CHAPTER 5

Smelting Reduction

(Experimental III)

The fifth chapter deals with the analysis of experimental data generated on smelting reduction of the composite pellets made from upgraded waste. The dissolution behaviour of the individual pellet as well as bulk dissolution of the pellets are discussed in terms of yield and other output of the smelting reduction.

5.1 Smelting Reduction

The need for an alternate ironmaking technology arises out of the demand to conserve the depleting reserves of good quality coking coal, to make use of non-coking coal reserves dispersed across the country and to take advantage out of large price differences between imported metallurgical coal and non-coking coal. The scenario forced innovators to look for alternative coal-based iron production routes[95]. In order to overcome the above, scientist and technologists have been working for quite sometime specially in the second half of last century to develop suitable process of ironmaking, called smelting reduction (SR) process, using non-coking coals and iron ore[15]. Smelting reduction technology was conceived in late 1930s. The development of SR processes goes back to 1950s. The laboratory scale fundamental studies on the smelting reduction of iron ore were started first by Dancy in 1951[97]. However, serious efforts started from 1980 onwards. In late 1950s and earlyl960s, steel manufacturers were interested in developing a technology that could convert iron ore into crude steel in just one step. In late seventies and early eighties, concerted efforts were made in many parts of the world to develop a process of making liquid iron similar to blast furnace using non-coking coal[15]. In recent years, about twenty smelting reduction processes have been under development throughout the world. The basic principle of a SR process is to melt the pre-reduced iron ore/sinter/pellets with non-coking coal and oxygen or hot blast in a reactor. The aim of all the SR processes is to consume the least amount of coal and oxygen to make the process fuel-efficient [97].Smelting reduction technology is a coal-based ironmaking process and thus different from the conventional coke based blast furnace technology. Smelting reduction is a generic name for a gamut of oxy-coal liquid ironmaking technologies each of which have characteristic process features. The terms smelting reduction refers to a process where reduction of iron ore is carried out at high temperature to obtain liquid iron using non-coking coal and oxygen with a substantial part of the reduction taking place in the liquid oxide phase. In most smelting reduction processes, a certain fraction of oxygen is removed by solid state reaction and the rest is removed in the liquid state. Ideally, a SR process should have near 100 pct reduction of iron oxides in the liquid state in one step in a single reactor, SR technology exploits the principle that coal can be gasified in a bath of molten iron. The primary objective of all SR processes is to overcome the existing problems of BF and DRI technologies [15]. The basic approach is to produce liquid iron in a reactor using molten bath where iron-bearing materials are reacted with non-coking coal and oxygen to produce liquid hot metal.

5.2 Induction Furnace

5.2.1 Principle

Induction melting furnace is basically a transformer in which the primary side is the furnace coil through which the current flows; and the charge, being melted and/or superheated, acting as short circuited secondary. Due to the electrical current passing through the power coil eddy current is induced in the charge, which generates heat within the charge. There is no need of heat transfer to the charge because heat is generated within the charge itself. Therefore, there is no limit of the maximum attainable temperature except that imposed by the material of the rammed crucible and the metallurgical behaviour of metal-slag-lining interaction. It is, therefore, very likely to excessively superheat the melt, if the furnace operators are not vigilant enough. From the standpoint of thermal engineering, an induction furnace is a nearly perfect system, since the heat is generated in the place where it is to be consumed [121].

The coreless induction furnace consists of a refractory container, capable of holding the molten bath, which is surrounded by water-cooled helical coil connected to a source of alternating current. Induction heating is the heating of an electrically conducting object immersed in a varying magnetic field. An alternating electromagnetic field induces eddy currents in the metal thereby electrical energy gets converted to heat. The quantity of heat evolved depends on the resistivity of the charge. The object being heated may not be a magnetic material to heat efficiently. All that is required is that it should have reasonably good electrical conductivity. In coreless induction furnaces, lines of magnetic force close through the air, which offers a large resistance to their passage and thus significantly reduces the useful magnetic fluxes[122].

The electromotive force (E) of induction is calculated as follows[54]:

$$E = 4.44\ \Phi_{max}.\ f.\ n.\ 10^{-8}\ \text{volt} \qquad \ldots(5.1)$$

where Φ_{max} = magnetic flux density,

f = alternating current frequency,

n = number of the inductor turns.

If Φ_{max} drops, the required electromotive force of induction can be retained by increasing current frequency.

The depth of the surface layer of a metallic charge, where the density of induced current is large, is called penetration depth. The heat required to melt the charge is developed mainly in that layer. The penetration depth (h_p) may be as follows:

$$h_p = 5.03 \text{ x } 10^3 \sqrt{\left(\frac{\rho}{\mu f}\right)}\ \text{cm} \qquad \ldots(5.2)$$

where ρ = resistivity of the charge, ohm.cm,

μ = magnetic permeability,

f = frequency, Hz.

Large furnaces require lower frequency than smaller ones. The energy (w) that is transformed into heat in the charge is as follows:

$$w = I^2\ n^2\ 2\pi^2\left(\frac{d}{h}\right) \sqrt{(\rho\mu f.\ 10^{-9})}\ \text{watt} \qquad \ldots(5.3)$$

where I = current in the inductor, ampere,

d = mean diameter of crucible, cm,

h = depth of metal in the crucible, cm.

