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Optimization Studies of Hot Metal Desulphurized and Basic Oxygen Furnace Slags in Sinter Making at JSW Steel Limited

Sharanappa Kalshetty
Assistant General Manager
JSW Steel Limited,
Toranagallu, Karnataka

Rudramuniappa MV
Professor
VSKUB University,
PG Centre, Nandihalli, Sandur

VR Sekhar
Vice President Agglomeration
JSW Steel Limited,
Toranagallu, Karnataka

Ratnakar Bonda
Junior Manager
JSW Steel Limited,
Toranagllu, Karnataka

***Abstract* - A large amount of various slags are being generated from steel melting process in integrated steel plants. Disposal of large quantities of slag becomes a big environmental concern. Slags generation from Steel Melting shop such as LD and HMDS Slag these slag has free CaO, which can replace some amount of flux in Iron Making burden. But due to high Phosphorous content in LD slag and high Sulphur in HMDS, these slags are not directly used in sinter making. In agglomeration these slags usage could be the ideal approach to maximize its use in sinter feed and thereby increase in the productivity and quality of the sinter plant which will reduce the cost of production due to available free Cao and Fe %. The process of micro-pelletisation followed by sintering may be considered for their utilization in the steel plants. In this paper an attempt has been made to compare the HMDS and LD Slag in sinter making through micro pelletisation route. It is shown encouraging results w.r.t to physical and chemical properties of sinter as desired by customer i.e. Blast furnace. Hence its is desired to use HMDS slag as substituent to LD Slag in iron ore sinter making .Thus, recycling of HMDS slag through the sintering process recovers lime, iron and magnesia and thereby saving of flux material and iron ore in future. Detailed Investigation was carried out through lab scale studies for estimating the maximum permissible limits of usage of LD Slag and HMDS slag in sinter making and to know the influence of addition on Tumbler Index and Phosphorous and Sulphur properties from low level 0 kg/Ton to High level 60 kg/t of sinter. From the test results it was found that 35kg/Ton - 40 kg/Ton will be the optimum level for usage in sintering with HMDS to get desired properties of the sinter as per the customer requirement which in turn helps in reduction of production cost the results are validated through Hypothesis testing two sample T Test.**

Keywords— HMDS, Optimization, HMDS-hot metal desulphurization station, BOF-Basic Oxygen Furnace, LD –Linz and Bonavitz, Hypothesis Testing

1. INTRODUCTION

Slags generated at iron making and steel making units are the largest quantities among all the solid/liquid wastes. Over the past decades, the steel production has increased and, consequently, the higher volumes of by-products and residues generated have driven to the reuse of these materials in an increasingly efficient way. In recent years new technologies have been expanded, and some of them are still under developing, in order to improve the recovery rates of slags. At the same time, the re-use of iron and steelmaking slags has also been expanded, and has led to a significant reduction in the environmental impact of these by products [6-10]. However slag generation remains an unavoidable step and focus on its re-cycling remains the greatest concern. Steel plant slags mainly include, blast furnace slag and steel melting slag (LD process slag). HMDS Slag is a by product of steel industry, which is generated during pre-treatment of Hot Metal before it is charged into LD converters for Steel Making. The by-products usually contain considerable quantities of Oxides of other elements like Fe, Si, and Mn & Ca. Most of the materials of

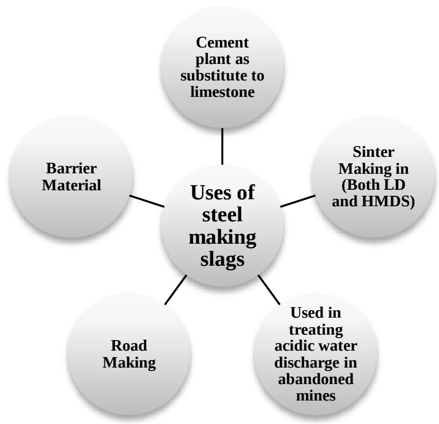

Figure 1 Applications of Slags

Steel plant wastes are recycled through sinter making in most of the countries. Because of its physical, chemical and mineralogical properties, it can be used as raw material in process like sintering. Recycling of LD Slag & HMDS Slag has the highest cost implication on sintering process. LD Slag & HMDS Slag contains high amount of CaO, iron, and MgO, thus recycling it through sintering process helps in the saving of flux and iron ore. The recycled wastes have some effect on sinter quality, strength and productivity. JSW Steel Limited is

