

Experimental research on the characteristics of softening and melting of iron ores as significant factor of influence on gas permeability of blast furnace charge

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Abstract. It is widely accepted as a cohesive zone is directly influenced by softening and melting properties of iron ores, preparations (crowded, pellets, which represents about 90%, of the loads with metal furnace intake), or uncooked (raw ores ranked). Important results can be obtained through the study of behavior of ferrous materials at temperatures above 1000 ° C. Starting from research methods presented in the literature, this paper presents itself in carrying out their own laboratory experiments, conducted with the aim of analysing the softening and melting properties of sinter iron cores.

1. Introduction

Cohesive zone of blast furnace interior is by definition located in the belly of furnace is the area composed of pastos iron ores of softening and melting solid, coke, acid slag drops that run upward in the gaseous phase reducing valves with countercurrent.

Gas permeability of this area is very low, only one running windows gas coke solidly placed between layers of ore in the process of softening and melting. The temperature at which softening begins ferrous raw materials is called the start temperature of the cohesive zone and write with T_{zc} , the temperature at which melting the ends of ferrous raw materials is called melting temperature and note with T_{top} . $DT =$ difference between them $T_{top} - T_{zc}$ actually determine the thickness of cohesive zone.

The cohesive zone is thicker the upward flow of gaseous phase is more difficult. Softening, melting temperatures as well as the spread between them is in close correlation with the physical and chemical properties of ferrous materials with consideration of load capacity, i.e. to sinter ferrous which represents 90% of the loads of minerals. Study on the influence of chemical composition of sinter of $Ib = CaO/SiO_2$ and GR (reductibility degree) its effects on the cohesive zone is of great importance because of the shape and its position depends on the development of processes in the furnace.

2. Methodology

Crowded samples which have been subject to reduction under load have been specially trained in industrial agglomeration of machine at the ICEM Bucharest.

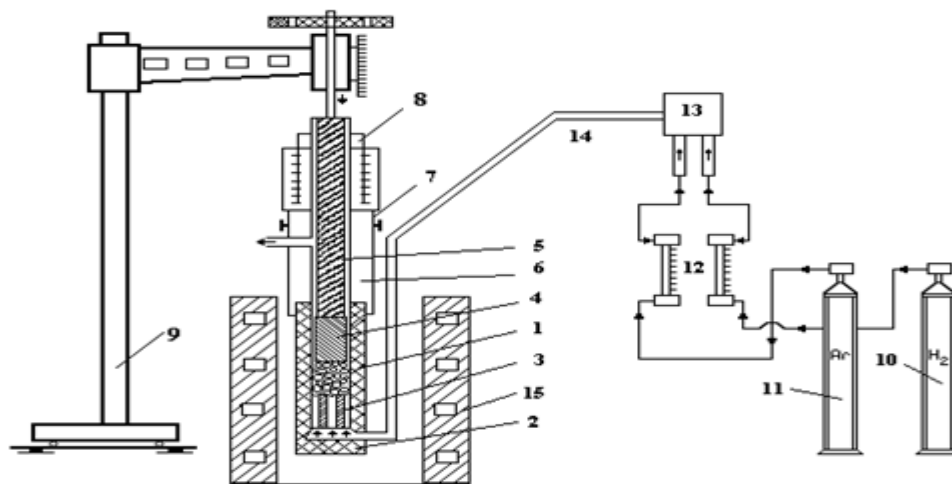
Crowded samples were taken from the mixtures listed in Table 1.



Tabel 1. The raw materials used in making crowded samples.

No sample	The raw materials %		Additions %			Initial mixture %			Sintered sample volume m ³
	Ore homogenized	Teliuc concentrate	Chalk	Coke	Ore	Teliuc	Chalk	Coke	
1	100	-	2999	8.2	60	-	18	4.9	0008
2	95	5	2908	8	57	3	17.4	4.8	00285
3	90	10	2815	8	54	6	16.9	4.8	00225
4	85	15	2724	8	51	9	16.4	4.8	00225
5	80	20	2630	7.5	32	8	10.5	3	0008
6	75	25	2540	7.5	30	10	10.2	3	0008
7	70	30	2445	7.5	28	12	9.8	3	0008
8	65	35	2350	7	26	14	9.4	2.8	0008
9	60	40	2255	7	24	16	9.0	2.8	0008
10	55	45	2165	7	22	18	8.6	2.8	0008
11	50	50	2070	6.9	20	20	8.2	2.6	0008

