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Reduction of Mill Scale by Carbon

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Abstract— *This paper studies the reduction of mill scale, pellets fine waste by coke breeze in the temperature range 800 to 900 ^{o}C. The results show that the loss in weight increase as the temperature increase and also the losses increase as the weight of coke breeze in the pellets increase.*

Keywords— *Reduction, Mill Scale, pellets, Coke Breeze.*

I. Introduction

Mill scale is one of the by-products produced during steel processing and its specific production is considerably high representing about 19-40 kg/t of hot rolled product, depending on the deformation technology used. The global production of steel during 2008 was 1125 million t and the corresponding mill scale produced is estimated to be 33million t on average. On the other hand, mill scale is considered as a rich iron source (> 70% Fe) with minimum impurities. Extensive research is being conducted for the recovery and utilization of the iron oxide that mill scale contains. Mill scale is used for magnetic storage, polishing, chemical manufacturing, pigment manufacturing, and biomedical application. The production of sponge iron from scale could be considered a highly profitable method of beneficiation. In this study, the reduction of composite pellets produced from mill scale using anthracite coal was investigated. Laboratory scale trials have been conducted to study the effect of the amounts of reducing agent, reduction temperature and reduction time. The trial results show that it is possible to use mill scale as a raw material in blast furnaces as well as in direct reduction plants producing sponge iron characterized by 84% Fe total, 82% metallic Fe and metallization degrees of more than 97%.[1]

Mill scale is a valuable waste material that contains a high amount of iron, little impurities and also is chemically stable composition. It is produced from the hot rolling processing in the steel industry. It can be recycled back to the sintering plant.[2]

Around 90% of mill scale waste is recycled in the iron and steel industry while a small amount can be used in cement plants and petrochemicals industry.

Mill scale contains both iron in elemental form and three types of iron oxides: Wustite (FeO), Hematite (α-Fe2334O) and Magnetite (FeO). The chemical composition of mill scale varies according to the type of steel produced and the process used. The iron content is normally around 70 %, with traces of non-ferrous metals and alkaline compounds. The reduction of rolling mill scale to sponge iron powder is a new way to take advantage of a cheap by-product of the steelmaking industry.[3]

Electric furnace as metallic charge for steelmaking to obtain a product with lower residual content and improved properties [4-6].

Mechanical activation pretreatment of minerals by intensive milling can improve the efficiency of subsequent processes such as leaching, reduction, chemical synthesis, etc. Consequential benefits of mechanical activation, besides higher efficiencies, may include lower reaction temperatures and enhanced kinetics. As a result, the subsequent processing can be performed in simpler and less expensive reactors with shorter reaction times [7–9]. Several factors, most importantly the formation of new and additional surface area as well as the creation of lattice defects, are responsible for the mentioned improvements [7 10-15]. Different types of milling apparatus such as ball mills, planetary mills, vibratory mills, pin mills and rolling mills may be used for milling operations [16].

Mechanical treatment in a high energy mill generates a stress field within solids. Stress relaxation can occur via several channels: (1) heat release, (2) development of surface area as a result of brittle fracture of the particles, (3) generation of various sorts of structural defects and (4) stimulation of chemical reaction within solids. All relaxation channels cause changes in the reactivity of the solid substance under treatment, which is why the resulting action is called mechanical activation[17]. The concentration of the mechanically induced defects and their spatial distribution depend upon the condition of the energy transfer in the mill. These can also be influenced by varying the external conditions of stress. The creation of defects enhances the stored energy (enthalpy) in the solids and consequently causes a decrease of activation.

II. Experimental Work

2.1. Materials

A-Samples of mill scale were provided from hot rolling section of Iron and Steel Company (Helwan, Cairo, Egypt).

2.1.1. Chemical analyses of mill scale

The chemical compositions of the mill scale were analyzed by XRF apparatus is shown in table 1.

2.1.2. Coke breeze

The chemical composition of coke breeze used contains 86.992 % fixed carbon, 1.08% volatile matter, 10.26% ash, and 1.04 sulpher. [18]

While the X-ray analysis of coke breeze is illustrated in Fig.1. From which it is clear that it is mainly consists of graphitize and quartz (SiO_2).[18]

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TABLE (1): The chemical compositions mill scale

Compound	%
Fe_2O_3	70
Fe_3O_4	17.26
FeO	7.83
SiO_2	1.92
MnO	0.66
S	0.33
CaO	
MgO	
P_2O_5	P=0.23
Al_2O_3	
TiO_2	
BaO	
ZnO	
Na_2O	
K_2O	
Cl^-	
C	0.04
L.O.I.	

