INFLUENCES OF CARBONACEOUS MATERIALS ON THE QUALITY OF HEMATITE ORE PELLETS

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Abstract: Pellet induration at high temperature for its hardening is an energy intensive process. Therefore, in order to reduce the external energy requirement carbonaceous materials are added to supply in-situ energy on induration. In the present study, different carbonaceous materials viz. Jhamacoal, blast furnace flue dust, and coke powder have been added in pelletization of hematite ore fines to reduce the external energy requirement and to utilize the waste carbonaceous materials. It has been observed that green pellets' properties are within acceptable limits which are not affected by the presence of the carbonaceous material. The cold compressive strength (CCS) of pellets increases with increasing induration temperature. The furnace-cooled pellets show more strength than air-cooling. Blast Furnace flue dust added pellets show highest CCS among other carbonaceous material added in pellets which is 2515 N /pellet at 1280◦C. RI and RDI has also been influenced by the addition of other carbonaceous materials.

Key words: Induration temperature, cold compressive strength, reducibility index, reduction degradation index

1. Introduction

Utilization of low-grade iron ores and iron wastes generated during mining and beneficiation process in iron and steel making sectors is a very crucial task as fines and low-grade ores cannot be used in blast furnace (BF) operation directly[1-3]. Prior to use in BF operation, such huge fines and low-grade ores may be converted into pellets via pelletizing process (agglomeration technique). Iron ore concentrate pellets are usually hardened (induration/firing) at high-temperature either in a horizontal traveling grate or in grate-kiln furnaces. A very high induration temperature (say 1325°C) is required to obtain the sufficient strength of fired hematite pellets due to the absence of recrystallization and crystal growth of hematite until 1300-1350°C[1-4]. In addition to above, a huge amount of external energy is also required for induration of hematite ore pellets to obtain pre-requisite pellet properties due to absence of exothermic heat of reaction. Several investigators studied on use of coke [5-11] and waste oxides [12,13] in pelletization process, which may reduce the external supply of heat in pelletization. On the other hand, an excessive addition of carbon in pelletization of hematite leads to degradation of pellet quality[5-11]. The optimum values of pre requisite pellets properties such as cold compressive strength (CCS), reducibility index (RI) and reduction degradation index (RDI) are required to use in Blast Furnace iron making operation for worthy charge material. Therefore, optimization of induration conditions and carbon content of pellet is required in any plant. In the present study, different carbonaceous materials such as coke, Jhama coal and blast furnace (BF) flue dust were used in hematite ore pellets as an additive to maximize the utilization of carbon for in-situ heat generation and reduce the external energy requirements.

2. Experimental

2.1 Raw material characterization

The materials such as Noamundi iron ore (Hematite), coke, jhama coal and BF flue dust are used for following experiments. The chemical composition of iron ore, coke, jhama coal and BF flue dust are mentioned in Table 1.

2.2 Blain number

The blain number (specific surface area) is measured using Blaine air-permeability method**.** The Noamundi iron ore fines were ground in a ball mill for 18 minutes to obtain the Blaine fineness of 1870 cm^2/g.

2.3 Pelletization process

Raw materials such as iron ore, coke, jhama coal, BF flue dust, bentonite (binder) and limestone (flux) were ground into fines size of -100 μm by a ball mill for preparation of pellets. The ground fines were mixed thoroughly in the rotary conical mixer to get a homogenous distribution of charge materials.

Table 2.1 Chemical compositions of raw materials

Materials	Fe_t	Fe_2O_3	FeO	SiO_2	Al_2O_3	C
Iron ore	65	92.1	0.6	1.3	2.4	-
Coke	-	-	-	9.4	3.9	80
Jhama coal				7.4	0.4	73
BF flue dust	35	39.5	9.1	5.4	2.6	33
Bentonite	1.8	3.4	2.0	60	18.1	-

The green pellets prepared in disc pelletizer with the angle of 40-50^{o} and 30 rpm speed in 2 kg batch. The optimum quantity of water and binder was used for nucleation and growth of green pellets. The pellet size ranging from 9-16 mm has been maintained. The pellets are prepared with the varying amount of coke, jhama coal, BF flue dust. After preparation, the green pellets are subjected to characterization.

2.4 Characterization of pellets

2.4.1 Properties of green pellets

The green pellets are subjected to characterization to ensure that green pellets have certain properties such as green compressive strength, dry compressive strength and drop strength within the acceptable value. The green and dry compressive strength of pellets are measured as the forces at which the pellets breaks with applied force. The drop test of each sample of green pellets is performed by repeatedly dropping the green pellet samples of 10-11 mm size in a 10 mm thick steel plate from the conventional height of 0.45 m. The number of drops withstands by the pellet before breaking is termed as green drop strength.

