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BENEFICIATION OF AL-HUSSAINYIAT LOW GRADE IRON ORE BY SEGREGATION ROASTING

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ABSTRACT

Attempt has been made in the research and development laboratories of the State Company of Geological Survey and Mining to develop a process based on segregation roasting technique as an alternative approach to beneficiate Al-Hussainiyat low grade iron ore. The process comprises, segregation roasting in the presence of coke and alkali chloride followed by screening and wet low intensity magnetic separation, to separate the iron from the associated gangue. Various parameters including roasting temperature, roasting time, amount of alkali chloride, and ore particle size were studied. Under optimum conditions, a concentrate assaying 86% Fe_T and 2.6 % I.R ($SiO_2 + Al_2O_3$) could be achieved with a recovery of about 64 % Fe_T. These results appear promising for the current work, and a process in the field can be developed.

تركيز خام حديد الحسينيات واطئ النوعية بطريقة الاختزال الانفصالي

د.عبد الوهاب العجيل و سالي نعمة مهدي

المستخلص

جرت محاولة في مختبرات البحث و التطوير للشركة العامة للمسح الجيولوجي و التعدين لتطوير طريقة تعتمد على تقنية الاختزال الانفصالي كمنحى بديل لتركيز خام حديد الحسينيات واطئ النوعية . العملية تتضمن ، تحميص انفصالي للخام مع الفحم و احد الاملاح الكلوريدية و من ثم الغربلة و الفصل المغناطيسي الرطب واطئ الشدة لفصل الحديد عن الشوائب المصاحبة له. و لقد تم دراسة متغيرات عدة شملت درجة حرارة التحميص ، زمن التحميص ، كمية ملح الكلوريد المضاف و الحجم الحبيبي للخام . و تحت الظروف المثلى امكن التوصل الى ركاز للحديد يحتوي على 86 % Fe_T و 2.6 % I.R ($SiO_2 + Al_2O_3$) و نسبة استرجاع للحديد بحدود 64 % Fe_T . هذه النتائج تعتبر مشجعة للعمل الجاري و هناك إمكانية لتطوير هذه الطريقة.

INTRODUCTION

Al-Hussainyat iron ore is a low grade pisolitic ore, grading on average 25% Fe_T (total iron). According to the comprehensive mineralogical studies, which have been carried out by many workers, (Sofermines, 1975, Geomin, 1978, Etabi, 1984, Klockner, 1989 and Mahdi et al., 1993) the deposit is of a sedimentary origin and have been generated by precipitation process in fluvial close channel. The major textural element in the ore is spheres of about (0.1 – 20) mm (in diameter). The structure of this pisolite consist of a nucleus (quartz or rock fragment) surrounded by concentric layers of irregular thickness varying from few hundred microns to 1mm (Fig.1). The internal composition of the envelopes is very complex and composed of hydrated iron oxides intergrown sub microscopically with the gangue minerals (mainly alumina silicate in the form of clay). Microprobe analysis (Al-Ajeel, 1981) indicates that the total iron (Fe_T) of

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Fig. (1): Polished section shows the concentric layers of pisolite (Sofermines, 1975)

concentration is varied widely within the internal composition of the pisolite, as it is shown in Fig. (2). The ore, however, had been the subject of beneficiation studies since 1978. Because of the complex nature of the deposit coupled with poor liberation of iron bearing mineral, all attempts since then have invained to produce iron concentrate containing more than 50 % Fe_T and a recovery of about 67 % by conventional physical separation techniques such as gravity separation (Al-Ajeel, 1981, Klockner, 1989 and Sutapathy et al., 1989). Flotation (Al-Algawi, 1998 and Geomin, 1978). Magnetic Separation (Moslem, 1984, Ghanim, 1996 and Klockner, 1986) and Reduction Roasting (Geomin, 1978 and Al-Ajeel, 1986). On the other hand reduction smelting process was investigated (Al-Ajeel et al., 2003) using cupola furnace and foundry coke. The experimental variables, however, showed that a high grade pig iron containing 97 % Fe metal can be extracted. But, such attempt has not provided satisfactory results, so far as both the coke consumption rate and furnace performance. Nevertheless, the objective of the present work is to study the feasibility of using segregation roasting process as an alternative means to the conventional separation technique to enrich AL-Hussainyiat iron ore.

