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FUNDAMENTALSTUDYOFTHEEFFECTOFIRON REDUCTION ON THE BINDER TYPE IN IRONORE BRIQUETTE

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Abstract

As well known that the Iron and steel Industry has been priority policy by Indonesian goverment in order to meet requirement of iron and steel in community base. There were made to develope processes for producing iron for steelmaking that could serve as alternatives and/or supplementst to the conventional blast furnace in order to produce both of them save energy, low cost and environmental friendly. Fundamental study on the effect of the iron reduction on binder type in iron ore briquette was studied by using an electric furnace. In the experiments three types of samples were used. The iron ore were mixture by using low grade coal and three kind of binder for making iron ore briquette. The CO_2 and N_2 gas based were injected into the reductor as the reducing gas media. The reduction degree properties were expressed in terms of iron ore *reduction index (IRI). The iron ore reduction index was determined by mass change of the sample after reduced with CO_2 as gas media. The reduction degree iron in sample was characterized by using X-ray diffraction (XRD) analysis. The experimental results show that low gradecoalcontentandbindertypeareplayedanimportantroleonbriquettemassreduction. The mass reduction of iron ore briquette composed of 10 % low grade coal is faster compared to that composed without using low grade coal. The briquette by using heavy oil as a binder that higher mass reduction is obtained. The component in sample was dominated by Fe_2O_3, Fe_3O_4 and carbon It was shown that iron ore briquette by using asphalt as binder reduced of Fe_2O_3into Fe_3O_4 easily than that using heavy oil and benthonite*.

Keywords
Iron ore, low grade coal, binder type and reduced iron

1. Introduction

As well known that the Iron and steel Industry has been priority policy by Indonesian goverment in order to meet requirement of iron and steel in community needs. During the pass century, many efforts were made to develope processes for producing iron for steelmaking that could serve as alternatives and/or supplementst to the conventional blast furnace such as direct reduction iron in order to produce both of them save energy, low cost and environmental friendly.

Direct reduction refers to using gas or solid reluctant in the reaction of iron ore reducing into metallic iron below of the melting temperature. The products are called direct reduced iron (DRI). The coal-based direct reduction process makes ferric oxide metallic Fe into metallic iron under solid state. Some coal-based iron ore direct reduction processes are based on formation of composite pellets or briquette which consist of a mixture of fines of iron-bearing oxide, carbonaceous material, for example, coal, coke, or char and a small amount of binder. Then, the pellets or briquette are placed on a rotary hearth and the iron ore is reduced to iron by chemical reactions. The non uniformity of heating, heterogeneous reactions, the devolatilization of coal, and change in the pellet or briquette size make the reduction process very complicated.

Recently, as the electric furnace steel making industry has got great development, further researches on the characteristics of direct reduction iron (DRI) making still have practical significance. DRI making has excellent performance in energy saving, environmental protection, etc. The biggest advantage is that it does not need coking and sintering, and there is almost no harmful gases emission in the reduction process. Direct reduction is considered as the best method to reduce the high construction cost of blast furnace and to solve the environmental problems caused by blast furnace iron making. Due to the shortage of natural gas, coal based direct reduction still occupies an important position.

Many researchers are reported on coal-based direct reduction iron processes in the past two decades. Historical development and background of direct reduction processes was reported (Feinman J, 1999). The reduction of iron oxides by hydrogen was reported (Damien W *et al*., 2006) as a result the reduction of synthetic hematite samples is a multi-stage reaction with one or two intermediate oxides depending on temperature that in the range 550-900°C shows the increasing in temperature accelerates the reaction. The Influence of temperature and time on reduction behavior in iron ore–coal composite pellets size of about 15 mm was also reported (Yi M *et al*., 2014). Experimental results indicate that the reduction process is diffusion controlled below 900 °C. There is a change in reduction mechanism above this temperature and mixed control is observed up to 1100 °C above which reduction is phase-boundary controlled. The mass loss and direct reduction characteristics of iron ore coal composite pellet was also reported (Yi M *et al*., 2014). The mass loss rate increased rapidly from 800 to 1100 ^{o}C. The reduction process can be divided into three steps which correspond to different temperature ranges. The mathematical modeling of direct iron ore reduction with CO and H_2 gas mixtures process was reported (Raymond L., 2008). The coal-based direct reduction process of iron ore in a pellet composed of coal and iron ore mixture was also investigated by using a finite-control volume method (Jingyu S et al., 2005). It is found that the effects of convection in the gas medium on the temperature and the overall average reduction are very small. In this paper, we investigate the effect of low grade coal mixtures on iron productivity in direct reduction process by using a single briquette.

