Science of Sintering, **42** (2010) 193-202

doi: 10.2298/SOS1002193M

UDK 622.785:546.72:

Granulation of Coke Breeze Fine for Using in the Sintering Process

F. M. Mohamed, N. A. El-Hussiny, M. E. H. Shalabi*)
Central Metallurgical Research and Development Institute (CMRDI), Cairo, Egypt

Abstract:
Coke breeze is the main fuel used in the sintering process. The value of -3+1 mm. represents the most favourable particle size for coke breeze in the sintering process. About 20% of total coke fines (-0.5 mm) are produced during different steps of preparation. Introducing these fines during the sintering process proves to be very harmful for different operating parameters. Thus ,this study aims at investigating the production of granules resulting from these fines using molasses as organic binder and its application in sintering of an iron ore. The results showed that the granules having the highest mechanical properties were obtained with 14.5 wt % molasses addition. The sintering experiments were performed by using coke breeze in different shapes (-3+1 mm in size, coke breeze without sieving and coke breeze granules -3+1 mm). The reduction experiments, microscopic structure and X-ray analysis for the produced sinter were carried out. The results revealed that, all sinter properties (such as shatter test, productivity of sinter machine and blast furnace, reduction time and chemical compsition) for produced sinter by using coke breeze with size -3+1 mm and coke breeze granules were almost the same. The iron ore sinter which was produced by using coke breeze without sieving yielded low productivity for both sinter machine and blast furnace. Furthermore, using coke breeze without sieving in sintering of an iron ore decreases the vertical velocity of sinter machine and increases the reduction time.
Keywords: *Coke fine, Granulation, Iron ore, Sintering process.*

1. Introduction

The price of energy is dramatically increasing by the day. In this respect, coal and coke still preserve their importance as energy resources [1]. However, coke is of wider use because of its unique combustion properties, as well as its mechanical and structural properties [2]. Coke breeze act essentially as high carbon content , heat content and clean burning fuel is used primarily in iron ore sintering processes.

As a result of growth of the iron and steel industry all over the world, prime coking coal with adequate properties that yield metallurgical coke is becoming increasingly difficult to obtain, and hence this trend is becoming progressively more severe and therefore more expensive [3]. Thus, there is a considerable economic incentive to use coke breeze and / or low rank coals instead of coking coals whenever possible. Approximately 6.7% of the total energy consumed in iron and steel production is required for sinter operation [4&5]. The major world development around the sinter strand arelocated in four areas; energy consumption, productivity, process control and environmental control. Significant reductions

*) Corresponding author: shalabimeh@yahoo.com

in energy requirements have already been achieved in sintering plants as a result of installing heat recovery systems as well as improving ignition, decreasing air leakage, improved raw materials characteristics of ores and coke breeze as size and composition [6]. Regarding coke breeze size, it has been found that the coarse coke (-3.15 +1 mm) gave the best sintering results of the sintering process while fine coke (-1 mm) gave the worst results. Fine coke can be considered mainly the adhering material which forms a surface coating around granules. Fine coke burns quickly whereas the very coarse coke burns slowly and may widen the flame front with a possible loss of productivity [7-9].

There are huge amounts of coke fines produced inside the Integrated Iron and Steel plant. during coke transportation, handling and crushing of coke for use in the sintering process. Granulation is one of the agglomeration processes which convert the ore fines into granules of suitable size. Binders are important for holding the fine particles together during the granulation process. Either organic or inorganic binders can be used. Organic binders burn or volatilize during the firing. Consequently they don't change the chemical composition of the fired granules to any appreciable extent. There are different types of organic binders such as starch, petroleum bitumen, lignin liquor, carboxymethyl cellulose, molasses…..etc. Due to the comparatively high prices of most such substances, the only interest becomes using waste products of other industries such as molasses that is both cheap and locally available [10-14]. The aim of this work is to recycle the coke breeze fines of use in the sintering process after granulation in a disc pelletizer using molasses as a binder material.

