

Slag Engineering Methodology for Enhanced De-Sulphurisation Capability in Si Deoxidised Steels

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Abstract— The quality requirement of customers is becoming more stringent w.r.t low level of sulphur in final product for a better mechanical property of steel. High sulphur in steel leads to poor internal quality in the form of cracks and sometimes causes breakout during continuous casting of steel. In past, different works have been conducted by many researchers to investigate desulphurisation process in steelmaking. Very few studies are available on desulphurisation of steels deoxidised with Si-Mn having a lower basicity top slag. High sulphur in steel was one of the bottlenecks in improving the quality of steel as well as a reason for lower throughput of continuous casters at Durgapur Steel Plant (DSP). De-Sulphurisation of silicon killed steel is a difficult task owing to the inherent nature of steel melt as well as ladle top slag. The present work was carried out in improving the desulphurisation level in steels subjected to silicon killing. Slag engineering was done in a novel way to make conditions more conducive for desulphurisation of steels. Deoxidation and flux addition practice was modified in an innovative way to decrease the SiO₂ generation and also to reduce the oxygen potential of slag. Plant scale trials were conducted with modified deoxidation and flux addition practice. 60% De-S was achieved in heats i.e sulphur reduction from 0.039% (S in hot metal) to 0.015% (S in the final product). Process technology was established for the production of low sulphur steels at Durgapur Steel Plant.

Keywords—Steel Desulphurisation, Slag Engineering, Sulphide Capacity, Deoxidation, Inclusions, Clean Steel

I. INTRODUCTION

Requirements of customers are becoming very stringent with respect to low levels of total residuals (P, S, gases, inclusions) in steel. Sulphur in steel is mostly undesirable and is a detrimental impurity that affects the mechanical properties and the quality of the steel in a deleterious manner. Thus, desulfurization of steel i.e removal of sulphur from liquid steel is very much required. The desulphurisation of steel is a key process in ladle metallurgy that is mainly achieved in ladles during secondary steelmaking. A low level of sulphur in the end product is required for enhanced mechanical properties of steel. Sulphur in steel reduces the mechanical properties of steel by increasing brittleness; it also decreases weldability and corrosion resistance. The desulphurization process of steel in a ladle furnace with a suitably engineered refining slag is one of the most important refining operations in the steelmaking process.

Steel Melting Shop (SMS), of DSP basically produces a wide variety of silicon/aluminium killed steel grades through BOF-LF/VAD-CC routes. The average hot metal sulphur is 0.045%. Average final sulphur in Si-killed steels at Durgapur Steel Plant is 0.028%. The desulphurisation rate from BOF turndown to tundish is 17% and from HM to tundish is 37% only. High sulphur in steel is one of the

bottlenecks in improving the quality of steel as well as is one of the reasons of the low throughput of continuous casters at DSP. There are also some incidences of off heats/diversions due to high sulphur in steel at DSP.

The desulphurisation potential in a ladle refining furnace (LRF) is not only dependent on parameters like the temperature of the bath, the dissolved oxygen level in steel, initial levels of sulphur in the steel, but also largely depends on physicochemical characteristics of ladle top slag [1]. The basic requirements for efficient desulphurization are a minimum amount of easily reducible oxides in the slag, high basicity of slag, intense purging for slag metal reaction etc. Desulphurization in steel is mainly dependent upon the physicochemical properties of the ladle top slag. Properly deoxidized slag with good fluidity plays a vital role in desulphurization [2]. It is very important to limit the amount of carry over slag in the ladle during tapping as they contain easily reducible oxides like FeO and MnO which are detrimental to desulphurization capacity of the slag. Proper deoxidation practice also plays an important role in governing desulphurisation. Fully killed (Al, Al-Si) steel has a good desulphurisation potential. It is necessary to have a low oxygen potential in steel and slag in order to have a good degree of desulphurization.

De-Sulphurisation of silicon killed steel is a difficult task owing to the inherent nature of steel melt as well as because of ladle top slag. In the case of Si killed steel, the ladle top slag which is basically siliceous in nature has a lower sulphide capacity, lower partition ratio, and adverse physio-chemical characteristics (higher melting point & viscosity). Also, the oxygen potential of both the bath as well as slag is higher as compared to normal Al killed steels.

