized by heating in a muffle furnace at 1323 K for about 10 h. The carbon content in the decarburized slag was confirmed to be lower than 0.001 mass%. Three different slag compositions were prepared as given in Table 1. The slag compositions are also indicated in the CaO–Al₂O₃–MgO ternary phase diagram as seen in Fig. 2.

2.3. Procedure

The furnace assembly, but without placing metal and slag samples in the crucibles, was heated to 1873 K under an inert atmosphere. Then a predetermined amount of slag (55–57\times10^{-3} kg) was charged into the MgO crucible using an alumina lance. After complete melting of the slag was confirmed through X-ray fluoroscope image analysis, and the temperature in the furnace was stabilized, metal sample was charged into the metal sample dispensing container (either the alumina tube or MgO crucible). When complete melting was confirmed through the X-ray fluoroscope, the metal drops were dispensed either from the tubing by pressuring it from the top using a below or from the crucible by lifting the stopper. When metal drops had arrived at the bottom of the slag crucible, the stopper of the slag crucible was lifted and at the same time the slide gate at the lower end of the furnace tube was also opened. This allowed both slag and metal samples to be discharged together into the water tank where the samples were quenched. Metal droplets were then collected and subjected to measurement of the mass and chemical analysis. The whole process from metal dispensing to draining from the slag crucible was monitored and recorded using the X-ray fluoroscope. Figure 3 shows an example of the recorded images. The actual time for a metal droplet to travel through the slag layer was estimated from the recorded X-ray fluoroscope image which was 30 frames per second.

3. Results and Discussion

Metals of three different sulfur contents and slags of
three different compositions were used in the present study. Details of experimental results are summarized in Table 2. The total time in the table indicates the time span from the moment at which a metal droplet arrives at the slag surface to the time at which the metal droplet, together with the slag, is drained out of the crucible to the quenching tank by opening the slide gate. The falling time in the table is the actual traveling time of a droplet through the slag layer from the surface of the slag to the bottom of the crucible. The falling time was determined from the recorded image of the X-ray fluoroscope. Figure 4 shows the relationship between the drop size and falling time, where, as expected, the falling time is inversely proportional to drop mass. The terminal velocity of a particle traveling in a fluid is given by Eq. (1), which is determined by the balance of several forces acting on the particle, namely, the buoyancy force, gravity force and drag force which includes the friction factor:

$$u^2 = \frac{\Delta \rho gV}{\phi \rho A_p} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldOTS
tion factor ($\phi$) is given as

$$\phi = 12(1 + 0.15Re^{0.687})/Re \quad \text{..................(2)}$$

Terminal velocity can then be calculated by combining Eqs. (1) and (2). Comparison of the observed mean falling velocities with velocities estimated from Eqs. (1) and (2) is given in Fig. 5. It is seen that the observed velocities are lower in general than the calculated terminal velocities. Strictly speaking, Eq. (2) can be applied to rigid particles. The drag coefficient of a liquid droplet is generally smaller than that of a solid particle, mainly due to the internal circulation which occurs within the droplet. This fact should lead to the falling velocity being higher than calculated using Eq. (2), but the observation reveals an opposite trend. This discrepancy may be attributed to the fact that the falling velocity has not fully developed up to terminal velocity during the fall due to the short traveling distance, and also that a vigorous mass transfer (mainly sulfur and oxygen) takes place at the surface of the droplets which may cause interface instability due to a rapid change of interfacial tension. The latter appears to have a substantial influence on droplets movement as seen in Fig. 5, where discrepancy between observed and calculated falling velocities is larger for droplets with higher sulfur content (349 ppm).

Sulfur is known to be surface-active in liquid steel, and hence decreases the surface tension of the steel with increasing its content in the steel. Surface tension is in turn an important parameter for determining the dynamic shape of a droplet and internal circulation. Therefore, the influence of sulfur on falling velocity is due to the combined effect of the interfacial mass transfer and the surface tension change.

In Fig. 6, the extent of desulfurization is given against the droplet mass. Although the data scattering is a bit excessive, careful examination reveals that the extent of desulfurization decreases with increasing the droplet size. For slag composition A, desulfurization of more than 80% is achieved within a few seconds of reaction time.

Desulfurization should occur while a droplet falls through the slag layer and also while it remains at the bottom of the crucible before being drained to the quenching tank. Turkdogan et al.23 and Wu et al.14 reported that mass transfer is extremely rapid under the dynamic condition at which a metal droplet travels through a slag layer. They found that the rate under the dynamic condition was faster by two to three orders of magnitude than that in a static condition at which a slag layer was sitting on a liquid metal pool without stirring. If this were the case, the desulfurization observed in the present study should have occurred mostly while falling through the slag layer, and the extent of desulfurization while staying at the bottom of the crucible should be small. In order to identify the difference of the rate between the two different situations, the mean values of the apparent rate coefficient were evaluated and compared with the results of other investigators.

