EFFECT OF PHYSICO-CHEMICAL PROPERTIES OF LADLE FURNACE SLAG ON SULPHIDE CAPACITY AND SLAG VALORISATION OPTIONS

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Introduction

In the present work, physico-chemical properties of ladle furnace (LF) slags were studied on industrial context to assess its use as ladle flux at RINL-Visakhapatnam Steel Plant (VSP). The sulphide capacity (C_S) of slags was calculated using various models to evaluate their applicability on industrial scale. The effect of various physico-chemical properties of LF slag on sulphide capacity is investigated using plant data. Characterisation studies on Si/Mn and Si/Mn/Al killed ladle furnace slags were done and 5 trials were done by replacing CaO-Al_2O_3 based synthetic slag with Si/Mn/Al killed LF slag for treating Si/Mn killed heats.

Materials and Methods

For the present work, steel and slag sampling was done when the ladle arrives at LF and after LF treatment for around 25 heats. For slag characterisation and subsequent recycling, LF slag was collected from 3 Si/Mn/Al killed heats. The sulphide capacity of the slags was calculated using KTH[1], Taniguchi *et al.*[2], Young's[3] and S-S[4] models. The viscosity of the slag was calculated using modified Urbain model developed by Kondratiev *et al.*[5]

Results and discussions

Applicability of sulphide capacity models

The sulphide capacity of slags gives a good idea on desulphurisation kinetics. The equilibrium sulphur partition (L_{Se}) ratio was calculated[6] from Equation (1) where f_s is the activity coefficient of sulphur in the steel and a_o is the activity of oxygen in the steel. Comparison of R^2 was done for the measured (L_S) and equilibrium values of the sulphur partition ratios. It was found out that the KTH model agreed well with the

equilibrium values as shown in Table 1 and hence it is considered for calculating the sulphide capacity in the present work.

$$logL_{Se} = \frac{-935}{T} + 1.375 + logC_S + logf_S - loga_O \ldots (1) \quad (1)$$

Table 1: Comparison of the measured (L_S) and equilibrium sulphur partition ratio (L_{Se}) in log scale after desulphurisation for the different calculated values of log *C*s

Model for log Cs	Taniguchi *et al.*	KTH	S-S	Young *et al.*
R^2 for Log L_S *vs.* Log L_{Se}	0.897	0.917	0.882	0.872

*R^2 is a statistical measure of how close the data are to the fitted regression line

Characterisation of Ladle Furnace slag

The chemical composition of the slags was determined using a PANalytical axios XRF with WDXRF. To identify the slag mineralogy, XRD analysis was done and comparison of XRD peaks for different slags is shown in Figure 1a in which Dump Slag 1 and 2 are Si/Mn/Al killed slags collected from two different heats after finish of casting. The mineralogical phases present in the different slags and the physico-chemical properties are listed in Table 2 and the chemical composition in Figure 1b.

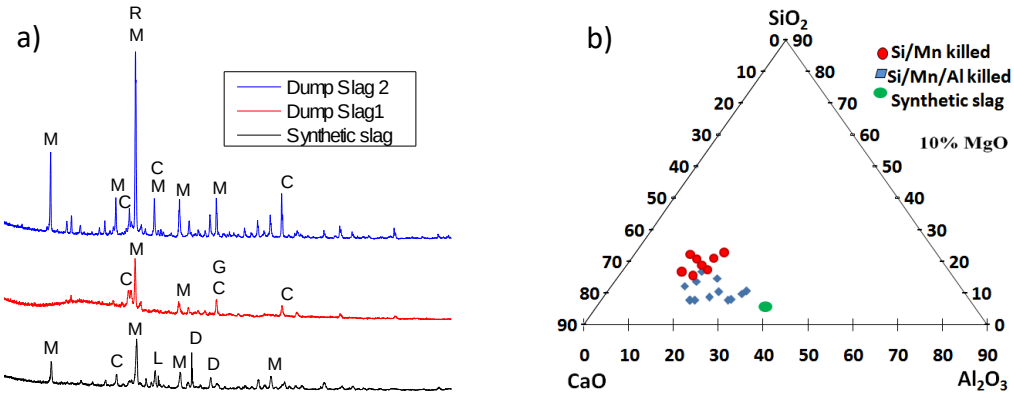

Figure 1: a) Comparison of XRD peaks (M-Mayenite, R-Merwenite, C-Di-calcium silicate, G-Gehlenite, D-Calcium di-aluminate, L-Larnite) b) chemical composition of the slags

