Recycling of Environmentally Hazardous Wastage of Integrated Steel Plants

Prince Kumar Singh¹, A Lava Kumar², Rabindra Kr Rai³, and Sanjay Srivastava⁴

Abstract— the iron and steel industry generates a great amount of ferrogeneous waste like Blast furnace flue dust and sludge to name a few. Investigation reveals that Blast Furnace sludge creates serious environmental hazard because it is used for landfill only. The recovery of metals and carbon from these flue dust and sludge become very important due to increase of the price of coke breeze and the decrease of the primary sources of metals. At the same time, it makes the environment safer by decreasing pollution. Experiments were conducted as per recent trends in international arena and pellets as well as sinters thus produced were characterized for international standard procedure.

Keywords--- waste, Flue dust, Sintering, Pellets.

I. INTRODUCTION

Production process in iron and steel industry involve the formation of large amounts of by product. These by products cause large volume of waste streams. The byproducts are a concern to the environment and add to the loss of revenue to the iron and steel producers. The steel byproducts for example dust and sludge cause environmental degradation, loss of high value metal, demand legal complication and finally make the world uninhabited for the generation to come [1]. These waste materials are primarily used for landfill but the utilization of these waste materials may reduce the fastly depleted the primary resources. The rising prices of metals make such utilization economically attractive [2]. In an integrated iron and steel plant, several ferrogeneous waste materials are generated. The reduction of iron oxide in Blast Furnace results in generation of number of solid waste. Those are Blast Furnace slag, flue dust and gas cleaning plant sludge (Blast Furnace Sludge). However flue dust and are dumped and hence require process of utilization. Although utilization of plant wastes for production of quality sinters is a recirculation technique [3] but at the same time it adversely affects the property of sinter so in this study we made the pellets [4-8] from the waste and then used these pellets for preparing of sinter. It decreases the fuel rate for the sintering process.

Many researchers have worked on recycling of plant waste as sinter. The objective of this work represents possible utilization of blast furnace flue dust and sludge from Durgapur Steel Plant after pelletization of both in a disc pelletizer using bentonite as a binder material through sintering process as a substitute of coke breeze due to high price.

II. EXPERIMENTAL

The raw materials used for pelletization are flue dust, sludge (chemical analysis as shown in Table II) and binders (dextrine, bentonite and molasses). The pellets produced after pelletizations are used for sintering with other ingredients iron ore, lime stone, dolomite and coke breeze. The chemical of the raw materials used is shown in the Table I.

The raw material is weighed according to the charge mix using electronic weighing machine. The pellets were prepared in a disc pelletizer with a diameter 56 cm, angle of inclination 36.210, disc rotating speed 29 rpm, and residence time of 10 minutes. Pellets were prepared by using binders (2, 3 and 4 wt%) with varying amount of raw materials. The green pellets were dried in air for two days and then the bentonite made pellets were heated up to 3000C for 1 hr and then isothermally indurated at 9000C for 1 hr at the same time dextrin and molasses made pellets were heated in an air oven at 1500C for 1 hr. The prepared green pellets are shown in the figure 1. Properties of the pellets were determined by using compression test, shatter index test and drop test methods. By using the most appropriate pellets, sintering was performed. The sintering experiments were conducted in a laboratory down draft sinter machine. The dimensions of the sintering pot are total height of pan 26.5 cm, hearth area 306.25 cm², top area – 542.5 cm². Capacity of the machine 16 kg. By keeping the iron ore and coke percentage fix in the charge mix with varying other ingredient, the basicity (CaO/ SiO₂) were also fixed for 1.5, 1.7, 2.2.
III. RESULTS AND DISCUSSIONS

3.1 Property of Pellets:

The properties of pellets and their strength with respect to amount of the binder are reported in Fig 1-3. According to which pellets made by mixture of sludge and flue dust with bentonite binder shows the highest strength as shown in shown Fig 3. The same result was also proved by compression test and drop test [9-10].

![Fig. 1 Pellets of Flue dust](image1)

![Fig. 2 Pellets of Blast Furnace sludge](image2)

![Fig. 3 Pellets of Blast Furnace sludge + flue dust](image3)

3.2 Productivity of Disc Pelletiser

Fig. 4 shows the variation of the productivity with effect of the binder. The productivity of the Disc Pelletier depends upon the yield of the pelletization process [11] and it was found good in case of bentonite as a binder.

![Fig. 4 Effect of binders on productivity of machine](image4)

3.3 Effect of waste on coke rate of sinter

The coke rate decreases with increase in waste(Fig 5). The waste contains some carbon (Fixed Carbon contained in Flue Dust is 9.05 % and in Sludge is 12.15%) which reduce the coke requirement during actual sintering. More carbon is available during the process.

