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Investigations into the Circulation Properties of Clinker Produced Combustion Furnace

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Abstract

The journal's goal was to measure the blast furnace slag's flow properties. The final slag obtained from the industry reveals shortness of the slag, while the industrial slag (actual slag from different blast furnace), synthetic slag prepared in the laboratory for pure oxides as obtained from market and iron bearing materials with various extents of reduction resembling that expected to be in the cohesive zone as per literature are chosen for measurement. The iron bearing materials show variation in the characteristics temperature with variation in the extent of reduction; SEM micrograph and XRD plots of the iron bearing material with different extended of reduction reveal compositional changes associated with structural changes. The synthetic slag does not show a clear trained at C/S ratio of 1.04 to 1.09 and 10.4 to 11.01 MgO %.

Keywords: Blast furnace, Cohesive zone, Quality of hot metal, C/S ratio

I. INTRODUCTION

Despite the rapid depletion of coking coal deposits in India and other parts of the world, the blast furnace route of iron manufacture will likely continue to be the primary method for producing pig iron, which will ultimately be transformed into steel. Thus, it is critical to comprehend and research the variables affecting operation efficiency, coke usage, hot metal quality, and, ultimately, the related greenhouse issue[25]. The operation of the blast furnace is based on the idea of countercurrent flow, wherein the rising hot gases, which are mostly nitrogen and reducing gases, meet the falling solid charge. Of course, the temperature, composition, and gas pressure all have a big impact on the process. The coke lumps remain solid and are in charge of maintaining the bed's openness even at the tuyer zone, whereas the majority of the charge material softens and melts at comparatively higher furnace temperatures. Conversely, the melted or softened materials limit the gas flow and alter the bed's permeability, allowing gas to pass exclusively through coke-slits[24]. This causes pressure to drop and has a significant impact on the gas-solid-liquid interface, which in turn affects the rates at which slag metal reacts and, ultimately, the blast furnace process used to make iron. The granular, cohesive, bosh, and hearth zones are among the several zones that can be loosely classified into the blast furnace. It is crucial to consider the cohesive zone when considering gas flow and bed permeability[26]. This zone is underneath the granular zone, where the iron oxide in the ore begins to reduce as a result of upward-moving CO-containing gases. Since "CO," a product of "C" and "O2," does the reduction rather than "C," directly, this reduction is referred to as "indirect reduction.[27]" Unlike the direct reduction, which is endothermic, this reduction is exothermic. It goes without saying that a larger percentage of indirect reduction in the blast furnace would result in less coke being used as a fuel to produce heat. Softening of the iron-bearing materials at the top and flow/liquid mobility of the same at the bottom of the blast furnace define the boundaries of the cohesive zone[23]. Consequently, the cohesive zone should form lower down the furnace in order to prolong the granular zone and increase the proportion of indirect reduction. This indicates that the cohesive zone should be pushed down the furnace by a greater softening temperature of the iron leaving the materials[28].

It stands to reason that a high softening temperature would arise from the current composition, pressure, and temperature conditions. It is crucial to vote in favor of narrowing the cohesive zone after this is accomplished. This implies that the zone's bottom end should advance toward its upper end. That is, the charge's flow temperature ought to be comparatively lower. Once more, the crucial element is the charge's composition as influenced by the current temperature and pressure levels. This reduction in the narrow cohesive zone would shorten the hot metal's traversal distance before it reaches the bosh and slow down the reaction between the ascending gases (which contain SiO) and the descending metal droplets. This would improve the hot metal's quality in comparison to the subsequent steel-making process by delaying the silicon peak[22].

The slag that emerges from the blast furnace is the last slag and does not represent the circumstances that exist in the cohesive zone. On the other side, the cohesive zone slag is unobtainable. Thus, it is possible to artificially generate in the laboratory slag that resembles that found in the cohesive zone, as described in literature, in order to analyze the relevant cohesive zone slag[21].