Desulfurization may be represented by the following reaction:

$$S + 2e^- \rightarrow (S_2) \quad \text{..................(3)}$$

where $S$ and $(S_2)$ are sulfur in the metal and in the slag, respectively, and $e^-$ represents electron. Desulfurization may be controlled either by mass transfer in the metal or slag phase or the interfacial reaction. Irrespective of the rate controlling step of the desulfurization reaction, however, the rate of desulfurization will follow a first order dependence on the sulfur concentration in the metal and can be represented by the following rate equation, Eq. (4):

$$-\frac{dC_S}{dt} = k_{app}\left(\frac{A}{V}\right)(C_s - C_s^e) \quad \text{..................(4)}$$

where $k_{app}$ is the apparent rate coefficient ($\text{m}^{-1}\text{s}^{-1}$), $A$ and $V$ the surface area ($\text{m}^2$) and volume ($\text{m}^3$) of the metal drop, and $C_s$ and $C_s^e$ are, respectively, the sulfur concentration in the metal at time $t$, and that in equilibrium with the slag. Under the present experimental conditions where a metal
droplet moves through a slag pool and always contacts a new slag, the equilibrium sulfur concentration in the metal \(C^e_s\) should be negligible; then the above equation can be simplified as,

\[- \frac{dC_s}{dt} = k_{app} \left( \frac{A}{V} \right) C_s \]  \hspace{1cm} (5)

Integration of Eq. (5) yields:

\[- \ln \left( \frac{C_s}{C^0_s} \right) = k_{app} \left( \frac{A}{V} \right) t \]  \hspace{1cm} (6)

It is then attempted to determine the apparent rate coefficient \(k_{app}\), tentatively assuming that there is little difference in the rate of desulfurization between during falling through the slag and staying at the bottom of the crucible. Figures 7–9 show the plot of the experimental data according to Eq. (6). Although showing some scatter, the experimental data generally follow Eq. (6). From the slope of the linear regression, the apparent rate coefficient is evaluated to be \(5.4 \times 10^{-5}\) m s\(^{-1}\) for Slag A, \(3.8 \times 10^{-5}\) m s\(^{-1}\) for Slag B and \(1.25 \times 10^{-5}\) m s\(^{-1}\) for Slag C. It is seen that the rate is influenced to a substantial extent by the slag composition. Comparison of the present results with those reported by other investigators will help elaborate the significance of these values. Deng and Oeters\(^{10}\) studied the mass transfer of sulfur from liquid iron into lime-saturated CaO–Al\(_2\)O\(_3–\)MgO–SiO\(_2\) slags at 1 873 K by employing a conventional arrangement in which molten metal and slag were held in an MgO crucible with a bottom blowing of argon gas at different rates. They concluded that the desulfurization was controlled by the mass transfer of sulfur in the metal phase, and determined that the mass transfer coefficient was \(5.52 \times 10^{-3}\) m s\(^{-1}\) with a low gas flow rate \((0.1 \times 10^{-3}\) m\(^3\) h\(^{-1}\)). It is noticed that this value is smaller by about one order of magnitude than the values found in the present study. The difference between the two studies is probably related to the difference in the experimental arrangement, particularly of the metal–slag contact. The contact between the metal and slag is much more dynamic in the present study, particularly during the time when a droplet falls through the slag. In the present experimental arrangement a metal droplet makes a dynamic contact with the slag while falling through the slag, followed by static contact while resting at the bottom of the crucible. Thus Eq. (6) can be further divided into two consecutive expressions:

1. During the dynamic contact,
   \[- \ln \left( \frac{C_s}{C^0_s} \right) = k_{app} \left( \frac{A}{V} \right) t \]  \hspace{1cm} (7)

