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Note

DRI Apparent Density and Its Strength

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1. Introduction

Now a days DRI (directly reduced iron) is a well known raw material to substitute scrap in EAF,[1,2] as a coolant in LD[3,4] steel and as a potential metallic feed in blast furnace. The strength of DRI made at present is sufficient for EAF use. The DRI if used in the blast furnace has to be strong enough to sustain impact (while dropping from top), wear (while sliding down the blast furnace) and also during the course of reduction to sustain the weight of over burden retaining its shape and size. Several workers[5,6] have suggested the possible use of DRI as a feed to the blast furnace if it could be produce with high strength.

The apparent density of DRI depends on the amount of metallic iron, gangue content and volume of pores, which are regulated by DRI analysis and reduction conditions (temperature, sinter time, mode of reduction *etc*.). In this study effort has been made to correlate the cold crushing strength (CCS) of DRI with its apparent density.

2. Experimental

In this investigation two different types of DRI were tested which included the iron ore pellets reduced in the bed of carbonaceous reductants and iron ore reduced by carbon

Table 1. The cold crushing strength (CCS) values of various reduced pellets.

Reduction Temperature, ^{0}C	Sinter Time, min	Pellets Reduced in Bed of Carbonaceous Reductants			Ore – Carbon Mixed Pellets		
		Code	Apparent Density, g/cm^3	CCS, N	Code	Apparent Density, g/cm^3	CCS, N
1000	0	OG_1	2.96	635			
1100	0	OG_2	3.32	635			
1150	0	OG_3	4.11	2155			
1200	0	OG_4	4.08	2205			
1250	0	OG_5	4.18	2845			
1250	5	OG_6	4.16	3140			
1250	10	OG_7	4.70	3335			
1250	15	OG_8	4.68	3530			
1250	20	OG_9	4.61	3480			
1250	25	OG_{10}	5.13	3385			
1000	0	OP_1	2.36	120	MP_1	0.41	145
1100	0	OP_2	1.98	540	MP_2	0.46	195
1150	0	OP_3	2.75	1325	MP_3	1.67	685
1200	0	OP_4	3.10	2600	MP_4	2.60	1665
1250	0	OP_5	3.23	3435	MP_5	2.82	1665
1250	5	OP_6	4.22	3630	MP_6	2.71	1865
1250	10	OP_7	4.05	3970	MP_7	3.17	2160
1250	15	OP_8	4.43	3580	MP_8	3.24	2650
1250	20	OP_9	4.87	3090	MP_9	3.54	3430
1250	25	OP_{10}	4.97	3185	MP_{10}	3.09	3040
1000	0	OC_1	p	NL	MC_1	p	NL
1100	0	OC_2	1.73	245	MC_2	p	NL
1150	0	OC_3	2.06	245	MC_3	0.91	295
1200	0	OC_4	2.30	390	MC_4	1.36	390
1250	0	OC_5	3.48	590	MC_5	2.30	540
1250	5	OC_6	2.99	930	MC_6	3.00	685
1250	10	OC_7	3.52	1420	MC_7	3.40	1225
1250	15	OC_8	3.79	1470	MC_8	3.42	1715
1250	20	OC_9	3.21	1665	MC_9	4.74	1765
1250	25	OC_{10}	3.53	1420	MC_{10}	3.51	1225
1000	0	OW_1	p	NL	MW_1	p	NL
1100	0	OW_2	p	NL	MW_2	p	NL
1150	0	OW_3	3.05	145	MW_3	1.12	100
1200	0	OW_4	2.30	145	MW_4	1.81	345
1250	0	OW_5	3.30	930	MW_5	1.90	470
1250	5	OW_6	3.48	1715	MW_6	2.48	980
1250	10	OW_7	3.77	2010	MW_7	3.53	1050
1250	15	OW_8	4.26	2795	MW_8	2.58	1620
1250	20	OW_9	4.48	3090	MW_9	4.59	2040
1250	25	OW_{10}	4.25	3090	MW_{10}	4.17	1080

OG, OP, OC, and OW: Iron Ore Pellets Reduced In Bed of graphite, petroleum coke, china coke and wood char respectively, MP, MC, and MW: Iron Ore – reductant mixed Pellets,(P= petroleum coke, C=china coke and W=wood char respectively, (Suffix numerals indicate pellet number), p = powder, NL: No Load

mixed in the pellets. Raw materials used, method of pellet preparation and techniques of reducing pellets have been given in another publications by the authors.[7,8)]

2.1. Determination of Apparent Density of Reduced Pellets

The apparent density of the reduced pellets were calculated as

$$\text{Apparent density} = \frac{\text{Final weight of the reduced pellet}}{\text{Final bulk volume of the reduced pellet}} \times 100$$

The bulk volume of the reduced pellets was estimated by knowing the average diameter measured at 20 different positions.

