Performance of Additive in Metal Separation from Nickel Ore

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Abstract. The potential resources and reserves of nickel ore in Indonesia is the third largest in the world. The potential quite large, but the nickel content found in nature is very small. To increase the added value of nickel ore, it is necessary to process/refine nickel ore. In addition, coal ratio parameter and process temperature in the reduction process, additive is also used as parameter for the composite reduction process. This research used 6 combination saprolite ore composite based on result of previous research. The objective of this research is to know the performance of additive in separation of metal from nickel ore based on result of XRD analysis.

XRD analysis is used to know chemical compound saprolite ore composite after reduction process. This results from XRD analysis shown that additive CaCO3 has the best performance additive with higher Fe and Tetrataenite content with percentage of coal ratio of 30% in temperature of 1300 °C. For additive Ca2SO4 percentage coal ratio 15% have higher Fe and NiFeO content in temperature of 1200 °C and 1300 °C.

1. Introduction

Nickel ore is the potential resources and reserves in Indonesia and the third largest in the world after New Caledonia and Philippines [1]. The potential for resources and nickel ore reserves are quite large, but the nickel content contained in nature very small. Laterite nickel ore divided into 2 types namely, Saprolite ore that has small Fe and large Ni content (around 1.5-2.5%), and limonite ore that has large Fe and small Ni content (around 0.8-1.5%) [2]. To increase the added value of nickel ore, it is necessary to process/refine nickel ore. The processing/refining technology of nickel ore is carried out through the Pyro metallurgy and Hydro metallurgy technique. The hydro metallurgy technique involves chemical reactions with other additional loads, while the Pyro metallurgy technique involves high temperatures and large energy [3].

The composite use to leads a better process, because it does not require cooking and sintering plants and minimize the use of gas. The uses of composite pellets raise the idea of using low grade iron ore to produce pig iron [4]. The process of mixing saprolite ore, coal, additive and bentonites; pelletizer, and drying are the process of making composites. In pyro metallurgy technique, reduction process is an important role in making nickel. Many parameters are involved in the reduction process. The availability of carbon along with processing time and temperature is the main concern in the reduction process [5], based on the result of previous experiment. In addition to the coal ratio parameter and process temperature in the reduction process [6], additive is also used as parameter for the composite reduction process.

The reduction process of saprolite ore composite is carried out in tube furnace with a temperature increase rate of 10 °C/minute. Composites are placed in the graphite crucible, that’s suitable for heating
samples in a tube furnace. Saprolite ore composites after reduction process is analyzed using X-Ray-Difference Diffraction (XRD). The XRD analysis uses to know the chemical compound. In this previous research of reduction process saprolite ore composite in Tube Furnace [7][8][9], 4 parameters are used, namely coal ratio, temperature, duration time and type additive with each 3 level. The results show that coal ratio, temperature and type additive affect nickel percentage content [7]. From the research of optimization of saprolite ore composite reduction process using Artificial Neural Network (ANN) and Adaptive Neuro- Fuzzy Inference System (ANFIS) method, the results show that the optimal combination is SB$_{15}$Ca$_{10}$P$_2$ with a percentage coal ratio of 15%, a temperature of 1200 $^\circ$C, process time of 3 hours and additive type of Ca$_2$SO$_4$ [8] [9]. From the research by [7] with Response Surface Methodology (RSM) method, it shows that the optimal combination is SB$_{30}$Ca$_{10}$P$_2$ with percentage coal ratio of 30%, a temperature of 1300 $^\circ$C, process time of 2 hours and type of additive of Ca$_2$SO$_4$.

The composite combination used in this research are SB$_{15}$Ca$_{10}$P$_2$ and SB$_{30}$Ca$_{10}$P$_2$ with temperature comparison of 1200 $^\circ$C and 1300 $^\circ$C and analyzed using XRD. To know additive performance, another type of additive, CaCO$_3$, is used in this research [7], because the composite combination with a type of additive CaCO$_3$ have higher percentage in Ni content in XRF result analysis. The result of XRF analysis in the previous research [7] is shown in figure 1. To compare the performance additive in separation metal of nickel ore, composite combination SB$_{15}$Ca$_{10}$P$_2$ is used. SB$_{30}$Ca$_{10}$P$_2$ with a temperature of 1200 $^\circ$C and SB$_{15}$Cc$_{10}$P$_2$. SB$_{30}$Ca$_{10}$P$_2$ with a temperature of 1300 $^\circ$C are used in this research. Saprolite ore composite combination reduction process in Tube Furnace is analyzed in XRD analysis. The objective of this research is to know the performance of additive in metal separation from nickel ore based on the result of XRD analysis.

![Graph](image_url)  
**Figure 1.** Type of additive with % mass Ni value.