2. Experimental Method

2.1Briquette Production Process

The sample of briquette consists of iron ore, coal and binder. The coal is selected as a low grade coal and it came from Meurebo (West Aceh, Indonesia). The iron ore is selected from Lhong (Aceh Besar Distric, Indonesia). The properties of used coal and iron ore are shown in Table 1.

The production conditions and process of the iron ore briquette are shown in Table 2. The low grade coal and iron ore were dried and crushed to the mesh size 2.36 mm separately by hand sieve before mixing together. The composition of low grade coal content in iron ore briquette was varied 10 and 20 in mass percentage and tar (heavy oil) was used about 10 in mass percentage as a binder. The mixer of low grade coal, iron ore and tar (heavy oil) was input in a die and compressed under the pressure of about 220 Map by pressing machine, respectively. The photograph of cylindrical iron ore briquette is shown in Figure 1. The diameter of bio-briquette was selected 30 mm. The mass of die charge was selected about 100 gram,respectively.

Table 1: *Properties of coal tested*

Samples	**Proximate Analysis [mass %, wet basis]**				**Fe [mass%]in ash**	**lorific value [kcal/kg]**
	Moisture	**VM**	**FC**	**Ash**		
Coal	5.83	46	42.77	5.40	3.5 %	5904

Figure 1: *Photo of iron ore briquette*

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mm. The mass of die charge was selected about 100 gram, respectively.

The experiments were performed in a laboratory scale electrically heated furnace. The reduction temperature was controlled of about 750°C in the redactor. The schematic diagram of experimental apparatus is shown in Figure 2. It is consist of an electrically heated batch furnace, temperature controller and a digital balance.

As shown in Figure 2, the tested iron ore briquette was suspended in basket by a wire linked to digital balance and was positioned in the center of the redactor. The CO_2 and N_2 gases were used as gas reduction media. It was feed into the redactor through a flow meter of about each of them 2 and 12 liter/min., respectively. The redactor was heated to a predetermined temperature to heat the sample. The sample mass loss was continuously measured by the digital balance. In this experiment assume that the influence of buoyancy on measured of the mass loss was neglected, respectively.

