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ORIGINAL ARTICLE

# The production of pig iron from crushing plant waste using hot blast cupola

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**Abstract** A production of pig iron has been conducted from crushing plant waste. The process of preparing pig iron was using hot blast cupola (HBC) furnace which was injected with charcoal powder to improve temperature process and reduction zone in the furnace. The process was started by washing process and magnetic separation of raw material as an effort to improve iron content degree from crushing plant waste. The next process was preparing the composite pellet with the particle size of −80 + 100 mesh and with the composition of 80% iron ore, 15% wood charcoal, and 5% bentonite. The result of pellet size was 2.5–4.0 mm. The experiment was continued to reduce pellet composite in the HBC furnace. The pig iron produced from this process contained of 93.62%Fe, 3.5%C, 1.55%Si, 0.87%Mn, 0.05%P, and 0.087%S.With this result, the pig iron produced already fulfill the metallurgical specification to be used in smelting industry.


## 1. Introduction

Crushing plant is one of important processing units in mining industry. Process sequences in mineral mine processing are started with crushing plant unit, to reduce bigger mineral size into desired size to use in the next processing. In the iron ore mining industry, fine iron ore waste is produced within 30% of total feeds in crushing plant unit. This is called as a waste because it cannot be used directly for smelting process into metal. With low iron content degree (Fe < 56%), Fe content degree improvement process is required for this iron ore waste to be able to use as feed material in smelting process into pig iron. Pig iron is a solid form of hot metal, obtained from iron ore or scrap recycling, and it is processed with blast furnace or electric arc furnace. Pig iron is used as a raw material for iron steel making and most of this material was imported. The pig iron (from scrap) availability is limited so that iron steel producers and foundry industries are not able to produce maximally. Imported scrap procurements often face problems because not all scraps have been separated from stuffs belonging to hazardous and toxic material waste. In the earlier 1970s and 1980s, in India occurred a massive growth of electric arc furnace (EAF) and induction furnace (IF) based steel making units, respectively. India is the only country in the world using induction furnaces on a large scale for production of steels. This had created a growing demand for steel scrap, as a result of which the scrap was in short supply. Moreover, significant improvements in steel plant yield, rolling technology and continuous casting processes have decreased the amount of in-plant generation of scrap. This ultimately has resulted into

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the shortage of scrap supply throughout the world and its fluctuating prices [1]. Fine iron ore smelting process in cupola furnace can be considered to be similar with the process in blast furnace with a little difference on kinetic reaction. In the blast furnace, iron ore or iron oxide is reduced by carbon dioxide (CO) formed as a result of carbon change in reduction environment [2]. Cupola furnace modification is made by adding hot air (500–700 °C) coming from burning process, and it is referred to as hot blast cupola. This hot air addition reduces coke consumption and it is able to improve reduction zone [3].

The use of wood charcoal in cupola furnace is recommended for a cupola capacity of 3 tons per day, and it is not recommended for bigger size of cupola. Wood charcoals will be easily broken as they are struck down by other raw materials because of low hardness and toughness of wood charcoal. The used wood charcoal will be more reactive compared with the use of coke, and the burning result will produce bigger amount of burning temperature easily decreases [4]. Previous researches were mainly conducted on iron ore smelting, however only a few researches conducted on wood charcoal injection to cupola furnace. Therefore this research conducted pig iron production by using hot blast cupola which was injected with wood charcoal powder in order to improve reduction zone in cupola furnace.

## 2. Methods

### 2.1. Material and equipment

Materials to use were iron ore waste and wood charcoal powder as they are shown in Fig. 1. The iron ore waste came from crushing plant located in Tanjung Bintang sub district of South Lampung district, in Lampung province. Wood charcoal powder was obtained from side product of charcoal sieving in wood charcoal industry located in Natar sub district of South Lampung district, in Lampung province. Bentonite was used as binder and coke was used as reducer and energy during the process. Lime stone ($CaCO_3$), steel scrap, castable, refractory brick, refractory cement and molded sand were used as supported materials in this research.

Equipments used in this experiment were iron ore washing machine, magnetic separator, pelletizer, mixer, hot blast cupola (HBC), blower, pouring ladle, thermocouple, hammer mill, and vibrating screen. AAS (Atomic Absorption Spectrophotometer) Shimadzu AA 7000, sieve shaker, calorimetric bomb, and oven were used for analyzing process.

### 2.2. Research procedure

The first procedure was iron ore waste raw material and wood charcoal powder preparations. Fe content in crushing plant waste was improved with washing and magnetic separation processes. Washing process was conducted using a modified sand washing machine. Its working principle was separating impurity materials with centrifugal force while water pressure force would make dirty ores to dissolve into sludge and pulp. Gravitation and decantation processes were subsequently conducted to separate both of them. Materials had been removed from their impurities were passed into magnetic separator to improve Fe degree into iron ore waste material. Charcoal waste preparation process was started by washing it by using *rotary screen washer*, where pressurized water was blown into charcoal waste to remove impurities in the material. This process produced wood charcoal material with size $<25$ mm free from soil impurities. To be able to use in this experiment, the wood charcoal waste should be milled by using hammer mill and disk mill and this process produced wood charcoal powder of $-40 + 60$ mesh size which was to be injected in the hot blast cupola furnace.

The second procedure prepared composite pellet as shown in Fig. 2. The palletizing process is one of the most important steps to furnish agglomerates of high quality with additional benefits of recycling the ultra fines within the steelmaking industry [5]. Composite pellet was made from raw material particle size of $-8 + 100$ mesh with composition of 80% of iron ore, 15% wood charcoal, and 5% bentonite. Resulted pellet size was 2.5–4.0 mm and this is called as green pellet. This green pellet was let aside in the open air for $3 \times 24$ h and then dried in oven with temperature of 110–120 °C. The third procedure was reducing composite pellet in the hot blast cupola (HBC) furnace (Fig. 3). Reduction stage was started by furnace initial heating with 150 kg coke. Then, 150 kg scrap, 50 kg coke, and 15 kg lime were entered into the furnace. When furnace condition had been stable, the use of scrap was reduced by 10%, 20%, 30%, and 40% until 0% of feed weight. At the same time, injection of wood charcoal powder into HBC furnace was conducted with screw feeder system.


**Figure 1** (a) Iron ore powder from crushing plant waste and (b) charcoal powder from screening leftover.

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