The tests we made shown that the higher is the reduction degree the higher is the crushing degree. Because pre-reduced materials obtained by reducing the iron ores (crude or prepared) are used in the blast furnace or the electric arc furnace, replacing the iron scrap, it is very important to know the behaviour of these materials during the heating – the correlation between the reducing degree and their melting and softening temperatures.

**Figure 1.** The experiment plant

1- graphite crucible; 2- gas distributor; 3- intermediary plate; 4 - piston; 5 - rod;
 6 - graphite support; 7 - seal device; 8 - piston support; 9 - fixed support; 10 - H₂
 cylinder; 11 - reducing gas cylinder; 12 - measuring device; 13 - gas mixer; 14 - gas
 pipe; 15 - induction electric furnace

That is why we tested the softening of these materials. The plant we used to run these tests is presented in Figure 1.

The way of the experiments was the following:

-crushed and punctured in the material has been chosen fraction of 3-5 mm of which for experimentation have used amounts ranging between 240-310g, selected quantity must fill the graphite crucible in which reduction reaction occurs;

-heating of the sample was made with the speed of 50-60 degrees/min;

-starting at 750° C is inserted into the sample It with the flow of 6.5-7.5 l/min;

-from 900° C is introduced with H₂ flow rate of 5 l/min up to 8 l/min so that the samples have a degree of reduction between 50-78%;

-the temperature is measured at 3 minute and interval from the time the piston movement at a distance of approximative 2 minutes;

-total of the piston stroke corresponding to a reduction of height equal to half of that of the sample and represents the beginning of melting characteristic (T_{top}) and travel of the piston is at the beginning of the characteristic started softening (T_{zc});

-after cooling and evacuation from the Crucible, the sample weighs in again and analyzes its layout.

3. Results

Experimental results are presented in Table 2.

Table 2- Experimental data on the characteristics of the softening and melting of sinters samples.

Nr of samples	Chemical composition							The degree of reduction (%)	Characteristic points		
	FeO (%)	SiO ₂ (%)	CaO (%)	MgO (%)	Al ₂ O ₃ (%)	Fe (%)	lb		T _{zc} (°C)	T _{top} (°C)	ΔT (°C)
1	1,26	13,72	25,53	3,28	4,11	39,53	1,86	58,44	1010	1230	220
2	1,53	13,90	24,74	1,86	1,40	42,03	1,78	62,50	765	1240	475
3	3,11	13,75	24,71	1,29	2,16	41,18	1,79	70	1080	1320	240
4	6,59	10,28	26,16	3,72	0,28	43,65	2,54	68	1010	1230	220
5	8,52	10,60	24,73	3,40	1,76	43,13	2,33	69,80	1000	1330	330
6	7,40	11,05	23,56	5,45	1,96	43,18	2,13	70,35	980	1375	395
7	4,51	12,96	24,63	0,72	1,56	47,49	1,90	69,80	980	1210	230
8	10,5	12,64	24,11	2,80	3,06	44,26	1,90	53,60	1025	1240	215
9	3,64	11,10	24,37	4,74	1,89	44,94	2,1	54,64	1100	1270	170
10	3,94	10,08	24,72	2,49	0,21	44,98	2,45	58,50	1100	1250	150
11	8,60	10,38	20,35	1,57	0,31	46,81	1,95	56,51	1020	1240	220

The experimental data were processed mathematically statistical, obtaining based on their charts in Figures 2-16.