A review of the literature indicates that there are decreases above sixty percent when the iron-bearing material enters the cohesive zone. A porous iron shell encloses the initial liquid that is produced as a result of the reaction between the reduced iron ore (wustite) and gangue. As this shell descends, it encounters extreme temperature and pressure conditions and also becomes carburized. It collapses under pressure, lowering its melting point and exposing the liquid at its center to the outside world[20].

It is possible to simulate this in a lab setting. Pellets can be made, reduced to varying degrees, and then analyzed to determine the melting/softening point temperature. It is possible to document how composition affects the softening/melting temperature. A study of this kind would shed light on the relationship between the composition and the characteristic temperatures for softening/melting, which in turn may be utilized to affect the production of hot metal quality, the amount of coke consumed, and the process of creating iron[19].

II. EXPERIMENTAL WORK

Flow Characteristics of Blast Furnace Slag

The flow properties of the slag sample are examined using a high temperature microscope.

There are four features of its temperature that need to be examined:

- The softening temperature (ST)
- Temperature hemispherical (HT)
- Temperature of flow (FT)
- Initial deformation temperature (IDT)

The definitions that follow are based on German Industrial Standards 51730. [18]

Experimental Apparatus

- **High Temperature Microscope**

The typical temperatures are recorded using the Heating Microscope technique. Figure 5 displays an image of the Leitz heated microscope. Fig. 2.1 shows the instrument's schematic diagram[9]. The sample, which is a 3 mm cube, is heated in the microscope assembly's electric furnace. A camera records the sample's shape change as a result of heating. To identify the four typical temperatures, a grid-division that is photographed concurrently with the sample and the temperature at which it is being heated is helpful[8].

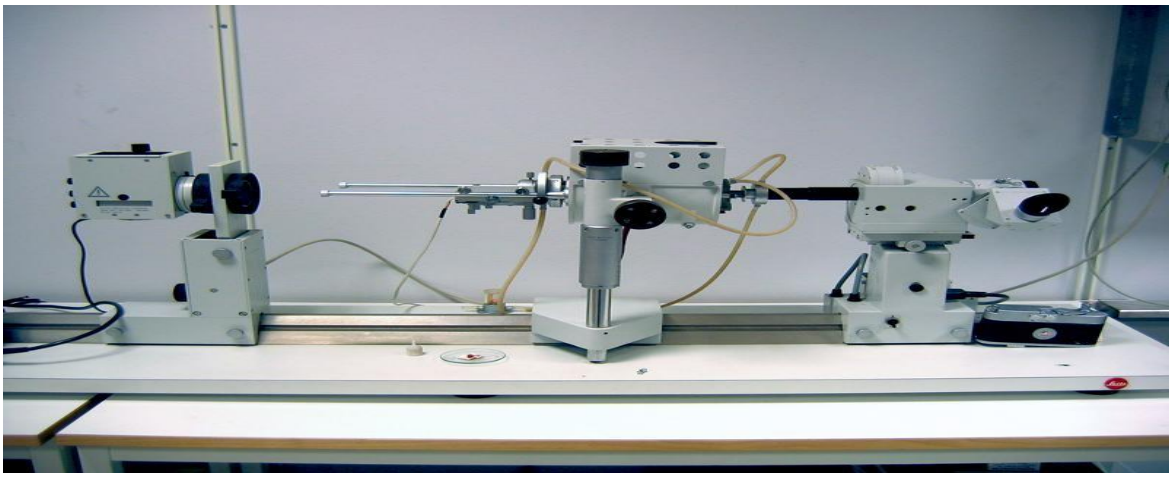
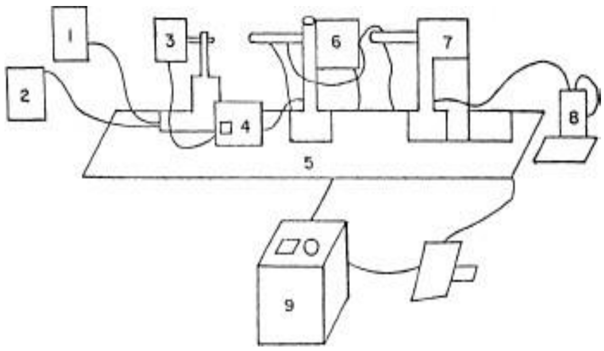


