Study on reducing briquetting iron ore with El-Dekhaila iron oxide waste by carbon together hydrogen gas

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Abstract: Reduction of El-Baharia iron ore mixed with El-Dekhaila iron oxide waste briquette by coke breeze and hydrogen was carried out in the temperature range 700 to 950 oC. In reduction kinetic study the most satisfactory model was to take the slope of the initial linear region of fractional reduction vs. time curve as a measure of rate constant (k). In k vs. 1/T plots were straight line from which Activation Energy was calculated.

Key words: Iron ore, El-Dekhaila iron oxide waste, briquette, Reduction by coke breeze together with hydrogen, kinetic reduction model, energy of activation.

1. INTRODUCTION

Iron is believed to be the tenth most abundant element in the universe, and the fourth most abundant in the earth's crust. Iron is the most used of all the metals, comprising 95% of all the metal tonnage produced worldwide. Iron is extracted from its ore, and is almost never found in the free elemental state. In order to obtain elemental iron, the impurities must be removed by chemical reduction [1].

El-Dekhaila iron Co. imported the pellets from the outside of Egypt, during the transportation from outside to Company, lot of fine (waste pellets fine) formed, this fine was not suitable for the reduction inside the furnace of reduction [2].

The reduction of iron ores by hydrogen is a gas-solid reaction which occurs in two or three stages. For temperatures higher than 570°C, hematite (Fe_2O_3) is first transformed into magnetite (Fe_3O_4), then into wustite

(Fe_{1-y} O), and finally into metallic iron whereas at temperatures below 570°C, magnetite is directly transformed into iron since wustite is not thermodynamically stable [3].

The recycling of some iron oxide waste characterized by high iron oxide content such as El-Dekhaila iron oxide pellets waste during the sintering of iron concentrate. The results show that, replacement of iron ore concentrate with 10% iron oxide pellets fine increases the amount of ready made sinter, sinter strength and productivity of both sinter machine and blast furnace yard [4].

It was found that pure hydrogen as reducing agent gave a higher extent of reduction than a mixture of CO-H_2. Sulfur and phosphorus are partially removed in gaseous form from the ore; within the temperature range examined, sulfur removal increased with increase in temperature, whereas phosphorus removal was favorite at lower temperature [5].

The aim of this work is to study the briquetting the El- Baharia Oasis iron ore with El-Dekhaila fine waste pellets and reduce its in static bed by coke breeze and hydrogen.

2. EXPERIMENTAL WORK

2.1. Raw material

2.1.1 Iron ore

Iron ore ore samples was supplied by the Egyptian Iron and Steel Company, The chemical composition of iron ore is as follows:-

Fe_{total} = 52.35 %, MnO = 2.92%, SiO_2 = 10.84%, CaO = 0.39%, MgO = 0.18%, Al_2O_3 = 1.44% , S = 0.74%, TiO_2 = 0.16% , BaO = 1.17%, ZnO = 0.15%, K_2O = 0.27%, Na_2O = 0.25%, P_2O_5 = 0.5 %. [6-8]

The X- Ray analysis of El-Baharia iron ore is illustrated in figures 1. From which it is clear that El-Baharia iron ore mainly consists of hematite and quartz [6-8].