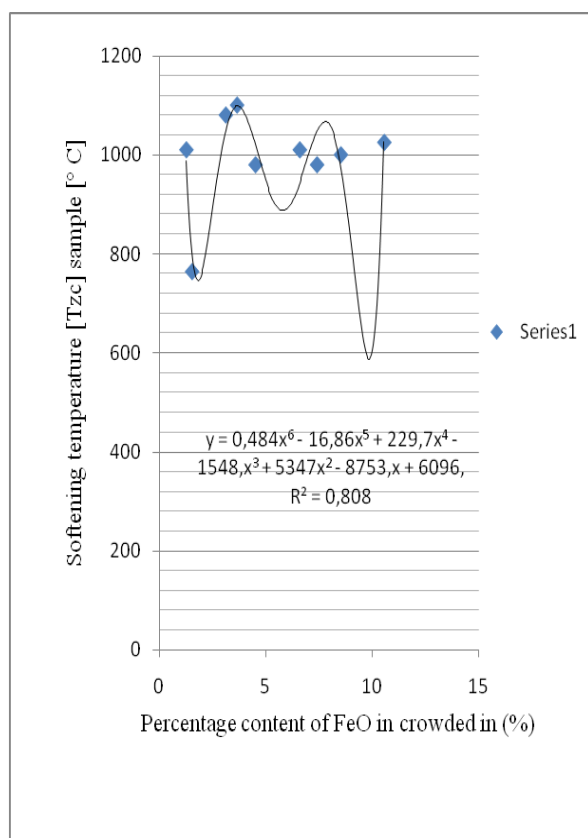


Figure 2. Graphical representation of the correlation between the softening temperature of iron agglomerate Tzc and percentage content of FeO.

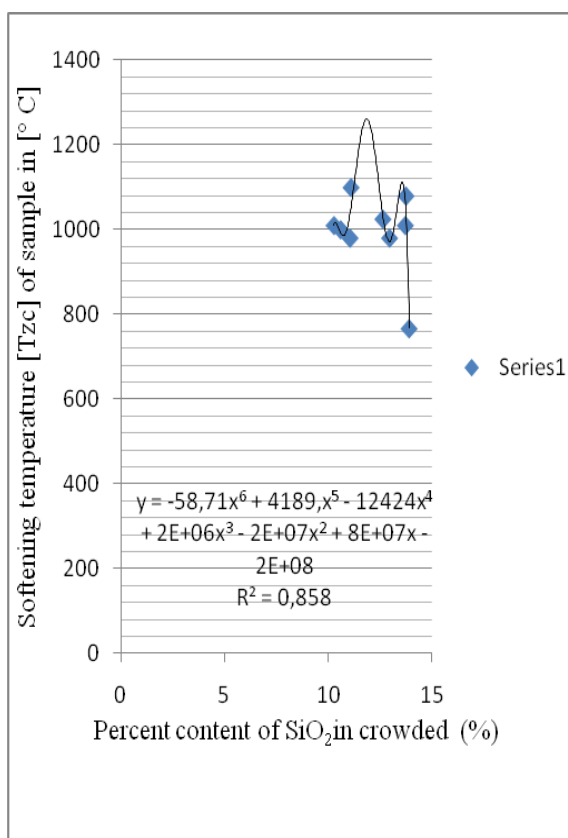


Figure 3. Graphical representation of the correlation between the softening temperature of iron agglomerate Tzc and percentage content of SiO2.

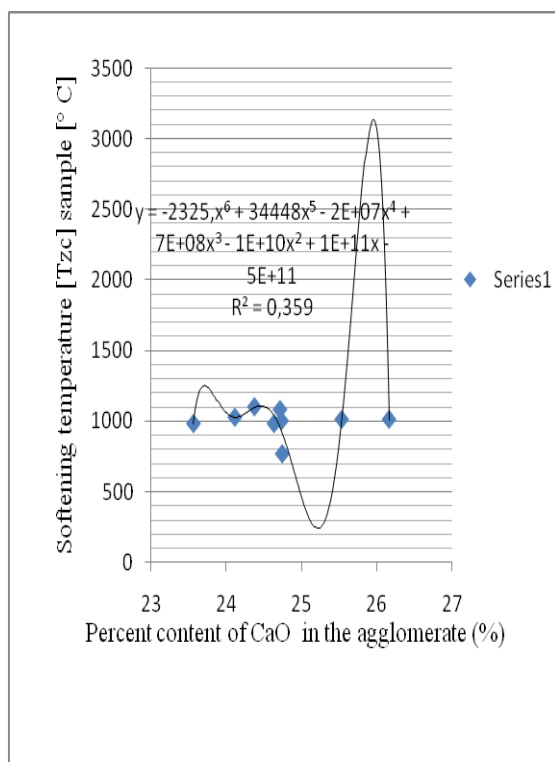


Figure 4. Graphical representation of the correlation between the softening temperature of iron agglomerate Tzc and percentage content of CaO.