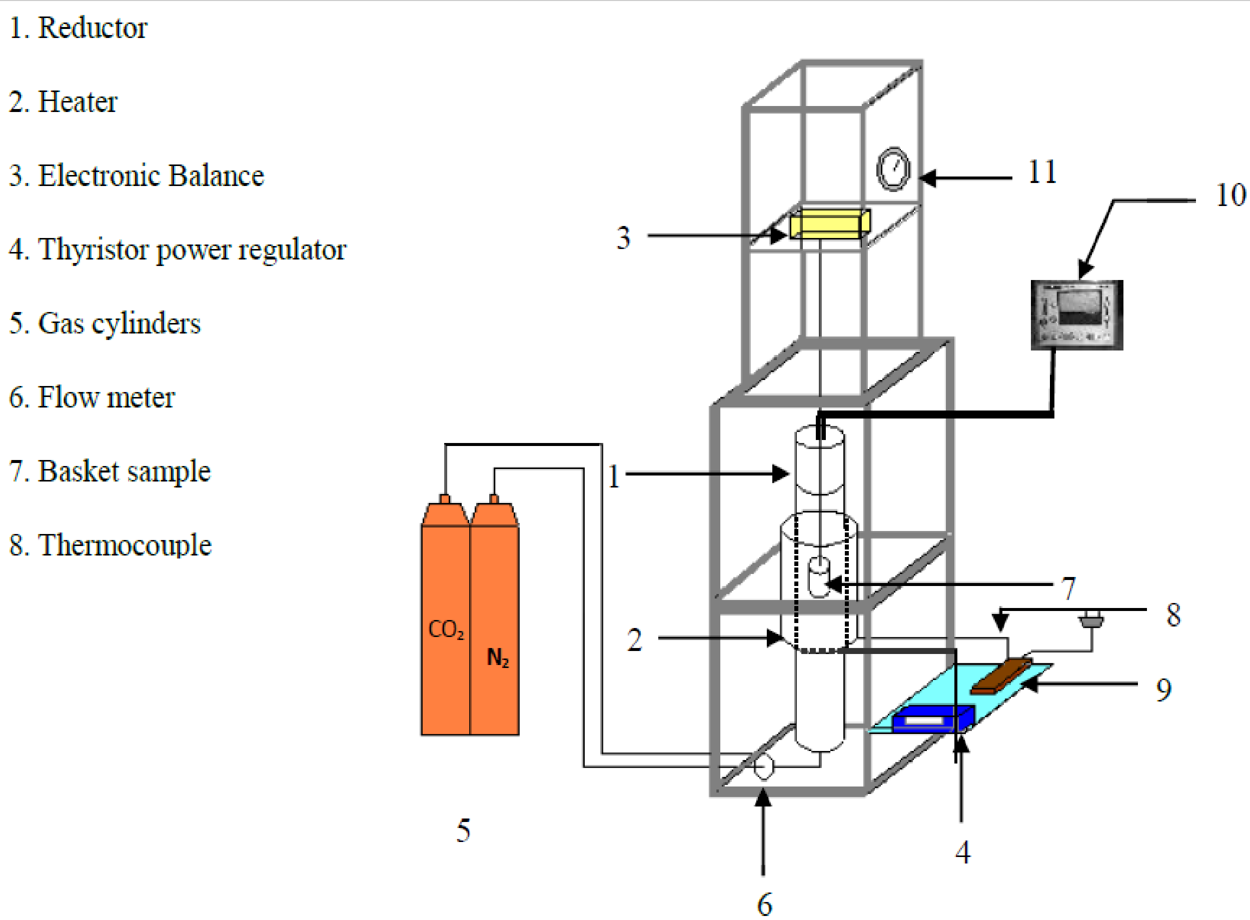


Figure 2: *Schematic of the experimental apparatus*

Table 2: *Conditions and process of iron ore briquette*

Sample	Percentages of sample [%]	Dia. of briquette [cm]	Pressure [MPa]
Iron ore	100	3	220
Coal – iron ore	80 - 20	3	220
Coal – iron ore – heavy oil	80 – 10-10	3	220
Coal – iron ore – asphalt	80 – 10-10	3	220
Coal – iron ore – benthonite	80 – 10-10	3	220

3. Result and Discussion

Mass decreasing fraction of iron ore briquette

During the reduction process, mass of sample reduces continuously over the time. This phenomenon occurs because of loss the substances contained in iron ore briquette. The experimental result of mass decreasing fraction during reduction process under temperature is about 750 ^oC shown in Figure 3. From the figure, the ratio of sample mass reduction is calculated as follow:

$$BRR = (M_0 - M_t)/M_o x 100\% \quad (1)$$

Where BRR is briquette reduction ratio, $M_0$and $M_t$are initial and mass loss at the time $t$of iron ore briquette, respectively. Thus, the un-reduced mass fractionis

$$\text{Un-reduced mass fraction} = 100\% - BRR \quad (2)$$

From the experimental results show that low grade coal content and binder type are played an important role on briquette mass reduction. The mass reduction of iron ore briquette composed of 10 % low grade coal is faster compared to that composed without using low grade coal. The briquette by using heavy oil as a binder that higher mass reduction is obtained. This phenomenon occurs because heavy oil has easier evaporated rather than benthonite. The graph also shows that at beginning of reduction process, the mass reduces significantly. The reason for this significant reduce is because the outer of sample contains volatile matter. At the middle of process, mass reduces gradually because the sample has mineral matter content.