The product (In) is called *ampere-turns*. The energy that is transformed into heat in the charge is proportional to the square ampere-turns and to the square root of resistivity and frequency.

5.2.2 Advantages of Induction Furnace

Melting in induction furnace offers the following advantages[123]:

i) Induction furnaces have high flexibility in which even a small quantity of metal of any composition can be melted. The furnace can be started with the cold charge and no molten hot heelis required. The melting process is also quite simple.

ii) The induction furnaces have an extremely high rate of melting. The melting time is generally about one hour due to higher power to charge ratio.

iii) The control of temperature is very easily and quickly obtained within a wide range.

iv) Highly alloyed steels can be melted without appreciable loss of alloying elements. The actual metallic yield of liquid steel from scrap is also exceptionally good.

v) Clean atmosphere in the furnace during melting leads to efficient control of composition.

vi) The electromagnetic forces acting on the melt cause an intensive bath movement that gives efficient stirring action and homogenize the melt.

vii) High quality metal and alloys, free of hydrogen and nitrogen, can be produced by this method.

viii) Operating costs are lower because of low refractory consumption, low power consumption, absence of electrodes, better heat utilization, and shorter melting time.

ix) Requires less floor space and relatively free from pollution.

5.2.3 Laboratory Induction Furnace

A laboratory induction furnace at Metallurgical and Materials Engineering Department of M. S. University of Baroda (Make: Inductotherm India) having 15 kW power rating and 6 kg melt capacity is shown in Figure 5.1. The unit operates on 460 V, three-phase, 50 Hz, 20 kVA power source with an output of 9600 Hz. It is a variable induction power (VIP) furnace having two types of water cooling system: i) a closed loop internal system which circulates demineralized water and includes the heat exchanger, and ii) an external water system which provides water to cool shell and heat exchanger of the internal system and also the furnace coil.

The furnace bottom was properly leveled with alumina ramming mass. The gap between glass wool and steel former was filled by dry alumina ramming mass. Ramming was done manually. The graphite crucible was filled with steel scrap as charge material and then putting to the induction furnace for melting.

Fig. 5.1: Laboratory Induction Furnace

5.3 Mould Preparation

Sand mould was prepared before the heat. Green sand and bentonite (2 pct) were mixed thoroughly in muller with approximately 9 pct water to prepare the moulding sand. Cope and drag portion of the mould box was first filled with the moulding sand and then ramming was done. Vertical mould cavities were made by piercing cylindrical wooden rods in the rammed moulding sand. Venting was done to facilitate the easy escape of gases generated during casting. Moulds were thoroughly dried by oil fired burner before pouring of liquid metal.

5.4 Smelting Reduction of Composite Pellet in Induction Furnace

Smelting reduction of waste-coal composite pellets was carried out in a laboratory induction furnace at Metallurgical and Materials Engineering Department of M. S. University of Baroda. The experiments were designed to investigate i) dissolution behaviour of composite pellets in molten bath, and ii) bulk dissolution of composite pellets in molten bath to produce steel/cast iron and to assess the recovery of iron.

5.4.1 Dissolution Behaviour of Composite Pellet

Initially the furnace crucible was filled with mild steel scrap. Before switching on the furnace, the demineralized water circulation through heating coil and induction panel was set on. The crucible was filled with steel scrap and furnace was switched on with initial power supply of 4 to 5 kWh and gradually raised to 10 kWh. Within half an hour the steel scrap was melted and chemically homogenization took place. Sample of liquid metal was taken for analysis. Now liquid metal bath was ready to receive the composite pellet. To study the dissolution behaviour of composite pellets in molten bath, a single composite pellet was put in the molten bath and was visually observed that how the composite pellet dissolved in the molten bath and the time required for complete dissolution was noted. This was repeated several times. It was observed that the16-17 mm diameter composite pellets completely dissolved in the molten bath at an average 27 seconds.

5.4.2 Bulk Dissolution of Composite Pellets

Table 5.1 shows the variables for smelting reduction of composite pellets in induction furnace. The experiments were carried out to observe the bulk dissolution of composite pellets in molten bath to produce steel/cast iron and to assess the recovery of iron (in terms of yield). Initially the furnace crucible was filled with mild steel scrap. The switching on the furnace as described earlier, within half an hour the scrap melted and formed molten bath i.e. hot heel. A small amount of liquid molten metal, as sample, was collected for initial chemical analysis of the melt. Composite pellets were charged in small batches to hotheel. Preheating of pellets took place due to the radiation from hotheel and subsequently reduction and dissolution of pellets occurred in hotheel. Some amount of lime powder was added for easy slag formation. After complete dissolution of pellets and slag-off, the liquid molten bath was allowed to homogenize for some time. The fluidity of molten metal increased with time which led to the homogenization of bath due to convective stirring within liquid molten bath. Slag was removed with the help of steel (TMT) rod. Liquid molten metal was poured in earlier prepared sand mould. The casting was knocked out after solidification and samples were cut for chemical analysis and testing.