2. Materials And Experiments

2.1. Materials

Coke breeze was provided by the Egyptian Coke Co., whereas the Egyptian Iron and Steel Co. supplied their ore and limestone. Tabs I, II show the chemical composition and sieve analysis of raw materials. Molasses which is used as a binder in granulation process was obtained from El-Hawamdia Sugar Co.

From Tab. II it is clear that, about 23.5% of the coke breeze is of size less than 0.5 mm. Fig.1. shows that the X-ray diffraction of the iron ore indicates that it mainly consists of hematite and limonite.

Tab. I. The chemical composition of main components of raw materials.

Components, %	Iron Ore	Limestone	Coke Fine
Fe_{total}	50	-	2.24
SiO_2	9.14	1.05	3.203
Al_2O_3	2.06	0.78	2.0
CaO	1.9	54.67	0.732
MgO	0.35	0.12	0.082
P_2O_5	0.44	-	0.04
MnO	3.83	-	-
Na_2O	0.349	-	0.022
K_2O	0.61	-	0.106
F.C	-	-	84.76
CO_2	-	42.81	-

Tab.II. Sieve analysis of coke fine and iron ore.

Sieve diameter, mm	Coke breeze, %	Iron ore, %
+ 4.7	26	23.1
- 4.7 + 3	12.8	8.7
- 3 + 2	9.1	11.4
- 2 + 1	15.2	15.8
- 1 + 0.5	13	11.6
- 0.5 + 0.2	9	15.2
- 0.2 + 0.1	7.2	4.6
- 0.1	7.3	9.5

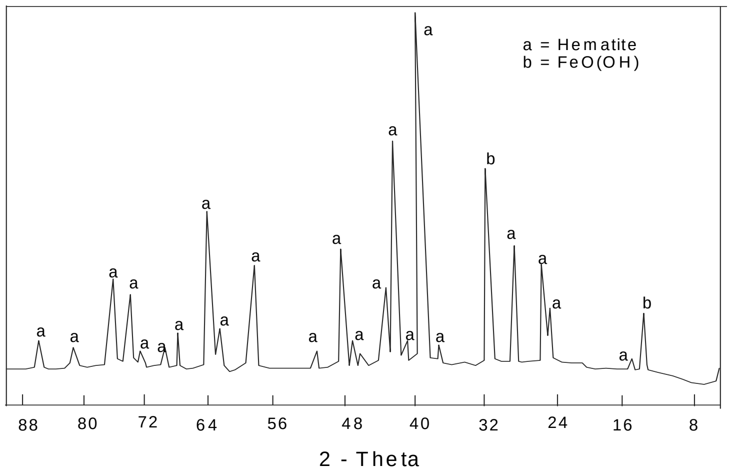

Fig.1. X-ray diffraction of iron ore.

2.2 Apparatus and Experiments

The granules were prepared in a disc pelletizer of diameter 400 mm, collar height 100 mm, angle of inclination 60 ^{o}, disc rotating speed 17 rpm and residence time 10 min. Coke fines -0.5 mm (200 gm) were feed to the pelletizer. The predetermined moisture amount (10% water + different percentage of molasses: 10, 11.5, 13, 14.5, 16 and 17.5%) was then sprayed onto the rolling bed of material in the pelletizer. The green granules in the size range 1-3 mm diameter were screened out to calculate the productivity of the granulation process and were used in the present study. The green granules produced were dried in a drying oven at 110 ^{o}C for 2h, to ensure the evaporation of all water used during the granulation process. The dried granules were then subjected to sintering.

Sintering experiments were conducted in a laboratory down draft sinter pot (5 kg). Air flow was provided by two fans in series which were capable of producing a suction pressure in excess of 12 kPa. The raw material (iron ore) was mixed with limestone, 30% of the charge sinter return and 6% coke breeze and amount of water (9% of the charge) was added through mixing the raw materials. The sinter charge basicity (CaO/SiO_2 =0.9) was kept constant throughout all experiments.

