Use of halide solution to improve the RDI and RI of sinter : A Case Study

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Key Words: RDI & RI, Sinter, CaCl2, Blast Furnace

ABSTRACT

The reduction-degradation index (RDI) of sinter is an important parameter to estimate the quality of sinter in low temperature zone (450-550°C) of blast furnace. Hence, it is of great importance to reduce the RDI of sinter which improve the permeability of blast furnace burden column for a stable and smooth performance resulting high yield and low consumption. In the last few years, many researchers have studied and reported the method for improving sinter quality by adding halide solution on to surface of the manufactured sintered ore. Some sinter producers also established from practices that spraying CaCl2 solution on to the sinter surface will reduce the RDI of sinter.

In this paper, at Jindal Steel & Power Ltd., Raigarh, under laboratory conditions, a study was conducted on the RDI and RI (reduction index) of sinter, which was immersed with different concentrations of CaCl2 solution. The lab results showed the RDI and RI of sinter decrease with the increase of Cl- concentration. With comprehensive consideration of the RDI and RI of sinter, when the concentration of Cl- reaches a certain level (let say X%), the RDI of sinter will be significantly reduced and at the same time RI will not be affected. On the basis of the laboratory results, a pilot plant study has been done and finally the same has been erected for the existing sinter plant successfully.

INTRODUCTION

Jindal Steel & Power Limited (JSPL) is a major player in steel, power and mining. JSPL is part of US$ 17 billion O. P. Jindal Group. JSPL is operating a state-of-the-art 3 million ton per annum (MTPA) capacity steel plant at Raigarh, Chhattisgarh. The plant is equipped with world-class production facilities and is regularly supplying steel products adhering to domestic and international specifications. Direct Reduced Iron (DRI) from the sponge iron facility (world's largest coal based sponge iron manufacturing unit) and Hot Metal from Blast Furnace are used as feed material for production of crude steel. Crude steel is produced using a mix of DRI and Hot Metal in 3 x 100 Ton UHP-EBT Electric Arc Furnaces. These furnaces have eccentric bottom tapping (EBT), supersonic lancing and carbjet facilities. Steel is refined and desulphurised in 4 x 100 Ton capacity Ladle Refining Furnaces (LRF) facility which is aided by 2 Vacuum Tank Degassers and a RH-Degasser capable of producing vacuum levels of less than 1 mbar, for the production of high end grades. Through its hot rolling mills namely, Rail & Universal Beam Mill (RUBM), Plate & Coil Mills, Medium & Light Structure Mill (MLSM), Wire Rod Mill (WRM) and Bar Rod Mill (BRM), JSPL today sports a product portfolio that caters to varied needs in the steel market. The major steel products are rounds, billets, blooms, beam blanks, slabs, channels, angles, beams, columns, rails, plates and coils. The installed capacity of JSPL in India is shown in Table 1.

Table-1: Installed capacity of JSPL, Raigarh, India

At Raigarh	
Captive Power Plant	358 MW
DRI Plant	1.32 MTPA
Blast Furnace	1.67 MTPA
Steel Melting Shop	3.25 MTPA
Sinter Plant	2.53 MTPA
Coke Oven Plant	0.8 MTPA
Lime Dolo Plant	0.32 MTPA
Rail & Universal Beam Mill (RUBM)	0.75 MTPA
Plate & Coil Mill	1.00 MTPA
Medium & Light Structure Mill (MLSM)	0.7 MTPA

The 224 sq. m sinter plant at JSPL, Raigarh is a unique plant in many aspects. M/s Outotec of Germany designed and supplied the critical equipment's for this plant. This plant is based on the latest sinter making technology. It is designed to produce 2.53 million tonnes of gross sinter per annum, i.e. 320 T/hr.

2. WHAT IS SINTERING PROCESS AND SINTER

Sintering is the process of agglomeration, where heat is produced by combustion of solid fuels within moving beds of loosely packed particles, i.e., iron ore and other raw materials, to agglomerate them into a compact porous mass (Fig. 1).

Sinter helps in utilization of fines generated during the mining operations or in plant operation. Metallurgical waste like mill scale, flue dust, rejected lime fines, LD slag, LD sludge, etc. can also be used in form of sinter (Fig. 2). Cost and consistency in quality of hot metal can be improved with the help of sinter charge. The productivity and performance of blast furnace also increases with the use of sinter.

