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Optimization of Sinter FeO at Sinter Plant, Tata Steel Kalinga Nagar

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ABSTRACT

The analysis presented herein shows that impact of sinter FeO on BF fuel rate is more significant at higher productivity levels (greater driving rates) than sinter RDI. Since typical levers to control sinter RDI are not available (gangue content, etc.) at Tata Steel Kalinganagar (TSK) due to the significant proportion of sinter in the BF burden, controlling sinter RDI at present in TSK requires higher heat input during sintering, which, generally leads to higher sinter FeO. From data analysis, the suggested band of operation for sinter FeO is 10.4 – 10.8%. In this band of sinter FeO, RI value can be maintained at 73.5-75.5% with RDI ~ 28-32%. Considering the narrowed band of sinter FeO that is preferable for blast furnace operation, there is a scope to reduce carbon rate by 3- 4 kg/t GSn (tonne of Gross Sinter) from its present level of operation (62 kg/t GSn to 58 kg/t GSn average) at the sinter plant.

Keywords— Sinter FeO, RDI, RI, fuel rate, K value

INTRODUCTION

The sinter plant at Tata Steel Kalinganagar (TSK) was commissioned in January 2016. The sintering machine area is 496m^2 with state-of-the-art cooler design and advanced high intensity mixing-granulation systems. Plant is designed to use iron ore fines from its captive mines situated in state of Odisha and Jharkhand. The process of iron ore sintering involves partial melting of the ore fines and fluxes and solidification of the melt along with unfused particles forming sinter. The process is extremely complex due to very short time for which the material is at melting temperature and a host of different melting behaviour constituents. The degree of complexity further increases with increasing number of ore fines in the mixture. Once composition of an ore mix is fixed, FeO can provide an indication of sintering conditions [1]. An increase in the FeO content in sinter has been found to lower (improve) the RDI. Blast furnace productivity and coke rate are known to be positively affected as slag volume decreases [2]. At TSK, sinter is the major agglomerate in blast furnace (BF) burden. Sinter % used in BF constrains the limits of gangue content in sinter (due to its effect on BF slag rate). Under this constraint to maintain sinter properties, additional heat input is required during sintering operations to maintain sinter properties in a desirable range for BF (sinter RDI <30%). With higher heat input, there is greater reduction of hematite phase to magnetite phase (indicated by sinter FeO). This analysis tries to ascertain the impact of operating at high sinter FeO on BF performance thus, determining the desirable band of sinter FeO for consumption in the blast furnace using the current iron-bearing raw materials.

EFFECT OF SINTER FeO ON BLAST FURNACE FUEL RATE:

Fig 1 shows the impact of sinter FeO content on the BF fuel demand at high driving rates. Total corrected fuel rate is considered. Data considered from 1st June 2018 till 15th May 2019 (HM Production > 10,000 tpd). Fuel rate is normalized w.r.t agglomerate %, hot blast temperature, coke ash and moisture loading. Lower sinter FeO implies a higher degree of oxidation in the product sinter (higher Fe_2O_3), which makes the sinter more reducible (indirect reduction in the BF) for a given Al_2O_3 and MgO content, thereby reducing fuel rate. In this analysis, sinter Al2O3 is kept in a band of 2.4 -2.6% and Sinter MgO 2-2.2%. Therefore, a lower sinter FeO is generally desirable to reduce fuel rate in the blast furnace.

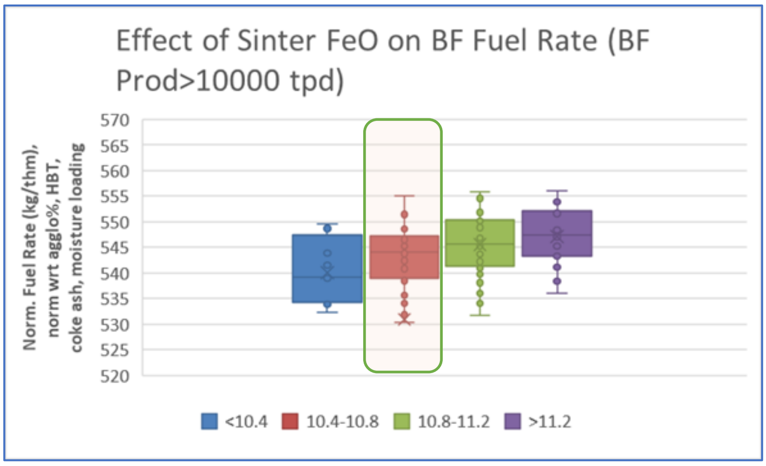

Fig. 1: Impact of sinter FeO, % on BF fuel rate, kg/thm

EFFECT OF SINTER FeO ON FURNACE PERMEABILITY, K:

Fig. 2 shows the impact of sinter FeO content on the ease of furnace burden movement and gas flows as measured by permeability (total K). K value has been filtered for agglomerate % to reduce the effect of change in metallic burden. The filter of high productivity ensures that the effects of change in bosh gas volume are kept to a minimum with bosh gas volume in the 8900 Nm3/min to 9200 Nm3/min (avg. bosh gas volume = 9000 Nm3/min). Drop in sinter FeO (for a given sinter Al2O3 and sinter MgO content) may lead to an increase in K value in granular zone (upper K trend in Fig 2 below) with slightly higher RDI, but results in a significant lowering of K in lower part of furnace (lower K trend in Fig. 2 below) due to a narrower softening-melting zone owing to the more reducible sinter [3].

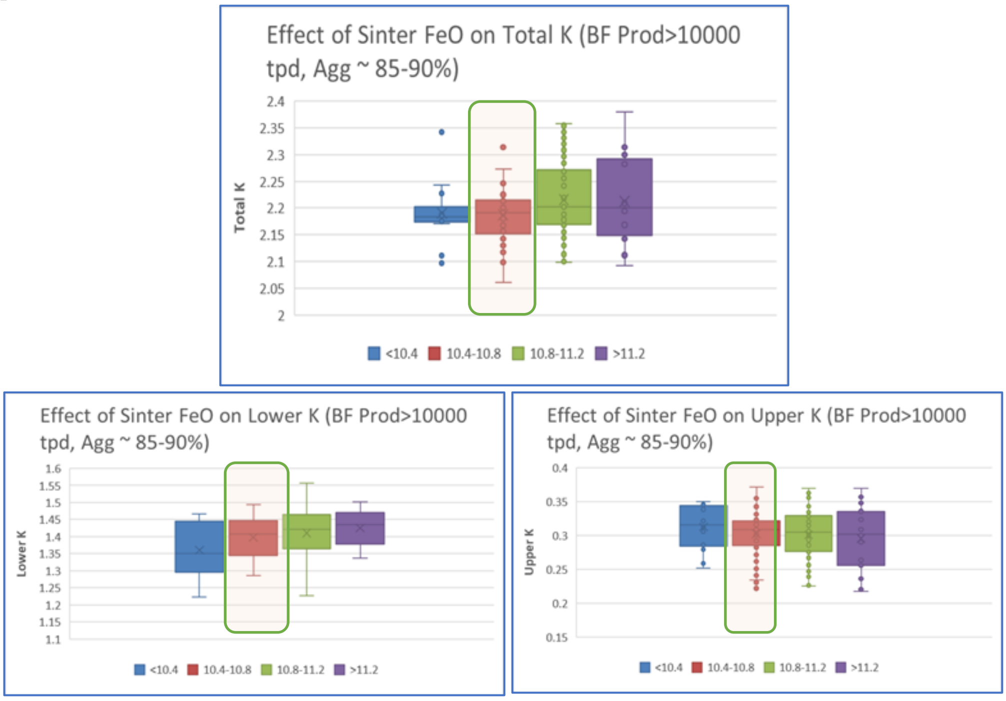

Fig. 2: Impact of sinter FeO, % on furnace permeability, K; lower K and upper K

COMBINED EFFECT OF SINTER FEO ON BF FUEL RATE AND TOTAL K:

Based on the analysis above, an inference is sought on the optimum band of sinter FeO that aids both a lower fuel rate in BF and ease of burden movement. For sinter FeO below 10.4%, the number of data points is quite less to make a statistically significant judgement on BF fuel rate and burden permeability resistance (Total K). From the figures, the increase in sinter FeO is generally leading to a higher fuel demand in the blast furnace. However, in the sinter FeO band of 10.4 – 10.8%, the furnace permeability is comparatively better. At very low FeO, probably due to poor RDI, there is an increase in K value (as suggested by higher upper K, implying generation of fines in the BF). Considering the impact on furnace permeability and limited set of data points at very low sinter FeO levels, it can be suggested that from the current data analysis, in the band of sinter FeO between 10.4 to 10.8%, there is an optimized fuel rate and K value in the furnace.