2. Material and Methods

2.1. Materials

The type of materials used in this research is saprolite ore from Pomala, Southeast Sulawesi, Indonesia. Saprolite ore contains small Fe and large Ni content (around 1.5-2.5%). The sampling of material for the manufacture of saprolite ore composite is carried out directly from mining products in Pomala. Samples of mining results in Pomala undergo a grinding process to get a finer composition, then carried out by sampling using the Coning and Quartering method. Saprolite ore composite are produced by mixing percentage of saprolite ore, coal, additive and bentonite. Process of mixing, pelletizer and drying are the process of making saprolite ore composite. The composites produced in diameter 1.2-2
centimeters are used in figure 2. Saprolite ore composite that used in this research are SB_{15}Ca_{10}P_{2} and SB_{30}Ca_{10}P_{2} with each weighting 500 grams detail in table 1.

![Figure 2. Saprolite ore composite.](image)

Table 1. Saprolite ore composite.

| Composite   | Saprolite ore (gram) | Coal (gram) | Bentonite (gram) | Additive (Ca2SO4) (gram) | Total weight (gram) |
|-------------|----------------------|-------------|------------------|--------------------------|---------------------|
| SB_{15}Ca_{10}P_{2} | 374                  | 66          | 50               | 10                       | 500                 |
| SB_{30}Ca_{10}P_{2} | 308                  | 132         | 50               | 10                       | 500                 |

The reduction process of saprolite ore in Tube Furnace through pyro metallurgy technique need high temperature and large energy. The reduction has several parameters that are used to get the optimal combination. The parameter that used in this research are % coal ratio, temperature, and type of additive.

2.2. Methods

Combination saprolite ore with the parameter that used in reduction process in Tube Furnace results Saprolite ore combination. Saprolite ore combination used in this research are in table 2.

Table 2. Saprolite ore combination.

| Composite   | % coal ratio | Temperature (°C) | Type of additive |
|-------------|--------------|------------------|------------------|
| SB_{15}Ca_{10}P_{2} | 15           | 1200             | CaSO_4           |
| SB_{15}Ca_{10}P_{2} | 15           | 1300             | CaSO_4           |
| SB_{30}Ca_{10}P_{2} | 30           | 1200             | CaSO_4           |
| SB_{30}Cc_{10}P_{2} | 30           | 1300             | CaSO_4           |
| SB_{15}Cc_{10}P_{2} | 15           | 1300             | CaCO_3           |
| SB_{15}Cc_{10}P_{2} | 30           | 1300             | CaCO_3           |

Saprolite ore composite combination with reduction process in tube furnace detail in Table 2. After reduction process, the composite will be analyzed using XRD.

2.3. Characterization

After reduction process, saprolite ore composite will be analysed using XRD. The XRD analysis uses to know the chemical compound. Furthermore, XRD analysis used to determine the different mineralogical phases present in the reduced ore [10]. The result of XRD analysis than analyzed between composite SB_{30}Ca_{10}P_{2} and SB_{30}Cc_{10}P_{2} at temperature 1300 °C, composite SB_{15}Ca_{10}P_{2} and SB_{15}Cc_{10}P_{2} at temperature 1300 °C, composite SB_{15}Cc_{10}P_{2} and SB_{15}Cc_{10}P_{2} at temperature 1300 °C, and composite SB_{15}Ca_{10}P_{2} and SB_{30}Ca_{10}P_{2} at temperature 1200 °C.
3. Result and Discussion

3.1. Results

Saprolite ore composite combination in Table 2 was reduced through the reduction process in tube furnace. The results of the saprolite ore composite were reduced through the reduction process in tube furnace and analyzed using XRD in Figure 3-7. From Figure 3 between composite composite SB$_{30}$Ca$_{10}$P$_{2}$ and SB$_{30}$Cc$_{10}$P$_{2}$ at temperature 1300 °C, composite SB$_{30}$Cc$_{10}$P$_{2}$ have high Fe content and similarity tetrataenite content compare at composite SB$_{15}$Cc$_{10}$P$_{2}$. That concludes the type of additive CaCO$_3$ is better than Ca$_2$SO$_4$ for percentage coal ratio of 30%. Figure 4 XRD analysis between composite SB$_{15}$Ca$_{10}$P$_{2}$ and SB$_{15}$Cc$_{10}$P$_{2}$ at temperature 1300 °C shows that SB$_{15}$Cc$_{10}$P$_{2}$ has higher Fe and Trevorite content compared to composite SB$_{15}$Ca$_{10}$P$_{2}$. This concludes the percentage coal ratio of 15%, the additive type of CaCO$_3$ is better than Ca$_2$SO$_4$. The percentage coal ratio 15% and 30%, type of additive CaCO$_3$ is better than Ca$_2$SO$_4$ because of the higher content of Fe, tetratenite and trevorite (NiFeO).