Recovery of iron (i.e. yield) was calculated as follows:

Iron yield (%) = $\frac{\textit{Iron present in product x 100}}{\textit{Total iron present in the charge}}$

$$= \frac{\textit{Total iron in output as cast sample x } 100}{\textit{Total iron from scrap} + \textit{Iron from composite pellet} + \textit{Iron from starring rod}}$$

$$= \frac{(W_5 \; x \; F_6) \; x \; 100}{\{[(W_1 - W_2) \; x \; F_1] + (W_3 \; x \; F_2 \; x \; F_3 \; x \; F_4) + (W_4 \; x \; F_5)\}} \qquad \text{...(5.4)}$$

Where W_1 = Weight of MS scrap, kg

W_2 = Weight of sample taken for chemical analysis before pellet addition

F_1 = Fraction of Fe present in initial melt

W_3 = Weight of composite pellets charged, kg

F_2 = Fraction of iron oxide present in composite pellets

F_3 = Fraction of purity of iron oxide

F_4 = Fraction of Fe present in iron oxide (i.e. 112/160 = 0.7)

W_4 = Weight of TMT rod dissolved during stirring the melt, kg

F_5 = Fraction of Fe present in TMT rod

W_5 = Weight of product, kg

F_6 = Fraction of Fe present in product

Table 5.1: Variables for Smelting Reduction of Composite Pellets

Sr. No.	Variable	Number	Remarks
1	Steel plant Waste pellet	3	JSW Dust, JSW Sludge, VIZAG Sludge
2	Steel Scrap	1	From Local Market
3	Percentage of Pellets charged	4	5%, 10%, 15%, 20%
4	Fe_{tot}/C	1	3.11 (as per stoichiometry)

5.5 Chemical Analysis Using Optical Emission Spectrometer (OES)

Chemical analysis was done by Optical Emission Spectrometer (OES) at Metal Heat Treaters, V U Nagar, GIDC Anand. When a metallic element is excited by an electrical arc or spark, every element present in sample emits light in form of wavelengths that are specific for that element; this is the basic principle of OES. The emitted light passes through a narrow vertical slit and is dispersed with a grating or prism. The location and intensity of the spectral lines produced by the samples are compared with the lines produced by suitable standard samples of known composition. Emission spectrographic technique can be applied to almost every type of sample[108]. The final steels produced using composite pellets of dusts/sludge (after beneficiation) in induction furnace were tested for its composition by Optical Emission Spectrometer.

Tables 5.2 and 5.3 show the chemical analysis of all initial samples (i.e. homogenized molten bath) and chemical analysis of products. Table 5.4 shows chemical composition of TMT rod.

Table 5.2: Chemical Analysis of All Initial Samples

Heat No.	pct									
	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Fe
1B	0.457	0.187	0.431	0.0154	0.017	0.0331	0.0046	0.0384	0.0088	98.7
2B	0.459	0.19	0.491	0.0149	0.0162	0.0339	0.0041	0.046	0.0052	98.6
3B	0.23	0.112	0.524	0.0139	0.0183	0.0337	0.0144	0.0397	0.0049	98.5
4B	0.2	0.042	0.15	0.038	0.047	0.078	0.011	0.053	0.00083	98.9
5B	0.326	0.189	0.314	0.0185	0.0377	0.0389	0.0281	0.0444	0.0191	98.3
6B	0.243	0.0755	0.399	0.0169	0.0196	0.0337	0.0044	0.0394	0.0051	99.0
7B	0.238	0.194	0.478	0.0135	0.0192	0.0405	0.0108	0.041	0.0572	98.5
8B	0.16	0.036	0.13	0.026	0.038	0.059	0.012	0.042	0.00074	98.7
9B	0.418	0.183	0.285	0.017	0.0257	0.0361	0.0076	0.0463	0.0081	98.7
10B	0.316	0.0829	0.347	0.0117	0.0139	0.036	0.0042	0.0418	0.003	99.0
11B	0.306	0.672	0.649	0.0147	0.0425	0.0301	0.0297	0.037	0.0746	97.2
12B	0.17	0.019	0.096	0.029	0.043	0.075	0.019	0.044	0.001	98.9

Table 5.3: Chemical Analysis of All Final Products

Heat No.	pct									
	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Fe
1A	1.29	0.107	0.527	0.0263	0.0199	0.0376	0.0056	0.0362	0.0027	97.8
2A	1.45	0.0163	0.294	0.0389	0.0332	0.0473	0.0054	0.0439	0.0028	98.0
3A	0.97	0.0544	0.24	0.0201	0.0174	0.0334	0.0054	0.0428	0.0021	98.5
4A	3.44	0.88	0.66	0.085	0.084	0.1	0.009	0.045	0.021	94.1
5A	1.45	0.268	0.865	0.0416	0.0256	0.0387	0.0061	0.0329	0.0113	97.1
6A	1.32	0.0335	0.218	0.0233	0.0196	0.0313	0.0046	0.0362	0.0024	97.8
7A	1.45	0.0364	0.314	0.0345	0.0447	0.113	0.007	0.0377	0.0024	97.8
8A	2.59	0.02	0.1	0.047	0.069	0.074	0.009	0.039	0.002	96.5
9A	1.43	0.133	0.38	0.0445	0.0545	0.0428	0.0073	0.0415	0.0018	97.7
10A	1.23	0.0523	0.328	0.0312	0.0291	0.0473	0.0509	0.0447	0.0033	98.0
11A	1.45	0.503	0.585	0.0332	0.0241	0.0859	0.0078	0.0427	0.0141	97.1
12A	1.97	0.039	0.17	0.058	0.15	0.091	0.015	0.04	0.00055	96.9