The green charge was loaded over the sinter bed layer (0.5 kg sinter + 10 mm size). The green raw mix was then ignited with a gas flame for a period of 1.5 min. The ignition was done under suction pressure of 5.88 Kpa, while sintering was performed under a uction pressure of 11.76 kPa. The sintering time was determined by the time elapsed from the start of ignition until the exhaust gas temperature reached its maximum value. At the end of the sintering experiment the produced sinter was drooped on to a steel plate laid on concrete and then the sinter cake was screened over a sieve +7 mm to determine the productivity of the sintering machine as calculated from the formula:

$$P = 14.4\ K\ \rho\ V\ \text{ton/m}^2.\text{day}$$

Where K is the percentage of ready made sinter from the charge (+7mm),
ρ is bulk density of the charge, ton/m^3,
V is vertical velocity of sintering machine (V = H/T) m/min.
H is the height of the charge in sinter pot and T is the time of sintering, min.

The shatter test was done to calculate the sinter strength where the sinter cake +7 mm was dropped four times from a height of 2 m then the out sinter after the shatter tester was screened over a 7 mm sieve After that, the sinter strength (η) was calculated as the percentage of (+7 mm) sinter after shatter test related to the ready made sinter strength ($\eta\% = W_1/W_2 * 100$), where, W_1, W_2 represent the weight of sinter (+7 mm) after and before shatter test respectively[15].

The productivity at blast furnace yard was calculated according to the equation ($P_{B.F} = p * \eta$), where, $P_{B.F}$ = the productivity at blast furnace yard, ton/m^2.day, p= the productivity of sintering machine, ton/m^2.day and η= shatter index +7 mm, % [16].

3. Results And Discussion

3.1. Effect of the amount of molasses added on the productivity of green granules

Fig. 2 shows the effect of adding different amount of molasses (10, 11.5, 13, 14.5, 16 and 17.5% molasses, with constant amount of water 10%) on the productivity of the granulation process. It is clear that the productivity of granules -3+1 mm increases with increasing the amount of molasses until it reaches its maximum value at 14.5% molasses.

This may be attributed to the fact that increasing the molasses content leads to an increase in the coalescence mechanism and the number of liquid bridges between the particles of coke breeze fines [17]. The decrease in productivity by increasing the molasses content above 4.5 % is probably due to the formation of large granules having size bigger than 3 mm.

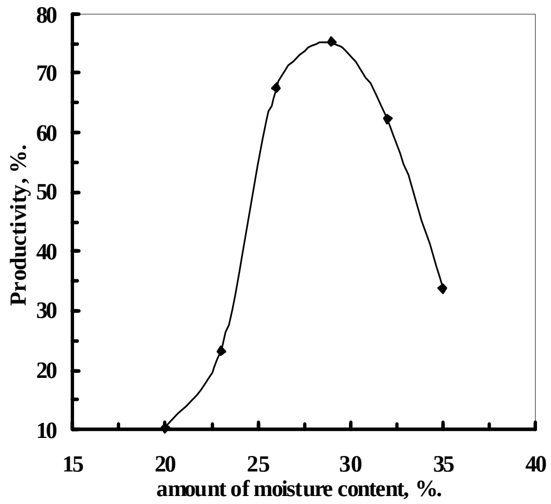

Fig 2. The effect of moisture content on the productivity of green granules (Moisture content =.amount of molasses + 10 % water)

3.2. Effect of amount of molasses added on the compressive strength of dried granules

Fig. 3 indicates the effect of adding different amount of molasses on the compressive strength of dried granules. It is clear that increasing the percent of molasses increases the compressive strength of the dried granules. This may be attributed to the fact that increasing molasses added leads to an increase in the contact points between the particles of coke fines and decrease the distance between them so the compressive strength of dried granules increases[18].

From both Figs. 2, 3, it is clear that granules suitable for the sintering process can be obtained by adding 14.5 % molasses.