![Fig. 5 Effect of waste on coke rate](image5)

3.4 Effect of waste on sintering strength :

The sinter strength increased with increasing flue dust and Blast Furnace sludge (mixed) pellets (Fig 6). This is attributed
to increasing amount of melt in the charge with increasing amount of flue dust and Sludge pellets.

Fig. 6 Effect of waste on sinter strength

Fig. 7 Effect of waste on productivity

3.5 Effect of waste on Productivity

Productivity increases slightly with increase in basicity (SiO₂/CaO) as well as waste addition (Fig. 7). Productivity is directly linked with sintering rate. Addition of CaO increases the sintering rate because it undergoes endothermic dissociation. Microscopic studies showed that the bulk of original material was liquid during sintering. High surface tension and low viscosity of the melt combined with short solidification time and high temperature co-efficient of viscosity have led to rapid sintering.

3.6 Effect of waste on reducibility of sinter

The reducibility was done in Reduction furnace by carbon mono oxide at the rate of 1.5 ltr / min, at temperature 900°C and reduction time 90 min. Percentage Weight loss = (W_i – W_f) / W_i x 100 where W_i is Initial weight and W_f is Final weight.

The graph (Fig. 8) shows that the percentage of weight loss or reducibility decreased with increase in the waste percent in the sinter mix. This may be due to the fact that the magnetite (Fe₃O₄) phase which is less reducible than hematite, increases in the sinter mix with increasing the amount of flue dust and sludge pellets in sinter charge and this need more coke to reduce.

Fig. 8 Effect of waste on reducibility of sinter

3.7 Micro structural analysis of sinter

Sinter sample having 20% waste and 1.7 basicity was analyzed under the Optical Microscope. The microstructure revels that sample, consisted of re-oxidized hematite and few magnetite phase. Slag phase consist of Calcium silicate and Calcium ferrite are also present. The presence of such phases is confirmed with the XRD pattern.

Fig. 9 Microstructure of sinter sample

3.8 XRD analysis of Sinter

The X-ray diffraction of the sinter having 20% waste and 1.7 basicity, indicates that the sinter consist of hematite phase mainly with magnetite and slag (CaSiO₃) phase.

Fig. 10 XRD Pattern of sinter sample
IV. CONCLUSION

From the above study it can be concluded The most suitable pellets (8-10 mm) of wastes produced were of Blast Furnace sludge and Flue dust (mixed together) using bentonite (4%) as binder in a disc pelletizer at angle of inclination 36.21°, rotating speed 29 rpm and residence time of 10 min and these were used in sinter making.

**Pellets when used in sintering of iron ore**
- Mechanical properties of sinter improved.
- Production increases.
- Coke rate decreases.
- FeO content decreases but Fe content increases.
- Reducibility of sinter decreases with increase in waste amount.

Sinter made with waste pellets having basicity 2.2 has a better mechanical strength. Using waste materials leads to decrease the amount of fluxing material.

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**REFERENCES**


[10] Principles of extractive metallurgy by T. Rosenquest; Mcgraw Hill.


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**TABLE I**

CHEMICAL ANALYSIS OF RAW MATERIAL

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Fe(t)</th>
<th>CaO</th>
<th>SiO₂</th>
<th>MgO</th>
<th>Al₂O₃</th>
<th>LOI</th>
<th>Ash</th>
<th>V.M.</th>
<th>F.C.</th>
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<tr>
<td>Iron ore</td>
<td>52.8</td>
<td>-</td>
<td>2.94</td>
<td>-</td>
<td>2.45</td>
<td>2.38</td>
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<tr>
<td>Lime</td>
<td>-</td>
<td>72.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Lime stone</td>
<td>-</td>
<td>49.24</td>
<td>6.93</td>
<td>1.12</td>
<td>1.28</td>
<td>39.06</td>
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<td>Dolomite</td>
<td>-</td>
<td>26.98</td>
<td>3.49</td>
<td>19.82</td>
<td>1.48</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coke breeze</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>22.07</td>
<td>5.10</td>
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**TABLE II**

CHEMICAL ANALYSIS OF WASTE

<table>
<thead>
<tr>
<th>Waste</th>
<th>Fe(t)</th>
<th>CaO</th>
<th>SiO₂</th>
<th>MgO</th>
<th>Al₂O₃</th>
<th>Na₂O</th>
<th>K₂O</th>
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<td>Sludge</td>
<td>26.78</td>
<td>8.50</td>
<td>11.89</td>
<td>4.12</td>
<td>3.85</td>
<td>0.07</td>
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<tr>
<td>Flue Dust</td>
<td>42.0</td>
<td>5.95</td>
<td>6.83</td>
<td>2.12</td>
<td>3.12</td>
<td>0.22</td>
<td>0.56</td>
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