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Beneficiation of Coal from Bonehau, Mamuju Regency of West Sulawesi Province Using Column Flotation

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Abstract

Coal is a heterogeneous substance with organic and inorganic and associated with a number of mineral matters that can reduce coal quality. Coal combustion will convert mineral matters into ash content that can affect furnace performance. Coal beneficiation is the process of improving coal quality with a number of methods to reduce ash content and increase coal calorific value. One of the coal beneficiation method is flotation which involves a solid phase in the form of coal particles, a liquid phase in the form of water, and a gas phase in the form of air bubbles as factors that affect the flotation process. This study aims to determine the coal quality, and to analyze the effect variables on ash content and calorific value. The methods used in this study were microscopic optical and X-Ray Diffraction (XRD) analysis for coal mineralogy and proximate analysis and calorific value analysis for coal quality. The column flotation method using flotation time, grain size, and collector dosage as research variables. The results of coal mineralogy analysis showed the coal sample contained of quartz, pyrite, moganite, and graphite with 5.07% of ash and 5,207 cal/g of calorific value. Results of the flotation experiment reveal that the lowest ash content were 2.83% which was found with the grain size of 60 mesh, a flotation time of 10 minutes, and 20 mL of collector dose. The highest calorific value analysis results were 5,835 cal/g which obtained at a grain size of 100 mesh, flotation time of 15 minutes, and a collector dose of 20 mL.

Keywords: Flotation Column, Coal Beneficiation, Ash Content, Calorific Value

Introduction

Coal is a non-renewable natural resource or mining excavation material that can be depleted and cannot recover or return to the original condition (Fitriyanti, 2016). Coal is one of the most widely used types of fuel besides fuel oil, so coal is classified as a conventional fuel. Coal can be categorized based on the amount of carbon and water contained in the coal. The categories include anthracite, bituminous, sub-bituminous, lignite, and peat, which is the lowest quality coal (Faizal et al., 2015). Indonesia's reserves of proven coal are mostly low quality with lignite (59%), sub-bituminous (27%), bituminous (14%) and anthracite (<0.5%) of the total reserves. The use of proper coal

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processing technology will improve the quality of Indonesian coal, which will have an impact on the economic competitiveness of the Indonesian nation (Pasymi, 2008).

Coal beneficiation is one of the most effective methods for removing minerals (such as gangues and pyrite) and pollutants (such as sulfur) before the burning of coal. In general, the beneficiation process of low rank coals is more often to done than bituminous and anthracite coals (Xia, et.al., 2015).

Flotation is one of the coal beneficiation methods which is a physico-chemical methods. Flotation is a process of separating valuable minerals from their impurities based on mineral surface properties, namely hydrophobic (non-wettable) and hydrophilic (wettable) properties and is based on differences in particle surface properties (Haryono, et.al., 2020).

Basically, the flotation separation process is a complex process due to the many influential operating parameters. In general, these parameters are viewed from two main factors, namely physical / dynamic factors (cell design, column dimensions, stirring, air flow rate, grain size and air bubble size) and chemical factors (pH, reagents and slurry concentration) (Jaya, et. al., 2020). Column flotation is flotation using a column as a container for mineral separation. (Haryono, et al., 2020). Coal is intrinsically hydrophobic due to its chemical composition of aromatic and aliphatic groups on the surface. In practice, poor coal flotation can occur due to a decrease in the hydrophobicity of the coal surface. Maceral groups with different physical and chemical properties will control the overall behavior of the coal including its hydrophobicity (Ding, 2009).

One of the objectives of coal beneficiation is to reduce the ash content of coal. Ash is an impurity element that interferes with the quality of coal, such as soil, rocks, minerals, and others (Nukman and Poertadji, 2006). Coal ash is formed through material called mineral matter. This mineral matter will have a harmful impact on the use of coal in the process of combustion, carbonization, gasification, liquefaction, and other uses. This coal content can be minimized by performing various cleaning processes that can be done easily (Ayhan, et.al., 2006). Coal beneficiation process is mostly used to reduce the ash content of coal and increase the calorific value of coal. Therefore, this research will discuss coal processing using column flotation method with consideration of several research variables.