Various earlier work carried out on desulphurisation basically focuses on either desulphurisation of steel using a highly basic slag or in steels deoxidised by aluminium. However, in many steel grades, deoxidation is carried out by Si and Mn. In these Si killed steels the ladle top slag basicity is low ranging from 1.2 to 1.8. The studies on improving desulphurisation of silicon killed steel in slag with lower basicity comprising of CaO–SiO₂–Al₂O₃–MgO system are few. The present paper discusses the various measures taken to improve the desulphurisation potential in silicon killed steels by creating the conditions conducive for desulphurisation. Slag engineering was done in a novel way to make slag physico-chemical characteristics favourable for desulphurisation of steels. Deoxidation and flux addition practice was modified in an innovative way to decrease the SiO₂ generation and also to reduce the oxygen potential of slag. The work carried out has resulted in a higher degree of desulphurisation in steel.

II. RELATED WORK

Sulphur is a strong surface active element. Sulphur in molten iron can exist in two forms i.e either as an interstitial solution or in form of partially substitutional solutions. It has been seen that activity of sulphur rises considerably when silicon and carbon are present in the steel. That is why the hot metal can be desulphurised more easily than steel.

The solubility of sulphur in solidified iron is limited i.e ~ 0.002% (max.) at ambient temperature. Upon cooling when steel solidifies the solubility of sulphur decreases and it is ejected from the solution as iron sulfide (FeS). FeS forms a eutectic with the neighboring iron. This eutectic segregates at the grain boundaries of iron.

The temperature of Fe-FeS eutectic is relatively low ~ 988°C. This low melting eutectic deteriorates the connection between the grains and results in a steep decrease in mechanical properties of the steel (i.e causes brittleness) at the Rolling, Forging temperatures. This brittleness of steel at higher temperature operations is called hot shortness which is basically due to the presence of low-melting iron sulfides which got segregated at grain boundaries. The following deleterious effects of sulphur become more prominent when the oxygen content in steel is low [3]

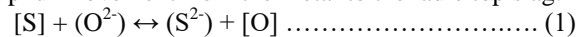
- i. Intergranular weaknesses and cracks in steel during solidification due to the formation of undesirable sulphides.

- ii. Sulphur increases the brittleness of steel and when it exists in the form of sulphide, the sulphide inclusions act as stress raiser points in steel products.

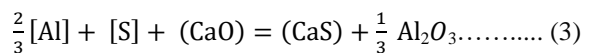
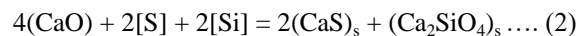
Thermodynamics & Kinetics of Desulphurisation

For desulphurisation reaction between slag and metal, it is evident that only those phases which are the liquid at steelmaking temperature, participates in the desulfurization reaction. Normally slags saturated with CaO give better results w.r.t desulphurisation of steel. The solid phase of CaO in slag is essential to maintain the liquid phases in slag fully saturated with CaO, hence the activity of CaO in the liquid phase is expected to be equal to unity [4].

The following reaction is normally used to describe sulphur movement from the metal to the ladle top slag:



Where [A] indicates component dissolved in the metal and (A) indicates component dissolved in the slag. For silicon and aluminium killed steel, desulfurization reaction takes place as per equations 2 and 3



Many relationships are available for expressing slag desulphurization potential. Most of the correlations are functionally dependent on each other. They are mainly sulphide capacity, sulphur distribution coefficient, desulphurisation potential of slag, optical basicity, levels of FeO & MnO in slag etc.

Sulphide Capacity of Slag

Sulphide capacity of slags is a significant property that plays a fundamental role in the analysis and control of desulphurization reaction. It is the potential capacity of a fully homogeneous molten slag to absorb sulphur during slag metal reaction. Sulphide capacity of slag is dependent on factors like temperature, and other parameters like physio-chemical characteristics of slag. Sulphide capacity is used to estimate the amount of sulphur that a slag will retain under a specified condition [5]. It is also used to establish the sulphur partition ratio between slag and metal at equilibrium conditions.