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a 12.0 Mtpa integrated steel plant and produces 1400 to 1500 tons of LD Slag & HMDS Slag per day. Laboratory pot grate sintering experimentation has been carried out to study the effect of LD & HMDS Slag addition on sinter productivity, and physical and metallurgical properties. The LD Slag & HMDS Slag in the sinter mix was varied from low level 0 Kg/Ton to High 60 kg/t of sinter. HMDS Slag found better than LD Slag due to its High Cao and TI %.

2. HMDS SLAG GENERATION AT JSW STEEL

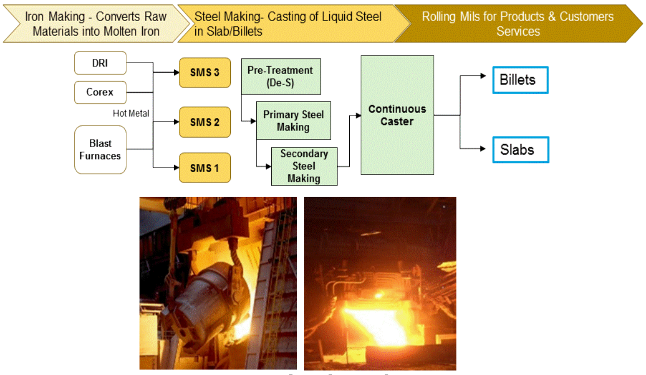

Figure 2 Steel Melting Shop overview

LD and HMDS Slag is a waste material (by product) generated in process of steel making.

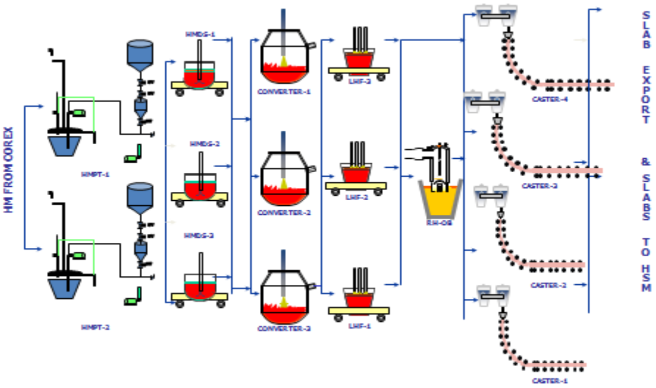

Figure 3 Steel making Shop-1 process and HMDS Slag generation

Figure 3 shows the Steel making process and LD and HMDS Slag generation at JSW Steel limited. JSW Steel Limited is a 12 Mtpa integrated steel plant and produces 3200 tons of steel making slag per day and in that HMDS Slag is 1400 to 1500 t/day. This LD & HMDS Slag consists of 45.75% CaO, 22.0 % Fe and 8.22% MgO. Thus, recycling of LD & HMDS Slag through the sintering process recovers lime, iron and magnesia and thereby saving of flux material and iron ore. Due to high content of CaO one can replace HMDS Slag by limestone in sintering process. At present most of the steel plants in the world are reusing HMDS Slag as a flux instead of limestone in sinter making. At JSW Steel Limited steel making slag is completely dumped or used for ground filling after crushing. Based on the earlier trials at JSW steel making slag is being used up to 40 kg/t in COREX and 50 kg/t in blast furnace. However with the increasing capacities, amount of disposal of huge amount of steel slag is a real challenge. To utilize HMDS Slag in sinter making basic studies are required to know the influence of HMDS Slag addition on sinter chemistry, productivity and sinter properties. The higher phosphorus content in the HMDS Slag is the main restricting factor for utilizing in the sinter making. To optimize the HMDS Slag in sinter making trials have been planned in lab scale and varied the HMDS Slag in the sinter mix from 0 to 60kg/t of sinter.