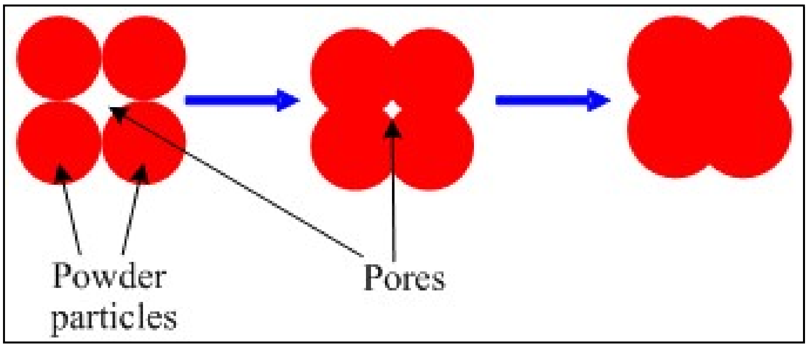

Fig-1: Sintering process


Fig-2: Sinter

3. MECHANISM OF RI AND RDI IMPROVEMENT IN SINTER

The strength of sinter during reduction (RDI) and reducibility of sinter (RI) are of greater significance and have drawn considerable attention of the researchers since the furnace performance is largely decided by these indices. Understandably, the fines generated inside the furnace in the stack zone or during reduction affect the permeability of the stack zone, increase the pressure drop and disturb the gas distribution. All these factors result in decrease in driving rate and adversely affect the CO utilization with ultimate consequence of higher coke rate and lower productivity.

To maintain the reducibility of sinter unchanged, it is of great importance to reduce the RDI (Reduction-Degradation Index) of sinter, which will improve the permeability of Blast furnace burden column, So as to realize stable and smooth performance and keep high yield and low consumption. Under laboratory conditions, study on RDI & RI (Reduction index) of sinter was proposed, in which the sinter was immersed in solutions with different types of concentrations. The result show that Cl- is the main factor for reducing the RDI of sinter and the RDI & RI of sinter decrease with the increase of Cl- concentration. With comprehensive study of RDI & RI of Sinter, when the concentration of Cl- is 2%, the RDI of sinter will be significantly reduced and RI will be affected.

The RDI of Sinter is an important parameter to estimate the quality of sinter in low temperature zone (450-550oC) of blast furnace. At JSPL, in BF# 2, the desire RDI and RI value of sinter is 20-25 and 59-62 respectively. In upper part of blast furnace, sinter is reduced by CO and H2 causing the phenomenon of low temperature reduction degradation, which will increase the quantity of the dust on the top of furnace and make permeability of burden column worse, resulting in unstable performance, higher coke rate, lower outputs, uneven gas flow distribution. When reduced at 900 oC, CaCl2 crystals that were absorbed on the surface of sinter and on inner wall of pores gradually volatilized.

If the volatilization of CaCl2 crystals in closed pores increased to a certain amount, gas partial pressure of local micro area in closed pores would be higher than that of outside reducing gas (CO), and it would become difficult for reducing gas (CO) to get into closed pores inside the sinter. Excessive volatilization of CaCl2 crystals would also block open pores and cause excessive local partial pressure and then the entry of reducing gas would be stopped. All of these would reduce the effective contact area of reducing gas and sinter in unit time. Therefore, the rate of reduction of sinter would decrease in a certain period of time, leading to the decrease of reduction index. Also at low temperature that increasing of CaCl2 concentration on immersing solution, CaCl2 cannot be completely volatile and residual CaCl2 would hinder the reduction of Sinter. Therefore, the excessive increase of the concentration improves the low-temperature reduction performance and affects the reduction of sinter simultaneously.

CaCl2 crystal is absorbed on the outer and internal surface of sinter, and has surface reaction with Fe2O3 which inhibits Fe2O3 transforming to Fe3O4. The internal stress of crystal transformation is abated and the RDI of sinter is decreased accordingly. When the concentration is too high, incomplete volatilization of CaCl2 will affect the reduction rate and the RI of sinter will be decreased. The results of reduction experiments on sinter immersed in different kinds of solution shows that Cl- could reduce the RDI of sinter.

4. EXPERIMENTAL PROCEDURE

Sinter samples applied in the experiment were taken from Sinter Plant, JSPL, Raigarh with size of 10 - 12.5 mm. The chemical composition of sinter was WFe(T) = 55 – 56.5%, WFeO = 9 – 10.5%, WCaO = 9 – 10.5%, WMgO = 1.5 – 2%, WSiO2 = 4.5 – 5.5%. The basicity of the sinter was in the range of 1.8 to 2.3.