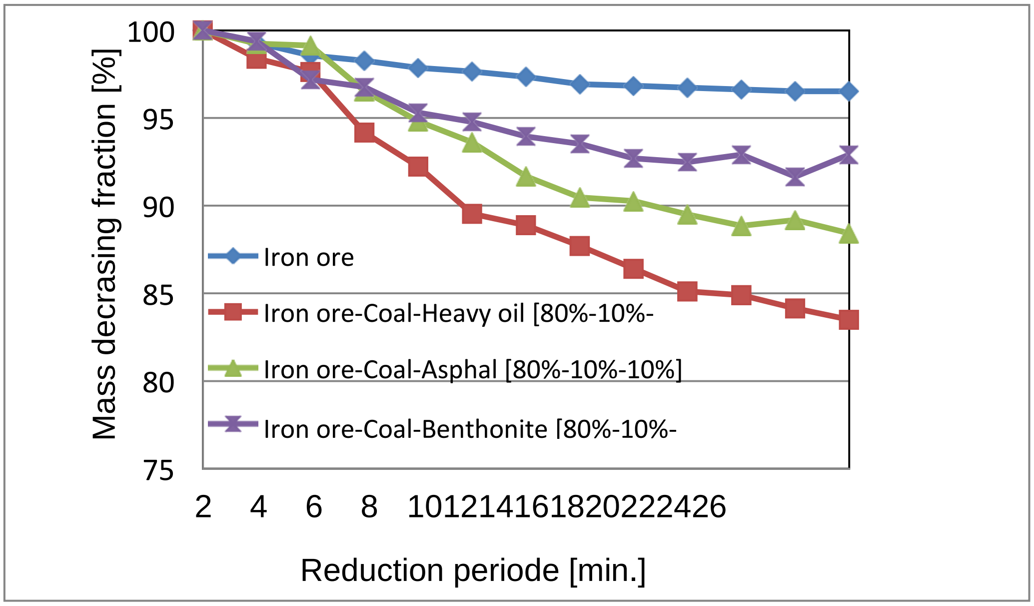
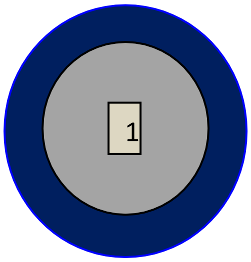


Figure 3: *Profile of iron ore briquette mass decreasing fraction.*

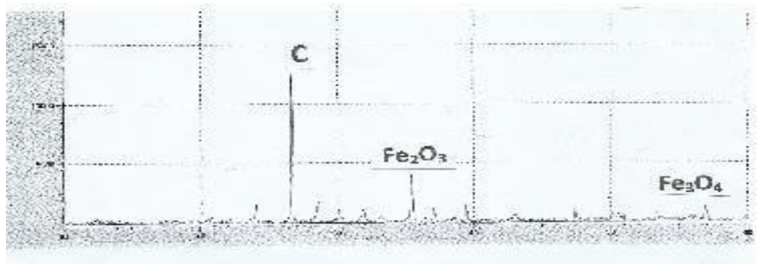
X-ray diffraction (XRD) analysis

The furnace temperature was raised to the required temperature was about 750 ^{o}C, respectively. Then, iron ore briquette was suspended in basket by a wire linked to digital balance and was positioned in the center of the electric redactor during 26 min, respectively. Then the samples were taken out from the redactor and put in desiccators while N_2 gas was used as dilution. In order to determine the degree of reduction reaction, the samples was taken at the center of reduced briquettes as shown in Figure 4. The samples was crushed and further analyzed by XRD apparatus. Incidence angle 2θ from 10° to 60° was used to identify the forming stage of the product.