The sulphide capacity of a slag can be represented as:

$$C_s = \frac{K_1 \cdot a_{O^{2-}}}{f_{S^{2-}}} = (\%S)_{slag} \cdot \sqrt{\frac{P_{O_2}}{P_{S_2}}} \dots\dots\dots (4)$$

Where $a_{O^{2-}}$ is the activity oxygen of in slag is is phase, P_{O_2} and P_{S_2} , partial pressure of O_2 (g) and S_2 (g) and, $f_{S^{2-}}$ is activity coefficient of sulphur present in slag. K_1 is the equilibrium constant for the desulphurisation reaction:

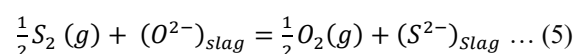


Figure 1 shows the sulphide capacities of the slag system consisting of $\text{CaO-Al}_2\text{O}_3\text{-SiO}_2$ at different slag compositions. For an optimum slag composition to achieve an effective desulphurisation, compositions nearer to the line ab ($-\text{Log } C_s = 1$) should be ensured. Compositions close to the line a-b have CaO activity value close to unity as well as high basicity which are important parameters for desulphurization [6].

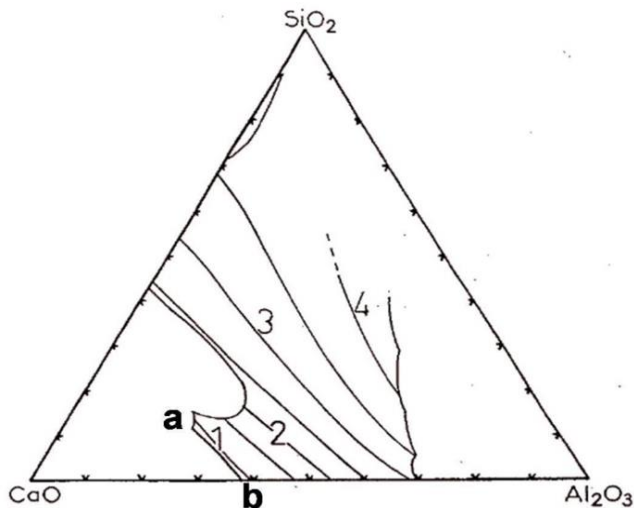


Figure 1. Isothermal section of slag system, $\text{CaO-SiO}_2\text{-Al}_2\text{O}_3$ at 1650°C showing the Log of Sulphide capacity with composition in mass % [6]

It is understood that desulphurization capability is improved with higher slag basicity. Basic slags have a high quantity of basic oxides (CaO mainly) which acts as network breakers and has the ability to liberate its oxygen ion (O^{2-}) in substitute for sulphur dissolved in steel. Many correlations are available between sulphide capacity and basicity. Three different sulphide capacity models are shown in figure 2. The three models in figure 2 show that increased basicity improves sulphide capacity of slag [7].

Viscosity of Ladle Top Slag

Thermo-physical property of slag greatly influences the kinetics of the ladle metallurgical operations. The interaction between slag and metal during the ladle refining is significantly affected by the viscosity of both the steel and slag. At lower viscosity of the slag, the transfer rate of sulphur from liquid steel to ladle top slag is improved because of higher the slag/metal interfacial area [8]. A low melting point, fluid CaO rich slag can be obtained by adding an accurate proportion of Al_2O_3 . In some steel plants, the viscosity is adjusted by the addition of CaF_2 [8]. Viscosity values for steels are well established at steel making conditions but the viscosities of slags are not well established. Slag viscosities are an extrapolation of temperature and composition in a multi-component slag system [9].

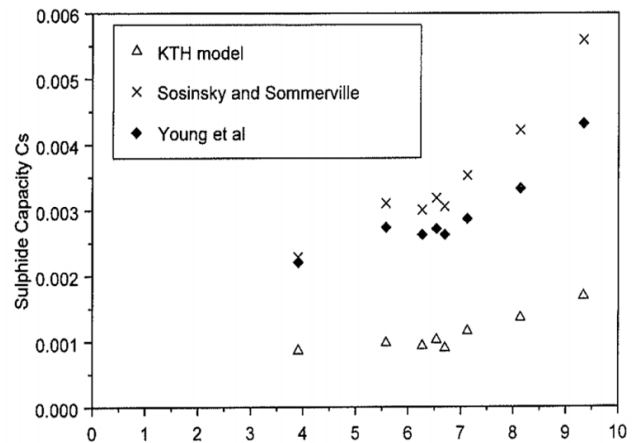


Figure 2. Sulphide Capacity values as functions of basicity [7]