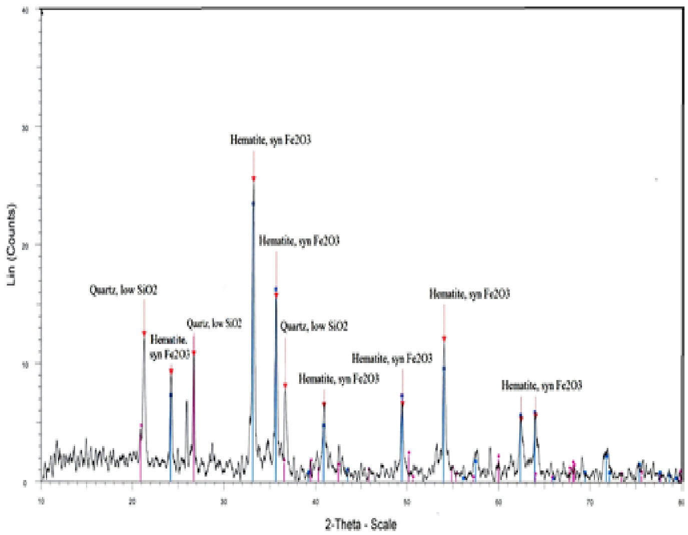


Fig.1. The X- Ray analysis of El-Baharia iron ore

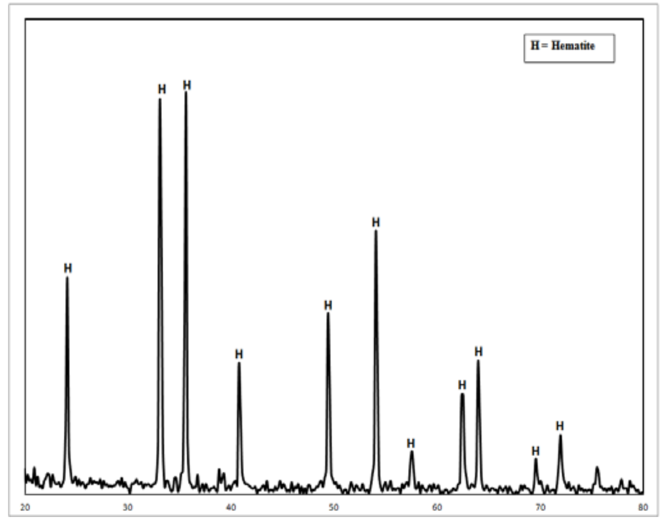


Fig.2. X-ray of El-Dekhela Pellets waste

2.1.2. El-Dekhaila waste pellets

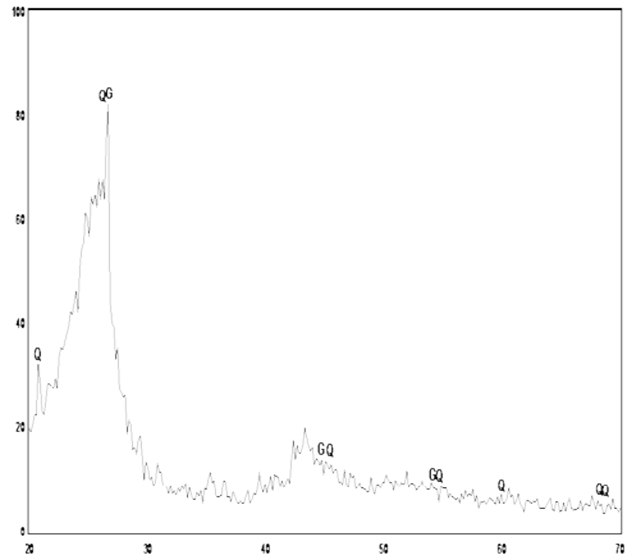
El-Dekhaila waste pellets which used in this work was delivered from El-Dekhaila steel Company (Alexandria, Egypt) the chemical analyses of this fine are, Fe $_{total}$ = 66.5%, Fe_2O_3 = 95%, SiO_2 = 1.5% and CaO = 0.7% [9,10].

X-ray of the El-Dekhaila pellets waste illustrated in Fig.2, from which it is clear that the main compound of this waste is hematite [9.10].

2.1.3. Coke breeze

The chemical composition of coke breeze used contains 86.992% fixed carbon, 1.08% volatile matter, 10.26% ash, and 1.04 sulfur [11].

While the X- ray analysis of coke breeze is illustrated in Fig.3. From which it is clear that it is mainly consists of graphite and quartz (SiO_2) [11].



G: - Graphite Q: - Quartz SiO_2

Fig. 3. X- raty of Coke breeze

2.2. Preparation of the Briquetting and Its Physical Properties

The raw materials were grinding in vibrating mill to powder with size less than 75 micrometers. The fine of powder (10 gm [80 % of ore with 20 % of El-Dekhila) are mixed with different percentage of coke breeze fine and 2.5 % bentonite and then pressed in the mould (12 mm diameter and height 22 mm) under pressure load 275 MPa using MEGA.KSC-10 hydraulic press. The briquette subjected to drop number test and crushing strength tests. Ten green or dry briquettes are individually dropped from a height 46 cm to steel plate before they show perceptible cracks or crumble. The number of drops is determined for each briquette. The arithmetical average values of the ten briquettes yield the drop number .The average crushing strength is done by compressed 10 briquettes between parallel steel plates up to their breaking [12-15].