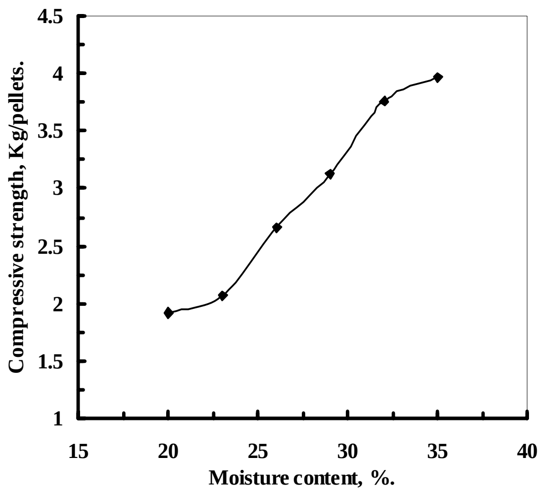

Fig.3. Effect of moisture content added on the compressive strength of dried granules.

3.3. Effect of coke breeze shape on the parameters of sintering process.

Sintering experiments were carried out by adding 6% coke breeze with different shape (coke breeze after sieving -3+1 mm, coke breeze without sieving and coke breeze granules -3+1 mm) at the following constant conditions, (water 9%, sinter return 30%, firing time 1.5 min, and basicity 0.9%). All experiments were repeated 3 times and average values were taken as results.

3.3.1. Effect of coke breeze shape on the vertical velocity of sinter machine.

Fig. 4 shows the effect of coke shape on the vertical velocity of sinter machine. From this figure, the vertical velocity of sinter machine is the highest value in case of using coke breeze with size -3+1 mm and of lowest value in case of using coke breeze without sieving. While through using coke breeze granules yield an in-between vertical velocity. This means that using of granules develop a higher vertical velocity than using the coke breeze as received without sieving. This is due to the presence of about 20% coke fine (- 1 mm) in the as-received unsieved coke which leads to a decrease in the permeability of sinter bed.

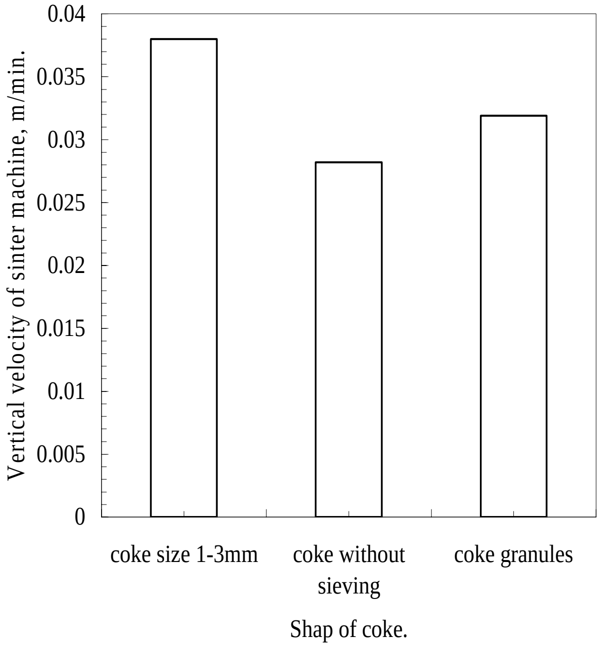

Fig.4 Effect of coke shape on the vertical velocity of sinter machine

3.3.2. Effect of coke breeze shape on the strength of the produced sinter

It is clear that, the highest value of sinter strength appears in case of using coke breeze with size 1-3 mm (Fig. 5), while the lowest value of strength is produced in case of using coke breeze without sieving. It is also clear that the use of coke breeze granules in the sintering process increases the strength of produced sinter. This is due to the presence of 20% fines in the coke breeze without sieving which leads to a decrease in the temperature of the heating zone and subsequently decreases the rate of the solid reactions between the different minerals [9]. In addition, the use of fine coke breeze allows the formation of many regions which are poorly supplied with heat because of chaotic distribution of fuel throughout the sintering materials. This also may be due to the formation of single blocks of small size, which has a bad effect on the product strength [11].