Fig 2.1: Pictorial view of Leitz heating microscope



1. Cooling water tank
2. Cooling water recirculating tank
3. Light source
4. Regulating transformer for light source
5. Optical bench
6. High temperature electrical furnace with specimen carriage
7. Observation and photo microscope
8. Digital thermometer
9. Regulating transformer for high temperature electrical furnace

- **Planetary Ball Mill:-** By producing a high grinding energy, these mills—also known as centrifugal mills—are used to grind samples into a colloidal fineness. A Gilson Company four-stationed planetary mill is shown in Fig. 7[7]. One of the vile is filled with the samples, and as seen, many balls are added. The cover plate is placed over the vile before it is inserted into the machine. The machine operates once the viles are mounted and fastened. The revolving platform is not related to the bowls, and the bowls' rotational direction is opposite that of the platform. The motion is reminiscent of the teacup and saucer found in certain theme parks[6].

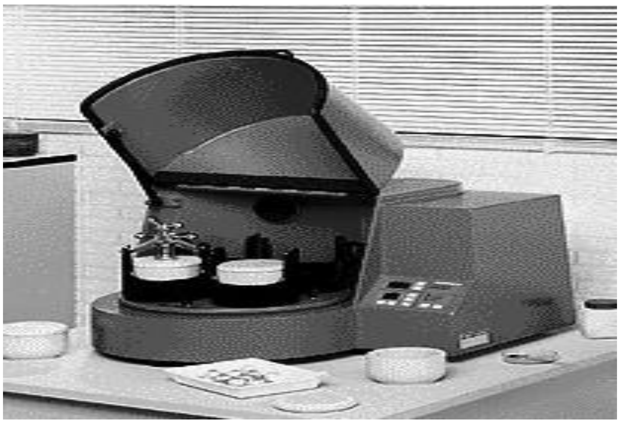


Fig. 2.2 A four station Planetary Ball Mill

The grinding balls are thrown across the vile and strike the opposite walls at extremely high speeds as a result of the centrifugal forces' alternating addition and subtraction[5]. The balls roll halfway through the vile. Planetary action provides a 20g acceleration and a 2/3 reduction in grinding time compared to a basic centrifugal mill[3][4].

- **Abrasion Tester Mixer**

The slag samples are mixed in the Abrasion Testing mixer. The combination of major oxides is placed into a plastic container holding a fixed 25 grams of total weight (containing weighted proportion composition of all the major oxides)[2]. It is possible to combine three of these containers to make 75 grams. Because the mixing needs to be smooth and uniform, weights are taken individually for each 25 g container based on calculations[1].

Fig 2.3: Abrasion Testing Mixer

Next, insert this plastic container into one of the mixer's three revolving chambers. For proper mixing, one lakh revolutions are needed, which is finished in six hours. It takes three of these sessions to thoroughly combine 75 grams. Thus, it takes 6 days to prepare the 145 grams of synthetic slag sample that is needed. This technique results in extremely uniform mixing, giving us fully mixed oxides.

Sintering Furnace:-

In order to bond the slag material by diffusion, the resultant pellets are sintered in a sintering furnace at a temperature of around 1680 degrees Celsius. Firing is done at this temperature because it is the same as the temperature that the slag experiences after exiting the blast furnace. When uniform mixing is achieved, proper firing may be carried out with ease[18]. Two platinum crucibles, each holding a separate slag, are positioned in two crucible holders. So, two slags can be prepared at once. The slag is then progressively brought to room temperature in water while the crucible is placed in various containers after reaching the desired temperature[17].