IMPACT OF SINTER RDI ON BF FUEL RATE AND FURNACE PERMEABILITY:

Fig 3 (a) and (b) shows the influence of sinter RDI on BF fuel rate and total K. For sinter RDI > 32, the number of data points is quite less and hence making a judgement in this regime on the BF fuel rate and Total K would not be meaningful at this stage.

Analyzing Figures 3 (a) and (b), it is observed that although the furnace is quite eased at lower RDI (below 26%), the fuel demand is quite high. Both the fuel rate and K value are optimized in the RDI band of 28-32%. For sinter RDI>32%, the number of data points is less and hence a statistical judgement is not possible at this stage. With sinter FeO in the band of 10.4 – 10.8%, RDI is being maintained in a band of 26 -31% (with mean around 28%).

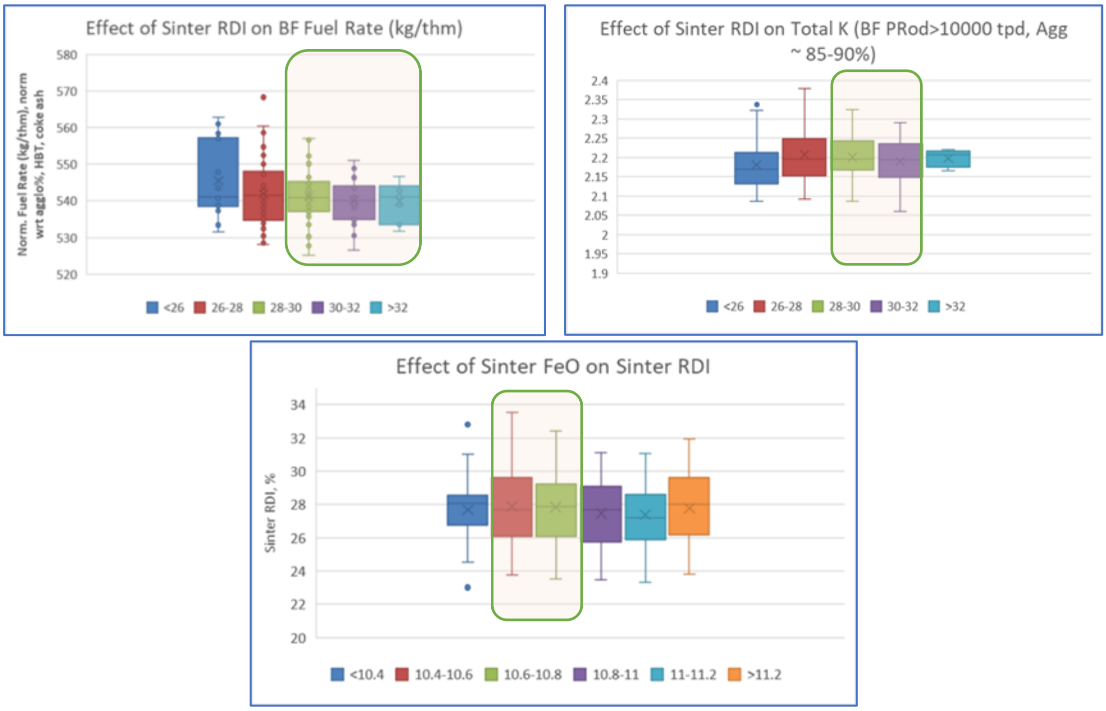

Fig. 3(a): Impact of sinter RDI on BF fuel rate and performance and (b) Impact of sinter RDI on total K and (c) Impact of sinter FeO on sinter RDI

SUGGESTED BAND OF OPERATION FOR SINTER REDUCIBILITY INDEX (RI, %):

Fig. 4 shows the bands of sinter RI for different bands of sinter FeO. Since the number of data points below sinter FeO of 10.4 % is less, no judgement is made on this regime as of now. In principle, a drop in sinter FeO generally increases the RI of sinter. Considering the favourable band of sinter FeO 10.4-10.8%, an RI of about 73.5 – 75.5% is to be maintained. In order to tune the lower end of the optimal range of sinter FeO at these sinter Al_2O_3 levels, it is recommended to conduct trials, specifically aimed at the impact of sinter FeO < 10.4%. This will enable generation of a larger data set at these lower levels so that a well-defined lower limit could be established for the optimal sinter FeO.