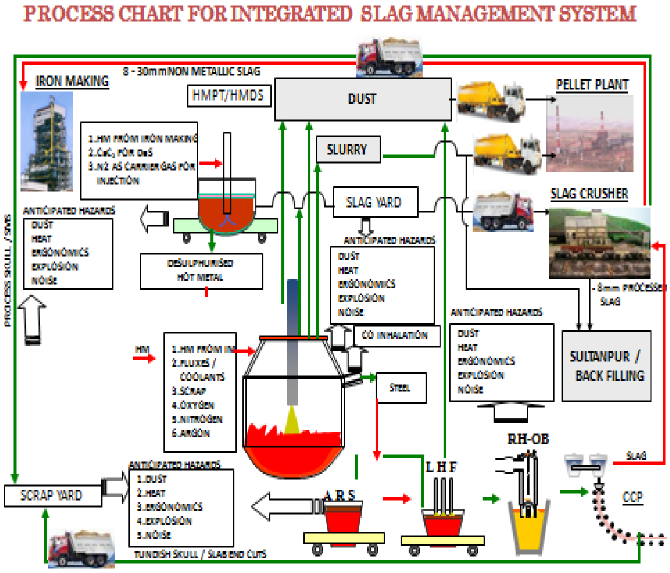

Figure 4 Process Chart for Integrated Slag Management System

Pot grate sintering experiments were carried out in laboratory by using the same raw materials which are used in the sinter plant. The crushed LD & HMDS Slag of -6 mm size was collected from the slag yard of steel making shop. The coke breeze which is a byproduct of coke oven plant is used as fuel. In total 7 experiments were carried out by varying the LD & HMDS Slag addition from 0 to 60kg/t in sinter base mix. The basicity and MgO was kept constant for all experiments. Small piles were prepared by layering the iron ore fines, coke breeze, limestone, dolomite, burnt lime and return fines and HMDS Slag on weight basis.

Figure 5 Disposed LD & HMDS slag at slag yard

All these constituents were thoroughly mixed. After ensuring proper mixing of these raw materials, the base was transferred to the granulation drum. Granules were prepared in the granulation drum by maintaining a granulation time of 7 minutes. The time required for different actions in the granulation cycle is as follows: Dry mixing – 2 min; water addition: 2 min; granulation – 3 min. The raw mixture having a weight of 70 kg was granulated with 8% moisture. After granulation, the material from the granulation drum was

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transferred to the sinter pot having an inner diameter of 300mm and a height of 600mm and subsequently sintered in the pot under a suction of 1300mm of WG. The sintering conditions were kept constant for all the experiments. The pot grate test conditions are given in **Table 2** and the experimental setup is shown in **Figure 3**. Chemical analyses of the raw material as well as sinter products were carried out by using XRF.

TABLE 1 RAW MATERIAL MIX PROPORTION

	%	IRON ORE	LIME STONE	DOLOMITE	CALCINED LIME	COKE BREEZE	HMDS SLAG
HMDS Slag	0	50.32	8.39	7.12	0.90	5.27	0.00
	10	50.09	8.07	6.87	0.90	5.30	0.77
	20	49.87	7.79	6.57	0.90	5.31	1.56
	30	49.55	7.59	6.29	0.90	5.34	2.33
	40	49.32	7.33	5.97	0.90	5.35	3.15
	50	49.12	7.06	5.68	0.90	5.36	3.88
	60	48.84	6.81	5.34	0.90	5.38	4.73
LD Slag	%	IRON ORE	LIME STONE	DOLOMITE	CALCINED LIME	COKE BREEZE	LD SLAG
	0	55.91	9.31	7.91	1.00	5.86	0.00
	10	55.65	8.97	7.63	1.00	5.89	0.86
	20	55.41	8.66	7.30	1.00	5.90	1.73
	30	55.05	8.43	7.00	1.00	5.93	2.59
	40	54.80	8.14	6.63	1.00	5.94	3.50
	50	54.58	7.84	6.31	1.00	5.96	4.31
	60	54.27	7.57	5.93	1.00	5.97	5.26