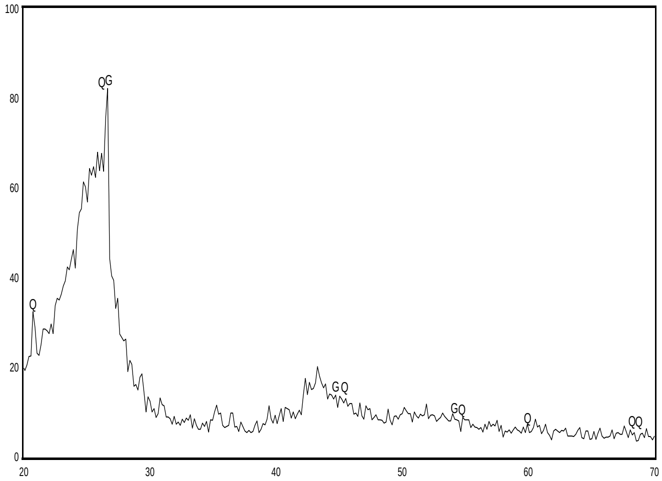

Fig. 1. X- ray Diffraction of coke breeze

2.1.3. X-ray diffraction of the mill scale

X-ray diffraction analyses of mill scale were conducted to determine qualitatively its phase composition. This analysis was carried out using Broker AXS_D8 Advance. The investigated samples were finely ground to pass through 0.076 mm sieve to remove the effect of particle size on the obtained X-ray diffraction pattern.

The mineral composition of the analyzed samples was qualitatively determined from their XRD pattern using XRD data of minerals given by ASTM which are stored in the memory of the computer of the apparatus. The results of the X-ray diffraction analyses for mill scale are illustrated in Fig. 2.

2.2 Experimental Procedures

2.2.1. Preparation of Sample mill scale and coke breeze in the form of Pellets

Preparation of samples for the pelletizing process was carried out by mixing the mill scale with coke breeze fine were prepared in a disc pelletizer of diameter 400 mm, collar height 100 mm Fig. 3, angle of inclination 60 ^{o}C, disc rotating speed 17 rpm and residence time 10 min. The materials were feed to the pelletizer. The predetermined moisture amount (10% water + 2% of molasses) was then sprayed onto the rolling bed of material in the pelletizer. The green pellets in the size range 5-7 mm diameter were screened out to dry in a drying oven at 110 ^{o}C for 2 h, to ensure the evaporation of all water used during the process.

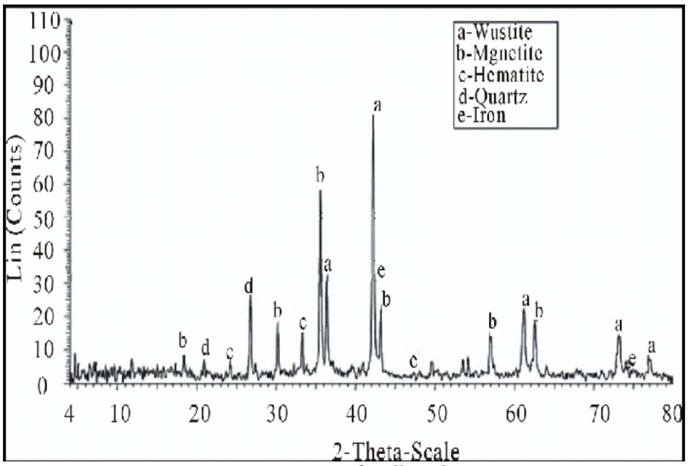

Fig. 2. X-Ray of Mill Scale

Fig. 3. Disc pelletizer equipment.

2.2.2. Determination of the quality of pellets.

2.2.3.a. Drop damage resistance test

The produced pellets were subjected to mechanical tests[19-21] The drop damage resistance indicates how often pellets can be dropped from a height of 45 cm before they show perceptible cracks or crumbed. Ten pellets are individually dropped on a steel plate until their breaking. The mean value of the tested briquettes or pellets gives their average drop number.

2.2.3. b. Compressive strength test

The average compressive strength tests of pellets is controlled by compressing at least 10 of briquettes or pellets between parallel steel plates (4) up their breaking. The mean value of the tested pellets gives their compressive strength [22]

Fig. 4. MEGA.KSC-10 hydraulic press.

2.3 Reaction Procedure of Mill Scale with Carbon

The reaction of pellets of mill scale with carbon was done in the thermo gravimetric apparatus Fig. (5). It consists of an vertical furnace, electronic balance for monitoring the weight change of reacting sample and temperature controller, The pellets 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 ˚C. Then the sample was placed in the hot zone. The nitrogen flow rate was 0.5 1/min during experiments, and at the end of the run; the samples were withdrawn from the furnace and kept in the desiccator. The percentage of weight loss was calculated according to the following equation:-

Percent of the Weight loss (Percent of reduction) = [(Wo −Wt)×100 /Oxygen mass] (1)

Where:

Wo: the initial mass of mill scale sample after removal of moisture;
Wt: mass of sample after each time, t;
Oxygen mass: indicates the mass of oxygen percent in mill scale in form FeO & Fe_2O_3.


