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Replacement of Split Coke Charge in Cupola Operation: A Green Chemical Approach

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ABSTRACT

The cupola is a refractory lined shaft furnace and the basic fuel is coke. The main objective of the present work is the utilization of waste material (Rice husk briquette) of low C.V. to 50% eq. of split coke charge. Bed coke remains unaltered due to breakdown of rice husk briquette on heating in a cupola. The experiment was carried out in a single blast cupola 23-inch internal diameter (ID). Four charges were tested out of eight charges. There was no change in composition, melting rate, spout temperature, and slag chemistry, but SO_2 emission was reduced to 23.13%. Some smoke is coming through charging door due to high volatile matter (60%), which may be overcome by introducing excess O_2/Divided Blast Cupola.

Keywords: Cupola, Rice husk briquette, Divided blast cupola, Cokeless cupola, SO_2, SPM

INTRODUCTION

About 65% of cast iron is melted in cupola. Cupola fuel is coke, which is high cost now. A cupola is a vertical shaft furnace into which iron, alloys and fluxes are charged at the top and molten iron and slag are drawn off at the bottom [1-3]. The shaft is partially filled with coke to a specified height (coke bed). The bed is burnt by introducing combustion air around shaft one or two horizontal plain. As the melting proceeds, bed coke was consumed and additional coke is charged into the shaft to maintain the height of bed. Coke provides all the heat required for melting and superheating the iron and for slag formation. It also provides sufficient CO in the furnace atmosphere to prevent the oxidation of iron/alloying elements. The coke must also support itself and the charge materials physically. Coke also provides carbon for carbonization of molten iron to specific carbon content. The coke must be high in strength, low in impurities and high in carbon. But coke fired cupola emits too much suspended particulate matter (SPM), SO_x etc. Gas fired cupola is not popularized in India due to high cost of refractory balls. This work was aimed to observe the effects of coke replacement [4-5] on furnace performances, metal and slag chemistry, environmental effect and properties of cast iron [6-11].

MATERIALS

Charge materials used in this investigation are listed in Table -1 with composition, while proximate and ultimate analyses of all fuels are given in Table -2.

Details of Rice Husk

Paddy rice as one staple food for over 50 percentage of the world population is cultivated by over 20% of world population and covered 1 percent of the earth's surface. The global paddy rice production had been increasing continuously on an average rate of 16.48 million tons in the last 10 years, with the production of 2011 around 718.3 million tons, valuing around 240 billion US dollar. The main paddy rice producing countries are China, Egypt and Cuba, which contributes to 27.51%, 0.63% and 0.77%, respectively of the global paddy rice production. On an average paddy rice consisted of 72% of rice, 5-8% bran, and 20-22% husk. India produces 120 million tonnes paddy and 24 million tons of rice husk per year.

Rice husk from mill→ Sieving→ Grinding → Palletizing with high pressure.

Table - 1 Materials

Component	C (%)	Mn (%)	Si (%)	S (%)	P (%)	Ash (%)
Pig	4.08	0.67	2.22	0.029	0.104	
F/R	Previous	Days	Casting			
MS	0.20	0.60	0.15	0.03	0.035	
Fe-Mn		70				
Fe-Si			70			
Limestone						< 5.00

Table - 2 Fuel Analysis

Results of analysis	Moisture (%)	V.M. (%)	Ash (%)	Fixed Carbon (%)	Gross C.V. Kcal/Kg	Bulk Density gm/mL	C (%)	H (%)	S (%)	N (%)	O (%)
Coke	1.23	0.58	12.39	87.03	6647	1.06	64.49	2.29	0.42	1.48	10.61
Rice husk	9.62	60.54	15.35	24.11	3540	0.35	68.47	5.27	0.096	0.43	5.39

Equipment

Cupola trials were made in an acid lined, 23-inch ID (Fig. 1). Combustion air supplied by 20 H.P. Motor, Blower at 4500 r.p.m. Exhaust gas was passed through pollution control device, dry cyclone separator with wet scrubber. Chemical test was done by spectrometer (Metavision), mechanical tests were done by 20 ton locally made machine, hardness measurement was made by Brinnel cum Rockwell, 250 kg. (Fine testing machine), and microstructure by inverted type metallurgical microscope.