Table 2 Pot Grate Sinter Test Conditions

Parameter	Magnitude
Bed height, mm	600
Hearth layer, mm	50
Suction, mm of WC	1300
Ignition Temperature, ºC	1150
Ignition time, sec	120 sec
Moisture content, %	8

Figure 6 Pilot Scale Pot grate sintering machine

3. RESULTS AND DISCUSSIONS

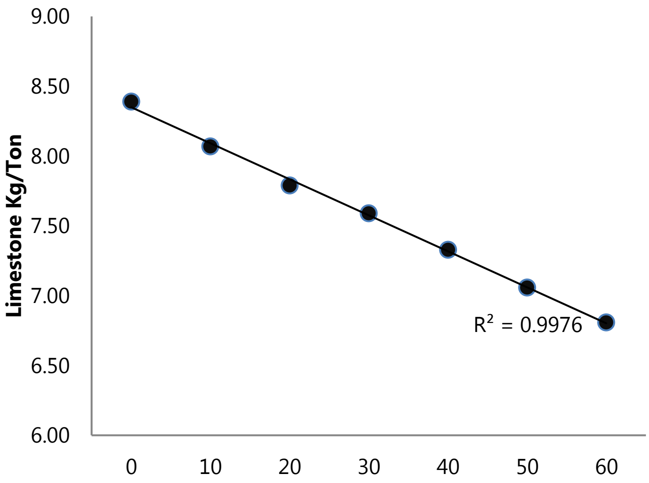

Figure 7 Influence of HMDS addition on limestone addition

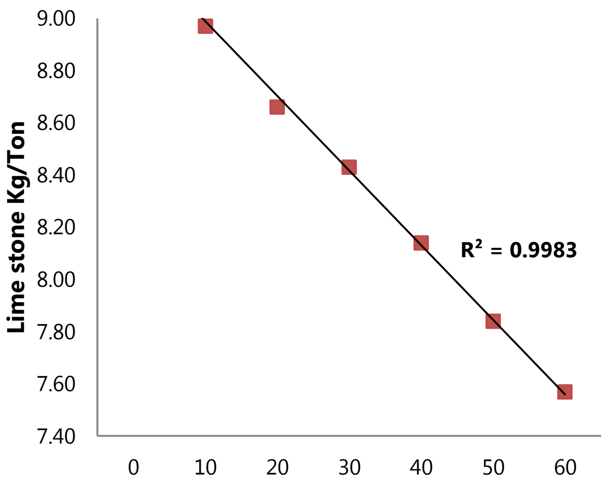

Figure 8 Influence of LD Slag addition on limestone addition

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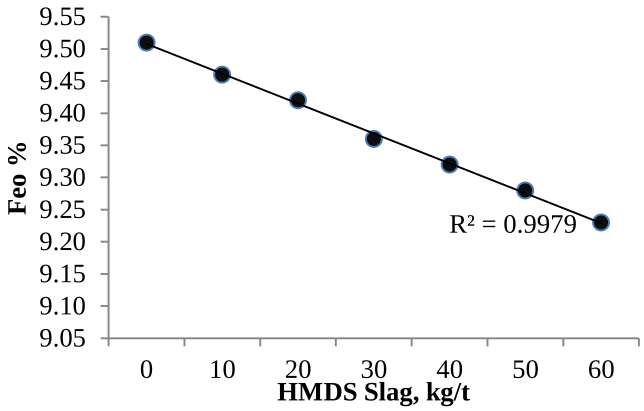