4.1 Preparation of sinter samples

The sinter immersion was carried out at room temperature. 2 kg sinter samples were put into 2 litre solution of certain concentration or CaCl2 can be sprayed half of an hour later, the sinter samples were removed from the solution and dried (1050C, 4 hours). The concentration of CaCl2 solution was changed from (0.30 % to 1.20 %.)
The total mass of sinter used for RDI and RI tests in a run was about 30 kg.

4.2 Analysis of RDI & RI of sinter
2 kg of sinter samples were sprayed with different concentrations of $CaCl_2$. The study adopted the JIS method to determine the RDI & RI of sinter. In the RDI test approx. 500 gm sinter was reduced by reducing gas (CO 20%; CO_2 20%; N_2 60%) at 5000C for 60 min. The total gas flow rate was 15 litre / min. After that, N_2 was used as protective gas and the sinter was cooled to room temperature. Then, the sinter was put into the small rotary-drum with a rotate speed of 30 revolutions per min for 10 min. Finally, the sinter was sieved by 3.15 mm square hole sieve. The percent of sinter with size less than 3.15 mm dividing the total sinter was the RDI of Sinter.

In the RI test, sinter was reduced by the reducing gas (CO 30 %, N_2 70%) at 900 oC for 180 min. During the beginning 20 min of reduction, the mass change was recorded every 3 min, and then it was recorded every 10 min. after 3 h of reduction, N_2 was used and cooled to room temperature. The aapparatus used for determination of RI and RDI of sinter has been shown in Fig. 3.

At last, chemical analysis was made and RI of sinter was calculated

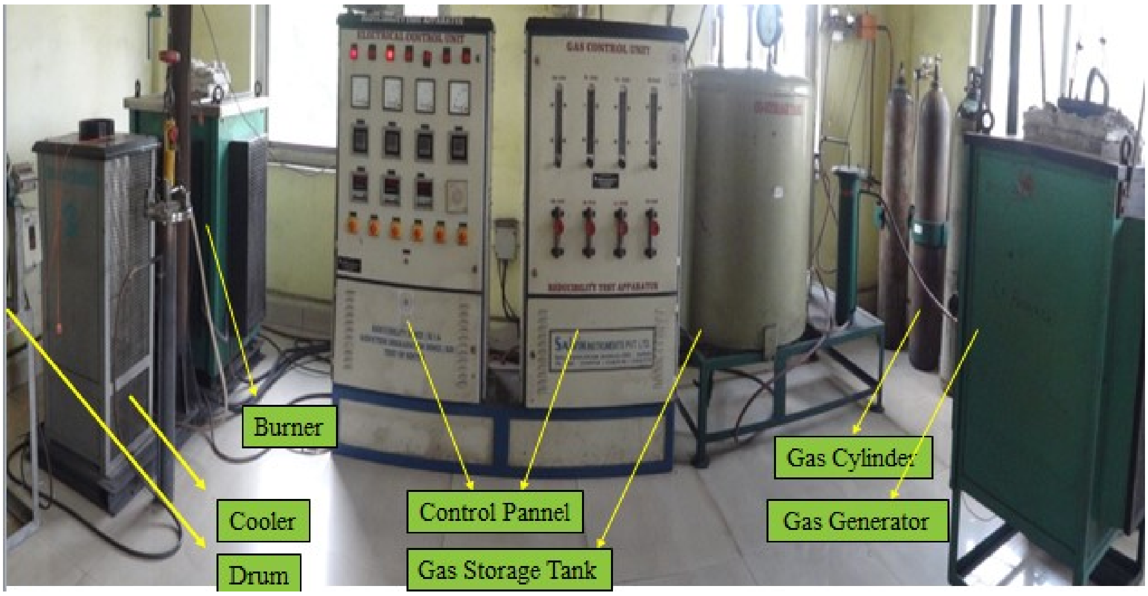

Fig-3: Apparatus for determination of RI and RDI of sinter

5. RESULTS AND DISCUSSION
The experimental results of sinter reduction sprayed with different solutions with different concentration of $CaCl_2$ are tabulated in Table 2 and Fig. 4 and Fig. 5.