2.3. Reduction Procedures

The reduction of the briquette by carbon of coke breeze and hydrogen were done on thermo gravimetric apparatus (A schematic diagram of thermo gravimetric apparatus is shown in Fig. 4 [7-11, 16-,22]. It consisted of a vertical furnace, electronic balance for monitoring the weight change of reacting sample and temperature controller. The sample was placed in a Ni-Cr basket which was suspended under the electronic balance by Ni-Cr wire. The furnace temperature was raised to the required temperature (700-1000 °C) and maintained constant to ± 5 ºC. Then samples were placed in hot zone. The nitrogen flow rate was 0.5 l/min on all the experiments was passed at initial time and after the end of reduction only, the weight of the sample was continuously recorded and at the end of the run, the samples were withdrawn from the furnace and putted in the desiccators. The amount of removable oxygen and carbon monoxide was determined by the weight loss from the sample (Wo-Wt) during the experiment of reduction .The percentage of losses was calculated according to the following equation :-

Percentage of losess = [(Wo-Wt)/ Wo] *100 (1) Where:- Wo the initial mass of sample .g.

Wt mass of sample after each time ,g.

3. RESULTS and DISCUSSIONS

3.1. The effect of percentage of coke breeze added on the physical properties of the produced in green and dry briquettes forms

Figs 5-8 show the relationship between the change of amount of coke breeze vs. the drop damage resistance and compressive strength of the wet briquettes and dry samples for 3 days, at constant amount of bentonite (2,5%) as binder From these figures, it is clear that when the amount of coke breeze increases, both the drop damage resistance and compressive strength decreased.