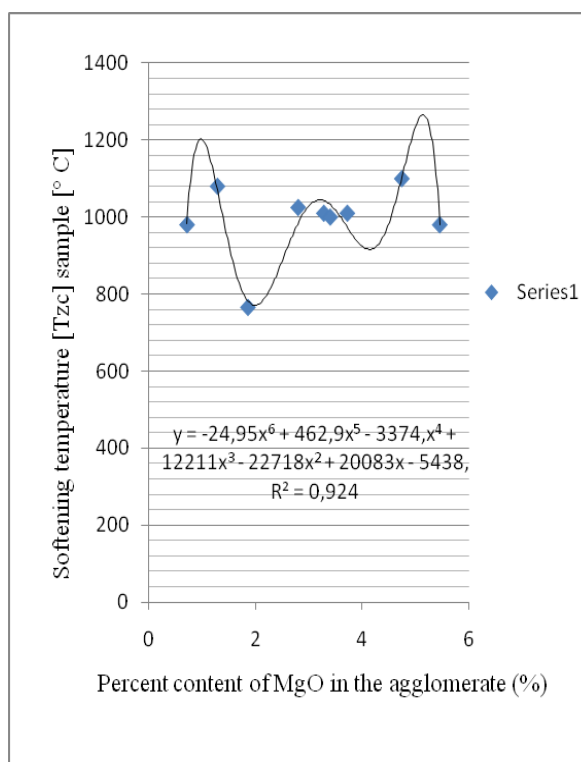


Figure 5. Graphical representation of the correlation between the softening temperature of iron agglomerate Tzc and percentage content of MgO.

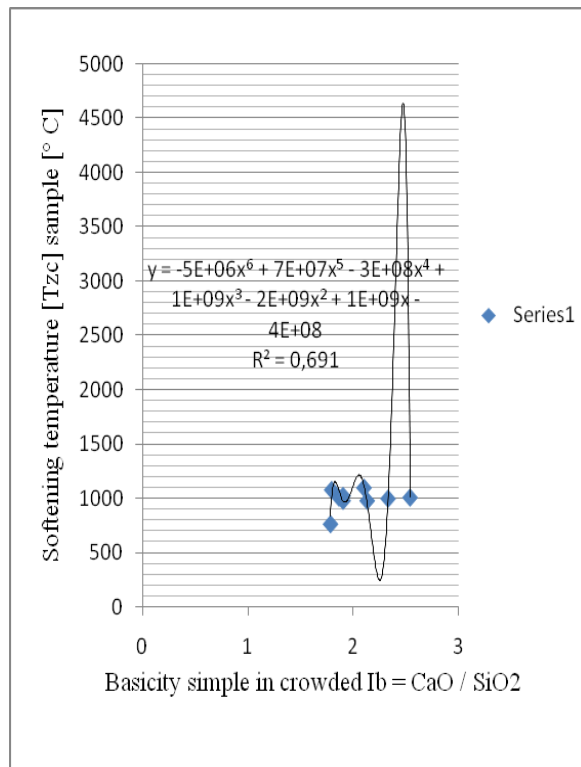


Figure 6. Graphical representation of the correlation between the softening temperature of iron and basicity Tzc simple Ib=CaO/SiO2.