Research Methods

The type of research used is quantitative research with experimental methods. The coal samples in this study were collected at Bonehau Subdistrict, Mamuju Regency, West Sulawesi Province.

1. Sample characterization

The sample characterization process is carried out using four types of analysis, which are microscopic analysis to see the appearance of minerals in coal polishing samples, XRD analysis to see the mineral contained in coal samples, proximate analysis and

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calorific value analysis to see the quality of coal. The sample characterization process will be used as initial data and as a comparison material for the initial quality of coal and coal after the column flotation processed.

2. Experimental

Sample preparation is carried out on coal samples by reducing the size to produce coal samples that are suitable for flotation needs, includes sample size reduction, sieving, and sample weighing. Coal flotation activities are carried out in the workshop of the Mining Engineering Department, Faculty of Engineering, Hasanuddin University.

Research variables are divided into three types, namely control variables, independent variables, and dependent variables. The control variables used in this research are pine oil (20 mL) as frother, 14L water volume, 50 gr sample weight, and oleic acid as collector. The independent variables used in this research are grain size (100 mesh, 80 mesh, 60 mesh, and 40 mesh), flotation time (5 min, 10 min, and 15 min), and collector dosage (20 mL, 30 mL, and 40 mL). Last, the dependent variables of this research are ash content and calorific value.

Coal flotation was conducted in several stages, namely the addition of reagents and conditioning process, flotation process, and filtering or dewatering process.

Result and Discussion

1. Characteristics of coal sample

Microscopic analysis was carried out on the polished sample that had been prepared. The results of the microscopic analysis showed quartz, pyrite, and clay minerals as impurities in the analyzed coal sample.

Figure 1 shows the mineral quartz, which is one of the most important oxide minerals found in coal. Based on the figure, the appearance of quartz minerals has a black color with an irregular shape and has a distribution and different sizes. Nursanto, et al., (2011) explain other type of quartz is fine crystal quartz that is formed from solution after coal deposition. Quartz in this coal is mostly dissolved silica from the weathering of carbonate minerals. Other minerals shown in the photomicrographs are clay minerals which has a gray appearance and is found in the coal vein. Clay minerals are formed from moganite minerals found in coal samples. Nursanto, et al., (2011) describe that clay minerals which are the most dominant group found in coal, around 60-80% of the total mineral matter. Clay minerals formed in the second phase (secondary) are generally produced by the transformation of the first phase clay. Clay mineral associations in coal seams are usually found in the form of scattered fine inclusions and as clay bands. In addition to quartz and clay minerals, the coal samples analyzed also have sulfide minerals in the form of pyrite minerals. From the photomicrographs, pyrite has a white appearance with a metallic luster and has a very fine size. Pyrite is found in the form of the most common syngenetic Fe-Sulfide with pyrite crystals smaller than 2 microns, found in speroidal or framboidal form and associated with vitrinite (Nursanto, et al., 2011).

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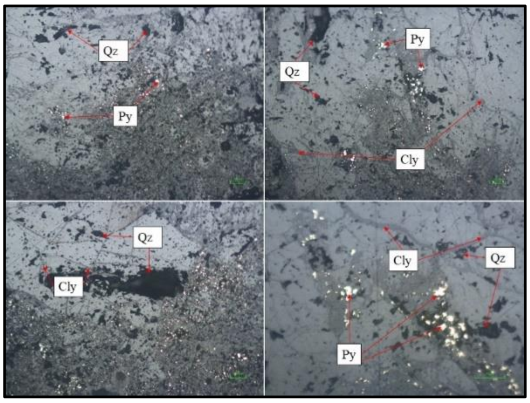

Figure 1 Coal sample photomicrographs

The results of XRD analysis based on the diffractogram show that the composition of minerals contained in coal samples is 56.4% of carbon graphite, 39.1% of quartz, and 4.4% of moganite. Diffractogram which is the result of XRD analysis are reveal in Figure 2.

