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Analysis of Upgrading Process of South Sumatera Low Rank Coal

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Abstract
This research aims to find a method of removing moisture of Indonesian low rank coal by using a combined equipment of evaporator and heater. The heating equipment was controlled at varied temperatures of 343 K, 353 K and 363 K. This method is expected to increase heating value and reduce moisture content of coal. Based on this study, the removal of moisture content of Indonesian low rank coals was affected by the heating temperature and particle size of coals. Ambient air was passed through the evaporator tubes to decrease the temperature until reaching the dew point temperature of the air and then through the heating elements of a heater before entering the fluidised bed of pulverized coal. The results of this research showed that the heating value of coal can be increased up to 35.4% and also the moisture content can be reduced up to 29.8%, both at heater temperature of 363 K and particle size of (-20 +40) mesh.

1. Introduction

Coal is a variegated mineral origenated through the accumulation of wood and other biomass that was later covered, compacted and transformed into rock over a period of hundreds of thousands of years. Principally, it consists of carbon, hydrogen, and oxygen with less amounts of sulphur and nitrogen. Other constituents are the ash-forming inorganic compounds distributed throughout the coal. Coal origenated through the accumulation of wood and other biomass that was later covered, compacted, and transformed into rock over a period of hundreds of thousands of years. The changes from lignite through the stages of subbitumious, bituminous coal, and ultimately to anthracite are characterized physically by decreasing porosity and increasing gelification and vitrification. Chemically, there is a decrease in volatile matter content, as well as an increase in the percentage of carbon, a gradual decrease in percentage of hydrogen.

Coal may be classified according to rank, expressing the progressive metamorphism of coal from lignite (low rank) to anthracite (high rank). Rank is based on a dry, ash-free basis for low-rank coals, and on percentage of fixed carbon, calculated on a dry, ash-free basis, for higher rank coals. Anthracite coal is coal of highest metamorphic rank and it is also known as “hard” coal. It burns slowly with a pale blue flame and may be used primarily as domestic fuel. Anthracite coal has dry fixed carbon of 78% to 98% and dry % moisture of < 2% to 14%. Bituminous coal burns with smoky flame and may also contain 15-20% w/w volatile matter. It has heating values of 23589 to 31451 (kJ/kg) or higher. Subbituminous coal is not as high on metamorphic scale as bituminous coal and has often been called “black lignite”. It has calorific values of 18648 to 25836 (kJ/kg). Lignite is the coal that is often distinguished from the subbituminous coals as having a lower carbon content and a higher moisture content. Lignite may dry out and crumble in air and is certainly liable to spontaneous combustion. It has calorific value of less than 14154 to 18648 (kJ/kg). It is a brownish-black coal of low rank and is also referred to as "brown coal". Mechanically, lignite is easily fractured, but not spongy like peat [1].

Many techniques can be applied for upgrading the low rank coals, such as drying, blending, cleaning, briquetting and chemical upgrading. Basically, all techniques used for upgrading the low rank coal aim to eliminate excess moisture (water vapor) and unwanted organic and inorganic materials from the coal [2].

Many researchers have conducted research to improve the quality of low rank coal. One method that is carried by blending lignite and bituminous coal or lignite coal and other lignite coal. For blending them, an additive behavior was found for ash, volatile matter, and calorific value. Overall, it can be seen that coal properties of low rank coals can be reasonably modified by blending them with different types of coals, and these can be both low rank coals, or one low rank coal and another high rank coal [3].

Due to the large amount of moisture in lignite coal, this research will be carried out to reduce moisture content using a refrigeration system. Previously, refrigeration systems were used for human comfort or as food preservatives, but in this case the refrigeration system will be used as a tool to reduce the moisture content of coal by dehumidification. The dehumidification process is one way that can be used to reduce the level of water vapor in the air as to cause the air humidity to fall so that it will give effect to coal. Researcher [4] has conducted research on low rank coal in South Sumatra with Flash dryers and Dehumidifiers which have resulted in increasing the coal's calorific value. Batubara peringkat rendah Sumatera Selatan memiliki kadar air yang cukup akan tetapi kadar abu dan sulfurnya rendah [5].