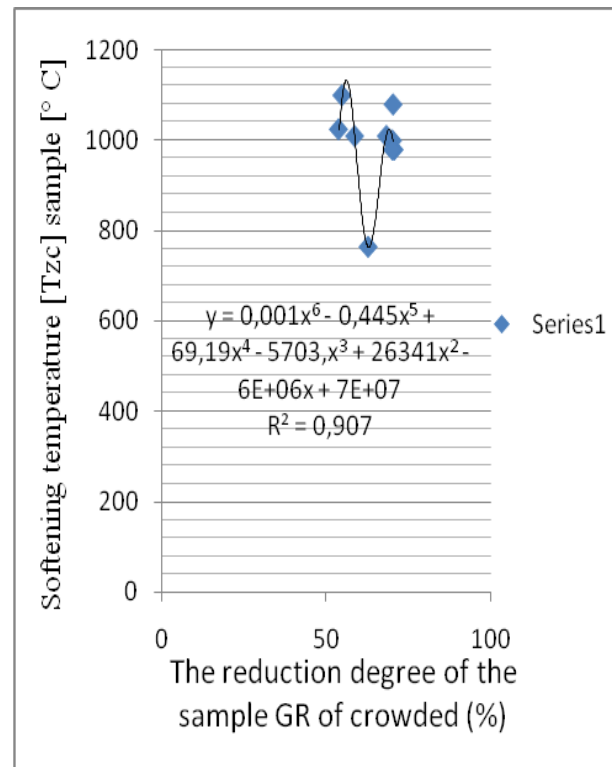


Figure 7. Graphical representation of the correlation between softening temperature of sinter ferrous Tzc and the reduction degree GR.

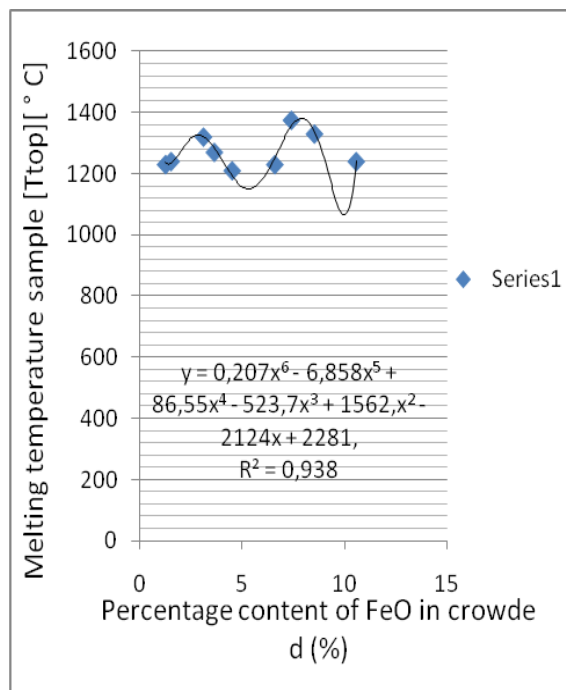


Figure 8. Graphical representation of the correlation between melting temperature of sinter ferrous Ttop and percentage content of FeO.

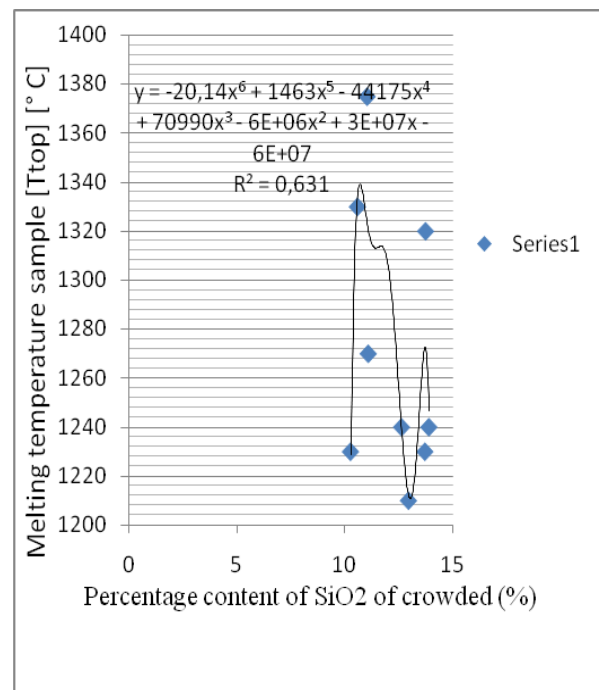


Figure 9. Graphical representation of the correlation between melting temperature of sinter ferrous Ttop and percentage content of SiO2.

