Characteristics of iron ore sinter with EFB addition

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Abstract. Utilization of EFB-derived biochar in sintering of iron ore has been conducted in this work with regards to the porosity of iron sinter. EFB has been heated up in argon atmosphere to 450°C in order to produce biochar. In the present work, the sintering process was conducted at 1150°C with variations of biochar content from 5% to 10%. In this case, the apparent density for iron sinter shows significant decrease as the biochar addition increase. The porosity of iron sinter showed a gradual increment from 5% to 7.5% and escalated at 10% biochar content. The results of porosity and apparent density were in line with the micrograph of iron sinter.

1. Introduction

The substitution of fossil fuels with renewable biomass is one of the ways to mitigate the CO₂ emissions in the steel industry. Sintering of iron ore produces large amount of flue gas containing pollutant. The combustion of fossil fuel produces main sources like CO₂, SO₂ and NO₂. It is very crucial to find clean and renewable energy sources to replace fossil fuels which make sinter production become eco-friendly. Replacement of fossil carbon by renewable biomass-based carbon is an effective measure to reduce CO₂ emission intensity in the blast furnace ironmaking process [1].

The depletion of fossil fuels resources and problems arising from this process have led to many researches on this matter in order to find the solutions for the problems. Then, biomass has been identified as a potential source for the renewable energy [2-4]. The advantages of using the biomass are that it can scale down the carbon dioxide product and help to alleviate climate change by reducing the greenhouse gases [5]. Besides, utilization of biomass can also decrease the emission of dangerous gases [6-7]. Chean et al., 2008 mentioned that use of sunflower seed husk as a supplementary fuel in iron ore sintering process is feasible to substitute 10% coke breeze [8] as biomass is a potential energy sources that can substitute fossil fuels [9-13]. The usage of biochar can mitigate the emission of hazardous gases such as CO₂, NOx, Sox dust etc. [14].

Iron sinter is produced from agglomeration of iron ore fines into compact granules by heating process to the partial fusion and coalescence bonding [15-16]. The structure of iron sinter produced is very important in determining the strength and reducibility of sinter to be charged into blast furnace operation [17]. By increasing the porosity distribution of iron sinter, the contact area for reducing gases are increased, that leads to increase in the efficiency of reducibility for iron sinter [18]. In this research, the effects of oil palm empty fruit bunch (EFB) addition on the production of iron sinter was investigated with regard to the porosity of the product.
2. Experimental procedures

2.1. Materials

Sintering materials which are iron ore, oil palm empty fruit bunch (EFB) and limestone were utilized in this experiment. Iron ore and EFB were taken from mining site in Bahau, Negeri Sembilan and local palm oil mill, respectively. Table 1 shows elemental composition of iron ore (Bahau, Negeri Sembilan). Iron ore was ground and sieved to small particle size of less than 150µm. The shredded EFB was used to produce biochar by heating up to 450ºC with heating rate of 10 ºC/min. The elemental composition of EFB was given in Table 2. Iron ore, biochar and limestone were mixed together and granulated in a bowl by using water binder. Then, the granulated samples were dried for 24 hours.

2.2. Experimental methods

The granulated samples were put in the electric furnace and set to 1150ºC with 10 minutes heating rate and 30 minutes holding time. Figure 1 shows the granulated iron sinter after sintering process. The porosity and apparent density of iron sinter were investigated. Micrograph of iron sinter was examined by using the SEM. Figure 2 shows schematic diagram of furnace for sintering and biochar making (1- Temperature controller, 2- Gas flow controller, 3- Gas container, 4- Gas filter, 5- Thermocouple, 6- Electric heater, 7- Green sample).

Table 1. Elemental composition of iron ore (Bahau, Negeri Sembilan).

| Compound | Fe | Al₂O₃ | MgO | SiO₂ | K₂O | TiO₂ | CrO₃ | MnO | Fe₂O₃ |
|----------|----|-------|-----|------|-----|------|------|-----|-------|
| Percentage | 51.92 | 9.20 | 0.44 | 14.87 | 0.06 | 0.52 | 0.06 | 0.23 | 74.23 |

Table 2. Elemental composition of EFB.

| Proximate analysis | wt% | Ultimate analysis | wt% |
|-------------------|-----|-------------------|-----|
| Moisture          | 6.80| Carbon            | 45.64|
| Volatile matter   | 83.94| Hydrogen         | 6.19|
| Fixed carbon      | 8.98| Oxygen            | 48.17|
| Ash               | 7.08| Nitrogen          | 0.35|

Figure 1. Granulated iron sinter.
Figure 2. Schematic diagram of furnace for sintering and biochar making (1- Temperature controller, 2- Gas flow controller, 3- Gas container, 4- Gas filter, 5- Thermocouple, 6- Electric heater, 7- Green sample).

3. Results and Discussion

Figure 3 shows the apparent density and porosity of iron sinter at 1150°C with variations of biochar addition. In this case, the apparent density for iron sinter shows significant decrease as the biochar addition increase from 5% to 10%. The porosity of iron sinter shows a gradual increment from 5% to 7.5% and escalate at 10% biochar content. For iron sinter at 10% biochar content has the highest percentage of porosity because the biochar in the sample was burnt and this left a porous structure without completely coalesce and assimilate with the iron ore.

Figure 3. Apparent density and porosity of iron sinter at 1150°C with variations of biochar addition.
Inferring to the Figure 4, it shows the micrograph of iron sinter at 1150°C with variations of EFB addition (a) 5% EFB content, (b) 7.5% EFB content (c) 10% EFB content. It can be seen that at 5% biochar content, a dense product was obtained with complete coalescence of iron sinter. On the other hand, iron sinter produced with 10% biochar content underwent incomplete coalescence and the product was less dense. Results of the porosity and apparent density proved that biochar content have strong effect on the structure and morphology of iron sinter.

![Figure 4. Micrograph of iron sinter at 1150°C with variations of EFB addition (a) 5% EFB content, (b) 7.5% EFB content (c) 10% EFB content](image)

### 4. Conclusion

In conclusion, the apparent density for iron sinter shows a significant decrease as the biochar addition increased from 5% to 10%. Morphology of the iron sinter revealed that the dense iron sinter has been produced in terms of agglomeration and coalescence of sinter particles at 5% biochar content. At 10% biochar addition, the biochar in the sample was burnt and left a porous structure without completely coalesce and assimilate with the iron ore.

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