Table 5.4: Chemical Composition of TMT Steel Rod

Analytes	Fe	C	Mn	S	P	Cr	Al	Cu	Si
pct	98.31	0.19	0.79	0.02	0.043	0.15	0.16	0.09	0.21

5.6 Results of Bulk Dissolution of Composite Pellets

5.6.1 JSW Dust

Table 5.5 and 5.6 show the chemical analysis of initial samples and products for JSW Dust composite pellets. Details of weight taken at every stage in smelting reduction of JSW dust composite pellets is shown in Table 5.7. Table 5.8 shows carbon (in product) and iron yield variation with addition of JSW dust composite pellet. Figures 5.2 and 5.3 shows variation of carbon (in product) and iron yield with addition of JSW dust composite pellets.

Table 5.5: Chemical Analysis of Initial Melts for JSW Dust Composite

Heat No.	pct									
	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Fe
1B	0.457	0.187	0.431	0.0154	0.017	0.0331	0.0046	0.0384	0.0088	98.7
2B	0.459	0.19	0.491	0.0149	0.0162	0.0339	0.0041	0.046	0.0052	98.6
3B	0.23	0.112	0.524	0.0139	0.0183	0.0337	0.0144	0.0397	0.0049	98.5
4B	0.2	0.042	0.15	0.038	0.047	0.078	0.011	0.053	0.00083	98.9

Table 5.6: Chemical Analysis of Products for JSW Dust Composite

Heat No.	pct									
	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Fe
1A	1.29	0.107	0.527	0.0263	0.0199	0.0376	0.0056	0.0362	0.0027	97.8
2A	1.45	0.0163	0.294	0.0389	0.0332	0.0473	0.0054	0.0439	0.0028	98
3A	0.97	0.0544	0.24	0.0201	0.0174	0.0334	0.0054	0.0428	0.0021	98.5
4A	3.44	0.88	0.66	0.085	0.084	0.1	0.009	0.045	0.021	94.1

Table 5.7: Details of weight taken at every stage in smelting reduction of JSW dust composite

HEAT No.	Weight of MS Scrap(W_1), Kg	Weight of Composite charged (W_3), Kg	Weight of product (W_5), Kg	Weight of sample taken for chemical analysis (W_2), Kg	Weight of TMT rod dissolved during stirring (W_4), Kg	Weight of slag produced, Kg
1	1.986	0.1045	2.036	0.028	0.223	0.066
2	1.94	0.2154	1.984	0.056	0.03	0.055
3	1.696	0.2993	1.965	0.087	0.344	0.1
4	1.38	0.344	2	0.062	0.711	0.064

Table 5.8: Carbon (in Product) and Iron yield variation with composite pellet charged for JSW dust

Heat No.	**Pellet Charged, pct**	**Carbon, pct**	**Iron yield, pct**
1	5.26	1.29	90.66
2	11.10	1.45	98.23
3	17.65	0.97	94.44
4	24.93	3.44	87.58

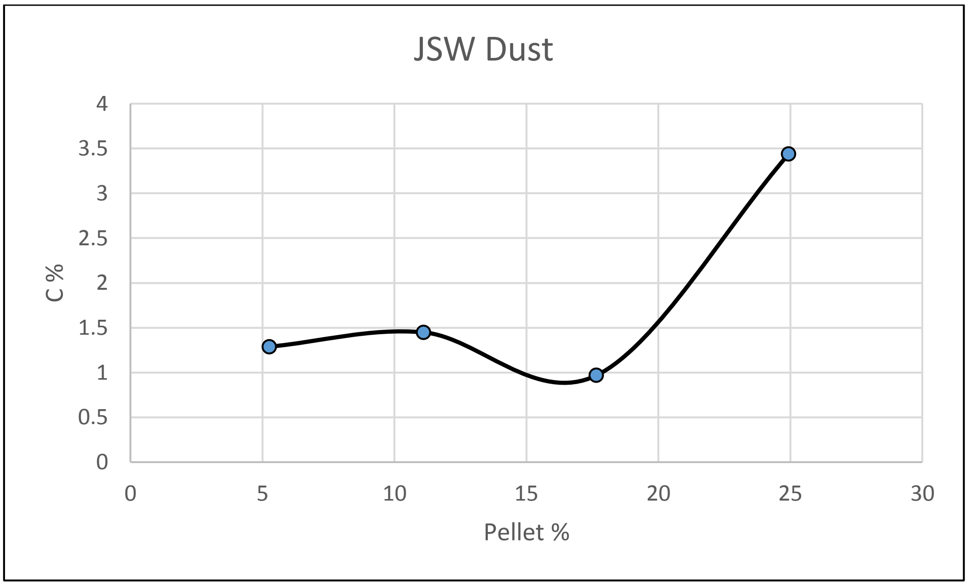

Fig. 5.2: Carbon (in product) variation with addition of JSW Dust composite pellet