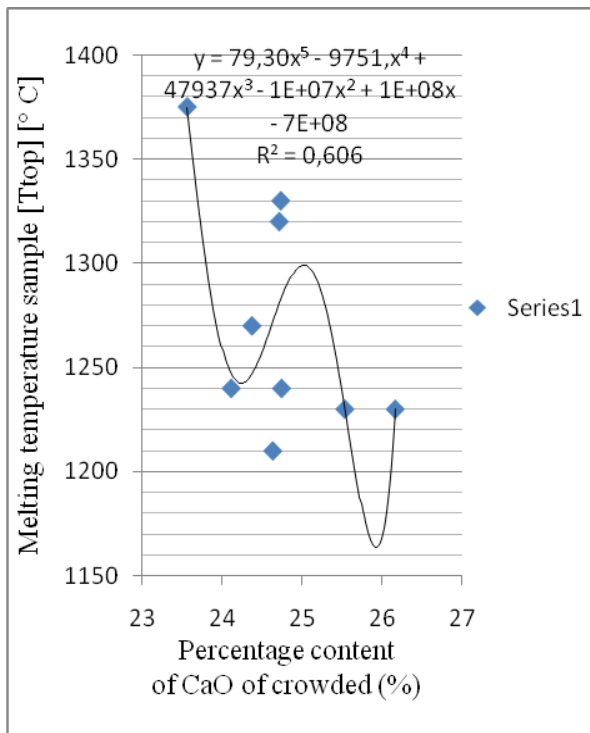


Figure 10. Graphical representation of the correlation between melting temperature of sinter ferrous T_{top} and percentage content of CaO.

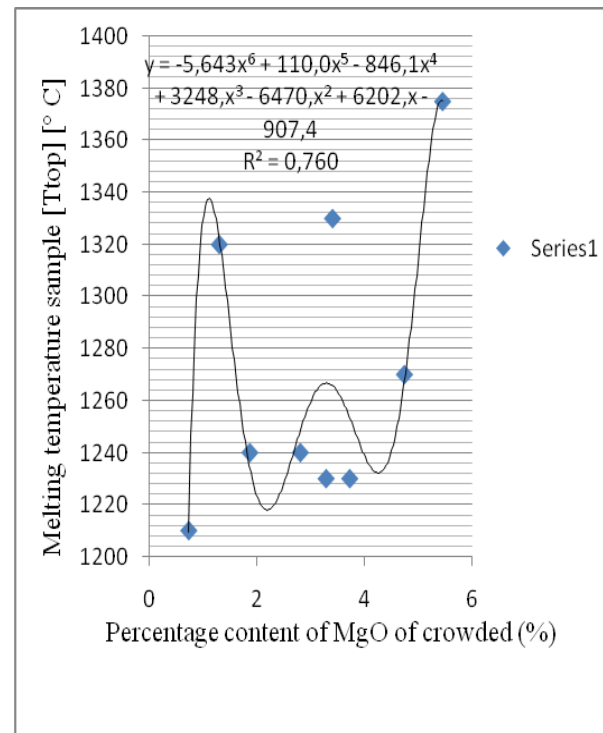


Figure 11. Graphical representation of the correlation between melting temperature of sinter ferrous T_{top} and percentage content of MgO.

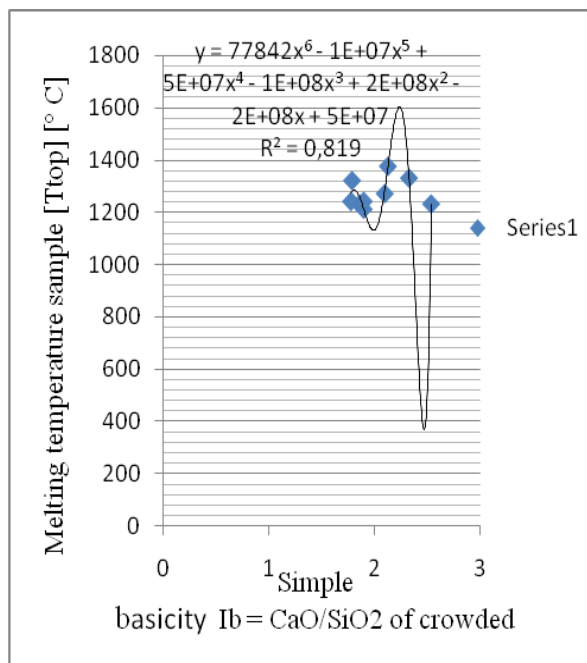


Figure 12. Graphical representation of the correlation between melting temperature of sinter ferrous T_{top} and simple basicity $I_b = \text{CaO}/\text{SiO}_2$.