2.2. Cold Crushing Strength of Reduced Pellets

Instron testing machine was used to determine the Cold Crushing Strength (CCS) of the reduced pellets using 4 900 N maximum load scale. The pellets were loaded ($0.0083\ \text{mm}\,\text{s}^{-1}$) slowly till it yielded. The minimum load required for breakage or deformation of the pellet was recorded as Cold Crushing Strength (CCS) in N.

3. Results and Discussion

The iron ore pellets were reduced at various temperatures (1 000 to 1 250°C) and sintered for various times (0–25 min). The iron ore was reduced by different reductants (graphite, petroleum coke, china coke and wood char). The reduction was conducted by adopting two methods (in-bed and mixed). The in-bed method consisted of keeping iron ore pellet in the bed of reductant where as in mixed mode the reductant was mixed with iron ore and palletized. The composition of iron ore and reductants together with reduction of iron ore pellet in-bed and mixed mode are given in our another publications.[7,8)] The apparent density and cold crushing strength of reduced pellets are given in **Table 1** along with reducing conditions.

3.1. Apparent Density of Reduced Pellets on Cold Crushing Strength

Figures 1 and **2** shows the CCS values of pellets reduced in the bed of carbon and ore–carbon mixed pellets with their apparent densities. It may be noted that with increasing apparent density the CCS values are found to increase for pellets reduced under both modes. It may be further noted that the pellets reduced under in-bed mode gave stronger pellets (3 925 N) at high density ($5\ \text{g/cm}^3$) compared to pellets reduced under mixed mode (2 450 N CCS at $5\ \text{g/cm}^3$ density).

The density of DRI would increase with metallisation of iron and its densification promoted by higher temperature and sintering time. The slower reduction rate giving plate iron would give high iron density and high CCS value due to better metal–metal bond. The fiber iron growth would give low density and low CCS value due to less

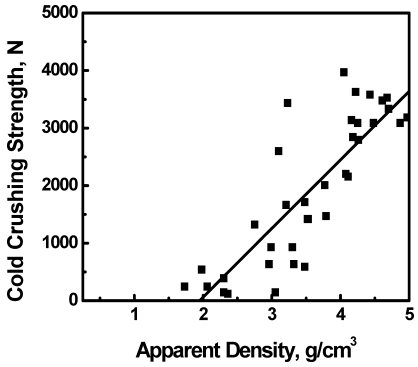

Fig. 1. Effect of apparent density of pellets reduced in bed of reductants on cold crushing strength (CCS).

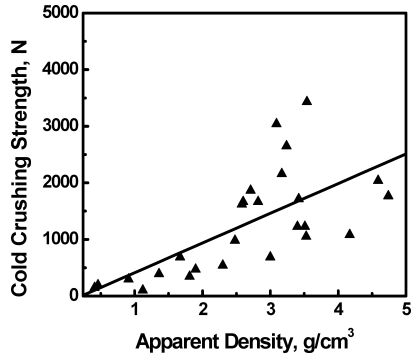

Fig. 2. Effect of apparent density of reduced iron ore–carbon mixed pellets on cold crushing strength (CCS).

metal–metal bond. This explains the increasing CCS value with high density for DRI reduced in bed of carbon. When the reductant is mixed with iron ore to cause reduction the ash present in the reductant increases the total gangue content in reduced iron. The metal–slag bond being weaker than metal–metal bond, the CCS values of DRI exhibiting mixed bond are found to be lower in strength than ore pellet reduced in bed of carbon showing metal bond.

4. Conclusion

(1) The cold crushing strength of reduced pellet was found to increase with its apparent density.

(2) The pellets reduced in-bed of carbon rendered higher CCS value (~3 920 N) compared to pellets reduced under mixed mode (~2 450 N) for DRI with apparent density $5\ \text{g/cm}^3$.

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