Fig. 5. The thermo gravimetric apparatus

III. Result and Discussion

Figures 6 and 7 show the effect of the amount of coke breeze added on drop number of green mill scale pellets and its strength. From which it is clear that as the amount of coke increase the drop number of mill scale pellets and its strength decreases.

Fig. 8 shows the Percentage of weight losses of mill scale contain different amount of coke percentage at 900 ^oC reaction from which it is clear that the loses increase as the amount of coke breeze increase.

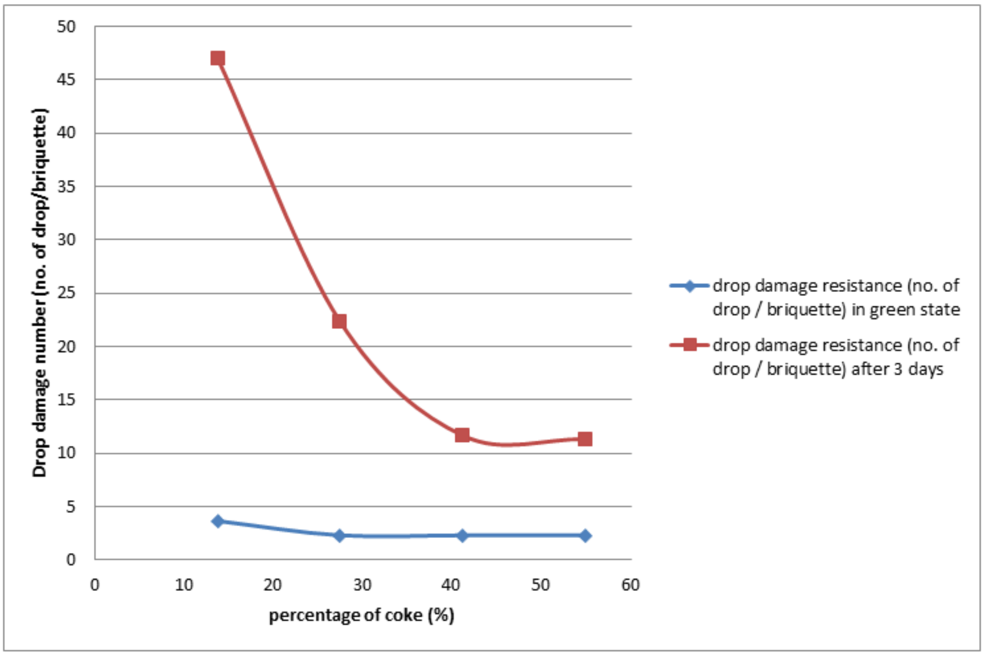

Fig. 6. Effect of the percentage of coke breeze presenting n the drop number of mill scale pellets

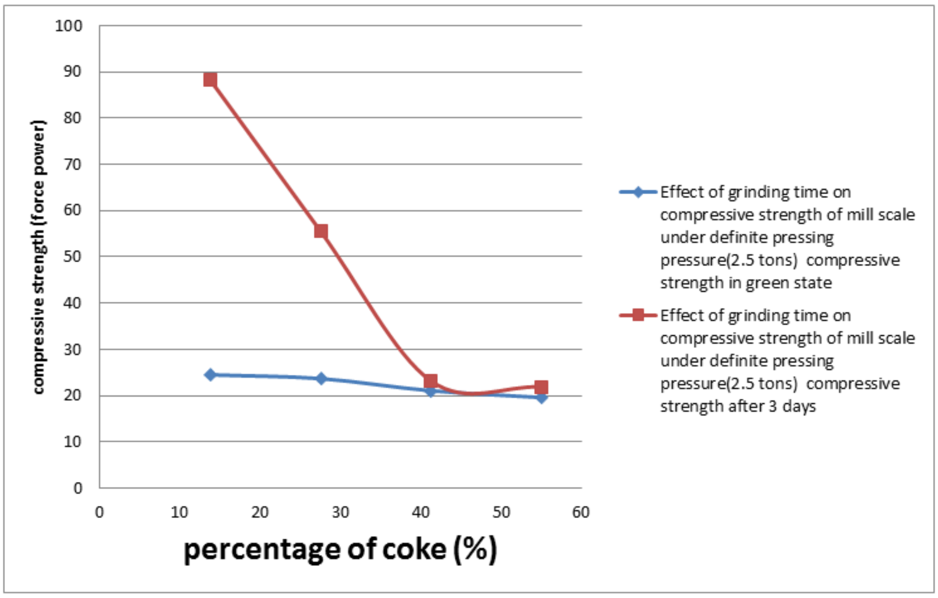

Fig. 7. Effect of the percentage of coke breeze on the strength of mill scale pellets