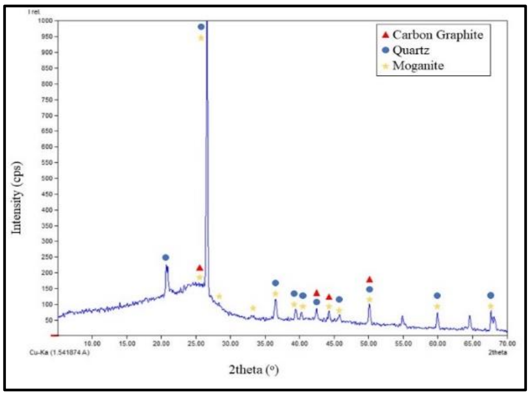

Figure 2 Results of XRD analysis of coal sample

The quality of coal sample in this study was determined based on several parameters, namely calorific value and proximate analysis which includes the determination of moisture content, ash content, volatile matter, and fixed carbon value. The results of coal quality analysis are shown in the table 1:

Table 1 Coal quality analysis results

Sample code	Prokximate Analysis (%)				Calorific value (Cal/g)	Fuel ratio
	IM	Ash	VM	FC		
U0W0C0	5.55	5.07	36.43	52.95	5,207	1.45

Based on table 1, we can determine the type of coal that has been analyzed with 5.55% of inherent moisture, 5.07% of ash content, 36.43% of volatile matter, 52.95% of

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fixed carbon, and 5,207 cal/g of calorific value. Based on the value of coal fuel ratio which is the value of the ratio between fixed carbon and volatile matter based on Frazer's fuel ratio coal classifications in Oni & Ehinola (2017) shows that the analyzed coal samples can be categorized as sub-bituminous coal.

2. Effect of experimental variables on ash content

The percentage reduction of ash content can be calculated using the following equation:

$$\text{ACR (\%)} = \frac{\text{IAC (\%) - FAC (\%)}}{\text{IAC (\%)}} \times 100\%$$

Where,
ACR : Ash Content Reduction (%)
IAC : Initial Ash Content (%)
FAC : Final Ash Content (%)

Based on figure 3, the ash content graph tends to decrease the longer flotation is carried out. While the ash deviation value graph increases the longer the flotation is carried out. Based on the results of the ash content analysis, the lowest ash content is 3.72% or 26.63% of ash reduction at a flotation time of 15 minutes. This proves that the longer flotation is carried out, the smaller the ash content value obtained and the higher the ash content recovery value (Vapur, et al., 2010).

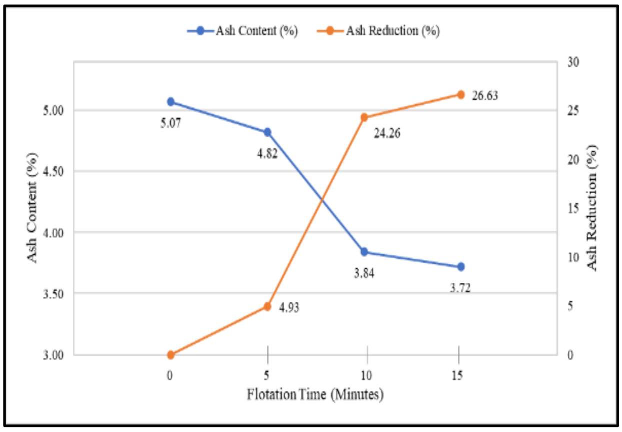

Figure 3 Graph of the effect of flotation time on ash content

Based on figure 4, the ash content graph tends to decrease when the collector dosage added is 20 mL, then increases when 30 mL collector dosage is added, then decreases again when 40 mL collector dosage is added. Based on the results of the ash content analysis, the lowest ash content is 3.32% or 34.52% of ash reduction at a 40 mL collector dosage used. This is due to the fact that the more collector dosage added will result in an increase in the viscosity of the slurry mixture so that the speed of movement of coal particles becomes small and inhibits the flotation process (Aladin, 2009).