Based on the background, the authors conducted a new study of decreasing moisture content in lignite type coal using a refrigeration cycle with a dehumidification system and performing several variations of heater laying both before the evaporator and after the evaporator and carrying out various variations of heater temperature 343 K, 353 K and 363 K.

2. Literature Review

Coal is a sedimentary rock, which is a hydrocarbon fuel, which is formed from plants in an oxygenfree environment and is subject to long-lasting effects of heat and pressure. Broadly speaking, coal consists of organic substances, water and mineral materials.

Coal is formed through the process of partial decomposition of plant substances under limited air conditions and accumulates to form a layer of swamp for a long time. This decomposition can occur through biological processes carried out by microbes with the help of pressure and heating. [6].

Indonesia's low rank coal contains high moisture, low calorific value, and spontaneous flammability and low sulfur and ash content so that quality improvement is needed before being used as fuel [7]. Similarly, [8] has examined Indonesia's low rank coal kinetics. His research results show that drying low rank coal requires drying temperatures, the size of coal samples, and certain relative humidity. Whereas, if this low rank coal is stacked in a stockpile under ambient temperature conditions often cause fires [9].

Coal can be classified according to groups, namely: Group I is Anthracite coals having the highest fixed carbon (FC) of 80% to 98%, and the volatile matter (VM) of 2% to 14%, (dry), Group II: is Bituminous coals having fixed carbon (FC) of 69% to 86%, the volatile matter (VM) of 14% to 31% or more, (dry), and the heating values of 25568 (kJ/kg) to 32543 (kJ/kg)., Group III is Sub-bituminous coals having the heating values of 19292 (kJ/kg) to 30217 (kJ/kg), and Group IV is Lignite coals having the heating values of 19292 (kJ/kg) or less [10].

In this research, a vapor-compression cycle refrigeration system is used to perform sensible cooling of ambient air. The main components of this refrigeration system include (a) Compressors, (b) Condensers, (c) Filter-driers, (d) Capillary pipes, and (e) Evaporators, and schematic arrangement of these components can be seen in Figure 1 below. Cooled refrigerant of air conditioning system is passed through evaporator coils in the air stream. When the temperature of the coolant is more than the temperature of air dew-point, no condensation takes place, the process is sensible cooling only and the air has a constant moisture content. [11]. The Vapor Compression Cycle is the most widely used refrigeration machine today. This refrigeration machine is a series of four prime sections namely evaporator, compressor, condenser and capillary pipe or expansion valve.

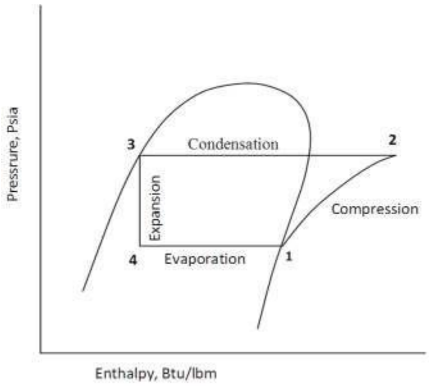

Figure 1. Vapor Compression Cycle of Refrigeration System

In this standard vapor compression cycle, refrigerants undergo four processes, namely: Compression process (1-2) involves the compression of saturated refrigerant at low temperature and pressure until reaching the higher condenser pressure, Condensation process (2-3) involves the phase change of refrigerant vapor to refrigerant liquid using a heat exchanger called a condenser, Expansion process (3-4) involves the expansion of saturated refrigerant liquid through an expansion device until the refrigerant pressure reaching the evaporator pressure, Evaporation process (4-1) includes the change of vapor-liquid mixture phase of refrigerant to saturated refrigerant vapor.

The psychrometric chart is a graphical display of air thermodynamic properties including temperature, humidity, enthalpy, moisture content and specific volume. In this chart, it can be immediately known the relationship between various air parameters quickly and in precision, both those related to the physical properties of the air and its thermic properties.