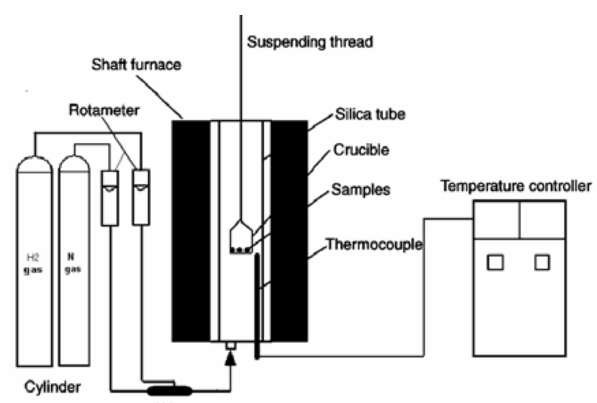


Fig.4. Schematic diagram of the reduction apparatus

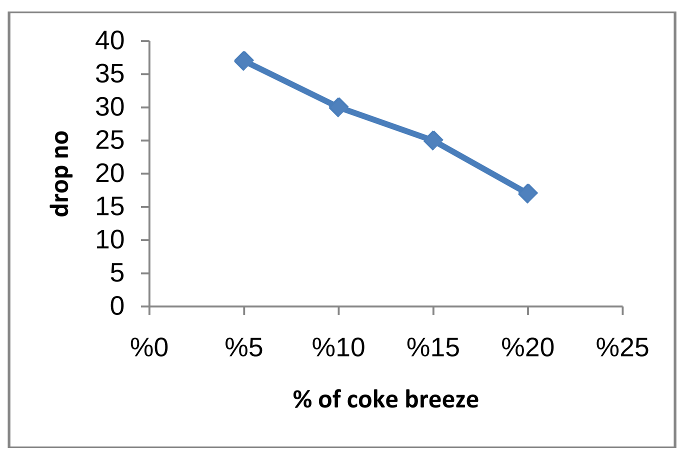


Fig.5 Effect amount of coke breeze added on the drop number of green briquettes

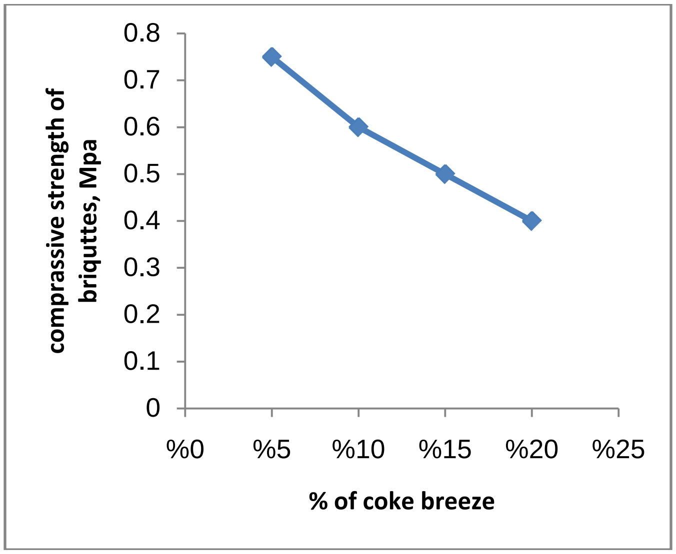


Fig.6 Effect amount of coke breeze added on the strength of green briquettes

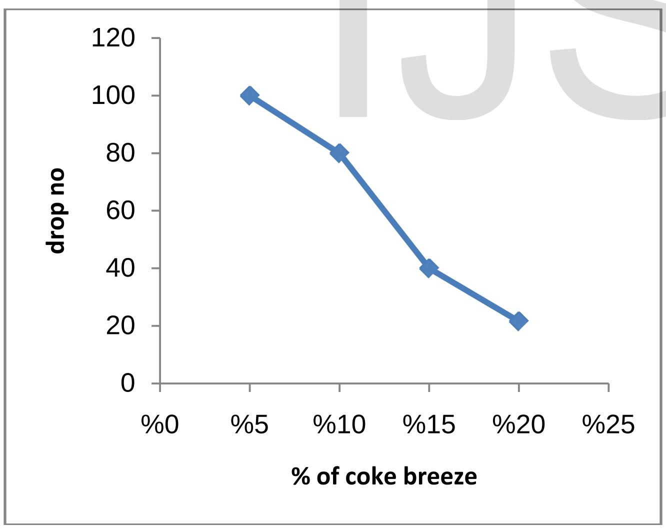


Fig.7 Effect amount of coke breeze added on the drop number of dried briquettes

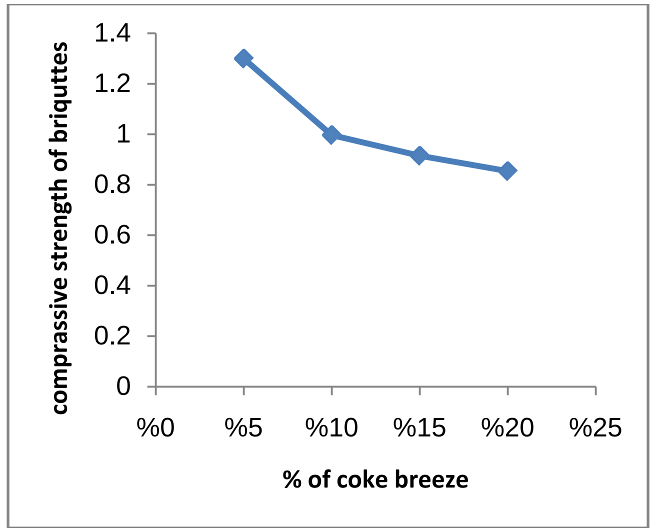


Fig.8 Effect amount of coke breeze added on the strength of dried briquettes

3.2. Effect of change amount of coke breeze on the loses of sample in present of hydrogen at 1000°C (1.5 liter / min)

Fig 9 shows the effect of changing the percentage of coke breeze on the losses during the constant hydrogen flow rate 1.5 l/min. From these figures, it is clear that as the amount of coke breeze increased the loses in weight decreased .