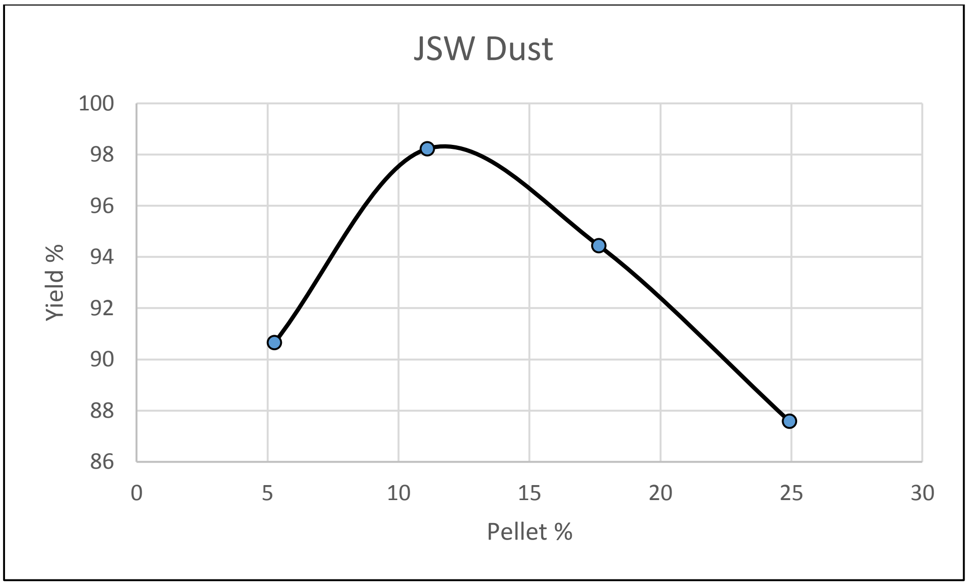

Fig. 5.3: Iron yield variation with addition of JSW Dust composite pellet

5.6.2 JSW Sludge

Table 5.9 and 5.10 show the chemical analysis of initial samples and products for JSW Sludge composite pellets. Details of weight taken at every stage in smelting reduction of JSW Sludge composite pellets is shown in Table 5.11. Table 5.12 shows carbon (in product) and iron yield variation with addition of JSW Sludge composite pellet. Figures 5.4 and 5.5 shows variation of carbon (in product) and iron yield with addition of JSW sludge composite pellets.

Table 5.9: Chemical Analysis of Initial Melts for JSW Sludge Composite

Heat No.	pct									
	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Fe
5B	0.326	0.189	0.314	0.0185	0.0377	0.0389	0.0281	0.0444	0.0191	98.3
6B	0.243	0.0755	0.399	0.0169	0.0196	0.0337	0.0044	0.0394	0.0051	99
7B	0.238	0.194	0.478	0.0135	0.0192	0.0405	0.0108	0.041	0.0572	98.5
8B	0.16	0.036	0.13	0.026	0.038	0.059	0.012	0.042	0.00074	98.7

Table 5.10: Chemical Analysis of Products for JSW Sludge Composite

Heat No.	pct									
	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Fe
5A	1.45	0.268	0.865	0.0416	0.0256	0.0387	0.0061	0.0329	0.0113	97.1

6A	1.32	0.0335	0.218	0.0233	0.0196	0.0313	0.0046	0.0362	0.0024	97.8
7A	1.45	0.0364	0.314	0.0345	0.0447	0.113	0.007	0.0377	0.0024	97.8
8A	2.59	0.02	0.1	0.047	0.069	0.074	0.009	0.039	0.002	96.5

Table 5.11: Details of weight taken at every stage in smelting reduction of JSW Sludge

HEAT No.	Weight of MS Scrap(W_1), Kg	Weight of Composite charged (W_3), Kg	Weight of product (W_5), Kg	Weight of sample taken for chemical analysis (W_2), Kg	Weight of TMT rod dissolved during stirring (W_4), Kg	Weight of slag produced, Kg
5	1.99	0.105	2.046	0.016	0.130	0.092
6	1.906	0.216	2.000	0.034	0.125	0.148
7	1.89	0.333	2.333	0.052	0.420	0.168
8	1.38	0.344	1.643	0.039	0.256	0.13

Table 5.12: Carbon (in Product) and Iron yield variation with composite pellet charged for JSW Sludge

Heat No.	Pellet Charged, pct	Carbon, pct	Iron yield, pct
5	5.28	1.45	93.95
6	11.33	1.32	94.31
7	17.62	1.45	96.12
8	24.93	2.59	91.51