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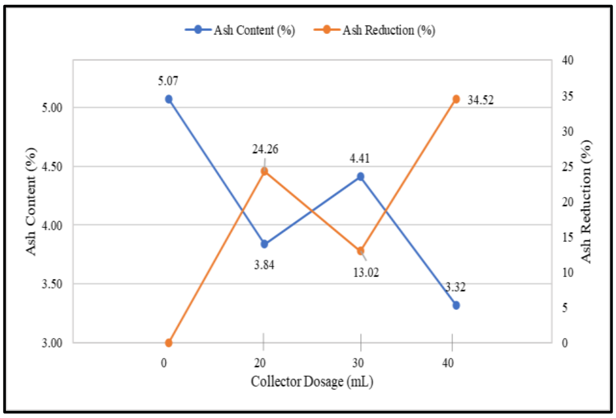

Figure 4 Graph of the effect of collector dosage on ash content

Based on figure 5, the ash content graph tends to decrease until grain size 60 mesh, but the ash content starts to increase at grain size 80 mesh. Figure 5 also shows that the optimal grain size was obtained at 60 mesh with the lowest ash content value of 2.83% or 44.18% of ash content reduction. Morris (1952) in Sokolovic and Miskovic (2018) explained that the maximum flotation rate is obtained in the middle grain size range and the flotation rate constant decreases for fine and coarse sizes. This occurs due to the low probability of bubble-particle collisions at fine grain size, while at coarse grain size will form a high probability of particle detachment from the bubble surface.

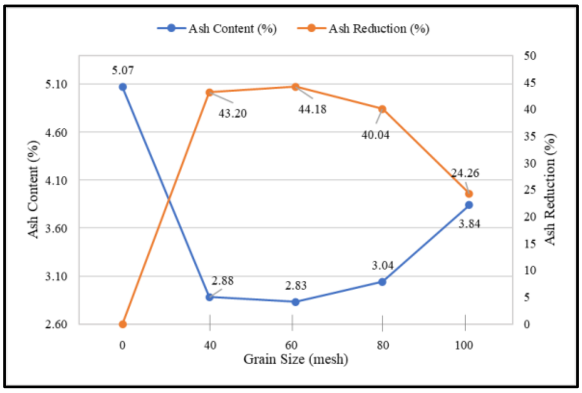

Figure 5 Graph of the effect of grain size on ash content

1. Effect of experimental variables on increasing calorific value

The percentage reduction of ash content can be calculated using the following equation:

$$CVI\ (\%) = \frac{ICV\ (\%) - FCV\ (\%)}{ICV\ (\%)} \times 100\%$$

Where,
CVI : Calorific Value Increasing(%)
ICV : Initial Calorific Value (%)

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FCV : Final Calorific Value (%)

Figure 6, it indicates that the effect of flotation time will form a calorific value graph that tends to increase the longer the flotation time is carried out. The highest calorific value is found at a flotation time of 15 minutes valued at 5,835 calorie/gram or 12.06% of calorific value increasing.

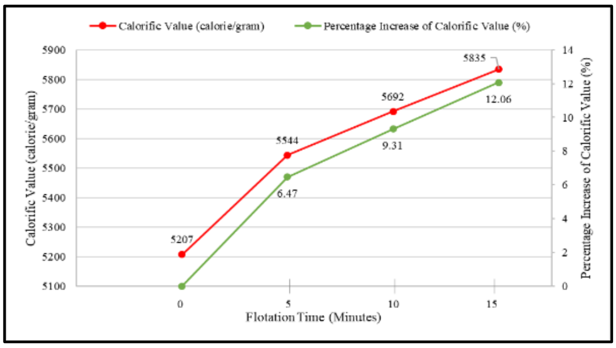

Figure 6 Graph of the effect of flotation time on calorific value

Based figure 7, it reveals the graph explains about there is an optimal collector dosage in the coal flotation process carried out, which is 30 mL collector dosage with a calorific value of 5,715 calories/gram or 9.76% of calorific value increasing.