Figure 9 Influence of HMDS Slag addition on FeO

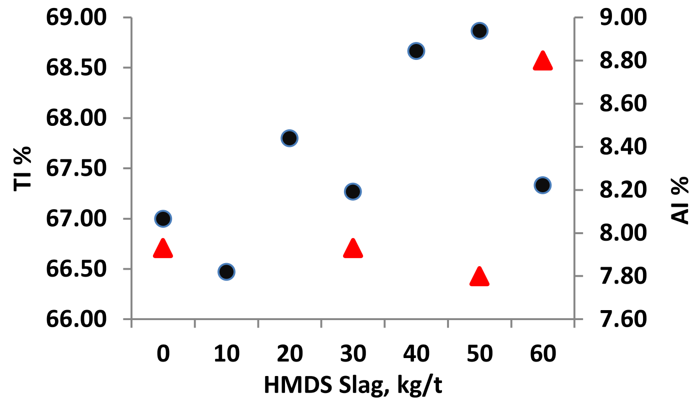

Figure 13 Influence of HMDS Slag addition on TI & AI %

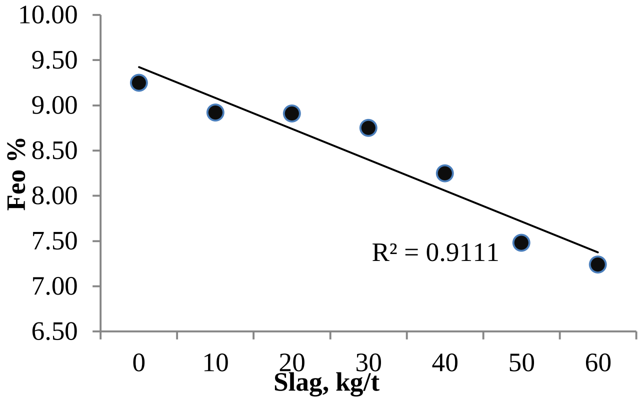

Figure 10: Influence of LD Slag addition on FeO

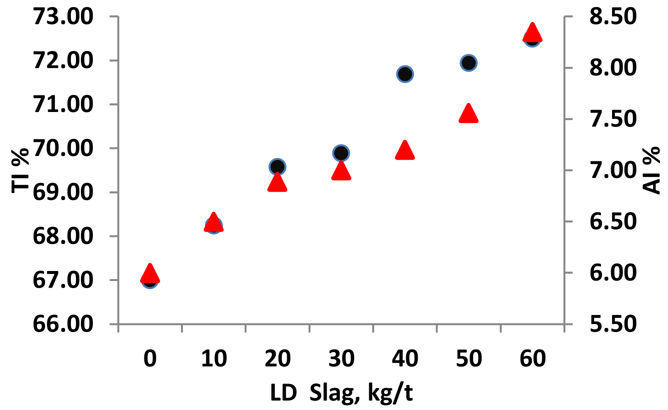

Figure 14 Influence of LD Slag addition on TI & AI %

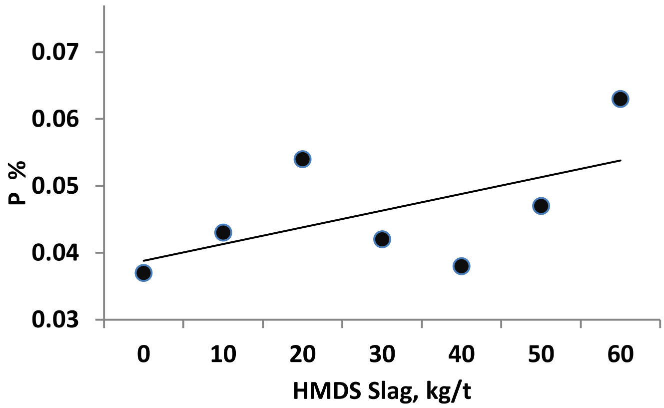

Figure 11 Influence of HMDS Slag addition on P%

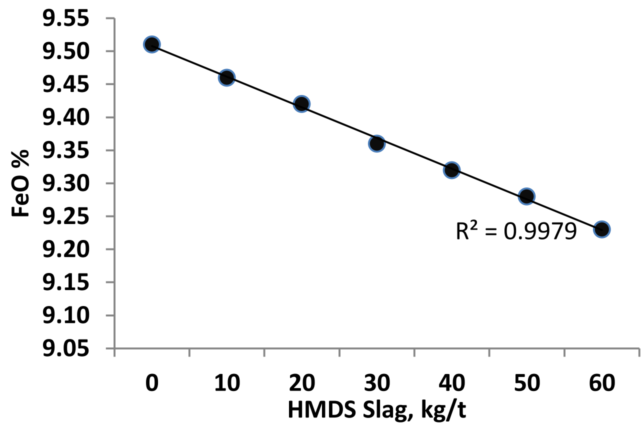