III. METHODOLOGY

Study of Conventional Industrial Practice

Steel Melting Shop of Durgapur Steel Plant (DSP) mainly produces wide variety of silicon killed steel through BOF-LF/VAD-CC/BRC route. The charge mainly consists of 125 tons of hot metal and ~ 10 tons of scrap. The average heat weight is around 118 tons. De-oxidation and alloying are carried out by the addition of coke, silico manganese & ferro silicon, etc. Lime (~ 6-7 kg/ton) is added to the ladle during tapping to achieve the desired top slag basicity for effective desulphurization and slag conditioning. Calcined bauxite (~0.8-1.0 kg/tcs) is also added as a slag modifier to make the slag fluid in nature for inclusion absorption, better slag metal mixing, and low noise level during arcing. Currently, no pet coke is added to the ladle bottom for initial de-oxidation by carbon. The problem faced by DSP is the high and fluctuating sulphur content of hotmetal. The average sulphur level in hotmetal is ~ 0.040%. Sulphur varies from an average level of 0.040% to as high as 0.074%. This high sulphur in steel is difficult to remove and ultimately leads to product diversion/down gradation. Incidences of strand break out are also evident due to the high sulphur content of steel. Only 37% desulphurization is achieved from hotmetal to tundish and from BOF turndown to tundish, % De-S is only 17.5%, which is quite a low figure which can be seen in figure 3.

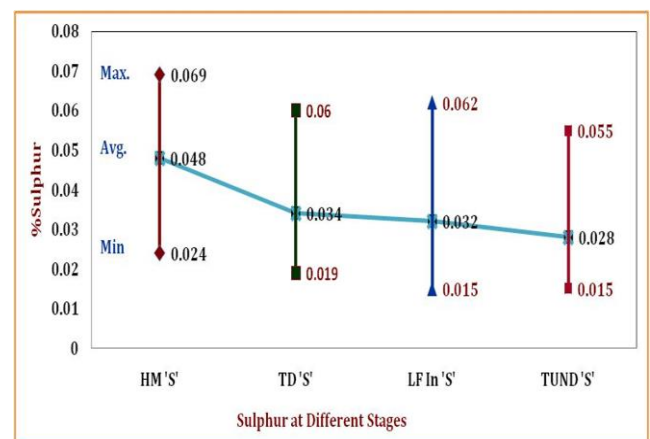


Figure 3. Sulphur level at different stages of steelmaking at SMS, DSP

The following approach was identified to achieve objectives desulphurisation level at ladle furnace at SMS, DSP:

- Identification of critical parameters responsible for lesser desulphurisation under DSP condition.
- Slag engineering to form low melting point slag & lowering the viscosity of the slag.
- Redesigning of deoxidation practice, flux, and refining practices to achieve a low level of dissolved oxygen in the melt as well as a lower level of easily reducible oxides in ladle top slag.

Identification of Critical Factors Affecting De-S

In order to firm up improvement measures, it was necessary to identify the main contributing factors which were affecting the de-sulphurisation of steel. To understand the specific reasons for low desulphurisation, the existing practice of secondary refining was studied in detail. Ladle top slag samples were collected at the LF final stage of refining to measure the slag melting point and viscosity using empirical correlations & FactSage. Analysis of existing practice of steel refining at LF revealed the following probable reasons responsible for lower desulphurisation:

- **Viscous slag during ladle furnace operation:** Physical observation of slag at Ladle Furnace revealed that slag was crusty in nature (figure 4). Ladle furnace slag samples were collected, their melting point and viscosity were calculated, where it was found that the average melting point of the slag was around 1510°C, which was very close to the the liquidus of steels (C: 0.10-0.23%) processed through LF. In order to maintain a fluid slag during refining and casting operation, the difference between melting point of slag and liquidus temperature of steel should be a minimum value of 40-50°C. The calculated viscosity was found at a level of 0.98 poise at 1600°C, which showed that slag, was quite viscous in nature (figure 5). Owing to the poor fluidity of ladle top slag, proper mixing of slag and metal at ladle furnace was not feasible, resulting in poor desulphurization. Optimization of slag composition and adoption of suitable flux addition was necessary for making a fluid slag for better slag metal interaction.