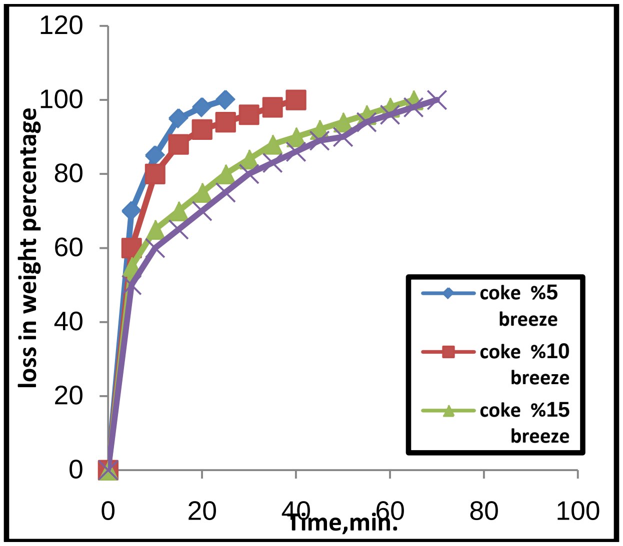


Fig.9, Effect of change amount of coke breeze on the loses of sample in present of hydrogen at 1000°C (1.5 liter/ min).

3.3. The Effect of temperature upon the loses percentage

In order to examine the effect of temperature upon the losses percentage of the briquettes (80% iron ore and 20% Eldekaila waste pellets mixed with 10% coke breeze formed), the experiments were carried out at 700 – 1000°C and under 1.5L/min hydrogen flow rate. The plots of the losess percentage versus time are shown in Figure 10 . From tiese figure, it was observed that the reduction temperature influence on the losses percentage. This may be due to the fact that as the loses percentage increases with increase in temperature as the number of reacting moles having excess of energy increased. Moreover, the raise of temperature may lead to an increase of the rate of mass transfer through diffusion as well as the rate of desorption [23-26].

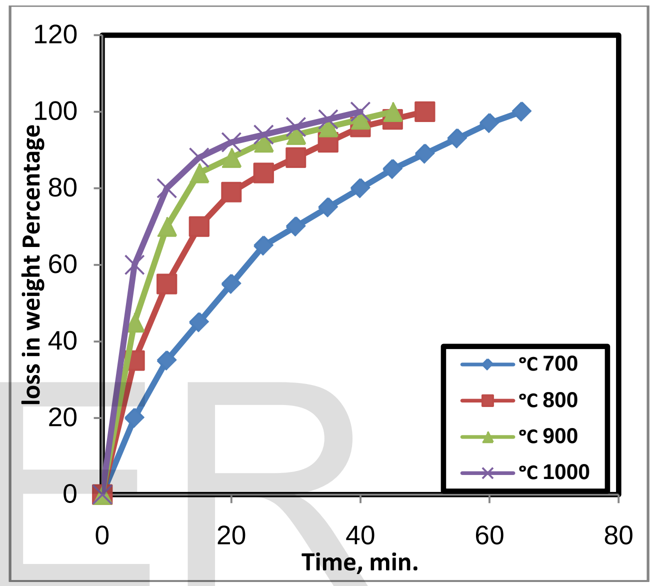


Fig.10. Effect of temperature on the losses weight briquette

3.4. Kinetics reduction of briquette

Kinetic studies for estimation of apparent activation energies were carried out for the briquettes at different temperatures range from 700˚C up to 1000˚C for different time intervals in the range of 0 - 70 min. equation geometrical contraction models[27]

$[1 - (1-R)^{0.5} = kt$

Where R is fractional reduction, t is time of reduction, k is the rate constant.

Fig.11 illustrate the relation between $1 - (1-R)^{0.5}$ against time of reduction for different reduction temperature . From which it is clear that the straight line was observed.

The natural logarithms were used according to the Arrhenius equation to calculate the activation energies of reduction reaction. The results illustrate in Fig.12 , from which it is clear that the activation energy= 32.472 kJ/ mole .