Table 2: Properties of different slags of RINL-VSP at 1600°C

Type of LF slag	Λ	C_Sx10^3 (KTH)	μ (Pa.S)	A/C
Si/Mn killed	0.74	3.02	0.23	0.18
Si/Mn/Al killed	0.77	4.01	0.09	0.41
synthetic slag	0.72	0.81	0.13	1.15

* Λ is optical basicity, C_S is sulphide capacity of slag, μ is viscosity of slag, A/C is Al_2O_3/CaO

Effect of slag properties on sulphide capacity

The effect of the optical basicity, A/C ratio, basicity (CaO/SiO_2 or C/S) and mole fraction of CaO on the sulphide capacity was studied as shown in Figure 2a and b. The

sulphide capacity was more when the A/C ratio is in the range of 0.2-0.3 and it decreased when the A/C ratio is beyond 0.3 which may be due to the decreased activity of CaO. The sulphide capacity of the slags increased with increase of basicity (C/S), optical basicity (Λ) and mole fraction of CaO (XCaO). The desulphurisation efficiency increased with sulphide capacity of the slags and decreased with the viscosity and wt% (FeO+MnO) of the slag.

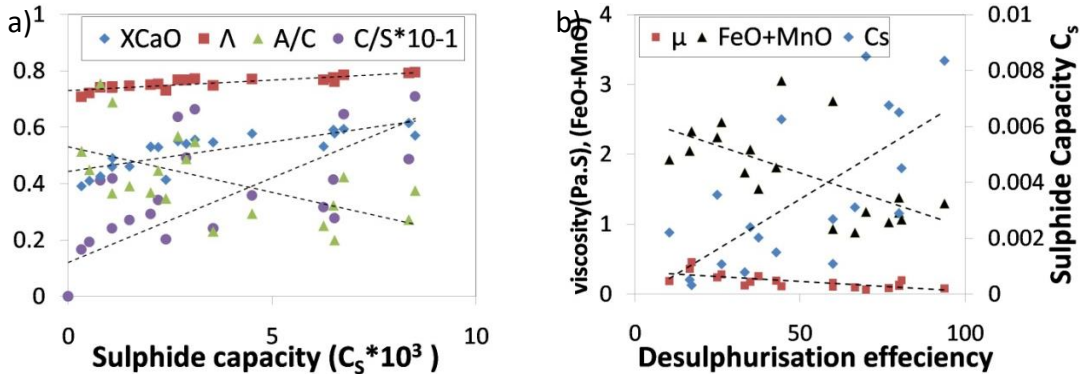

Figure 2: a) Sulphide capacity of slags as a function of various parameters b) Desulphurisation efficiency as a function of Cs, μ and (FeO+MnO)

Use of Si/Mn/Al killed LF slag as a flux for treating Si/Mn killed heats

Synthetic slag of around 1-1.3 tons/heat (155 tons) along with some lime is added at RINL-VSP for treating Si/Mn killed high carbon (0.65-0.80 wt% C) heats. As slag from Si/Mn/Al killed steel has considerable amount of CaO and Al_2O_3, trials were done by replacing synthetic slag with Si/Mn/Al killed slag. Addition of recycled LF slag was done in 3 heats with 60, 75 and 85% replacement and in 2 heats with recycled LF slag along with calcined bauxite (300 kg) and lime (300 kg) during tapping. Various parameters considered for comparing results of trial and regular heats are given in Table 3 and Figure 3b.