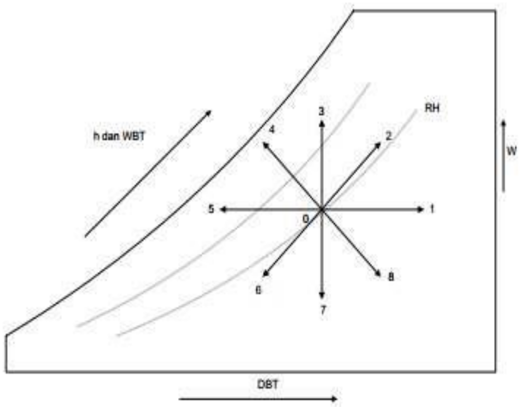

Figure 2. Psychrometric Chart

The change of state of moist water is referred to as a psychrometric process as shown in Figure 2. Such a process may involve any one of the following processes: sensible heating (0 - 1), heating and humidifying (0 – 2), humidifying (0 – 3), cooling and humidifying (0 – 4), sensible cooling (0 – 5), cooling and dehumidifying (0 – 6), dehumidifying (0 – 7) and heating and dehumidifying.

In this study, the process of cooling and dehumifying will occur when moist air passes through the evaporator tubes and the sensible heating process will also occur when cold-dry air passes through the heatig elements.

3. Research Methodology

The method used in this study was experimental conducted in a laboratory. The system used is a refrigeration system equiped with a heater having controlled temperatures of 343 K, 353 K and 363 K to reduce the moisture content of air so that it will have an influence on the moisture content of coal.

The equipments used in this research include air conditioning with a voltage of 380-415 VAC, 3 phase, frequency 50 Hz, maximum current of 22 A and a refrigerant capacity of 1.5 kg. The used instruments and measured variables in this research include thermometer for measuring air dry and wet bulb temperatures and refrigerant temperature, hygrometer for measuring relative humidity (RH) of air, air velocity sensor for measuring the air flow rate, and a fluidized bed of pulverized coal as shown in Figure 3. Note that DB = dry bulb sensor, RH = relative humidity sensor, and AF = air velocity sensor