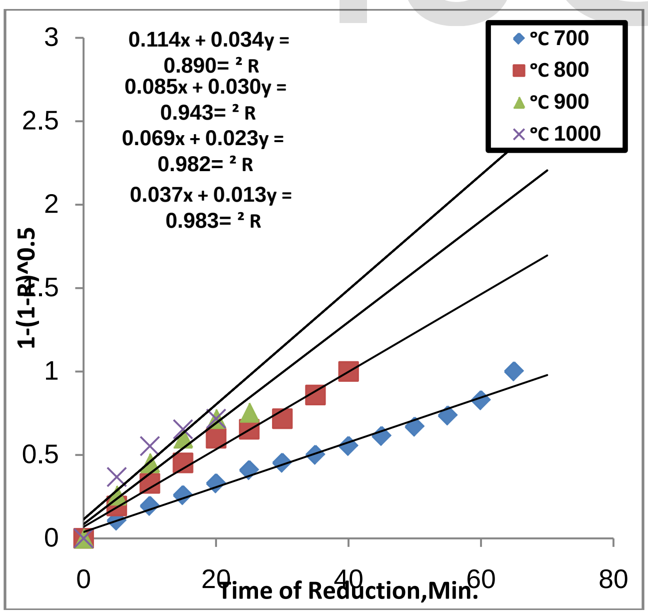


Fig.11. The relation between $[1 - (1-R)^{0.5}$ and time of reaction

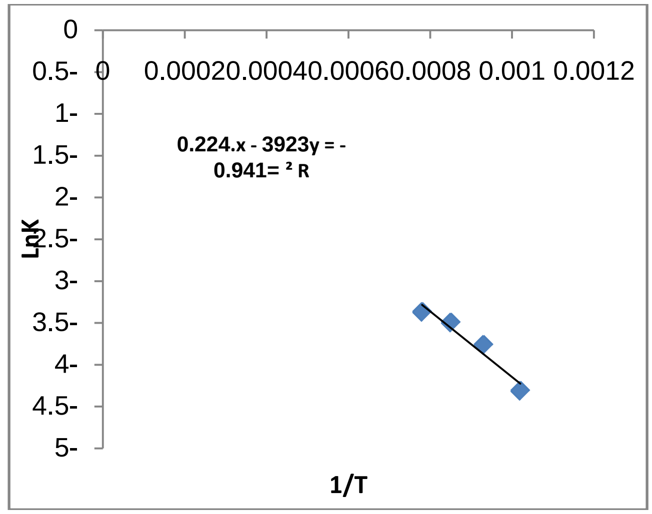


Fig.12. Relation between ln k and 1/T

Using equation R+(1-R)ln (1-R) =kt [27-28]

Fig. 13. illustrate the relation between R+(1-R)ln (1-R) against time of reactions for different reaction temperature . From which it is clear that the straight line was observed.

The natural logarithms were used according to the Arrhenius equation to calculate the activation energies of reduction reaction. The results illustrate in Fig.14 , from which it is clear that the activation energy= 26.48 kJ/ mole