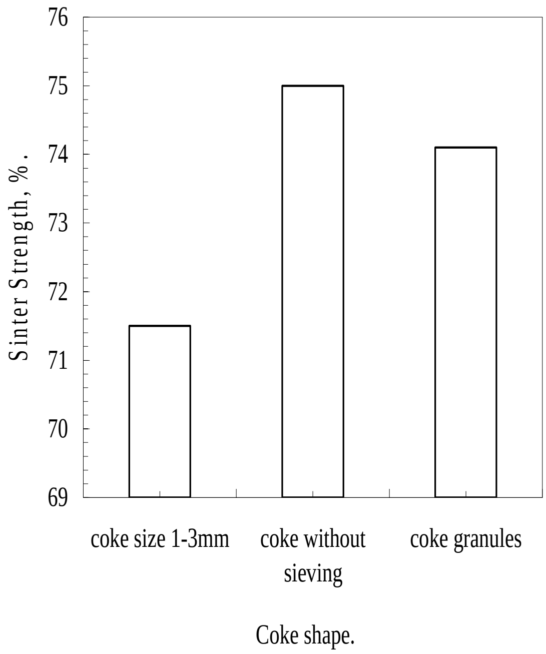

Fig.5 Effect of coke shape on the strength of produced sinter.

3.3.3. Effect of coke breeze shape on the productivity of sinter machine and blast furnace

Figs. 6, 7 illustrate the effect of coke breeze shape on the productivity of sinter machine and blast furnace. It is clear that the productivity of sinter machine and blast furnace increases in case of using either coke breeze with size -3+1 mm or coke breeze granules but it decreases in case of using coke breeze without sieving. This is due to improvement in the vertical velocity of sintering process as shown in fig. 4. In addition both combustion of coke breeze and sintering proceed simultaneously leading to an improvement in the productivity of sintering machine and productivity at B.F yard [12-13].

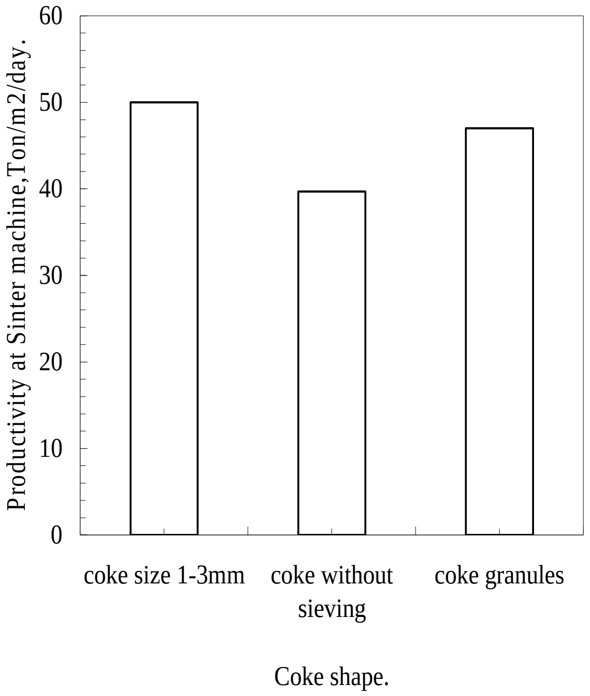

Fig.6 Effect of coke shape on the productivity of sinter machine.