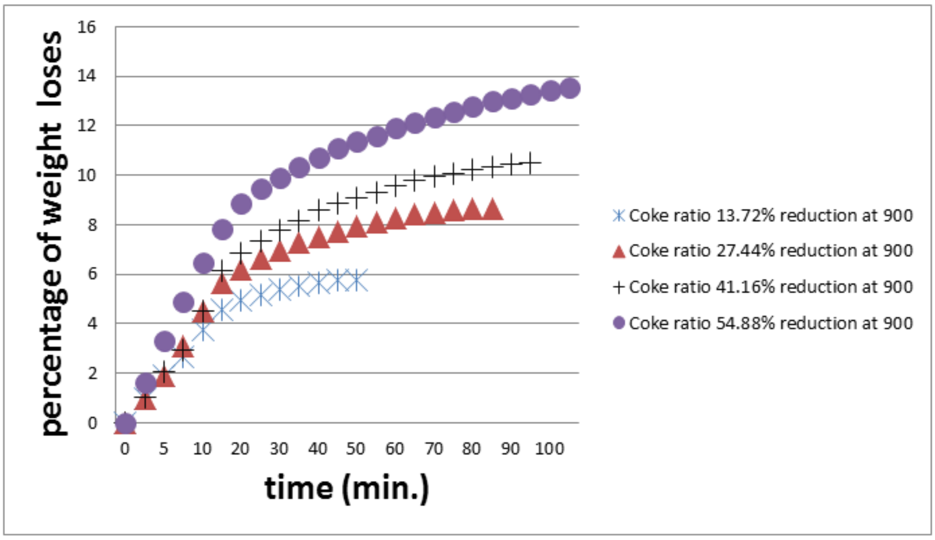

Fig .8. Percentage of weight losses of mill scale contain different amount of coke percentage at 900 ^oC reaction

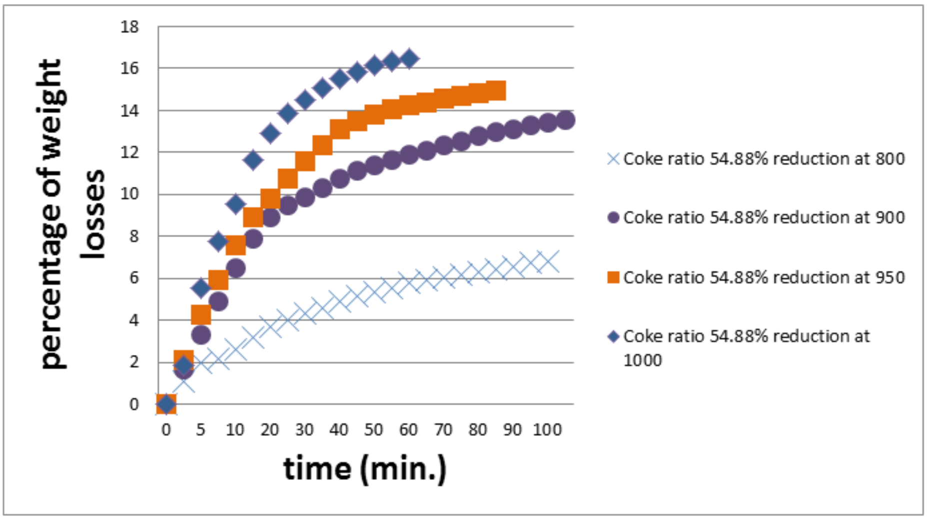

Fig. 9. Percentage of weight losses of mill scale containing coke breeze 84.88 %at different temperature of reaction

In order to examine the effect of temperature on the percentage of weight losses of mill scale contain coke breeze. Experiments were carried out at 800-1000^{o}C. Plots of the losses percentage as a function of time is shown in Fig. 9. From this figure, it is observed that the temperature influences significantly the reduction percentage. The increase of loss percentage with the rise of temperature may be due to the increase of the number of reacting moles having excess of energy which leads to the increase of losses rate. Also the raise of temperature leads to an increase of in the rate of mass transfer of the diffusion and rate of desorption.

IV. CONCLUSIONS

1- As the amount of coke breeze increases the drop number of mill scale pellets containing coke breeze and its strength decreases.
2- The Percentage of weight losses of mill scale contain different amount of coke percentage at 900 ^{o}C. The loses increase as the amount of coke breeze increase.
3- The temperature influences significantly the reaction. The increase of losses percentage with the rise of temperature may be due to the increase of the number of reacting moles having excess of energy which leads to the increase of losses rate. Also the raise of temperature leads to an increase of the rate of mass transfer of the diffusion and rate of desorption.

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