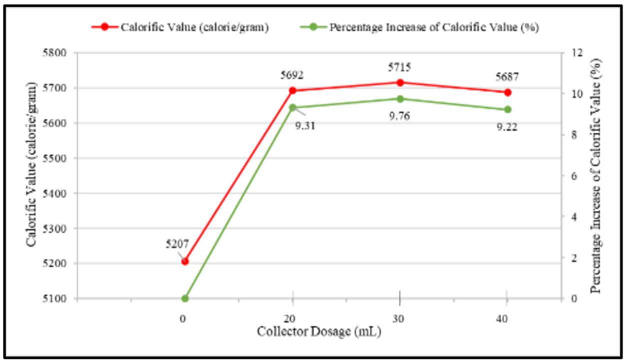

Figure 7 Graph of the effect of collector dosage on calorific value

Based figure 8, it shows the effect of grain size on the increase in calorific value, which relatively decreases with the smaller grain size of the beneficiated coal. The highest calorific value is obtained at a grain size of 40 mesh worth 5,752 calorie/gram or 10.47% of calorific value increasing.

2. Corelation between ash content and calorific value

The ash content analysis and calorific value analysis values for each research variable will be used as data to show the correlation between ash content and calorific value. Based

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figure 9, shows the correlation between calorific value and ash content, in which the higher the calorific value, the lower the ash content.

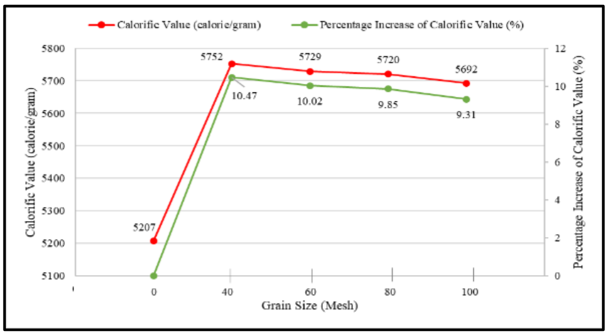

Figure 8 Graph of the effect of grain size on calorific value

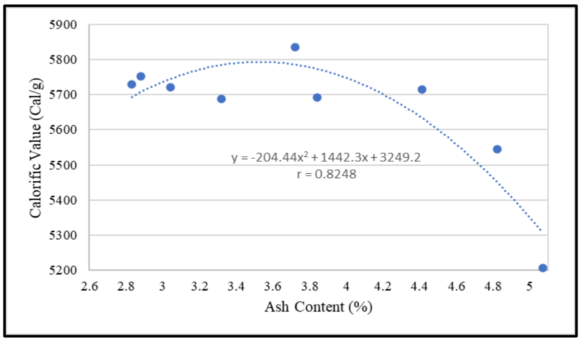

Figure 9 Graph of the effect of grain size on calorific value

Figure 9 indicates the correlation between ash content and calorific value, where the r value in the graph is 0.8248 with polynomial trendline regression, which explains that ash content affects the calorific value. Based on figure 9, the calorific value can be found using the following equation:

$$CV= -204.44(AC)^2+1,442.3(AC)+3,249.2$$

Several studies on the correlation of ash content and calorific value explain that the lower the ash content value, the greater the calorific value of coal (Yilmaz, et al., 2019). The correlation between ash content and calorific value is caused by the presence of unburned mineral matter in the coal sample, which interferes with the combustion process and produces a small calorific value. However, the high calorific value of coal does not only depend on ash content, but other parameters will also determine the calorific value of coal (Sugiarto et al., 2023).

Conclusion

Microscopic analysis results reveal quartz, pyrite, and clay minerals present in the coal sample. In addition, other minerals are also found in coal sample in the form of

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graphite and moganite. Based on the results of proximate analysis, the coal sample has 5.55% inherent moisture, 5.07% ash content, 36.43% volatile matter, and 52.95% fixed carbon content, and has a calorific value of 5,207 cal/g based on the results of calorific value analysis. The effect of variables on the lowest ash content reduction of coal is found in the sample with a grain size of 60 mesh, flotation time of 10 minutes, and collector dosage of 20 mL with an ash content value of 2.83% or 44.18% of ash content reduction from the initial ash content value. The highest calorific value is obtained in samples with a grain size of 100 mesh, flotation time of 15 minutes, and collector dosage of 20 mL with a calorific value of 5,835 cal/g or 12.06% calorific value increasing from initial calorific value.

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