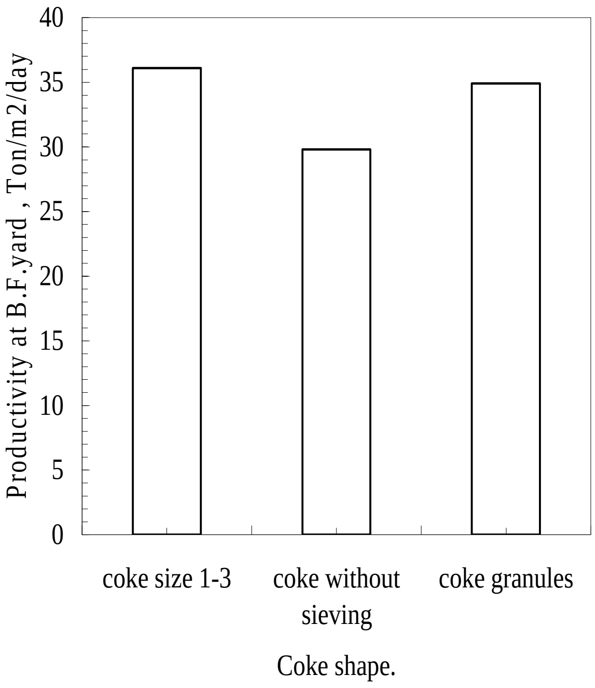

Fig.7 Effect of coke shape on the productivity of blast furnace.

3.3.4. Effect of coke breeze shape on the reducibility of the produced sinter

Fig. 8 illustrates the effect of coke shape on the reduction time of the produced sinter in the three aforementioned cases (reduction temperature 800 ^oC, hydrogen flow rate 1.5 l/ min) From this figure, it is clear that the reduction time is the same in case of either using coke with size -3+1 mm or coke granules (about 65 min) but it increases to 75 min in case of using coke breeze without sieving. This is due to the difference in the porosity of the produced sinter, as porosity decreases in case of using coke breeze without sieving as shown in Fig. 9, which illustrates the microscopic structure of the produced sinter in each case.

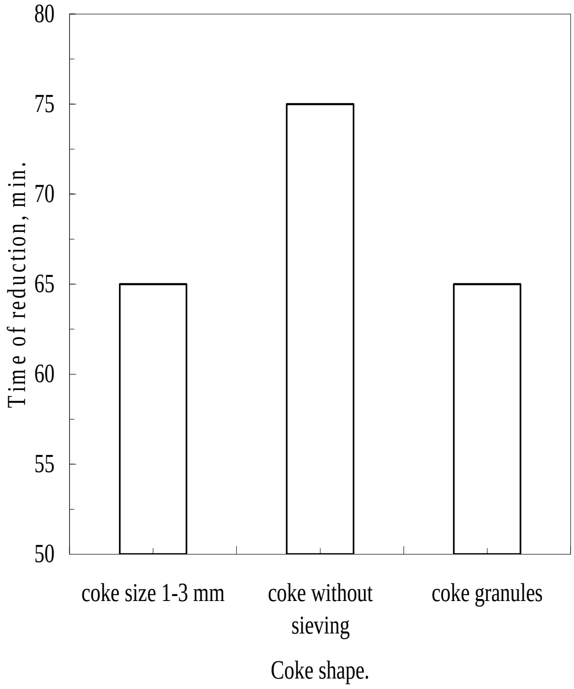

Fig.8 Effect of coke shape on the reduction time of produced sinter.

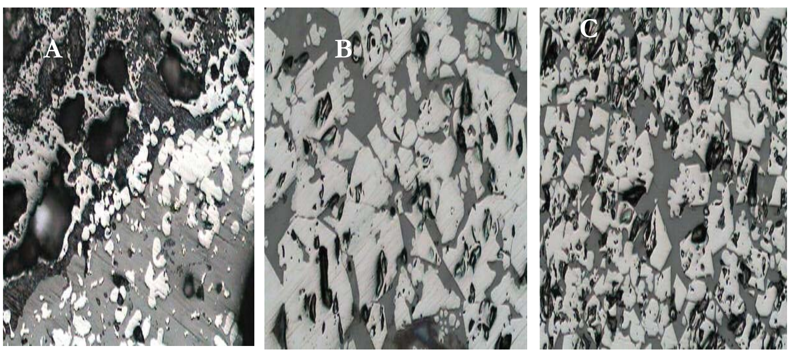

Fig.9 Microscopic structure of produced sinter by using different coke breeze shapes, (A = coke breeze -3+1 mm, B = coke breeze without sieving, C = coke breeze granules.)