Table-2 : RDI and RI value of sinter sample at different concentration of $CaCl_2$

% $CaCl_2$	RDI	RI

concentration	Before CaCl2 spray	After CaCl2 spray	Before CaCl2 spray	After CaCl2 spray
1.20	29.22	10.48	59.48	59.53
1.15	37.82	17.42	59.36	59.33
1.10	36.82	14.45	60.80	60.81
1.00	40.20	20.02	60.23	60.21
0.90	36.68	25.48	59.80	59.76
0.80	43.02	24.20	59.73	59.70
0.70	46.52	23.84	59.15	59.18
0.60	43.60	23.12	59.67	59.63
0.50	39.42	21.42	59.07	59.11
0.45	40.20	22.12	60.03	60.10
0.40	49.22	28.42	59.87	59.83
0.30	48.16	37.02	58.90	58.86

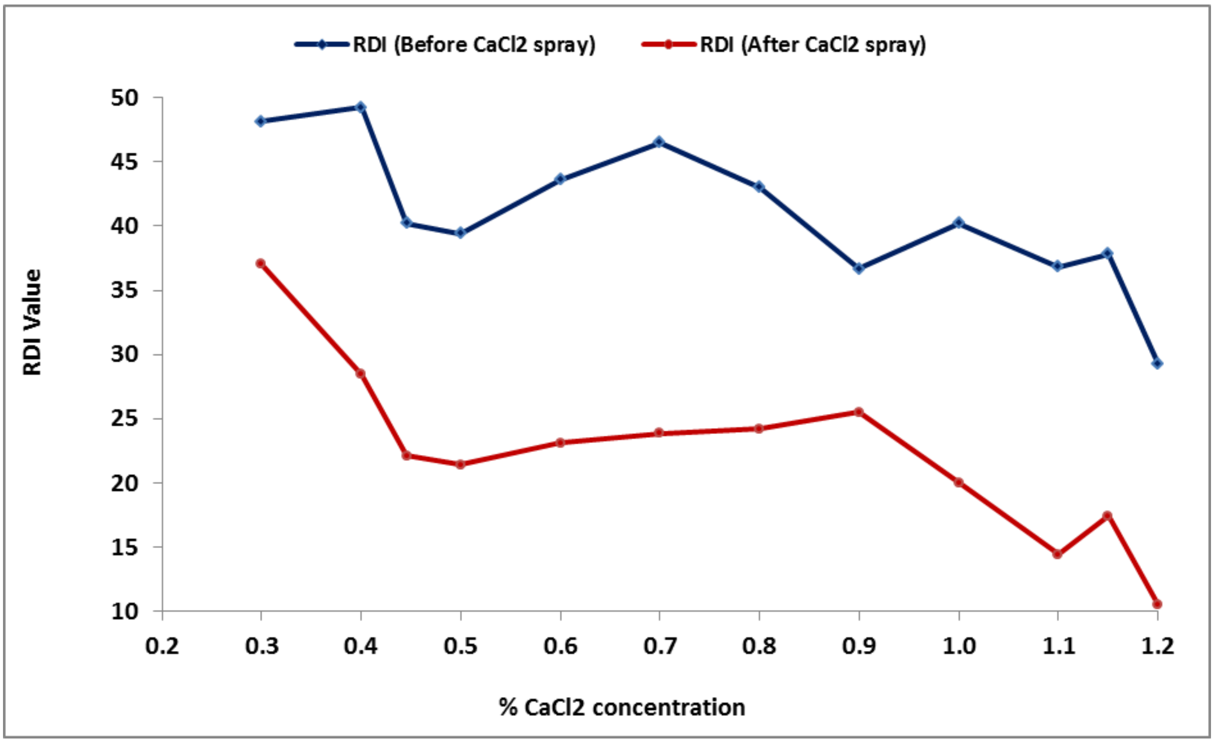

Fig-4 : The effect of different concentration of CaCl2 on RDI value of sinter

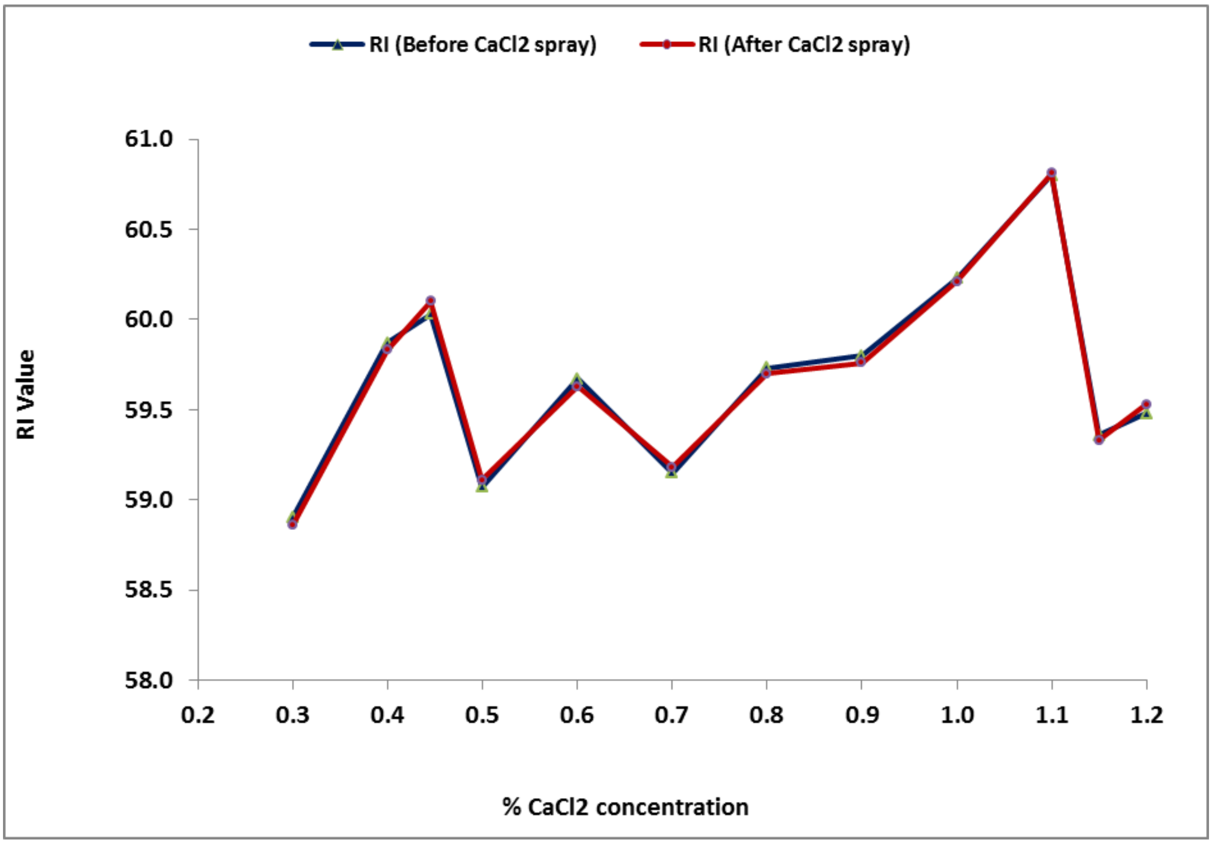

Fig-5 : The effect of different concentration of CaCl2 on RI value of sinter

It is clear from Table 2 and Figs. 4 & 5, it can be observed that with the increase in concentration of CaCl2, RDI of sinter decreases without much affecting the corresponding RI values. The sinter samples with CaCl2 spray shows lower RDI than sinter samples with no CaCl2 layer. In case the concentration of CaCl2 solution is controlled at about 0.9-1.0%, the RDI of sinter can be decreased and the reduction degree is basically unchanged. When the concentration of CaCl2 solution is increased further, the RI of sinter is not being varied much, however the RDI of the sinter is sharply decreased. When the concentration is high, the owing to incomplete volatization of CaCl2 which affect the reduction rate, and the RDI of sinter is reduced.

The sinter sprayed with CaCl2 solution in the area under reduction at low temperature of 500°C, CaCl2 can still accumulate in the sinter surface. The residual block the micro-pores on the sinter surface which damages the contact condition between the reduction gases, limits the hematite reducing to magnetite phase and reduces the internal stress resulting from expansion of crystal changes, and therefore RDI is significantly improved. With the increase of CaCl2 concentration, the number of the micro-cracks of the sinter is evidently decreased.

CONCLUSION

The results of reduction experiments on sinter sprayed with different concentration of $CaCl_2$ show that $CaCl_2$ can reduce the RDI of sinter without much affecting its RI.
The sinter samples with $CaCl_2$ spray shows lower RDI than sinter samples with no $CaCl_2$ layer. In case the concentration of $CaCl_2$ solution is controlled at about 1%, the RDI of sinter can be decreased and the reduction degree is basically unchanged.
When the concentration of $CaCl_2$ solution is increased further, the RDI of sinter will be restrained and the reducibility of the sinter will be sharply decreased. When the concentration is high, the owing to incomplete volatization of $CaCl_2$ which affect the reduction rate, and the RI of sinter is reduced.

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