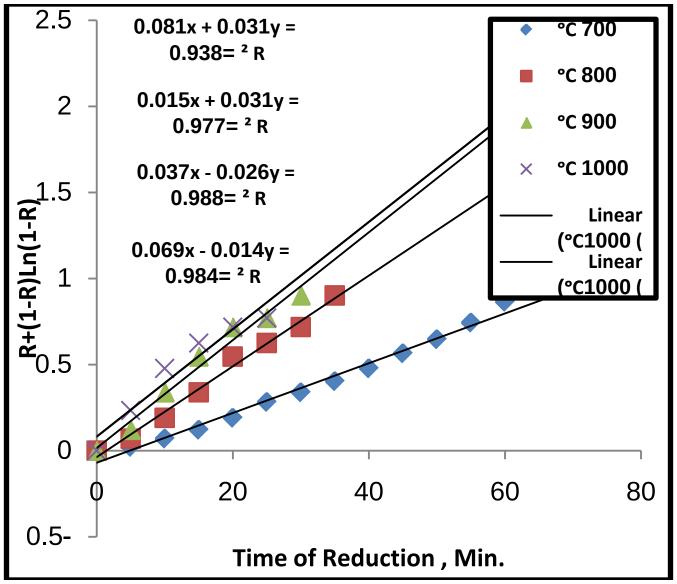


Fig.13. The relation between R+(1-R)ln (1-R) and time of reaction

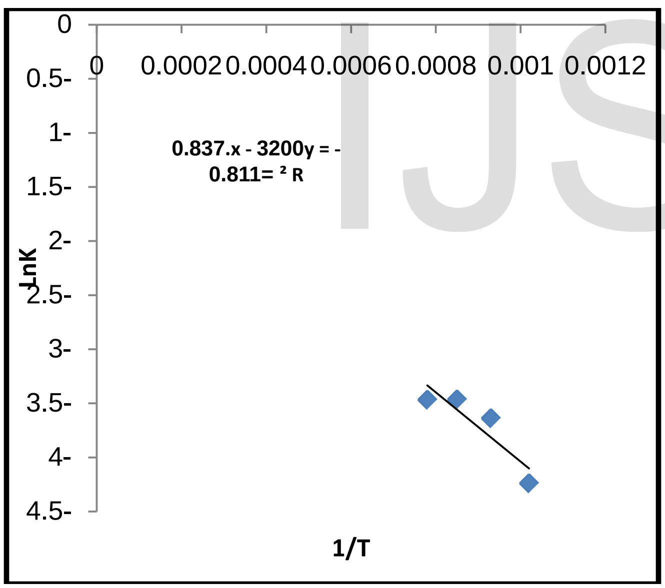


Fig.14. Relation between ln k and 1/T

3.5. X-Ray analyses of the reduced pellets.

X-ray analyses of the sample reduced at 800 and 1000°C shows that the present phases are metallic iron (syn. Fe), and some traces of magnetite [M] (Fe_3O_4) as shown in Figures 15-16

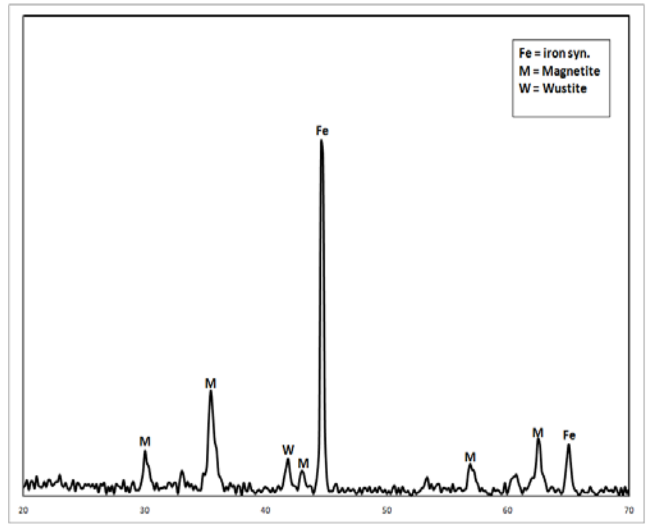


Fig. 15 X-ray analyses of the sample reduced at 800°C

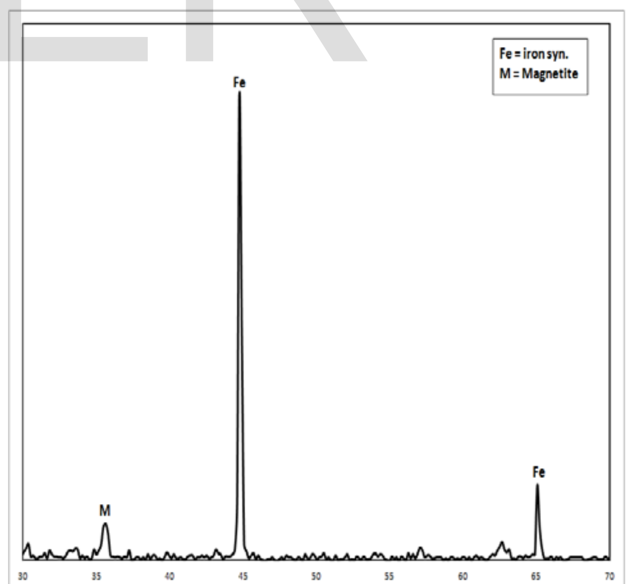


Fig. 16 X-ray analyses of the sample reduced at 1000°C

4. CONCLUSIONS

From the obtained results, the following can be concluded:

1. As the percentage of coke breeze increased in the briquette of iron ore with El-Dekaila waste pellets. both the drop number and compression strength of the briquette decreased

2. Reaction of the briquettes formed increased applying a higher hydrogen flow rate.

3. Using equation kt = $[1 - (1-R)^{0.5}$ The activation energies calculated for this process for the briquettes was 32.472 kj/mole

4. The activation energies calculated for this process for the briquettes Using equation:- **kt = R+(1-R)Ln(1-R)** was =26.48 kJ/ mole

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