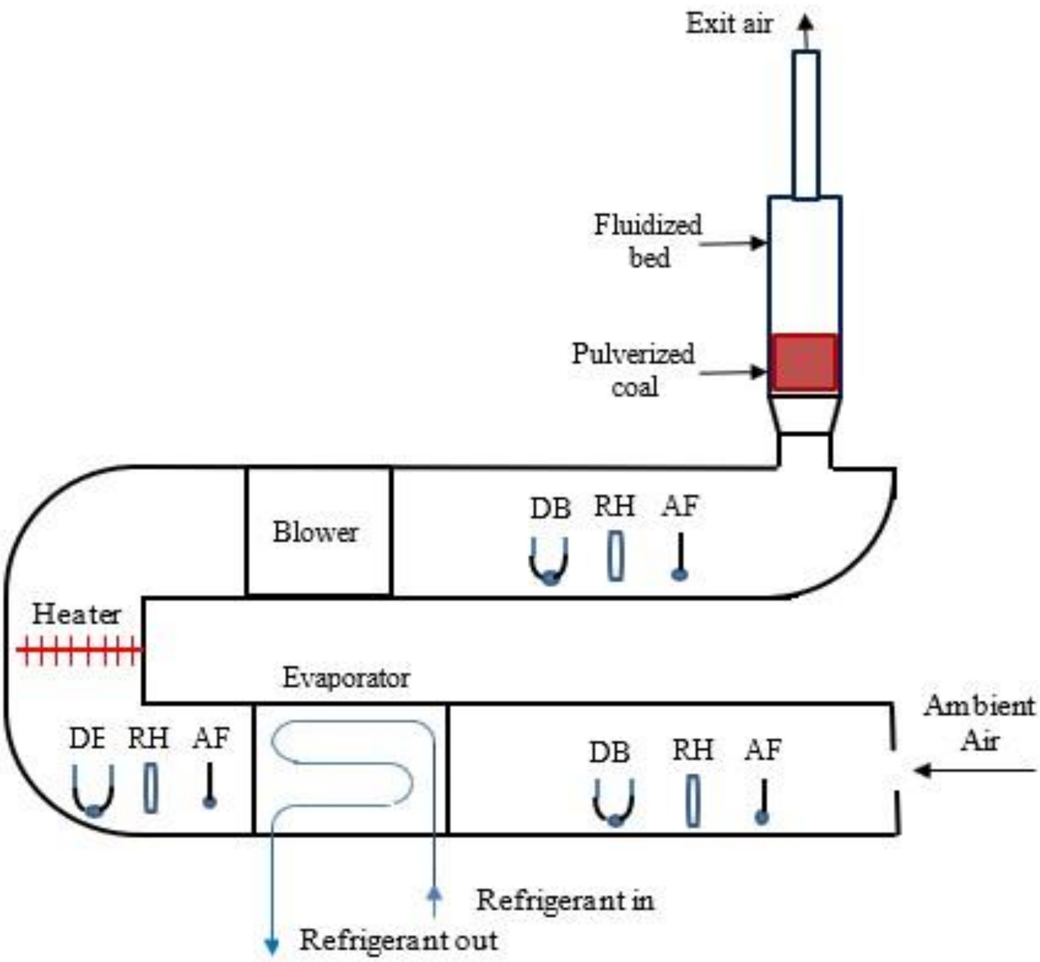

Figure 3. Equipment for Upgrading South Sumatera Low Rank Coal

Data in this research was collected at various Research Pattern (RP), as follows:

RP-1: Ambient air was passed through evaporator's coils of a refrigeration system and then the cold, dry air passed through a fluidized bed of pulverized coal with particle size of (-20+40) mesh.

RP-2: Ambient air was passed through evaporator’s coils of a refrigeration system, then the cold, dry air was passed through a controlled heater at temperature of 343 K, and finally the hot, dry air was passed through a fluidized bed of pulverized coal with particle size of (-20+40) mesh.

RP-3: Ambient air was passed through evaporator’s coils of a refrigeration system, then the cold, dry air was passed through a controlled heater at temperature of 353 K, and finally the hot, dry air was passed through a fluidized bed of pulverized coal with particle size of (-20+40) mesh.

RP-4: Ambient air was passed through evaporator’s coils of a refrigeration system, then the cold, dry air was passed through a controlled heater at temperature of 363 K, and finally the hot, dry air was passed through a fluidized bed of pulverized coal with particle size of (-20+40) mesh.

For all research patterns, the conditioned air was flowed through the fluidized bed of pulverized coal in fifteen minutes and then the coal was analized with proximate analysis.

4. Results and Discussion

After the experiment, the coal that has been conditioned is carried out laboratory tests and the following data are obtained.

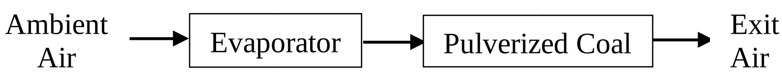

Figure 4. Research Pattern-1 for upgrading coal

Figure 5. Research Pattern-2 for upgrading coal

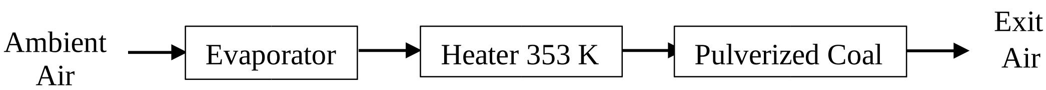

Figure 6. Research Pattern-3 for upgrading coal

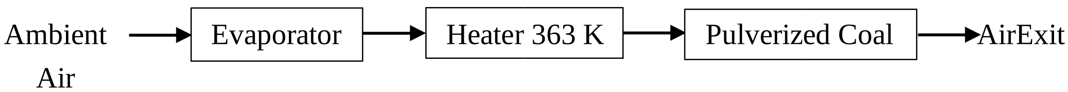

Figure 7. Research Pattern-4 for upgrading coal

In this study the refrigeration system serves to reduce the temperatures of dry balls and wet balls. Furthermore, when cold air reaches the dew point temperature, moisture condensation will occur which results in a decrease in the moisture content in the air. The conditioned air that comes out of the refrigeration system is then heated by a heater which is controlled at temperatures of 343 K, 353 K and 363 K, so that the dry and hot air when passed through pulverized coal can capture the water vapor contained in it. Decreasing the moisture content in pulverized coal will increase the heating value as shown in Table 1 below.