2.4.2 Properties of indurated pellets

The green pellets are indurated in electrically heated chamber furnace. The induration of green pellets is performed in varying temperature in the range of 400°C-1280°C for 10 minutes. The indurated pellets are cooled with different cooling rate to room temperature to measure the cold compressive strength (CCS) of pellets. Universal Testing Machine has been used to measure the cold compressive strength as per standard [IS -8625-1986]. The maximum loads at which the pellets undergo complete breakage are recorded. Same procedures were repeated for 15-20 pellets of each condition and the average value was reported as CCS. For measuring reducibility index (RI) and reduction degradation index (RDI) the pellets are indurated at 1280 ◦C for 10 minutes and with similar conditions as before. The RI and RDI of indurated pellets were measured as per standards (IS 11292 – 1985) [14] and JIS: M 8720 [2001]) [15] respectively.

3. Results & Discussion

3.1 Properties of green pellets

The green compressive, dry compressive and drop strength of acid pellets are shown in Table 3.1. The green pellets properties of all pellets are well above the acceptable level.

Table 3.1 Green pellets properties for coke added (CA), Jhama coal added (JCA), BF flue dust added (BFA) pellets at 1.5 % carbon.

Green properties	CA pellets	JCA pellets	BFA pellets
GCS ,kg/pellet	1.37	1.24	1.15
DCS ,kg/pellet	7.65	6.8	6.77
Drop No	13.2	11.4	7.7

3.2 Effect of cooling rate and induration temperature on strength of CA, JCA and BFA pellets

The effect of temperature and cooling rate on strength of pellets are reported in Fig 3.1(a & b). The CCS of furnace-cooled pellets show more strength than air-cooled. This may attribute to the formation of crystalline and glassy compounds during induration of pellets[2]. In case of too rapid cooling, crystalline and glassy compounds are affected. In case of furnace cooling, formation of crystalline phase and gassy phases are enhanced because of longer time of sintering in the furnace. The pellets are oxidized more under the high temperature condition consequently decrease the FeO content in pellets, which improves the pellet quality. The strength of furnace-cooled pellets (annealing) is more than that of air-cooling (normalizing) because of more recrystallization bond as reduced iron oxides are re –oxidized to stable iron oxide[13]. The strength of pellet is increased with increasing the induration temperature due to decrease in porosity, as induction temperate is increased [16]. It has found that apparent porosity of CA added pellets is decreased to 26.7 % at 1280◦C from 34.05 % at 1000◦C. approximately 21.0 % reduction in porosity as firing temperature is increased from 1000 to 1280◦C as mentioned in Table 3.2. The apparent porosity of pellets mainly depends on phase formation during induration of iron oxide pellets. Based on CCS result as mentioned in Fig 3.1 (a, b). The CCS of pellets are higher at induration temperature of 1280◦C for 10min. The CCS of coke added pellets, Jhama coal added pellets, BF flue dust and without carbon, added pellets are increased with increasing induration temperature as shown in Fig 3.1(a, b). BF flue dust added pellets show highest CCS among other pellets. The average value of CCS of BF flue added pellets is 2515 N /pellet at induration temperature of 1280◦C for 10 min. This is mainly due to the increasing amount melt phase with BF flue dust[12]. The RI of coke added (CA) jhama coal added (JCA) and BF flue dust added (BFA) pellets are well above the accepted level at 1.5 wt % carbon as mentioned in Fig.3.2. However, RDI of CA, JCA and BFA of pellets are decreasing with increasing carbon content beyond 1.5 wt % as depicted in Fig 3.3.