Figure 15 Influence of HMDS Slag addition on FeO

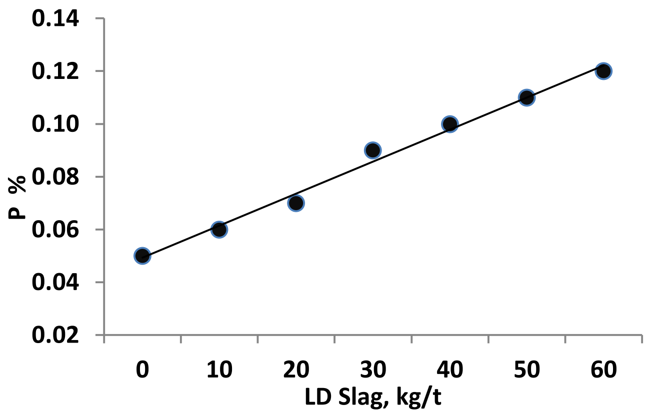

Figure 12 Influence of LD Slag addition on P%

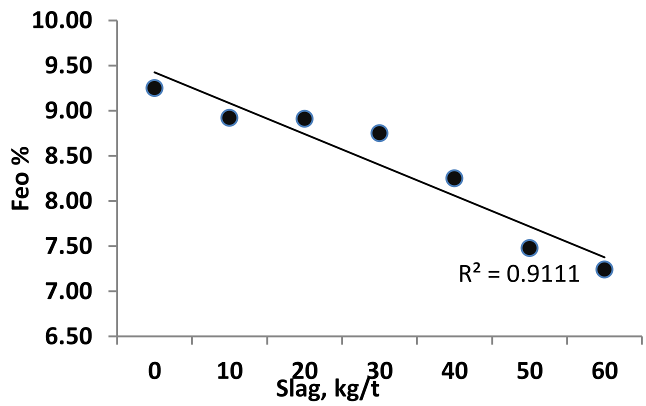

Figure 16 Influence of LD Slag addition on FeO

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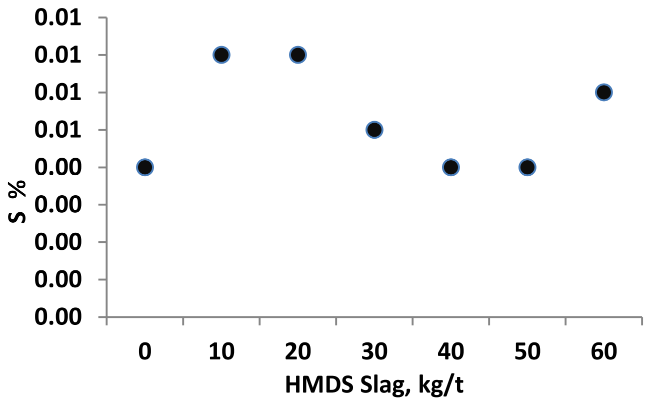

Figure 17 Influence of HMDS Slag addition on Sulphur %

Results validation through Two Sample T Test (Hypothesis Testing)