Figure 2.4: Sintering Furnace

Following burning and quenching, diluted HCl (50 percent water and 50 percent concentrated hydrochloric acid) is used to clean the crucibles. After cleaning, the slags that were adhered to the crucible's walls begin to gel. This process usually takes two days. Because platinum can easily withstand the extremely high temperatures attained during firing and because it is very nonreactive with the slags or the surrounding environment, platinum crucibles are utilized for the process[16].

Pelletizer Machine:-

The entire amount of slag is compressed between the dies under pressure to form pellets in the compression machine with 5-ton loads. As a result, tiny cylindrical pellets are produced, each of which is nearly identical in size[14].

Pelletization is done because the platinum crucibles used in the oxide firing process are very small and cannot hold powdered slag. By compacting the slag into pellets, the slag can be readily placed in the crucibles for the fire process, taking up less room[15].

Figure 2.5: Pelletizer Machine

Experimental Work:-

The goal of the "THREE" phases of the experimental effort is to identify the temperature characteristics of the B.F. slag in order to suggest a composition that would signal narrowing down. Among the three experimental phases are the following[10]:

1. Collecting B.F. slag from different industrial Blast furnaces; study of the flow characteristics and chemical analysis to determine the most desired composition (to ensure a narrow cohesive zone lower down the furnace).
2. In accordance with the first set of experiments, prepare synthetic slag in the lab using pure oxides that can be purchased from the market, mimicking the chemical composition of the slag with the best results (narrow cohesive zone lower down the furnace). Determine the flow characteristics of these synthetic slags and
3. (a) Hemetite pellets are prepared, with the composition varied to approximate that of the first series of trials[11].
   (a) Calculating the cold-set pellets' tumbler index and abrasion index
   (c) Sending the pellets to various reduction experts and
   (d) Characterizing the decreased pellets' flow properties.
   (e) Using XRD analysis to identify the various phases in these pellets.
   (f) Microstructure determination using SEM analysis.

Experimental Result and Discussion:-

PHASE- I INDUSTRIAL SLAGS

The compositional information of the slags from the nation's numerous blast furnaces is provided in Table 1 below.

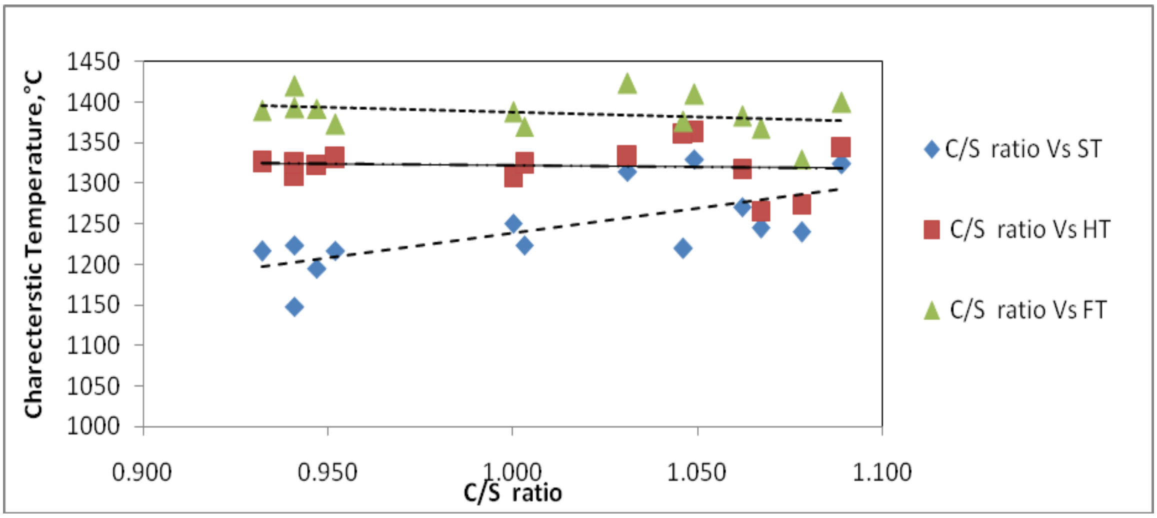
Table (1): Chemical Composition of Industrial Blast Furnace Slags