Figure 4. Crusty ladle top slag at Ladle Furnace

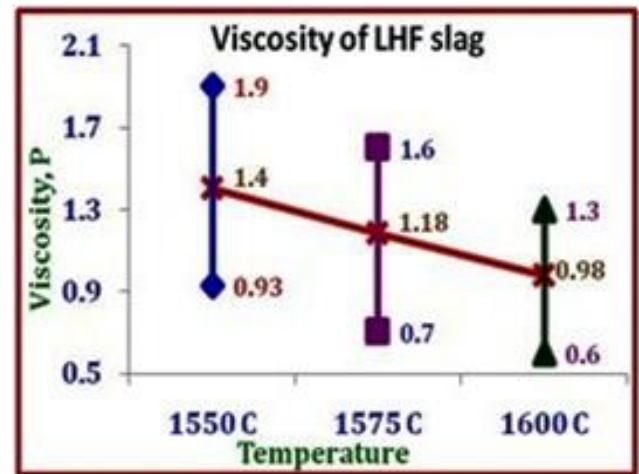


Figure 5. Viscosity of LHF final slag at the end of refining at LF

- **High oxygen potential of metal and slag:** Since the heats made at DSP are of silicon killed grade and deoxidation during tapping was done with SiMn, the level of dissolved oxygen in steel was normally around 30-40 ppm. It is also evident from the slag analysis that FeO + MnO content in the slag is higher, ranging from avg 6.05% (Table-1) to as high as 7.5 %. Sometimes slag is blackish in appearance. This shows that the slag is not properly deoxidized and hence not very conducive for desulphurization.
- **High carryover slag from BOF converter:** Primary steelmaking slag has a high percentage of easily reducible oxides. These easily reducible oxides are very detrimental for desulphurisation point of view. Some amount of this slag comes into the ladle from the BOF converter during tapping because of carryover of slag. The carryover slag from converter results in a high and variable amount of oxides like FeO and MnO to the ladle top slag. At DSP carryover slag is sizeable (~ 6-8 kg/tcs) and also varies considerably from heat to heat.

Table1. Ladle Furnace final slag analysis in conventional practice

CaO	SiO ₂	Al ₂ O ₃	MgO	FeO	MnO	Basicity
47.20	28.44	5.32	11.58	3.16	2.89	1.65

Plant Trials with Modified Practice

For improvement of steel desulphurization, plant trials were conducted separately for heats through bloom caster and vacuum arc degasser (VAD) unit. For bloom caster heats, initial deoxidation was carried out by the addition of ~ 100 kg pet coke in the ladle bottom. As the product of deoxidation by carbon is gaseous, it helped in good mixing of metal and slag and in the initial reduction of dissolved oxygen content. It was also beneficial for the steel cleanliness. Initial deoxidation with pet coke also helped in reducing silica content in ladle top slag which adversely affects the sulphide capacity of slag.

Calcined bauxite was used as slag fluidiser, and was added during the taping of steel. Alumina is considered as the third "best" flux after B₂O₃ and CaF₂ to break Ca₂SiO₄ complex and increase the solubility of CaO in slag. A

sizeable amount of alumina is required to increase the CaO solubility at 1600°C [9].

In plain silicon killed steel, there is remaining dissolved oxygen at the level of 35-50 ppm. In the base heats wherein dissolved oxygen level was measured after treatment finish in ladle furnace, the dissolved oxygen level was found in between 35-40 ppm. In order to minimize the dissolved oxygen level in steel melt, Al-Si deoxidation was introduced instead of plain Si deoxidation. For this, ~ 80 kg of Al was added in ladle bottom along with petcoke before the start of tapping. In order to make the slag fluid in nature for better slag metal mixing and inclusion absorption, around 200 kgs of calcined bauxite was added to the ladle during tapping from BOF.

Presence of FeO, MnO in ladle top slag greatly reduces the desulphurisation capability of slag. In order to reduce the levels of these oxides, the slag deoxidation technique was tried out. After completion of tapping, a 50-50-% mixture of FeSi fines & Coke fines (~ 60 kg) were added in the ladle top slag for reduction of FeO+MnO.

To assess the effectiveness of modified flux, de-oxidation and refining practices, data was collected for sulphur level in liquid steel for evaluation of product quality. The LF final slag was also collected for determining the viscosity and melting point of the modified slag. For VAD heats the lime addition was reduced from 1000-1200 kg to 850-900 kg. Slag deoxidation method was also adopted for VAD heats.

Further addition of flux (as required) and trimming addition of ferro alloys were carried in ladle furnace. Final LF slag samples were collected and analysed for comparison.