Segregation roasting process involves, heating an ore with a chloridizing agent (halide salt) in the presence of carbon and coal or coke. By a complex series of reaction (Wright, 1973) the valuable metal is extracted by chloridization from the ore and is deposited as metallic particles on the carbon. These segregated metallic particles are then amenable to concentration by conventional methods (flotation, (magnetic separation.. etc.). The reactions that generally assumed to take place are (Sutapathy et al., 1986) ; the generation of hydrogen chloride gas from an alkali or

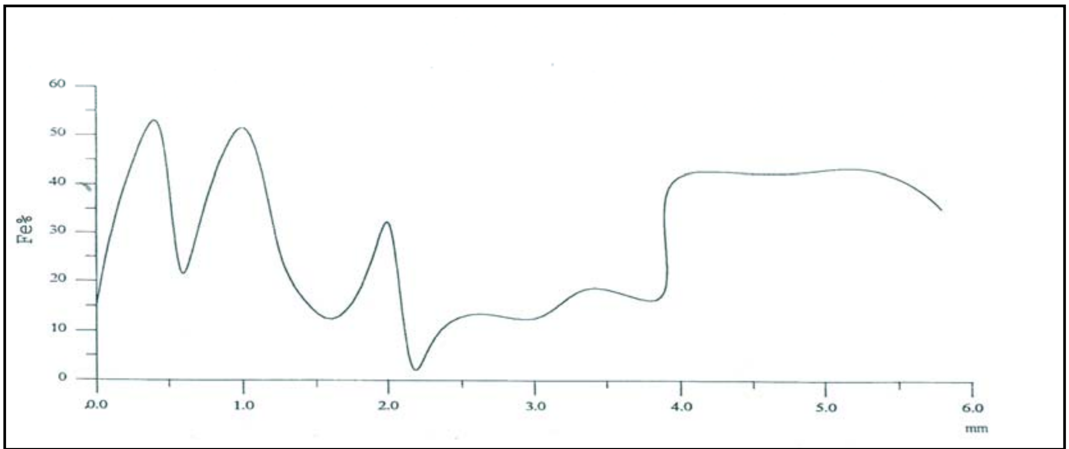


Fig. (2): Concentration of iron with respect to core of the pisolite

alkaline earth chloride, the reaction of hydrogen chloride with the metal oxide (in the present case; FeO) to form metal chloride by hydrogen that was generated by the reaction of carbon and moisture present in the charge. The reduction reaction takes places on the surface of the carbon.

EXPERIMENTAL WORK

Al-Hussayniyat pisolitic run of mine ore sample was as received crushed to pass 19 mm size , pretreated by wet method (Al-Ajeel et al., 1999) and the produced concentrate was subsequently dried and further crushed to pass 2.36 mm Specimen was then drun for total iron (Fe_T) and insoluble residue (I.R) chemical analysis . The results obtained are as 40 % Fe_T and 35.6 % I.R. (mainly as SiO_2 + Al_2O_3).

For the segregation roasting tests, predetermined, mined weight of the prepared ore sample was mixed with requisites quantities of coke and alkali earth salt ($CaCl_2$ was chosen for this work). The quantity of coke was of a bout 80 % excess of the stoichiometric requirements of the equation ($Fe_2O_3 + 3C = 2Fe + CO_2$).

The materials were fed into a horizontal stainless steel tube retort of 5cm diameter supplied with screwed cap with small hole at the center. The retort with the materials was closed, inserted in the tube furnace and then heated at the desired temperature for a certain time. At the end of the test the mixture was allowed to cool into room temperature, sieved on requested mesh and subjected to low intensity wet magnetic separation.

Initially, segregation roasting experiments were carried out at different temperatures (850 – 975) ^oC of 25 ^oC intervals for predetermined time and alkali salt amount, to arrive at the optimum operating roasting conditions for the segregation reaction .The roasting tests were conducted on ore samples of –2.36 mm particle size for an arbitrarily chosen time of 3 hours . The alkali salt amount added was of about 16% by weight of the ore sample. After cooling, the roasted charge was sieved at 0.106 mm sieve openings to separate the material into coarse (+ 0.106 mm) and fine (– 0.106 mm) fractions. Each fraction was then ground to pass 45 micron size and subsequently subjected to wet magnetic separation. The influence of ore particle size, roasting time and alkali chloride ($CaCl_2$) additive was studied. At the end of each run, samples of the magnetic and non–magnetic fractions were taken and chemically analyzed for total iron (Fe_T), metallic iron (Fe_m) and insoluble residue (I.R).