Serial No	CaO %	SiO_2 %	MgO%	Al_2O_3%	C/S	Remarks
1	34.04	32.05	10.09	19	1.062	The slag samples are collected from SAIL Rourkela; TATA Steel plant; Bhilai Steel plant and Bokaro Steel plant
2	33.25	30.84	11.01	20.89	1.078	
3	35.1	32.24	10.4	18.77	1.089	
4	33.4	31.3	10.4	19	1.067	
5	32.55	31.58	10.4	20.28	1.031	
6	33.61	32.05	10.09	20.05	1.049	
7	30.85	30.85	9.79	18.54	1.000	
8	36.2	34.6	7.05	17.9	1.046	
9	34.57	36.72	6.51	19.04	0.941	
10	34.15	34.06	6.5	18.07	1.003	
11	31.9	33.5	10.4	20.8	0.952	
12	31.9	33.7	10.5	20.6	0.947	
13	31.6	33.9	10.6	20.6	0.932	
14	31.8	33.8	10.5	20.6	0.941	

TABLE Π below gives the slag-wise characteristics temperatures.

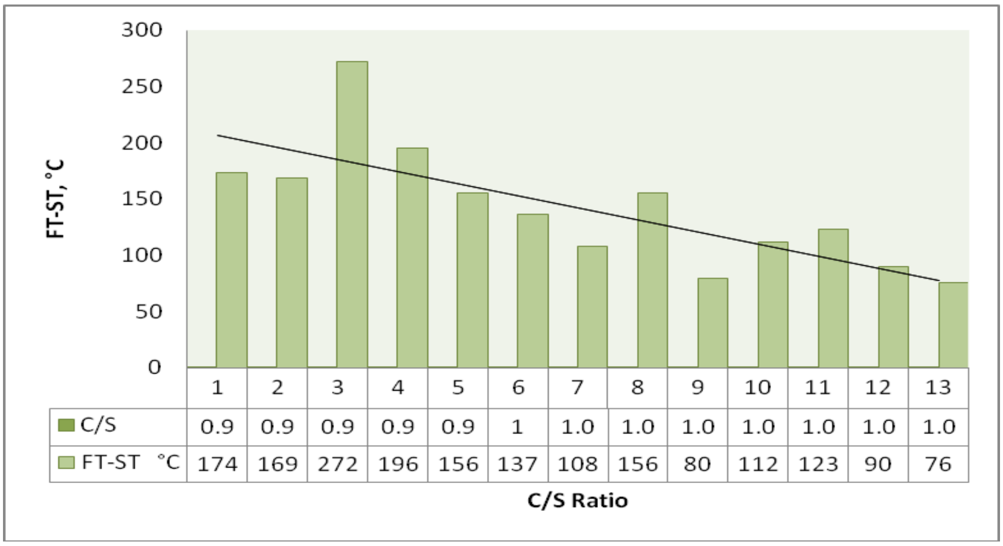
Serial No	IDT ˚C	ST ˚C	HT ˚C	FT ˚C	FT-ST ˚C
1	1203	1271	1318	1383	112
2	1220	1240	1274	1330	90
3	1210	1324	1345	1400	76
4	1204	1245	1266	1368	123
5	1225	1315	1335	1423	108
6	1217	1330	1363	1410	80
7	1200	1251	1307	1388	137
8	920	1220	1362	1376	156
9	827	1148	1310	1420	272
10	810	1224	1324	1370	146
11	817	1217	1331	1373	156
12	820	1195	1323	1392	196
13	813	1216	1326	1390	174
14	818	1224	1324	1393	169

Figure.2.6. Variation of different characteristic temperatures with C/S ratio



In Figure No. 2.6, the experimental data is plotted. The graphic illustrates how the c/s (CaO/SiO2) ratio increases the softening temperature of industrial slags. Additionally, it is evident that when the c/s ratio increases, the flow temperature at which the slag gains liquid mobility drops and, generally speaking, the rate of flow temperature decrease is minimal.