Figure 3. XRD analysis between composite SB$_{30}$Ca$_{10}$P$_{2}$ and SB$_{30}$Cc$_{10}$P$_{2}$ at temperature 1300 °C.

Figure 4. XRD analysis between composite SB$_{15}$Ca$_{10}$P$_{2}$ and SB$_{15}$Cc$_{10}$P$_{2}$ at temperature 1300 °C.
Figure 5. XRD analysis between composite SB$_{15}$Cc$_{10}$P$_2$ and SB$_{30}$Cc$_{10}$P$_2$ at temperature 1300 °C.

Figure 6. XRD analysis between composite SB$_{15}$Ca$_{10}$P$_2$ and SB$_{30}$Ca$_{10}$P$_2$ at temperature 1300 °C.

Figure 7. XRD analysis between composite SB$_{15}$Ca$_{10}$P$_2$ and SB$_{30}$Ca$_{10}$P$_2$ at temperature 1200 °C.
Figure 5 XRD analysis between composite $SB_{15}C_{10}P_2$ and $SB_{30}C_{10}P_2$ at temperature 1300 $^\circ$C shows that the type of additive CaCO$_3$ at temperature of 1300 $^\circ$C, composite combination $SB_{30}C_{10}P_2$ is better than composite combination of $SB_{15}C_{10}P_2$ because it has Fe and trevorite (NiFeO) content. The result from Figure 3, 4, and 5, conclude that $SB_{30}C_{10}P_2$ is the best performance additive at temperature of 1300 $^\circ$C with type of additive CaCO$_3$.

XRD analysis in figure 6 between composite $SB_{15}C_{10}P_2$ and $SB_{30}C_{10}P_2$ at temperature 1300 $^\circ$C, shows that type of additive CaSO$_4$ in coal ratio 15% has higher Fe and NiFeO content compared with coal ratio 30%. The result of XRD analysis is similar to figure 7 between composite $SB_{15}C_{10}P_2$ and $SB_{30}C_{10}P_2$ at temperature 1200 $^\circ$C coal ratio 15% has higher Fe and NiFeO content compared with coal ratio 30%, but in temperature 1200 $^\circ$C carbon content still appears and hasn’t been oxidized perfectly yet. In type of additive CaSO$_4$, coal ratio 15% is better than coal ratio 30% in temperature 1200 $^\circ$C and 1300 $^\circ$C.

Based on result XRD analysis from figure 3-7, in temperature 1300 $^\circ$C, with coal ratio 15% and 30%, type of additive CaCO$_3$ is better than because it contains more Fe, tetrataenite and trevorite (NiFeO) content than type of additive CaSO$_4$. In type of additive CaCO$_3$, in temperature 1300 $^\circ$C, coal ratio 30% is better than coal ratio 15%. But the different result with the additive type of CaSO$_4$, in temperature of 1200 $^\circ$C and 1300 $^\circ$C, coal ratio 15% is better than coal ratio 30%.

3.2. Discussion

Reduction process was affected by temperature and percentage coal ratio. The higher coal ratio, it can faster reduce. At higher temperature, if the percentage coal ratio small, the reduction process is difficult to detect. Based on the result of this research, XRD analysis shows that type of additive in CaCO$_3$ and CaSO$_4$, percentage coal ratio 30% contain higher Fe, fosterite, tetrataenite and trevorite (NiFeO) content in temperature 1300 $^\circ$C. But the different result in temperature 1200 $^\circ$C with a type of additive CaSO$_4$, percentage coal ratio 15% is better than percentage coal ratio 30% because has higher Fe and NiFeO content, but carbon content still appears and hasn’t been oxidized perfectly. It can conclude type of additive also affected in the reduction process in Tube Furnace, in addition to temperature and the percentage coal ratio and answer the objective of this research is to know the performance of additive in separation of metal from nickel ore based on the result of XRD analysis.

4. Conclusion

Composite and reduction process are important in making nickel. Coal ratio, process temperature, and additive are parameter of the composite reduction process in this research, based on the result of previous research [7][8][9] that uses the reduction process of saprolite ore composite in tube furnace. The reduction process of saprolite ore composite was carried out in tube furnace and analyzed using XRD to know the chemical compound. In this research, saprolite ore composite combination used are $SB_{15}C_{10}P_2$, $SB_{30}C_{10}P_2$, $SB_{15}C_{10}P_2$, and $SB_{30}C_{10}P_2$ at temperature of 1200 $^\circ$C and 1300 $^\circ$C. The results show that additive CaCO$_3$ has the best performance in separation of metal from nickel ore with higher Fe and tetrataenite content, percentage coal ratio of 30% and temperature of 1300 $^\circ$C. For CaSO$_4$ additive, percentage coal ratio of 15% is better than percentage coal ratio of 30% and have higher Fe and NiFeO content at temperature of 1200 $^\circ$C and 1300 $^\circ$C.

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