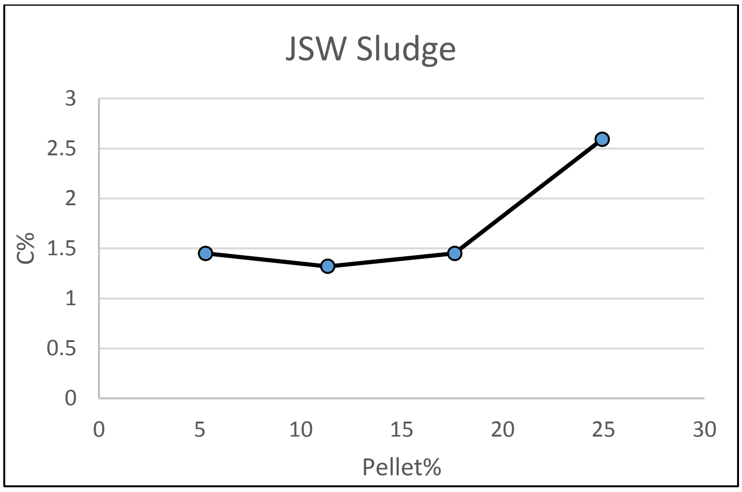

Fig. 5.4: Carbon (in product) variation with addition of JSW Sludge composite pellet

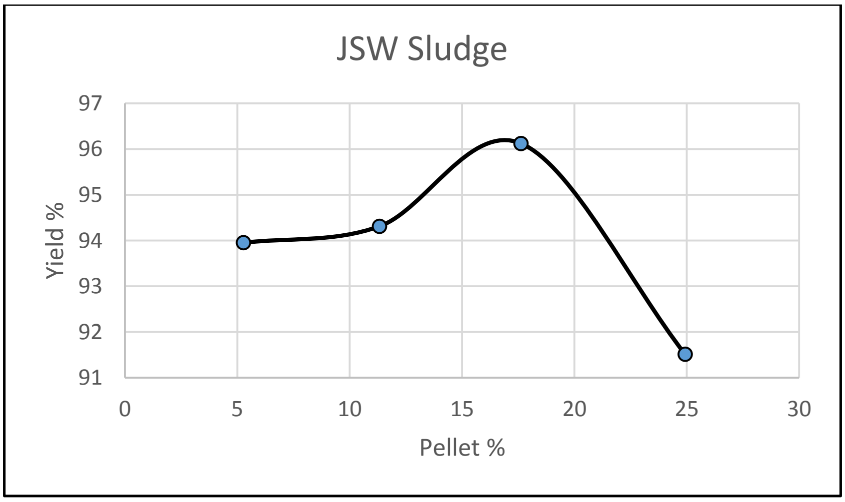

Fig. 5.5: Iron yield variation with addition of JSW Sludge composite pellet

5.6.3 **VIZAG Sludge**

Table 5.13 and 5.14 show the chemical analysis of initial samples and products for VIZAG sludge composite pellets. of weight taken at every stage in smelting reduction of VIZAG sludge composite pellets is shown in Table 5.15. Table 5.16 shows carbon (in product) and iron yield variation with addition of VIZAG sludge composite pellet. Figures 5.6 and 5.7 shows variation of carbon (in product) and iron yield with addition of VIZAGsludge composite pellets.

Table 5.13: Chemical Analysis of Initial Melts for VIZAG Sludge Composite

Heat No.	pct									
	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Fe
9B	0.418	0.183	0.285	0.017	0.0257	0.0361	0.0076	0.0463	0.0081	98.7
10B	0.316	0.0829	0.347	0.0117	0.0139	0.036	0.0042	0.0418	0.003	99
11B	0.306	0.672	0.649	0.0147	0.0425	0.0301	0.0297	0.037	0.0746	97.2
12B	0.17	0.019	0.096	0.029	0.043	0.075	0.019	0.044	0.001	98.9

Table 5.14: Chemical Analysis of Products for VIZAG Sludge Composite

Heat No.	pct									
	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Fe
9A	1.43	0.133	0.38	0.0445	0.0545	0.0428	0.0073	0.0415	0.0018	97.7
10A	1.23	0.0523	0.328	0.0312	0.0291	0.0473	0.0509	0.0447	0.0033	98
11A	1.45	0.503	0.585	0.0332	0.0241	0.0859	0.0078	0.0427	0.0141	97.1
12A	1.97	0.039	0.17	0.058	0.15	0.091	0.015	0.04	0.00055	96.9

Table 5.15: Details of weight taken at every stage in smelting reduction of VIZAG sludge

HEAT No.	Weight of MS Scrap(W_1), Kg	Weight of Composite charged (W_3) Kg	Weight of product (W_5), Kg	Weight of sample taken for chemical analysis (W_2), Kg	Weight of TMT rod dissolved during stirring (W_4), Kg	Weight of slag produced, Kg
9	2.48	0.131	2.880	0.028	0.510	0.096
10	2.41	0.3225	2.231	0.052	0.200	0.205
11	1.88	0.332	2.608	0.048	0.664	0.068
12	1.37	0.342	1.743	0.063	0.383	0.065