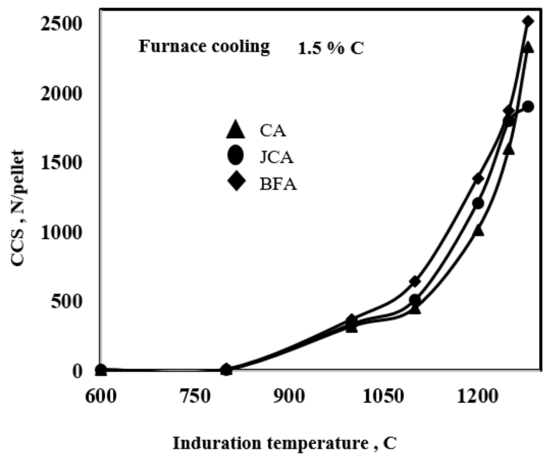

Figure 3.1 (a) Effect of temperature and furnace cooling on CCS of the pellets

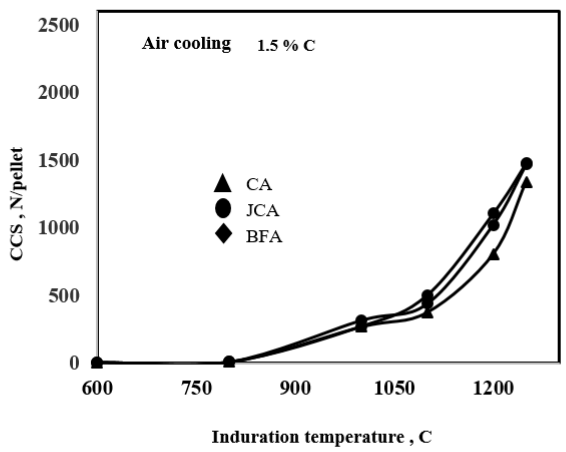

Figure 3.1 (b) Effect of temperature and air-cooling on CCS of the pellets

In case of BFA pellets, RI is decreased to around 50 % at two and 2.5 wt % C that is undesirable for blast furnace operation. However, RI of CA and JCA pellets are decreasing with carbon content at 2.0 and 2.5.This may due to the formation of more amount secondary hematite phase in final pellet as carbon in pellets reduce the iron oxide. The reduced iron oxides are re-oxidized to secondary hematite, which is a highly reducible phase in pellets[1,2]. However, RDI of CA and JCA pellets show very poor RDI value, which is not acceptable for use in plant practices. The RDI is higher at higher amount of carbon in pellets. More porosity and big pore size has a negative effect on RDI of iron ore pellet. This may due to higher amount of FeO and lower pore density in final pellets [10, 11].

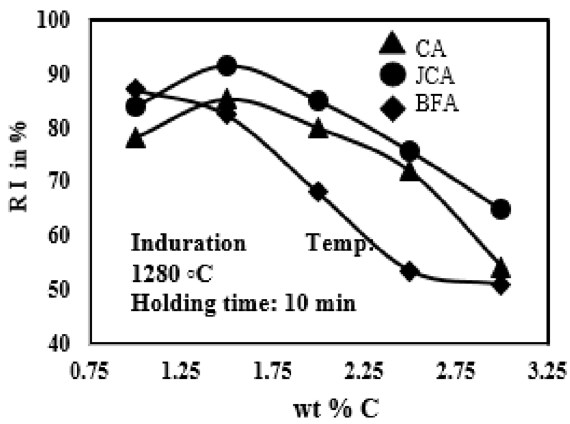

Figure 3.2 Effect of C % on RI of the pellets

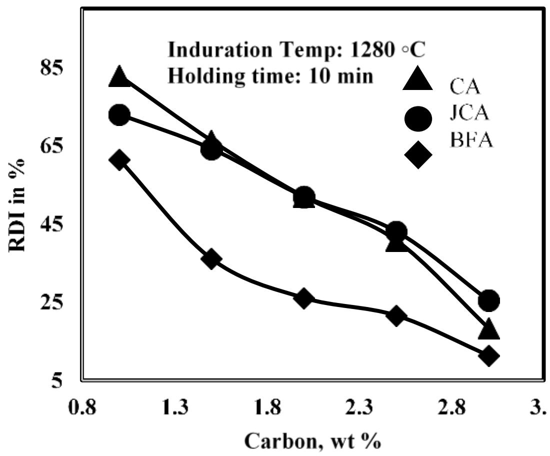

Figure 3.3 Effect of C % on RDI of the pellets

In case of BFA pellets, RDI is increased at 2.0 wt % because of the weakening of the structure of pellets and increased amount secondary hematite [12]. Therefore, BF flue dust added pellets show good pellets properties indurated at 1280◦C for 10 min (RI: 82.5 %, RDI: 36%, A.P: 27.5% and SI: 12.0%). The industry usually accepts RDI lower than 28 % and RI higher than 65 % for better blast furnace operation.

Table 3.2 Percentage of apparent porosity with different induration temperature for 1.5 % carbon

Induration Temp ,C	Apparent porosity (%)		
	CA pellets	JCA pellets	BFA pellets
1000	34	32.6	34.6
1100	32	31	33
1200	31	30	31
1250	29.8	28.5	29
1280	26.7	28	27.5

The industry usually accepts the lower value of RDI. The higher reducibility of iron oxide pellets is important for improving gas utilization and extent of indirect reduction is possible inside blast furnace operation.

4. Conclusions

1. Properties of green pellets such as green compressive, dry Compressive Strength and drop number are within acceptable limits.
2. The cold compressive strength (CCS) of pellet increases with induration temperature (600 to 1280 ◦C)
3. BF flue dust added pellet shows highest CCS among all the pellets. The average value of CCS of BF flue added pellets is 2515 N /pellet at induration temperature of 1280◦C for 10 min.
4. The reducibility index (RI) and reduction degradation index (RDI) of pellet decreases with increasing the carbon content for CA, JCA and BFA pellets
5. The carbon in pellet helps in reducing the induration temperature, which lowers the external energy requirements for induration pellets.

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