RESULTS AND DISCUSSION

• Effect of Segregation Roasting Temperature

The aim of this test was to investigate the effect of segregation roasting temperature at which metallic iron of high grade and recovery can be separated magnetically. The results of the chemical analysis obtained for the insoluble residue (I.R) , metallic iron (Fe_m) and total iron (Fe_T) of the magnetic (M and C) and non magnetic (N and T) fractions of the coarse (+ 0.106 mm) and (– 0.106 mm) portions in respect to roasting temperature are tabulated in Table(1) and presented in Fig (3). From the data, it appears that the major portion of the insoluble residue (I.R.) of the treated ore samples being reported to the non–magnetic fractions, in particular to that of coarse fraction (+ 0.106 mm), where's the major iron content (Fe_T) being reported to the magnetic fractions. The data shows that in these magnetic fractions (or iron concentrates) there is a substantial rise in Fe_T content coupled with significant decrease in I.R. content, as compared with that of the initial ore sample (I.R. 35 % and Fe_T 40 %). Table (1) shows that the I.R content of the magnetic concentrates does not exceed 11 % and as much as 80% Fe_T can be achieved. This finding indicates that an efficient segregation reduction operation had been worked out to reduce the higher iron oxide phase (Fe_2O_3) to lower oxides and metallic iron, which enable there separation from the associated gangue. The separation of metallic iron, (Fe_m) and total iron (Fe_T) as function of segregation roasting temperature is shown in Fig.(3) for coarse and fine magnetic concentrates .From this figure it can be seen that the highest grade of Fe_T (71 %) and that of Fe_m (59 %) in coarse concentrate was achieved at roasting temperature of 900 ^oC, beyond which it declined, reaching a low value at 975 ^oC. This may be attributed to the formation of fine iron bearing particles with increase in the segregation roasting temperature henceforth

Table (1): Magnetic separation results of segregation roasting at different temperatures

Temp. (°C)	Mag. Sep. Frac.	Coarse Fraction (+ 0.106 mm)			Mag. Sep. Frac.	Fine Fraction (– 0.106 mm)		
		I.R	Fe_m	Fe_T		I.R	Fe_m	Fe_T
850	M1	8.95	38	69.3	C1	–	–	–
	N1	30.66	5.85	38	T1	10	–	19.1
875	M2	9.24	38	69	C2	–	–	–
	N2	30.94	6.6	39.4	T2	11.2	–	17
900	M3	8.64	59	71.21	C3	4.4	26.6	63
	N3	37.9	4.27	25.34	T3	8.1	2	33.6
925	M4	9.6	46.8	71	C4	5.8	52	72.14
	N4	35.5	3.3	26	T4	11.3	2.5	30
950	M5	11	37	64	C5	3	73	79.2
	N5	43	3	16.5	T5	7.9	1.95	21.7
							R = 38%	
975	M6	11.2	26.6	57	C6	3.84	73.14	80.3
	N6	37.2	1.02	16.3	T6	8.5	0.84	21.8
							R = 36%	

M, C: (Magnetic fractions)
N, T : (Non-Magnetic fractions)
Fe_m: (Fe metal)
Fe_T : (Fe total)
R: (Recovery)