Table 3: Comparison of parameters after LF treatment for regular and trial heats

% replacement	Λ	C_Sx10³	μ (Pa.S)	L_S	ERO	A/C	η	LF Out Temperature °C
60	0.72	1.39	0.37	15	1.62	0.19	36	1541
75	0.73	1.75	0.39	12	1.89	0.21	23	1545
85	0.73	1.96	0.40	16	2.0	0.25	21	1521
50*	0.73	0.80	0.33	25	2.34	0.49	31	1539
50*	0.73	0.97	0.34	14	2.52	0.38	19	1540
Regular heats	0.72-0.75	0.6-3.3	0.26-0.46	8-35	1.5-2.0	0.36-0.51	17-38	1530-1550

*denotes heats treated with bauxite, ERO is (FeO+MnO), η is % desulphurisation, Ls is sulphur partition ratio

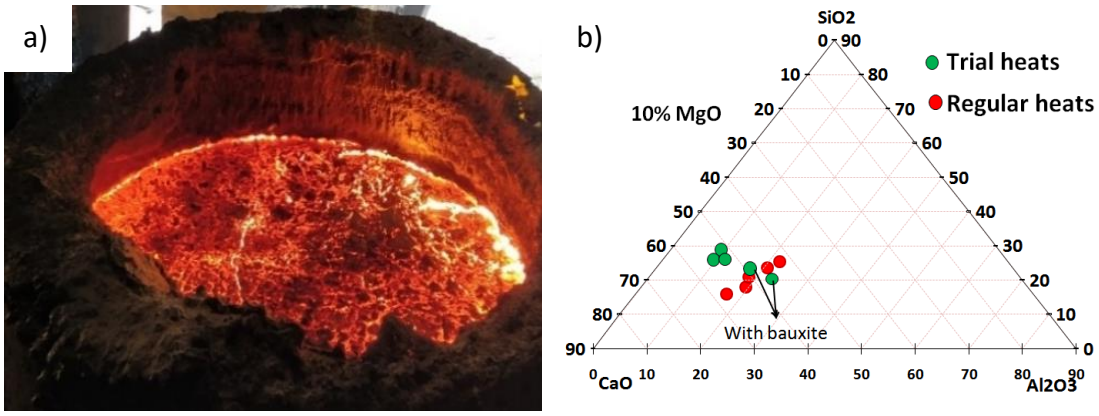

Figure 3: a) Appearance of top slag after addition of recycled LF slag during tapping
b) Comparison of "LF out" slag composition for regular and trial heats of High carbon grade

Conclusions

The slag basicity, temperature and Al_2O_3/CaO ratio have a considerable effect on the sulphide capacity of slags. Trials were successful with recycled LF slag and all the operating parameters were comparable for regular and trial heats. As LF slag obtained from Si/Mn/Al killed heats has considerable amount of CaO (45-55%) and Al_2O_3 (18-22%), it can be used as a replacement to synthetic slags and LF slags from Si/Mn killed heats as partial replacement to lime. Furthermore Si/Mn/Al killed slag mineralogy is comparable with CaO-Al_2O_3 based synthetic slags. Further study on slag designing for optimum desulphurisation and slag fluidity helps in effective valorisation of LF slags.

Acknowledgements

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References

1. M. Nzotta. D. Sichen, S. Seetharaman, "Sulphide Capacities in Some Multi Component slag Systems", *ISIJ Int*, **38** (11) 1170-79 (1998).
2. Y. Taniguchi, N. Sano, S. Seetharaman, "Sulphide Capacities of Cao-Al_2O_3-SiO_2-MgO-MnO Slags in the temperature Range 1 673-1 773 K", *ISIJ Int*, **49** (2) 156-163 (2009).
3. R.W. Young, J.A. Duffy, G.J. Hassall, Z. Xu, "Use of the optical basicity concept for determining phosphorus and sulphur slag/metal partitions", *Ironmak Steelmak*, **19** (3) 201-19 (1992).
4. J. Sosinsky, I.D. Sommerville, "The Sulfide Capacity of Metallurgical Slags", *Metall Trans B*, **17** (B) 331-37 (1986).
5. A. Kondratiev, E. Jak, "Review of Experimental Data and Modeling of the Viscosities of Fully Liquid Slags in the Al_2O_3-CaO-'FeO'-SiO_2 System", *Metall Mater Trans B*, **32** (B) 1015-25 (2001).
6. M. A. T. Andersson, P. G. Jonsson, M. Hallberg, "Optimisation of ladle slag composition by application of sulphide capacity model", *Ironmak Steelmak*, **27** (4) 286-93 (2000).