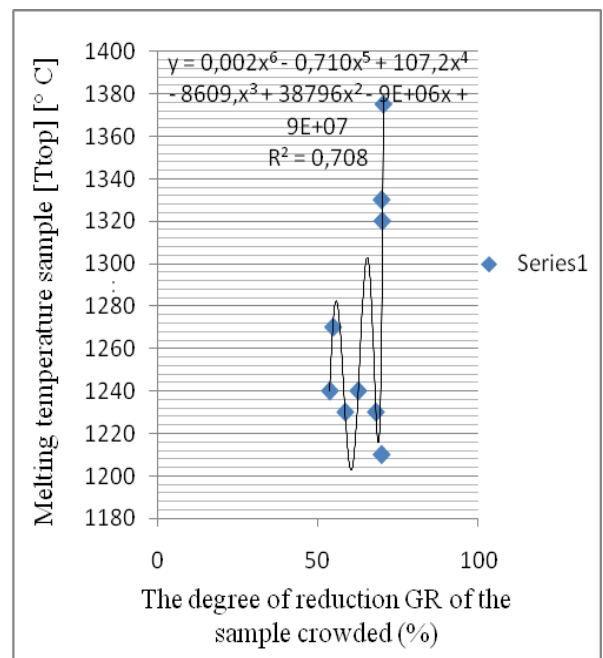


Figure 13. Graphical representation of the correlation between melting temperature of sinter ferrous T_{top} and degree of reduction GR.

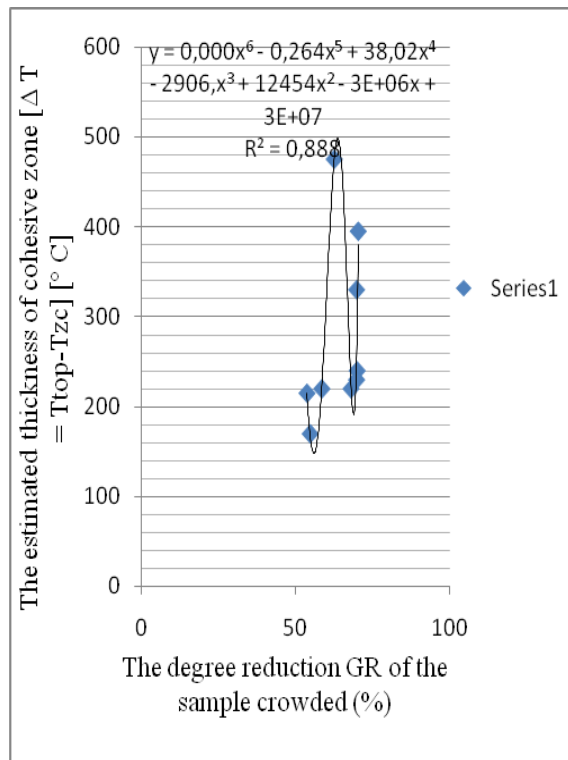


Figure 14. Graphical representation of the correlation between the estimated thickness of cohesive zone $\Delta T = T_{top}-T_{zc}$ and the degree reduction GR of the sample crowded