IV. RESULTS AND DISCUSSION

De-Sulphurisation of silicon killed steel is a difficult task owing to the inherent nature of steel melt as well as because of ladle top slag. In the case of Si killed steel, the ladle top slag which is basically siliceous in nature has a lower sulphide capacity, lower partition ratio, and adverse physio-chemical characteristics (higher melting point & viscosity). Also, the oxygen potential of both the bath as well as slag is higher as compared to normal Al killed steels.

Trials for desulphurization were carried out for bloom caster heats. During the trial period, heats were treated with suggested flux addition. The quality of slag was monitored at LF. The refining slag was found to be more fluid with the modified flux and deoxidation practice for bloom caster heats, as compared to normal practice. The analysis of slag samples of Si-Al killed bloom caster heats revealed a reduction in melting point and viscosity of LF slag which was achieved by incorporating initial de-oxidation by carbon and further killing by Al in combination with normal de-oxidation practice. Slag

viscosity reduced from 0.98 to 0.75 poise at 1600°C (figure 6) and slag melting point reduced from 1510°C to 1445°C (figure 7)

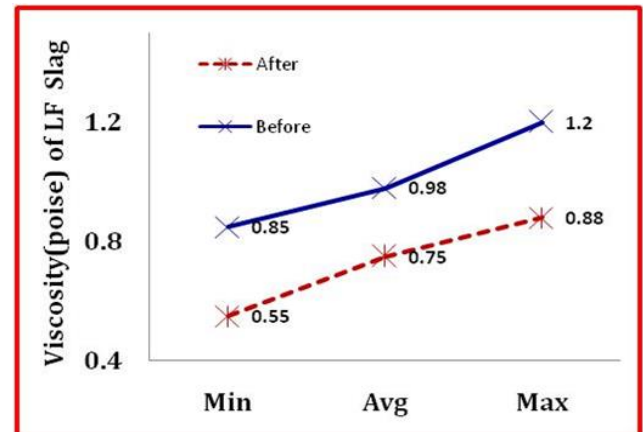


Figure 6. Viscosity of LF Slag at 1600 °C in conventional & modified practice

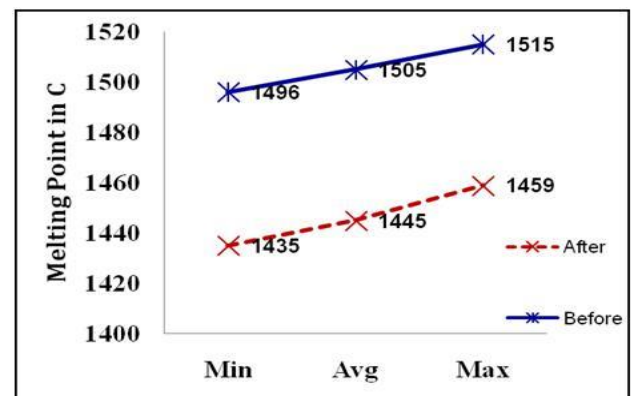


Figure 7. Melting point in conventional & modified practice

Due to the inherent characteristics of Si killed steels the De-S capability of slag is generally low (low sulphide capacity/ low sulphur partitioning ability of slag) as can be seen from figure 8. Figure 9 shows that the present slag system was falling into a region of low sulphur partition and sticky slag zone. Slag melting characteristics was worked out for the modified slag system which can be seen from figure 10.

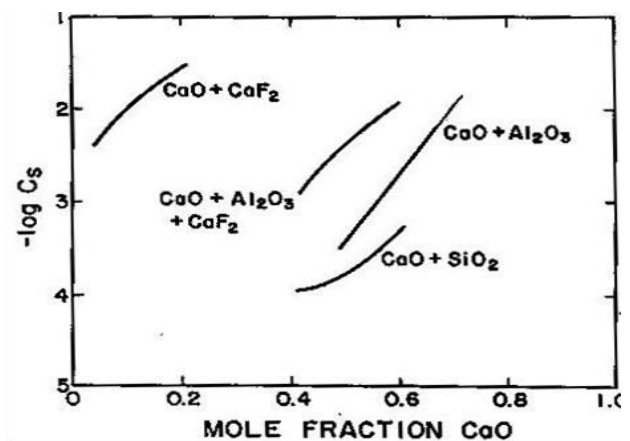


Figure 8. Sulphide capacities of different slag compositions

To make conditions more conducive for desulphurisation, changes in ladle top slag chemistry was achieved by incorporating Al-Si deoxidation and slag deoxidation method. The targeted ladle top slag chemistry is shown in table 2:

Table 2. The targeted ladle top slag chemistry

CaO	SiO ₂	Al ₂ O ₃	MgO	FeO+ MnO	Basicity
47-50	20-25	10-12	6-8	< 2	1.8-2.2

The modified practice helped in improving the desulphurisation of heats through bloom caster. Analysis of trial results showed an average tundish sulphur level of 0.015% as compared to 0.028% for earlier heats through bloom caster (Table 3). Around 62% De-S from HM to tundish was achieved in trial heats in which modified practice was followed. The modified practice helped to achieve a low dissolved oxygen level of 7-10 ppm as compared to 35-40 ppm and a low (FeO+MnO) level of < 2.5 % as against ~5% in normal practice. Changing the deoxidation practice from Si killed to Si- Al killed helped to reduce SiO₂ generation thereby increasing the average slag basicity from 1.7 to 2.04 which facilitated desulphurization. The Alumina level in the slag increased from 4-5% to ~9-10% in ladle top slag thereby improving the sulphide capacity of slag.

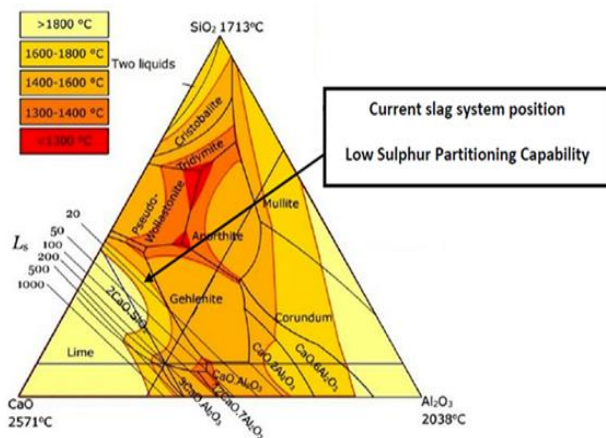


Figure 9. Position of current slag in low sulphur partition region

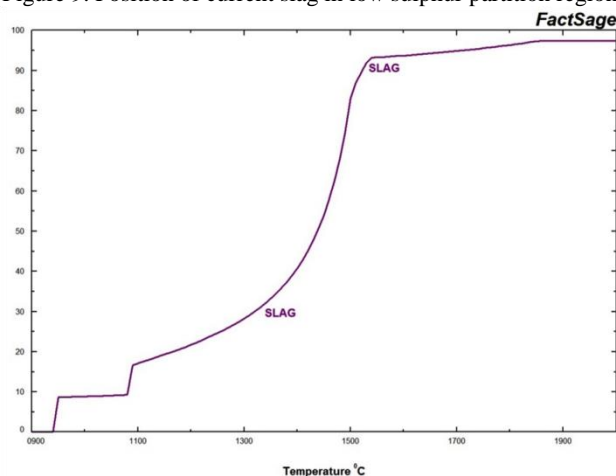


Figure 10. Slag melting behaviour showing around 90% slag liquid at 1600°C

In some trial heats required De-S was not achieved. During the analysis of the trial results it was found that, the rate of carryover slag was substantial in those heats. One of the preconditions for De-S is that the carry over slag from BOF to ladle should be as low as possible. The presence of easily reducible oxides in carry over slag makes the conditions for De-S unfavourable & since there is a limited treatment time available at the LFs, the extent of De-S achievable is less. We can see in figure 11, that in the cases when FeO+MnO level in slag is more, the appearance of ladle top slag is blackish (it is the case when carryover slag is higher), whereas in case of fully killed, lime saturated slag (which is beneficial for De-S) the slag appearance is white. The slag deoxidation technique was found to be very helpful in reducing the ladle top slag oxygen potential. A significant decrease in FeO, MnO levels was observed in heats through VAD in which slag deoxidisers were added. This in combination with controlling lime addition between 850-950 kg also helped in improving desulphurisation level in heats through VAD (Table.4).

In all the trials heats through bloom caster in which Al-Si deoxidation were practiced, no stopper rod fluctuations were observed. A very smooth casting was observed in heats in which aluminium was added. This is a good indication that no clogging tendency was found even with the addition of Al in the ladle during tapping. It is also very significant that no calcium treatment was carried out in the trials heats with Al addition. Apart from Al & coke addition in ladle bottom, all the other processing parameters were similar as compared to normal heat making at DSP for bloom heats.