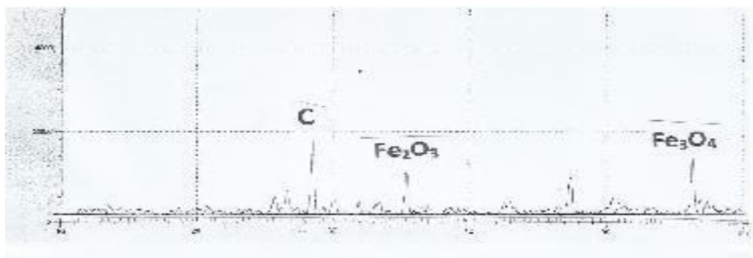


1. Center

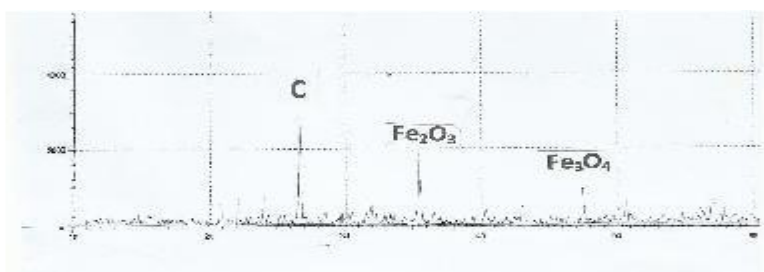
Figure 4: *Profile of cross section at position the sample was taken out.*



(a). XRD patterns for briquette [iron ore 80%, coal 10% and heavy oil 10%]



(b). XRD patterns for briquette [iron ore 80%, coal 10% and asphal 10%]



(c). XRD patterns for briquette [iron ore 80%, coal 10% and benthonite 10%]

Figure 4: *The profile of XRD patterns for reduced briquette with variation binder types*

Figure.4 shows the XRD patterns of their reduced briquette. The sample was taken in the center of reduced briquette. From the figure shows that component in sample was dominated by Fe_2O_3, Fe_3O_4 and carbon. The transformation of iron oxides can be observed from the corresponding change of the peak. It was shown that iron ore briquette by using asphalt as binder reduced of Fe_2O_3 into Fe_3O_4 easily than that using heavy oil and benthonite.

4. Conclusion

The fundamental study of the effect of iron reduction on the binder type in iron ore briquette was investigated. The experimental result shows as below:

- Low grade coal content and binder type are played an important role on briquette massreduction.
- The mass reduction of iron ore briquette composed of 10 % low grade coal is faster compared to that composed without using low gradecoal.
- The briquette by using heavy oil as a binder that higher mass reduction isobtained.
- The component in sample was dominated by Fe_2O_3, Fe_3O_4 and carbon It was shown that iron ore briquette by using asphalt as binder reduced of Fe_2O_3 into Fe_3O_4 easily than that using heavy oil and benthonite.

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REFERENCES

Damien Wagner, Olivier Devisme, FabricePatisson, Denis Ablitzer, (2006), "A Laboratory Study Of The Reduction Of Iron Oxides by Hydrogen" , Sohn International Symposium, 27-31 Aug. 06, San Diego, vol. 2, pp. 111-120.

Feinman J., (1999), *the AISE Steel Foundation, Pittsburgh*, PA.

Jingyu Shi, E. Donskoi And D. L. S. Mcelwain, (2005), " Modelling The Reduction of an Iron Ore-Coal Composite Pellet with Conduction And Convection in an Axisymmetric Temperature Field", Mathematical and Computer Modelling, vol. 42, pp 45-60.

Raymond Long bottom and LeivKolbeinsen, (2008), "Iron ore Reduction with CO and H2 Gas Mixtures Thermodynamic and Kinetic Modeling", Proceedings of the 4th Ulcos seminar, 1st & 2nd October 2008.

Yi MAN, Jun Xiao FENG, Yan mei CHEN, Jing zhi ZHOU Journal of iron and steel research International, (2014), "Mass Loss and Direct Reduction Characteristics of Iron Ore coal Composite Pellets ", 21 (12), pp1090-1094.

Yi MAN, Jun Xiao FENG, Yan mei CHEN, Jing zhi ZHOU, (2014) "Influence of temperature and time on reduction behavior in iron ore–coal composite pellets", Powder Technology, vol. 256, pp361–366.