Fig. 10 illustrates the X-ray analysis of the produced sinter in each case of coke breeze. From these diffraction patterns it can be observed that, the hematite and magnetite are the main minerals of the produced sinter. Wustite could be identified in the samples of sinter which were produced from coke breeze size 1-3 mm and granules of coke breeze. This is due to the fact that the temperature of heating zone when coke breeze is 1-3 mm and granules are present is higher than that in case of coke breeze sieving, leading to dissociation of higher oxides to the lower oxides.

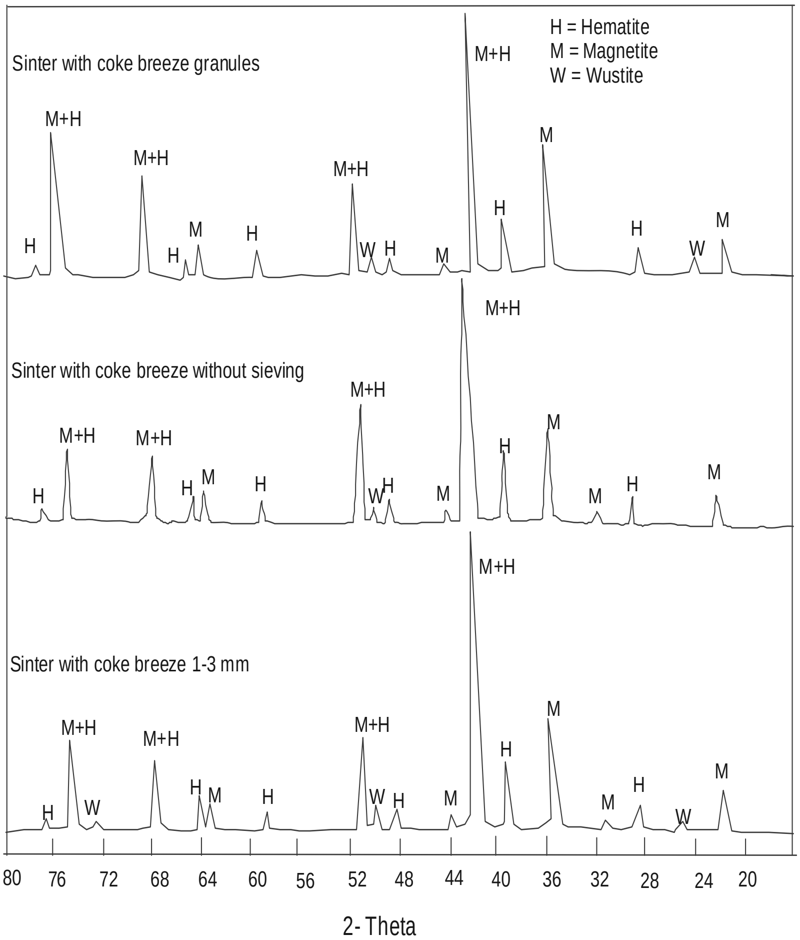

Fig. 10. X-ray diffraction of iron ore sinter by using different shape of coke breeze

4. Conclusions

1 The most suitable granules of coke fine are produced in disc pelletizer at angle of inclination 60 ^{o}, disc rotating speed 17 rpm and residence time of granules on pelletizer 10 min.

2 The results show that the granules possessing highest mechanical properties were obtained with 14.5 wt % molasses addition.

3 Using of coke breeze granules in the sintering process of an iron ore improves the vertical velocity of sinter machine, strength of the produced sinter and the productivity of both sinter machine and blast furnace than using coke breeze without sieving.