Fig. 1 Cupola

Fig. 2 Immersion pyrometer

Fig. 3 Cupola fumes

Procedure

The cupola was preheated with 50:50 steam coal, rice husk briquette and wood. Then coke was charged for further preheating and to establish coke bed. The fuel used to replace partially foundry coke were not added to the starting coke bed. The height of bed coke was set at 36 inch above the tuyeres.

First four charges were made with split coke only. Last four charges were made with 50% eq. rice husk briquette. Iron was tapped into a ladle and pigged in sand. Analytical and chill control samples of iron were taken from casting ladle, and slag samples were taken from slag stream. Temperatures were observed by immersion pyrometer (Fig.2) from the stream. Test samples were poured in green sand mould for tensile, hardness, metallography, and chill. Melting rate was measured by stop watch. At the end, cupola bottom was dropped and hot coke of the bed was quenched and weighted.

RESULTS AND DISCUSSION

Three days, three heats were taken with bed coke 400 kg.
First four charges made with: Pig - 400 kg., MS. - 20 kg., F/R - 280 kg., limestone - 20 kg., coke - 60 + 20 kg.
Last four charges made with: Pig - 400 kg., MS.- 20 kg., F/R - 280 kg., limestone - 20 kg., coke - 30 + 20 kg + 56 kg. rice husk briquette.

Table – 3

C (%)	Mn (%)	Si (%)	S (%)	P (%)	Spout temperature	Chill depth	Tensile MPA	BHN	Melting rate	Micro-FG	Drop coke
Results: On 22.10.16											
Coke only											
3.53	0.59	2.03	0.13	0.088	1409 ^{0}C	5 mm.	162	182	1.80 tons/hr.	150, IS 210	50 Kg
50% eq. rice husk briquette											
3.67	0.56	2.32	0.056	0.11	1409 ^{0}C	5 mm.	160	180	1.80 tons/hr.	150, IS 210	
Results: On 24.10.16											
Coke only											
3.61	0.59	2.17	0.14	0.11	1410 ^{0}C	5 mm.	160	180	1.80 tons/hr.	150, IS 210	60 Kg
50% eq. rice husk briquette											
3.45	0.48	1.97	0.063	0.1	1409 ^{0}C	5 mm.	162	180	1.80 tons/hr.	150, IS 210	
Results: On 23.03.17											
Coke only											
4.05	0.45	2.03	0.066	0.077	1410 ^{0}C	5 mm	164	182	1.80 tons/hr.	150,IS 210	
50% eq. rice husk briquette											
4.03	0.36	1.88	0.055	0.081	1410 ^{0}C	5 mm.	162	180	1.80 tons/hr.	150, IS 210	45 Kg

Table - 4 Slag Test

S. No.	Name of test	Reference	Test result	
			50% eq. rice husk briquette	Coke
1.	% SiO_2	Standard test method	44.64	45.14
2.	% CaO		15.60	23.00
3.	% Al_2O_3		10.27	10.60
4.	% MgO		1.43	1.02
5.	% FeO		18.88	11.54
6.	% S		0.015	0.105
7.	% P		0.156	0.205
8.	% MnO		2.50	2.04

Table - 5 Pollution Tests

	SO_2 (mg/Nm^3)	SPM (mg/Nm^3)	CO_2 (%) (v/v)	CO (%) (v/v)
Coke	180.17	110.78	7.8	< 1.0
50% eq. rice husk briquette	138.50	126.39	7.0	< 1.0

CONCLUSION

Tested with 50% eq. rice husk briquette in single blast cupola, 2 tons/hr. capacity:

- No significant effect on metal composition, pouring temperature, chill depth, melting rate, tensile strength, hardness and microstructure, and slag chemistry was observed (Table 3, 4 and 5).
- S was reduced by 23.13%, which means green cupola.
- Cost saving: coke - Rs. 24/- kg., rice husk briquette - Rs. 5/- kg.
- This method also has bio waste utilization.
- Due to high volatile matter (60 %), some fumes were coming through charging door. (Fig. 3), that may be averted by supplying excess O_2/or with divided blast cupola.
- There is also huge scope of increasing the percentage of rice husk briquette.

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