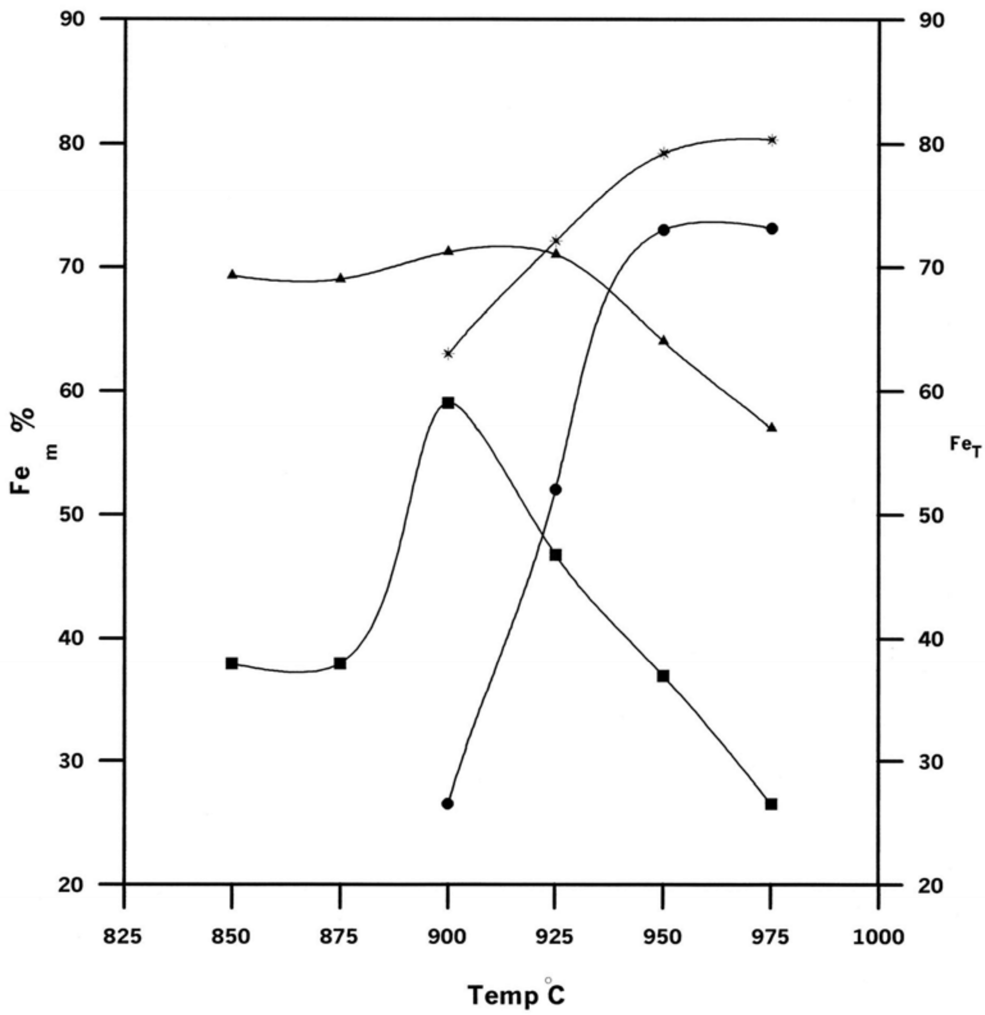
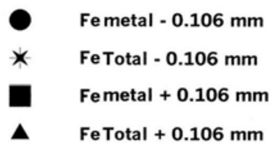


Fig. (3) Effect of segeration roasting temperature on Fe metal generation and Fe Total



transferred to the fine concentrate (– 0.106 mm). Because of this, it was found that the value of Fe_m and Fe_T increased with increase in roasting temperature and the highest values optioned was at 950 ^oC. At this temperature, minimum level of I.R. was found in the fine concentrate (– 0.106 mm) , it was in range of 3 % I.R. , but the iron recovery was considerably low and it was not more than 38 % .

• Effect of Ore Particle Size

Having determined the optimum segregation roasting temperature, which was found around 950°C; further experiments were conducted to establish the effect of ore particle size on the segregation roasting operation and iron separation. In this aspect two different particle sizes namely (–1.4 and –0.85) mm were tested. At the end of each run the materials were sieved at 0.150 mm sieve openings to obtain coarse (+ 0.150 mm) and fine (– 0.150 mm) fractions, which then were subjected to magnetic separation.

The chemical analysis results of the magnetic fractions of these tests are shown in Table (2). The results show that for the minus 0.85 mm size fraction, a high grade iron concentrate was obtained from the fine – 0.150 mm magnetic fraction. About 86 % Fe_T only 2.6 % I.R. (this corresponds to 2.06 % SiO_2, 0.38 % Al_2O_3) was obtained with iron recovery of about 63.7 %. These results reveal that the segregation roasting operation was highly enhanced with decreasing the particle size to (0.85 mm). To identify the effect of this particle size on iron concentrate and recovery at lower roasting temperature, further test was conducted at a temperature of 900 ^oC. From this test, an iron concentrate of about 83 % Fe_T with a recovery of 57 % was obtained. Also it was found that both grade and recovery of the iron concentrate of – 0.15 mm size was lower than that obtained at 950 ^oC. The results are shown in Table (3).

• Effect of Roasting Time

As the particle size of the processed iron ore was optimized at 0.85 mm and the roasting temperature at 950 °C variation in the roasting residence time was studied next. The results of the tests, performed at different roasting time (2, 3 and 4 hr) are presented in Fig. (4), which shows the effect of roasting time on grade and recovery of the iron concentrate. It is apparent from this figure that the highest grade of iron concentrate obtained was of about 86 % at a roasting time of 3 hr, henceforth it decreases to 83 % as the time increases to 4hr. Also the figure shows that the recovery has increased slightly as the roasting time increases (it increases from 64 % at 3hr roasting time to 66 % at 4hr time). However, 2 % increase in the recovery accompanied with one hour rise in roasting time would not considered a significant improvement to that gained at 3 hr roasting time. Consequently, the period of 3 hr is recommended as optimum roasting time.