Two-sample T for LD Slag vs HMDS Slag on Tumbler Index

	N	Mean	StDev	SE Mean
LD Slag TI (6.3mm),%	18	**76.526**	0.800	0.19
HMDS Slag TI(6.3mm),%	18	**77.136**	0.736	0.17

Difference = μ (TI (6.3mm), %) - μ (TI (6.3mm) %)
Estimate for difference: -0.610
95% CI for difference: (-1.131, -0.089)

T-Test of difference = 0 (vs ≠): T-Value = -2.38 **P-Value = 0.023** DF = 33

Two-sample T for *LD Slag* P % vs *HMDS Slag on* P %

	N	Mean	StDev	SE Mean
LD Slag P %	18	**0.08318**	0.00483	0.0011
HMDS Slag P %	18	**0.07531**	0.00660	0.0016

Difference = μ (P %) - μ (P %_1)
Estimate for difference: 0.00787
95% CI for difference: (0.00394, 0.01180)
T-Test of difference = 0 (vs ≠): T-Value = 4.08 **P-Value = 0.000** DF = 31

Two-sample T for LD Slag vs HMDS Slag on Sulphur %

	N	Mean	StDev	SE Mean
LD Slag	18	**0.01213**	0.00115	0.00027
HMDS Slag	18	**0.01239**	0.00113	0.00027

Difference = μ (S %) - μ (S %_1)
Estimate for difference: -0.000258
95% CI for difference: (-0.001030, 0.000515)
T-Test of difference = 0 (vs ≠): T-Value = -0.68 **P-Value = 0.502** DF = 33

Influence of Tumbler Index and abrasion index of the sinter is shown in **Figure 13 and 14.** Tumbler index decreased and abrasion index increased with increase in addition of LD slag and vice versa with HMDS Slag addition on Tumbler Index This is due to High CaO available in HMDS Slag which helped in improvement of Tumbler Index. Strength of sinter mainly depends on the phases present in the sinter and melts available for formation of sinter. Usage of limestone in the sinter base mix provides free CaO after calcination for melt formation and calcium ferrites formation takes place.The availability of CaO phase for assimilation and for melt formation decreases with increase in addition of LD slag. Decrease in availability of free CaO for melt formation and assimilation leads to formation of less calcium ferrites and poor bonding. Proper assimilation of fluxes with hematite during sintering process gives good mechanical strength [14]. Calcium ferrite is the major mineral constituent of the sinter structure and it imparts strength to the sintered mass. High content of calcium ferrites favors the tumbler strength of the sinter [15, 16]. From the test results it was found that maximum 2.5 to 3.0 % (30 to 35kg/t of sinter) HMDS Slag can be used in the sinter making to achieve desired properties of the sinter as per the customer requirement . Plant scale trails were carried out and results were validated through Hypothesis testing (Two sample T Test). It is found on Tumbler Index & Phosphorous HMDS Slag which is significant factor compared with LD Slag and vice versa with Sulphur

4. CONCLUSIONS

1. The FeO content of the sinter decreased with increase in HMDS Slag addition due to decrease in sinter bed temperature.
2. The phosphorous content of the sinter increased with increase in addition of LD Slag because LD Slag consists of high phosphorous where p value is <0.05
3. The Sulphur content of the sinter increased with increase in addition of HMDS Slag because HMDS Slag consists of high Sulphur but in Two sample T Test it is found in LD Slag also it exist where p value is 0.502.
4. Limestone percentage in the sinter mix decreased with increase in HMDS Slag addition because the high content of CaO in the HMDS Slag replaced part of limestone as fluxing material it is statistical proved through Hypothesis testing Two sample T Test where P Value is <0.05
5. Tumbler index decreased and abrasion index increased with increase in addition of LD slag. This is due to less availability of free CaO phase for assimilation and melt formation results in poor bonding.
6. Usage of HMDS Slag up to Mid-level 30 to 35kg/t of sinter (<2.33 to <3.15%) in the sinter through micro pellet route gives better physical and metallurgical properties of the sinter as per customer requirement and also it will reduce the cost of production alternative for limestone.

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