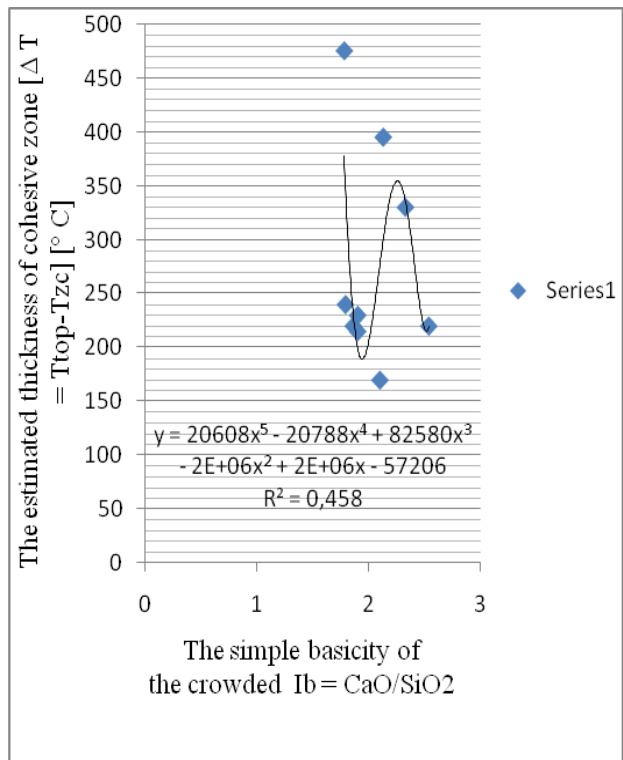


Figure 15. Graphical representation of the correlation between the estimated thickness of cohesive zone $\Delta T = T_{top}-T_{zc}$ and the simple basicity of the crowded $I_b = CaO/SiO_2$.

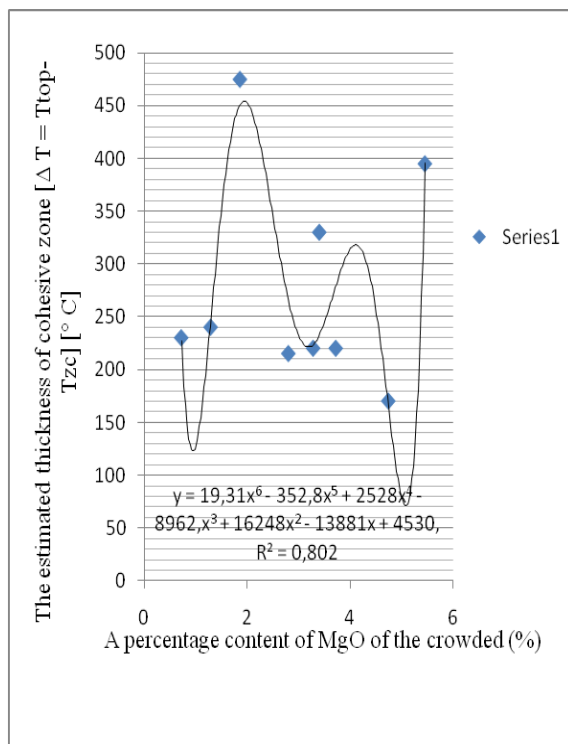


Figure 16. Graphical representation of the correlation between the estimated thickness of cohesive zone $\Delta T = T_{top}-T_{zc}$ and percentage content of MgO of the sample crowded.

4. Conclusions

Conclusions on softening and melting characteristics of the studied agglomerates can be summarized as follows:

- the increase in waste rock MgO to increase sinter characteristic T_{zc} , T_{top} , and $\Delta T = T_{top} - T_{zc}$ (samples No. 5, 6);
- further provided with tools as random parameter studied Al_2O_3 have not submitted acceptable correlation coefficients, however the growth of ΔT , which means a premature softening layers, a compactizare their faster, causing a decrease in permeability cohesive zone;
- further provided with tools drawn with CaO/SiO_2 report variables confirmed the trends of growth and melting point of softening point with increasing basicity;
- characteristic points are not influenced by the iron content variations;
- agglomerates with higher MgO contents melted harder and longer intervals, with approx 1080°C T_{zc} and T_{top} 1280-1410°C;
- it was noted that the growth of FeO in crowded place a sharp T_{zc} and T_{top} , what can be explained by the formation of compounds of the type fayalite, which leads to less permeable cohesive areas;
- the most powerful influence on the behavior of ferrous materials in the softening and melting, it is the degree of reduction of iron oxides, forming metallic iron support structures, which leads to ensure permeability layer plastic crowded condition.

This very important conclusion has led in the direction of a research study of reducibility and mechanical strength of components of cargo around the country, furnaces especially crowded samples.

References

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