Table (2): Effect of particle size on grade and recovery of iron concentrate
Segregation roasting temp = 950 °C
Roasting time = 3 hr

Particle Size (mm)	Magnetic Separation Fractions	+ 0.150 mm Size Fraction			Magnetic Separation Fractions	− 0.150 mm Size Fraction		
		I.R.%	Fe_m%	Fe_T%		I.R.%	Fe_m%	Fe_T%
1.4	M	20.24	35	26	C	4.46	72	81
	N	45.56	2.5	22	T	13.95	2.3	15.5
			R=41.3%				R=59.77%	
-0.85	M	14	31	60	C	2.6	75	86
	N	46.78	2.7	22	T	19.28	2.23	14.0
			R=38.7%				R=63.7%	

Table (3): Results of segregation roasting test carried out at 900 °C
Feed Particle Size = − 0.85 mm
Roasting time = 3 hr

Particle size (mm)	Mag. Sep. Fractions	I.R. %	Fe_m %	Fe_T %
(− 0.85+0.150)	M	18.72	26.6	56.42
	N	39.36	0.65	26.53
− 0.15	C	4.26	70.5	82.8
	T	18.28	0.65	16.2
				R=57.2 %

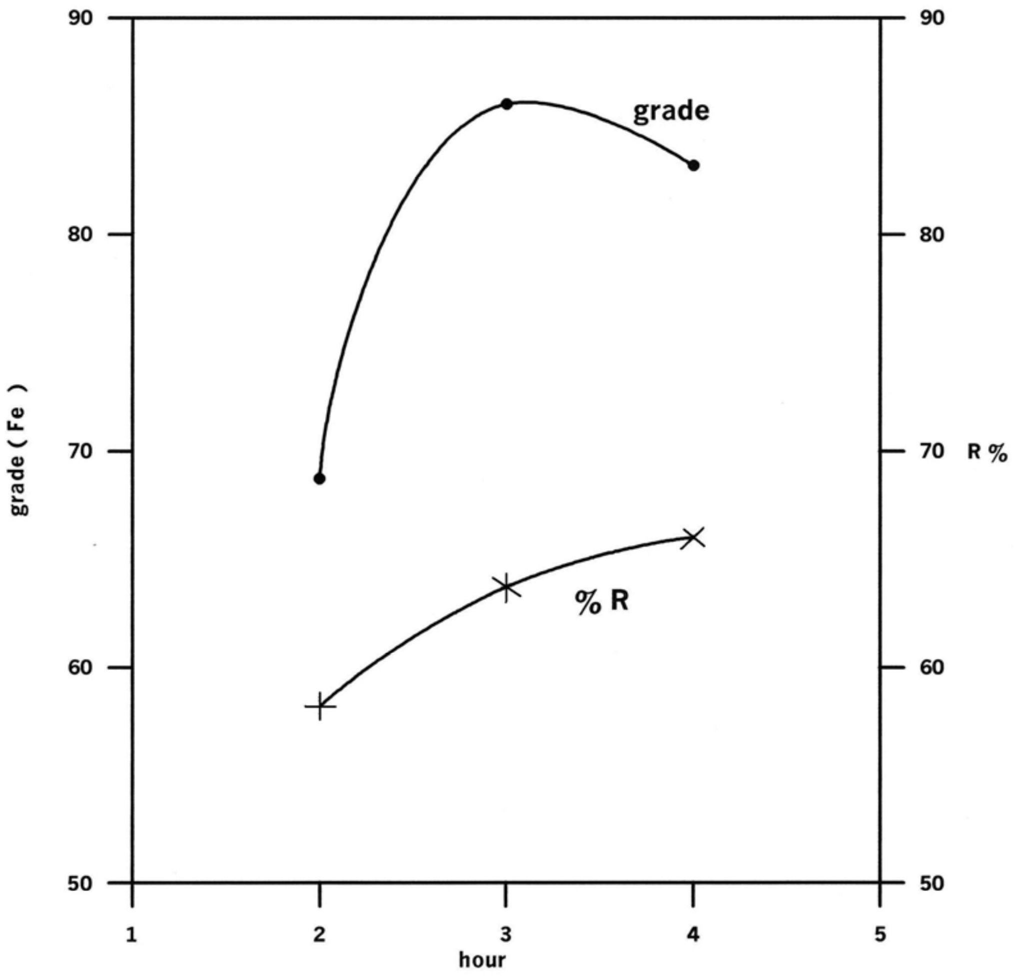


Fig. (4) effect of roasting Time on grade and recovery of Fe_T at $950\,^{0}C$ roasting temprature and - 0.85 mm particle size