2. During the static contact,
By using the value of $k_d$ reported by Deng et al.\textsuperscript{10} the value of $k_d$ is in the order of $10^{-3} \text{m s}^{-1}$ with slag compositions and temperatures similar to the present study. By using the value of $k_d = 5.52 \times 10^{-3} \text{m s}^{-1}$, the value reported by Deng et al.\textsuperscript{10} Eqs. (7) and (8) were solved simultaneously with each data set of the present study; the results are given in Fig. 11. It is clear that the slag composition exerts a definite influence on the rate of desulfurization while falling through the slag. Moreover, the values of $k_d$ ascertained by the linear regression of the data are larger by approximately two orders of magnitude than $k_t$ reported by Deng et al.\textsuperscript{10}, $2.8 \times 10^{-3} \text{m s}^{-1}$ for Slag A, $1.5 \times 10^{-3} \text{m s}^{-1}$ for Slag B, and $0.7 \times 10^{-3} \text{m s}^{-1}$ for Slag C. This finding that the overall rate of mass transfer of sulfur is greatly enhanced by dropping a metal drop through slag is in line with what Turkdogan et al.\textsuperscript{23} and Wu et al.\textsuperscript{24} have reported, as mentioned earlier, through study of Mn and Si transfer between carbon-saturated iron and SiO$_2$–MnO containing slag. They discussed some possible mechanisms which potentially enhance the transfer rate. Firstly, in a dynamic system where a metal drop falls through the slag, gasses which are produced as a result of chemical reactions are rapidly swept away from the leading surface to the wake of the falling droplet which ensures direct contact between the metal and slag over the majority of the interface. Moreover a falling metal droplet always makes a contact with fresh slag, which effectively maximizes the mass transfer in the slag phase. Secondly, emulsification in the vicinity of the metal–slag interface, which occurs due to low interfacial tension with the aid of interfacial reactions.\textsuperscript{10,25} Such emulsification greatly increases the reaction area. They concluded that under the dynamic conditions in which a metal drop falls through a slag layer, the emulsification plays a major role in enhancing transfer rates by greatly increasing the interfacial area. To the present study the first case may not be applicable, since the possibility that the gas phase will be generated by interfacial reaction is virtually nil. It was observed in the present study that metal droplets with higher sulfur content exhibited lower falling velocity, as seen in Fig. 5. Since sulfur is a surface-active element, and hence reduces surface tension, metal drops with higher sulfur content should be more susceptible to interfacial convection flow,\textsuperscript{10,16-25} which eventually leads to emulsification in the vicinity of the metal surface.\textsuperscript{10,14} Further lowering of interfacial tension may be facilitated by the interfacial reaction of sulfur transfer.\textsuperscript{14} Emulsification will retard droplets falling velocity, as the effective density of the droplet will be lower due to emulsification. This supports the observation that falling velocity was lower for droplets with higher sulfur content.

Some consideration on the effect of slag composition on the rate of desulfurization is in order. As the slag viscosity is the major physical property which affects surface emulsification, the effect of slag viscosity was examined by plotting the dynamic rate coefficient, $k_d$, against the slag viscosity in Fig. 12. It is seen that the dynamic rate coefficient decreases with increasing slag viscosity. This result tends to support the view that emulsification plays a major role for the enhancement of the rate of desulfurization. One might argue that the sulfide capacity of the slag may exert influence on the rate of desulfurization. Figure 13 shows the change of $k_d$ against the CaO/Al$_2$O$_3$ ratio which is considered to represent the sulfide capacity of slag. It is seen that
$k_d$ increases with increasing the CaO/Al$_2$O$_3$ ratio. It appears then that the sulfide capacity of the slag has a strong influence on the rate of desulfurization during dynamic contact. When slag viscosity was contrasted against the CaO/Al$_2$O$_3$ ratio (Fig. 14), however, it is not clear whether the increase of $k_d$ with increasing CaO/Al$_2$O$_3$ ratio is due mainly to the increase in the sulfide capacity of the slag or to the decrease in viscosity which enhances emulsification. Since it is possible for the desulfurization reaction represented by Eq. (3) to be enhanced by increasing the sulfide capacity of slag, the influence of slag composition on the rate of desulfurization may be considered due to the combined effect of physical (viscosity) and chemical (sulfide capacity) properties of the slag. The uncertainty in this area warrants further study.

As slag is an ionic solution, while metal is non-polar, the desulfurization reaction at the metal/slag interface may have to be interpreted in terms of electrochemical nature. In this regard, the cathodic reaction of Eq. (3) must be countered by an anodic reaction to satisfy electroneutrality. Considering the chemical compositions of the metal and slag, the most likely anodic reaction is the oxygen transfer from the slag to the metal:

$$\text{O}_2 + 2e^- \rightarrow \text{O}^{2-} \quad \text{(9)}$$

If this is the case, one mole of sulfur transfer from the metal to the slag should warrant transfer of the same number of moles of oxygen from the slag to the metal. Figure 15 shows the observed oxygen pickup versus those estimated from the sulfur transfer. Although there is some disagreement, particularly in the case of high sulfur transfer, oxygen transfer indeed occurred during the sulfur transfer. It is not clear whether other kinds of anodic reactions, for
instance, $(\text{O}_2^-) = 1/2 \text{O}_2(g) + 2e^-$, also occur.

4. Conclusions

The rate of desulfurization was investigated by dropping liquid iron droplets through the CaO–Al$_2$O$_3$–MgO slag layer at 1 600°C. The following results were obtained:

(1) Droplet falling velocity is lower with higher sulfur content in the metal.

(2) Sulfur transfer follows a first order reaction rate with respect to sulfur concentration of the metal.

(3) The rate of desulfurization during dynamic contact while falling through the slag layer is about two orders of magnitude larger than that of the static contact between the metal and slag.

(4) The enhanced rate of desulfurization during dynamic contact is attributed to the contact of fresh slag while falling, enhanced internal circulation in the metal phase, and most importantly emulsification of the metal/slag interface which greatly increases reaction sites.

(5) The rate of desulfurization is affected to a large extent by slag composition. It is tentatively assumed that slag composition influences the rate of desulfurization by affecting both emulsification of the metal/slag interface and the interfacial reaction of sulfur transfer.

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