According to U.K. Mohanty [12], the silicate network depolymerizes when basic oxide CaO is added. Smaller silicate groups, anionic units, or flow units are formed as a result. It is well known that the activation energy of the melt and its viscosity decrease as smaller anionic groups develop. In this case, the drop in viscosity may be analyzed in relation to the drop in flow temperature. It is also recognized that decreasing flow units, which are linked to decreasing viscous flow energy, require comparatively high oxygen levels, which are derived by increased basic oxide additions. As a result, increasing the basic oxide content gradually loses its ability to depolarize the flow, lower the flow temperature, and increase the liquid mobility of the low-viscosity slag. Consequently, as the c/s ratio increases, the flow temperature merely drops at a slower rate [13].



	1	2	3	4	5	6	7	8	9	10	11	12	13
C/S	0.9	0.9	0.9	0.9	0.9	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
FT-ST °C	174	169	272	196	156	137	108	156	80	112	123	90	76

Figure.2.7 . Variation of (FT – ST) with C/S ratio

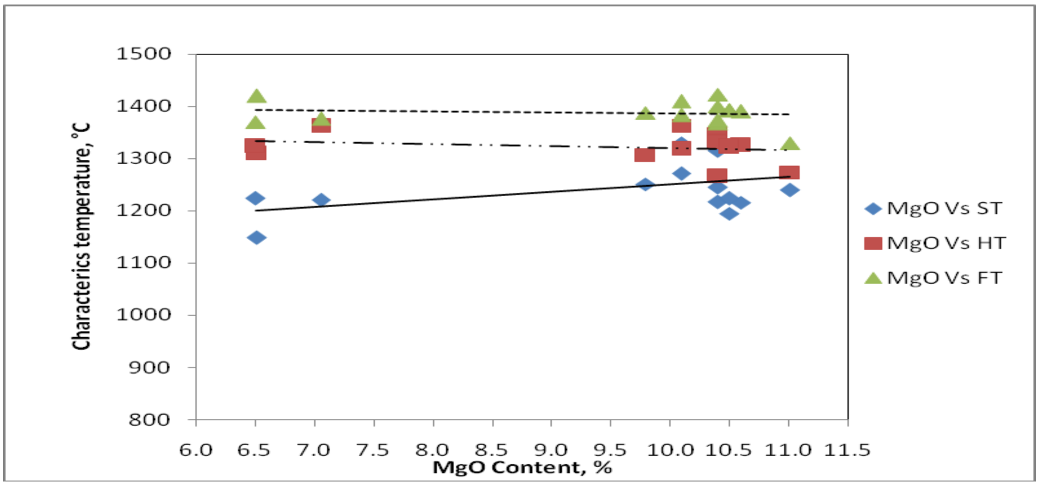


Figure.2.8 . Variation of different characteristic temperatures with MgO content

Table-III. %Reduction Vs characteristics temperature

% Reduction	Characteristic temperature			
	IDT	ST	HT	FT
10%	1180	1360	1524	1566
50%	1195	1424	1470	1583
65%	1284	1452	1494	1540