● Iron concentrate grade
× Iron recovery

• Effect of Alkali Chloride Additive

The effect of different percentages of alkali chloride on iron segregation; henceforth on iron concentrate grade and recovery are presented in Fig. (5). It is apparent from this figure, that these parameters increase as the alkali chloride increases up to 16 % wt, beyond which they declined sharply. This could be due to the filling up of the active reaction surface of the carbon by the halide. Accordingly, an amount of 16 wt % of the iron ore feed can be considered as optimum for the segregation roasting separation tested, in this work.

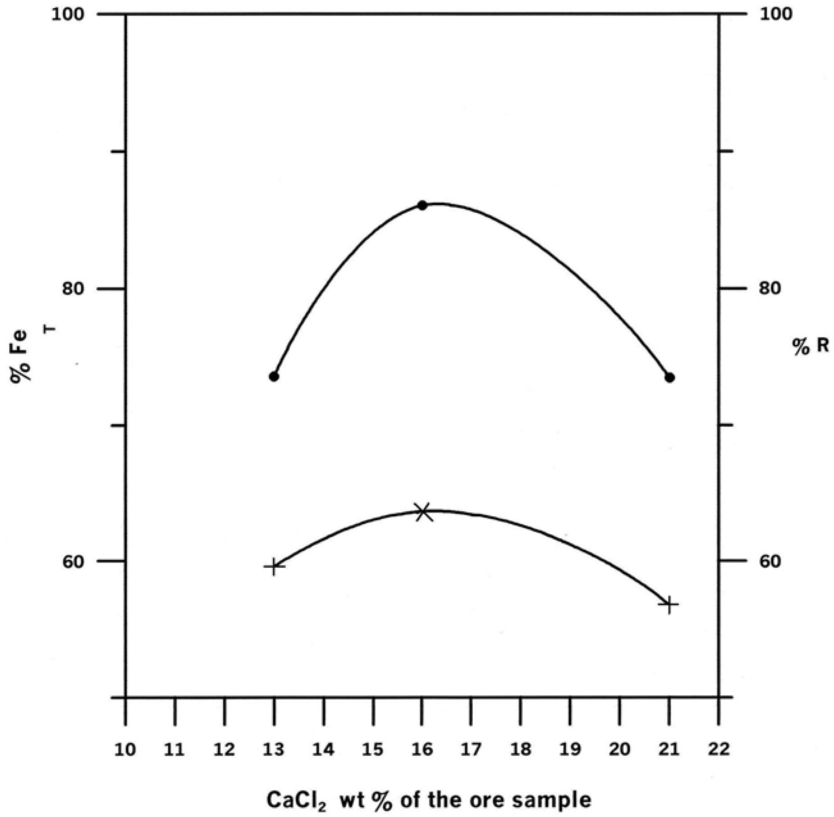


Fig. (5) Shows the effect of Calcium chloride amount on % Fe_T and Recovery

● % Fe_T
× % Recovery (R)

CONCLUSIONS

According to the results that have been presented for using segregation roasting technique as an alternative route to the conventional physical separation methods for the beneficiations of Al-Hussainyiat low grade iron ore, the following conclusion can be tested :

The segregation roasting process, which is in its early stage of development in this work, appears potentially applicable for the beneficiation of AL-Hussainiyat iron ore.

The success of the process depends on delectate balance between the reactions that convert iron oxides to metallic iron and the choice of the various operation parameters (temperature, ore particle size, roasting time, halide amount, and could be even the carbon amount and type) are very important.

The segregation and transport of metallic iron (Fe_m) from the ore particle, begins at 900°C roasting temperature, and it is concentrated in the fine fraction.

The recommended conditions, at which a high grade iron concentrate assaying, 86 % Fe_T and 2.6 % I.R (SiO_2+Al_2O_3) with Fe_T recovery of a bout 64 % could be achieved are as follow:

Roasting temperature = 950 ^oC
Roasting time = 3 hr
Ore particle size = (– 0.85 +0.15) mm
Alkali chloride amount = 16 % by weight of the ore

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