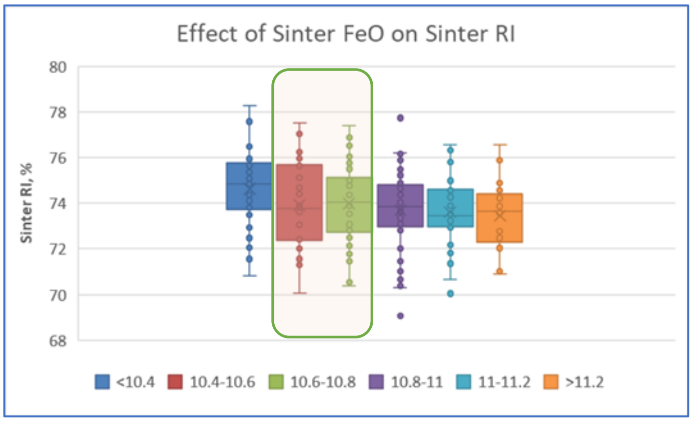

Fig.4: Impact of sinter FeO,% on Sinter Reducibility Index, RI, %

IMPACT OF OPTIMIZED BAND OF SINTER FEO ON CARBON RATE IN SINTER PLANT (TSK SP):

In TSK SP, the gangue content is limited by high sinter % in blast furnace burden. As a result, sinter RDI is being maintained by high heat input to increase the melt formation. The higher heat input, considering a similar band of sinter Al_2O_3, results in a greater degree of pre-reduction consequently, leading to a higher sinter FeO content. Based on the above analysis, there is a scope to operate at a lower sinter FeO based on its implications on the BF performance. This could result in a lowering of carbon rate at the sinter plant. Fig. 5 (a) and (b) shows the variation of carbon rate in sinter plant and resultant sinter FeO. Sinter Al_2O_3 for these data points were maintained in a narrow band to eliminate the effect of additional heat requirement for higher alumina input (which is to be accounted for by 2kg/t GSn in carbon rate for 0.1% increase in sinter alumina).

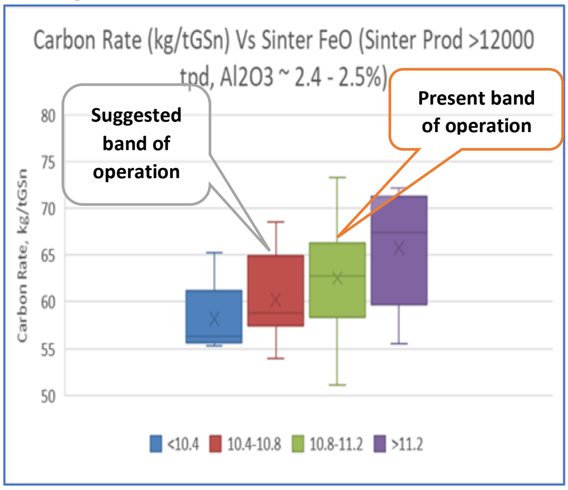

Fig. 5: Relationship between Carbon rate in sintering and Sinter FeO

At present, average carbon rate in TSK SP is around 62 kg/t GSn and the resultant sinter FeO is around 10.8-10.9%. Considering the reduced band of sinter FeO that is preferable for BF operation, there is a scope to reduce sintering carbon rate by 3- 4 kg/t GSn to about 58 kg/t GSn (Figure 5).

IMPACT OF OPTIMIZED SINTER CHEMISTRY ON BLAST FURNACE PERFORMANCE:

Based on the analysis conducted, a brief spell with optimized band of sinter FeO was trialed with stable sinter properties. The conditions and its impact on blast furnace operation is as shown in table 1 below:

Table 1: Results with Optimized band of Sinter FeO

Parameters	PERIOD I	PERIOD II
	20th June - 10th July 2019	1st Aug - 15th Aug 2019*
Sinter Properties		
Carbon Rate (kg/t GSn)	62.79	58.73
Sinter Production, tpd	14652	14388
Sinter FeO, %	10.8	10.5
Sinter Basicity, B2	1.79	1.85
Cum plus 10mm, %	59.9	60.4
Mean Size, mm	17.7	17.8
Minus 5mm, %	7.1	6.7
TI	75.8	76
RDI	25.9	25.2
RI	72.2	73.8
Blast Furnace Properties		
Production(TPD)	10393	10225
Coke Rate (Corr, kg/thm)	349	344
Coal Rate (Corr, kg/thm)	189	190
Fuel Rate (Corr, kg/thm)	538	534
Carbon Rate (Corr, kg/thm)	454	451
Normalized Fuel rate (kg/thm) wrt base (Agg%, HBT, coke ash)	*544*	*539*
Wind Volume (kNm3/hr)	341	338
Differential Pressure, bar	1.7	1.7
O2 Enrichment %	8.2	8.3
Blast Humidity (gm/Nm3)	29.8	28
RAFT, C	2220	2220
Hot Blast Temperature, C	1130	1137
Slag Rate (kg/thm)	354	356
Sinter %	75.9	75.4
Pellet %	12.6	13.1
Agg %	88.5	88.5
K	2.2	2.2
ETA CO	48.4	48.8
Coke Properties		
Ash %	15.2	15.1
Moisture %	1.9	1.7
CSR	67.6	67.7
CRI	23.8	23.2
M40	88.3	88.3

* Period of Shutdown not considered

While the period under consideration is limited, the operational data does indicate a reduction in fuel rate at both sinter plant and blast furnace with all other parameters affecting them being kept in a narrow band. Further trials to establish the results need to be carried out, specifically aimed at the impact of sinter FeO < 10.4%.

CHANGE IN SINTER FeO BAND OF OPERATION:

Based on the study, the target FeO of sinter plant was lowered in steps by optimizing levers to control the same. Of these, carbon rate was one of the levers. The progression of carbon rate and sinter FeO is shown in fig. 6. From August 2019, there has been a reduction in sinter FeO (average ~ 10.38%) with marginal drop in carbon rate (~ 58 k/tGSn). There has been no major deterioration in blast furnace performance in this period. Further analysis with a larger data set is in progress, with advanced analytics studies being conducted in parallel to further lower fuel rate by optimizing different operating parameters.

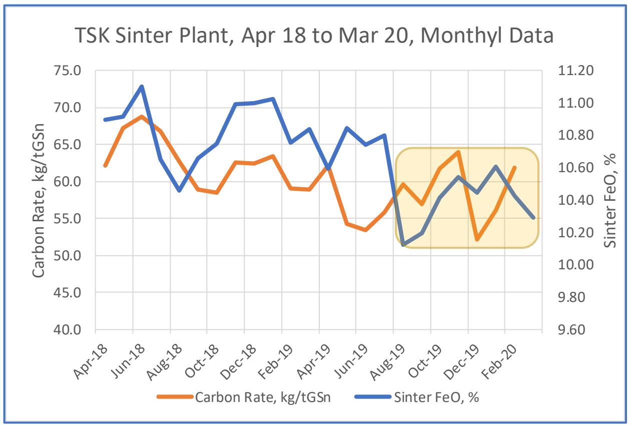

Fig. 6: Sinter FeO and Carbon rate at TSK Sinter plant, April'18 to March'20

CONCLUSIONS

The analysis shows that impact of sinter FeO on BF fuel rate is more significant at higher productivity levels than sinter RDI. Since other levers to control sinter RDI are not available (gangue content, etc.), controlling sinter RDI at present in TSK requires higher heat input which leads to higher sinter FeO. At high blast furnace driving rates, since the residence time of sinter in the low temperature zone is less, sinter with slightly higher RDI and RI will help in lowering fuel rate at the BF. From data analysis, the following suggestions are made:

a) Suggested band of operation for sinter FeO is 10.4 – 10.8%
b) In this band of sinter FeO, RI value can be maintained at 73.5-75.5% with RDI ~ 28-32%.
c) Based on this band of operation, the carbon rate adjustment at SP should happen when RDI is beyond this limit.
d) Considering the reduced band of sinter FeO that is preferable for operation there is a scope to reduce carbon rate by 3- 4 kg/t GSn from its present level of operation (62 kg/t GSn to 58 kg/tGSn average).

Based on the study, the target FeO of sinter plant was lowered. Fuel input was one of the levers to control the sitner FeO. There has been a reduction in sinter FeO (average ~ 10.38%) with marginal drop in carbon rate (~ 58 k/tGSn) from August 2019. There has been no major deterioration in blast furnace performance in this period. To tune the lower end of the optimal range of sinter FeO, it is recommended to conduct trials, specifically aimed at the impact of sinter FeO < 10.4%.

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