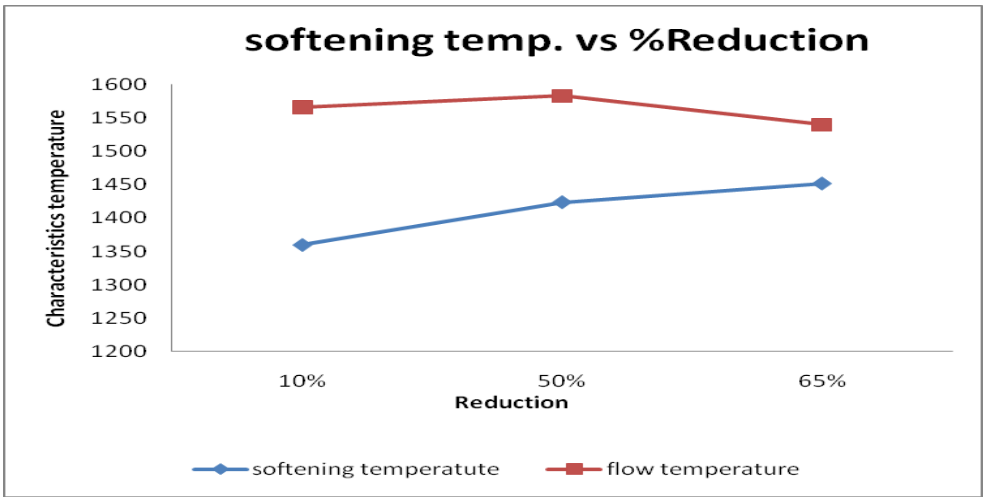
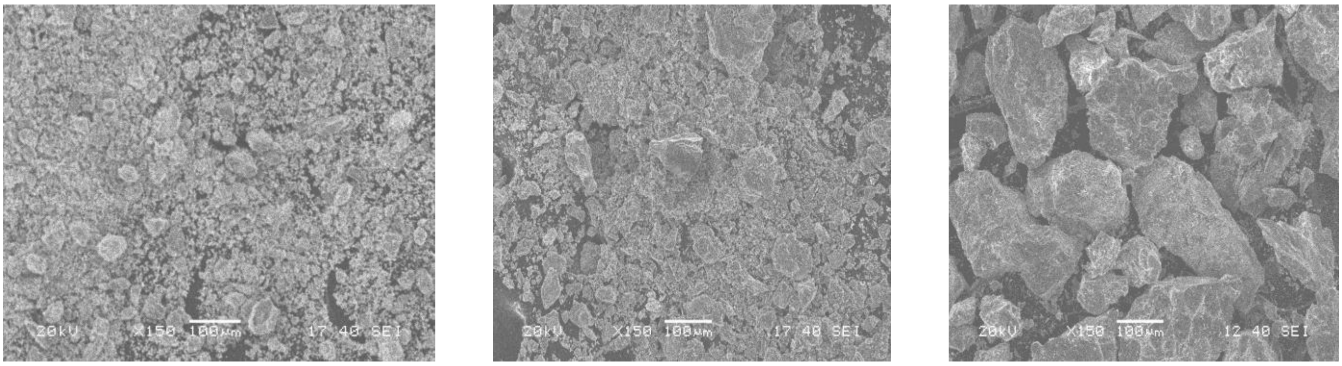


Figure.2.9 - %Reduction Vs characteristics temperature

Fig no.2.10 SEM micrographs at 150 magnifications



Conclusion:-

1. The high c/s ratio and high MgO content (C/S ratio 1.049 to 1.078 and MgO 10.09 to 11.01%) in blast furnace slags determine their flow properties, which produce a short slag.
2. The lack of tiny components in the slag that are overlooked during the preparation of the synthetic slags may be the reason why synthetic slags do not exhibit a clear trend of fluctuation with the variation of composition. This might possibly be a result of the blast furnace's current pressure and temperature levels, although slags with a 1.1 C/S ratio and MgO contents ranging from 4 to 8% might be interesting.
3. For the range of compositions examined, higher pre reduction levels created a favorable environment in the blast furnace, lowering the FT and raising the ST. However, more research is necessary to draw a firm conclusion.

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