Table 5.16: Carbon (in Product) and Iron yield variation with composite pellet charged for Vizag Sludge

Heat No.	Pellet Charged, pct	Carbon, pct	Iron yield, pct
9	5.28	1.43	94.52
10	13.38	1.23	81.93
11	17.66	1.45	98.33
12	24.96	1.97	93.11

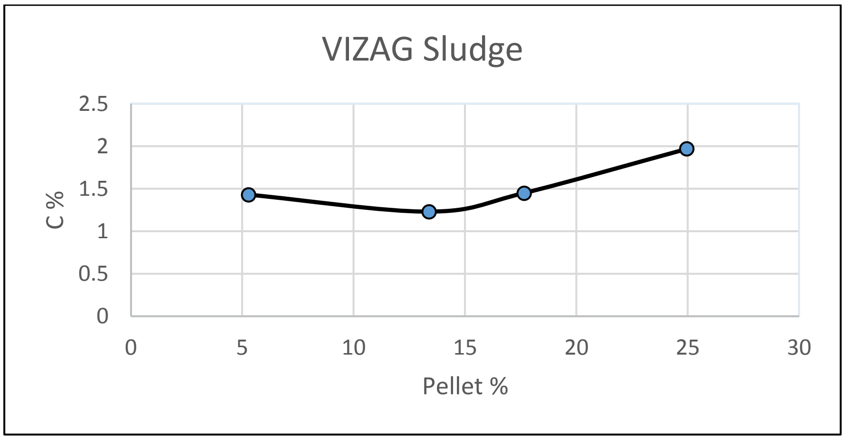

Fig. 5.6: Carbon (in product) variation with addition of Vizag Sludge composite pellet

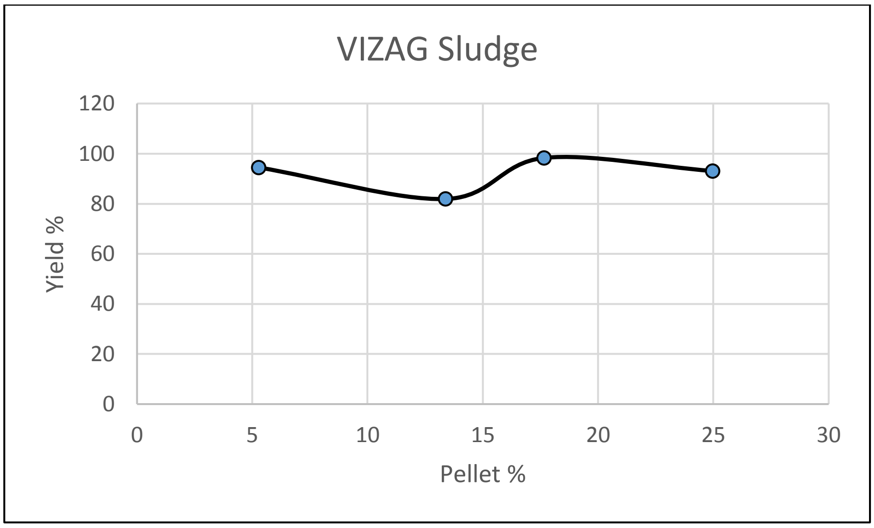

Fig. 5.7: Iron yield variation with addition of Vizag Sludge composite pellet

Figures 5.8 and 5.9 shows comparison of carbon (in product) and iron yield with addition of different composite pellets. Above 20 pct addition of composite pellets to the molten metal formed cast iron, due to higher carbon input along with composite pellets. There was some carbon dissolved from graphite crucible, due to more times were spend for dissolving the total composite pellets. As addition of composite pellets increases, carbon in product also increasing in general. Above 20 pct addition of composite pellets to the molten metal, in general, iron yield decreases due to loss of iron in slag.