Fig. 11 (a). LF Slag black in appearance (Higher Oxy Potential)



Fig. 11 (b). Completely deoxidised LF slag white in appearance

V. CONCLUSION AND FUTURE SCOPE

The Critical factors responsible for poor desulphurisation were identified. It was found that high FeO+ MnO in slag due to high slag carry over, high dissolved oxygen, and low basicity coupled with low fluidity of slag were the main reasons for poor desulphurisation at DSP.

The process of deoxidation and flux addition was modified. Initial deoxidation with carbon and further killing of the bath by Al in combination with the normal de-oxidation practice for bloom caster heats was established. Innovative slag deoxidation practice using coke+FeSi fines was found to be very beneficial for reducing ladle top slag.

These modifications helped in achieving average sulphur levels of 0.015% (as compared to 0.035% in base heats) in trials heats through bloom casters (~60% de-S from HM to tundish as compared to 37% earlier). In VAD heats where the slag deoxidation method was adopted, coupled with reduced lime addition (~850-950 kg), ~ 60% de-S (from 0.035% to 0.013% S) was achieved from HM to VAD finish.

In all the trial heats through bloom casters, no stopper rod fluctuations were observed. This is a good indication that in

the case of higher HM S, the suggested practice can be adopted for desulphurising the steel without having any apprehension of nozzle clogging. No calcium treatment practice was followed in trial heats. But any delayed addition of Al in the ladle furnace may result in a tendency of nozzle clogging.

This novel slag engineering method using calcined bauxite as slag modifier helped in increasing the solubility of CaO in slag resulting in lowering down of melting point of the slag. This method can be utilized for improving desulphurisation of steel whenever the hot metal sulphur is high.

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Table 3. Trial data of heats through bloom caster

Heat Id	HM 'S'	Ladle Additions							Tundish	% De-S
		Lime	Cal. Baux	SiMn	Al	FeSi	Pet Coke	Coke + FeSi	S	HM to Tundish
1	0.046	867	196	1615	80	154	209	-	0.017	63.04
2	0.045	861	214	1397	80	140	157	-	0.016	64.44
3	0.037	822	193	2016	80	99	74	-	0.015	59.46
4	0.038	811	195	1991	80	212	80	-	0.014	63.16
5	0.037	594	168	1579	-	215	215	60	0.013	64.86
6	0.037	812	198	1044	-	246	130	60	0.013	64.86
7	0.038	794	193	1902	-	193	90	60	0.017	55.26

Table. 4: Details of trials heats through VAD in which Slag Deoxidation were carried out

Heat id.	Ladle Analysis, %							Teeming Analysis, %						% De-S
	HM S	C	Mn	S	P	Si	Al	C	Mn	S	P	Si	Al	HM to Teem
1	0.034	0.43	0.58	0.033	0.019	0.2	0.002	0.62	0.72	0.009	0.027	0.22	0.005	73.53
2	0.038	0.505	0.56	0.043	0.015	0.2	0.002	0.625	0.76	0.017	0.016	0.25	0.003	55.26
3	0.039	0.38	0.54	0.03	0.018	0.2	0.001	0.64	0.73	0.014	0.02	0.23	0.004	64.10
4	0.037	0.31	0.5	0.04	0.018	0.2	0.002	0.45	0.78	0.016	0.024	0.27	0.013	56.76
5	0.034	0.43	0.58	0.033	0.019	0.2	0.002	0.62	0.72	0.009	0.027	0.22	0.005	73.53
6	0.035	0.46	0.58	0.03	0.013	0.22	0.002	0.615	0.73	0.012	0.024	0.23	0.005	65.71
7	0.037	0.315	0.5	0.032	0.018	0.11	0.001	0.45	0.76	0.013	0.022	0.26	0.005	64.86
8	0.05	0.35	0.65	0.04	0.018	0.2	0.002	0.61	0.74	0.014	0.021	0.2	0.006	72.00
9	0.048	0.39	0.57	0.05	0.022	0.21	0.002	0.63	0.81	0.02	0.028	0.2	0.007	58.33
10	0.047	0.4	0.57	0.035	0.017	0.2	0.002	0.63	0.77	0.017	0.026	0.23	0.005	63.83

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