Table 1. Increased Percentage in Coal Heating Value for Various Research Patterns

Research Pattern	Decreased percentage in coal moisture content	Increased percentage in coal heating value
1. Refrigeration system without heater	18.06	23.70
2. Refrigeration system with heater (343 K)	26.70	30.85
3. Refrigeration system with heater (353 K)	28.30	33.10
4. Refrigeration system with heater (363 K)	29.80	35.40

The results of testing on South Sumatra low rank coal after dry and controlled air was passed through pulverized coal can be seen in Figure 8 below.

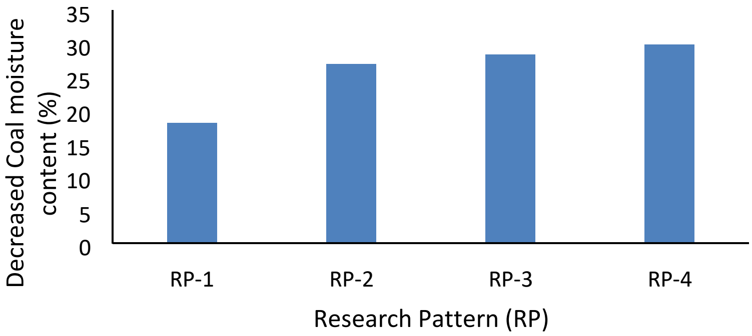

Figure 8. The effect of Research Pattern (RP) on Decreased coal moisture content (%)

Figure 8 shows that the further addition of heater at temperature of 343 K, 353 K and 363 K resulted in further decreased percentage of coal moisture content at 26.70, 28.30 and 29.80, respectively.

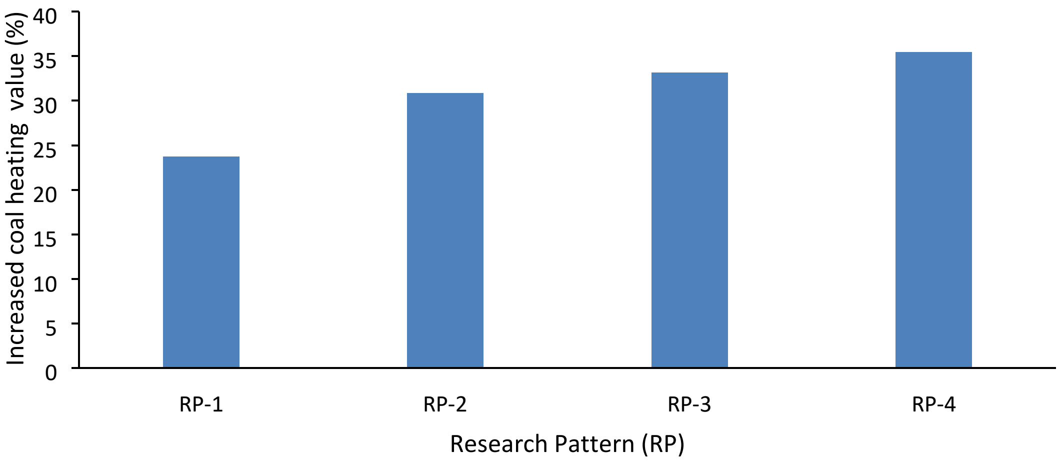

Figure 9. The effect of Research Pattern (RP) on Increased percentage of coal heating value (%)
Figure 9 shows that the further addition of heater at temperatures of 343 K, 353 K and 363 K resulted in further increased percentage of coal calorific value at 30.85, 33.10 and 35.40, respectively.

5. Conclusion

From the analysis and discussion of upgrading process of South Sumatra low rank coal, it can be concluded that the dry air condition after passing through the evaporator coils and continued with passing through a heater at temperature of 363 K can yield an increased percentage on coal heating value up to 35.40%. It may also be concluded that the higher the drying air heating temperature the higher the heating value of the coal.

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