5. References

1. C.Hiçyilmaz, N.E.Altun, A.S.Balci, Journal of Ore Dressing, 7 (2004) 8.
2. W. Yang, S. Choi, E. S. Choi, D. W. Ri, S. Kim, , Combust. Flame 145 (2006) 447.
3. A. Benk, M. Talu, A. Coban, Fuel Process. Technol. 89 (2008) 28.

4. J.Dartnell, in Proceedings of an International Conference Organized by the Metal Society and Held in Middlesborough, England, (June1997) 48-54.
5. F.Cappel, in Proc. 5th Int.Symp.on "Agglomeration", Bighton, UK, Institution of Chemical Engineers, (1989) 1-12.
6. P.R.Dawson, Ironmak. Steelmak. 20 (1993) 150.
7. K.H. Peters, H. Beer, H.W. Kropla, A. Rinne, in Proc., 5th Int.Symp.on "Agglomeration", Brighton, UK, Institution of Chemical Engineers, (1989) 51-70.
8. C.E. Loo, Ironmak. Steelmak. 18 (1991) 33.
9. D.F. Ball, Agglomeration of iron ores. American Elsevier Publishing Company, Inc, New York, 1973.
10. I. Toroglu, The Journal of Ore Dressing, 4 (2002) 10.
11. J.N. Leonard, D.R. Mitchell, Coal preparation 4th Ed AIME, New York, 1979.
12. A.W. Deurbrouck, R. E. Muck, Coal preparation chemistry of Coal Utilization, Martin A Ellitte Ed, John Willey and Sons. Inc., (1981), chapter 10.
13. N. Cornejo, A. Isidro, J. C. Ruíz, F. García, I. Gómez, I. Covián, Fuel, 75 (1996) 659.
14. F.M.Mohamed, "Pelletization of Some Egyptian Iron Ores" Ph.D. Thesis, Faculty of Science, Cairo Univ. Beni Suef Branch, Egypt, (2000).
15. N. A. El-Hussiny, " Influence of Some Factors Affecting on the Sintering Process of Egyptian Iron Ore", Faculty of Science, Cairo Univ., Cairo, Egypt, (1995).
16. A.A. Seddik, A. Z. M. Abouzeid & H. A. Al-Sinbawy, 2nd Metallugical Conference in A.R.E., 9-12 Dac., El-Tabbin, Cairo,(1978) 1-20.
17. K. Meyer, "Pelletization of Iron Ores", Springer Verlag. Berlin, Heidelberg, (1980).
18. B. K. Dhup, S. Sarkar, TISCO, 17 (1970) 139.

Садржај: *Кокс ке главно гориво које се користи у процесу синтеровања. Вредност -3+1 мм представља наповољнију величину честица кокса у процесу синтеровања. Око 20% финог кокса (-0.5 мм) се проињводи коришћењем различитих припремних корака. Увођење овог финог праха током синтеровања утиче лоше на различите парараметре. Циљ овог рада је проучавање производње гранула од овог финог праха коришћењем моласе као органског везива и примену на синтеровање руде гвожђа. Резултати су показали да су грануле са најбољим механичким својствима добијене са додатком 14.5 тежинских % моласе. Експерименти су вршени коришћењем кокса разлишитог облика ((-3+1 мм величина кокса без сејања и грануле -3+1 мм). Експерименти редукције су показали да својства синтеровања (као тест разбијања, продуктивност синтер машине и високе пећи, време редукције и хемијски састав) за производњу кокса величине -3+1 мм и гранула исте величине су скоро исти. Синтерована руда гвожђа произведена коришћењем кокса без сејања је имала малу продуктивност код синеровања и у високој пећи. Коришћење кокса без сејања приликом синтеровања гвожђа умањује вертикалну брзину синтеровања и увећава редукционо време.*

Кључне речи: *Фини кокс, гранулација, руда гвожђа, процес синтеровања.*