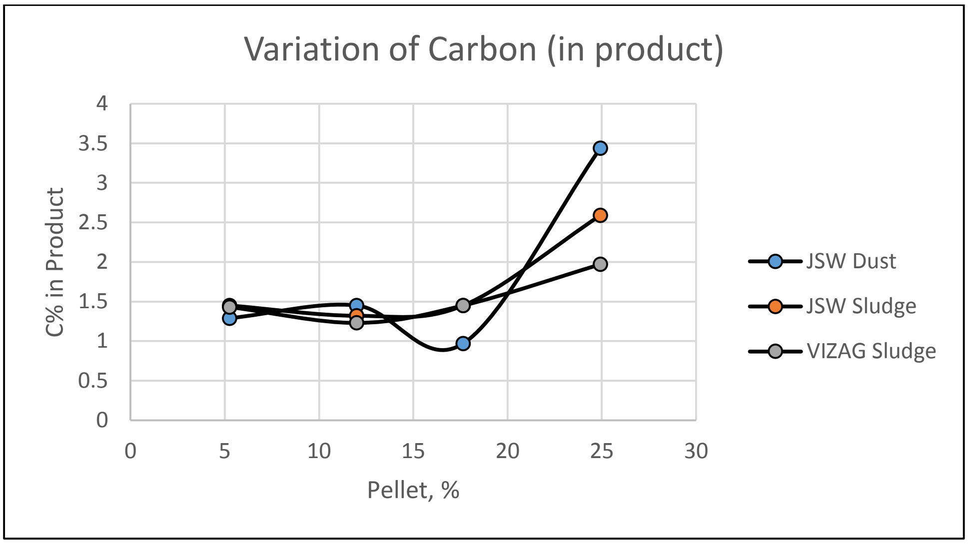

Fig. 5.8: Variation of carbon (in product) with addition of composite pellets

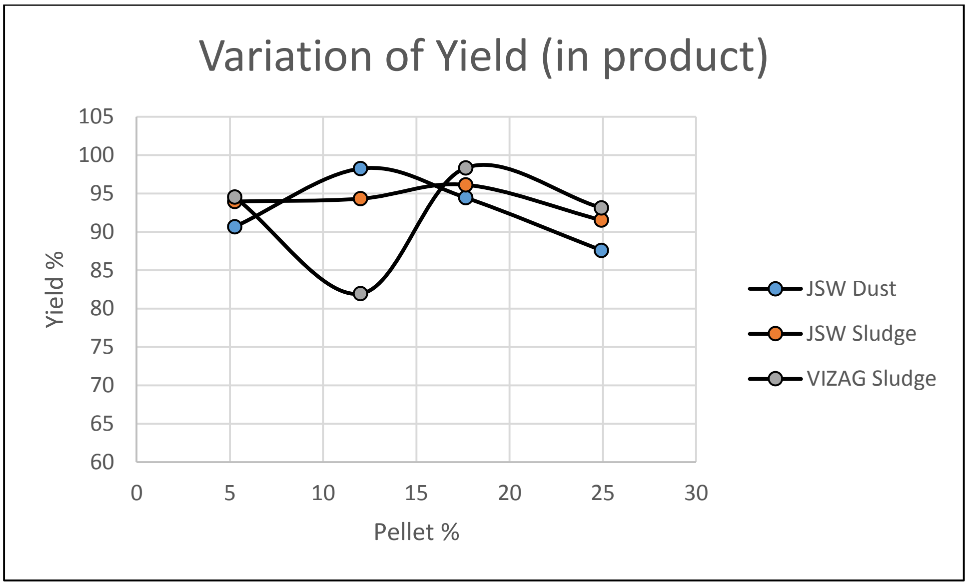

Fig. 5.9: Variation of iron yield with addition of composite pellets

5.7 Microstructure of Products (i.e. Steel/Cast Iron)

The solidified samples were first normalized at 850^0C for1hourand then the microstructural studies were carried out. Microstructure was observed under microscope using 2% NITAL as etchant and 100X magnification. The microstructure of steel/cast iron produced in all 12 heats and few are shown in Figure 5.10 to 5.12.

(a) (b)

Fig. 5.10: Microstructure of product by addition of JSW Dust composite pellet to the melt at (a)5.26 pct, (b) 24.93 pct (100X)

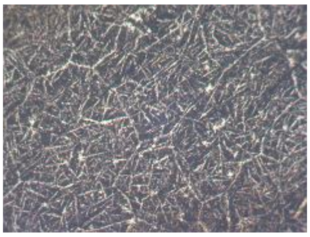

Fig. 5.11: Microstructure of product by addition of JSW Sludge composite pellet to the melt at 11.33 pct (100X)

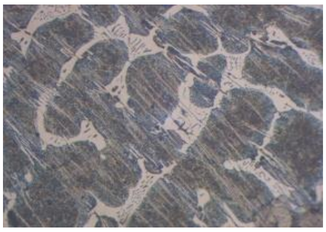

Fig. 5.12: Microstructure of product by addition of Vizag Sludge composite pellet to the melt at 17.66 pct (100X)

Figure 5.10 (a) shows more of pearlite and less of cementite (1.29 pct C) and Figure 5.10 (b) shows more of cementite and some pearlite (3.44 pct C). Figure 5.11 shows cementite at grain boundary and pearlite (1.32 pct C). Figure 5.12 shows more cementite percentage with pearlite (1.45 pct C). The microstructure reveals that as the percentage of composite pellets increases in the molten steel the cementite percentage also increases which is the result of increase in the carbon percentage of steel/cast iron produced.

5.8 Conclusion

1. It was observed that the composite pellets were completely dissolved easily at the molten bath
2. It was also observed that the16-17 mm diameter composite pellets completely dissolved in the molten bath at an average 27 seconds.
3. As addition of composite pellets increased, carbon in product also increasing in general.

4. Above 20 pct addition of composite pellets to the molten metal formed cast iron, due to higher carbon input along with composite pellets. There was also some carbon dissolved from graphite crucible, due to more time were spend for dissolving the total composite pellets.
5. The maximum yields were obtained 98.2 pct, 96.1 pct and 98.3 pct for JSW Dust composite, JSW Sludge composite and Vizag Sludge composite respectively.
6. Above 20 pct addition of composite pellets to the molten metal, in general, iron yield decreased due to loss of iron in slag.

By addition of composite pellets to the molten metal, steel/cast iron can be easily formed