UNDERGRADUATED THESIS

BENEFICIATION STUDY OF COAL FROM BONEHAU, MAMUJU REGENCY OF WEST SULAWESI PROVINCE USING COLUMN FLOTATION

Compiled and submitted by:

GABRIEL WENDIARTO WILLIAM
D111 20 1033

MINING ENGINEERING STUDY PROGRAM
FACULTY OF ENGINEERING
HASANUDDIN UNIVERSITY
GOWA
2024

APPROVAL PAGE

BENEFICIATION STUDY OF COAL FROM BONEHAU, MAMUJU REGENCY OF WEST SULAWESI PROVINCE USING COLUMN FLOTATION

Compiled and submitted by

GABRIEL WENDIARTO WILLIAM
D111 20 1033

Has been defended in front of the Examination Committee which established
for the completion of Mining Engineering Study Program
Faculty of Engineering Hasanuddin University
On 26th June 2024
and declared eligible

Approved by,

Supervisor,

Dr. Ir. Sufriadin S.T., M.T.
NIP. 196608172000121000l

Head of Study Program,

Dr. Ir. Aryanti Virtanti Anas S.T., M.T.
NIP. 197010052008012026

LEMBAR PENGESAHAN SKRIPSI

STUDI BENEFISIASI BATUBARA BONEHAU, MAMUJU, SULAWESI BARAT MENGGUNAKAN FLOTASI KOLOM

Disusun dan diajukan oleh

GABRIEL WENDIARTO WILLIAM
D111 20 1033

Telah dipertahankan di hadapan Panitia Ujian yang dibentuk dalam rangka Penyelesaian Studi Program Sarjana Program Studi Sarjana Teknik Pertambangan Fakultas Teknik Universitas Hasanuddin Pada tanggal 26 Juni 2024 dan dinyatakan telah memenuhi syarat kelulusan

Menyetujui,

Pembimbing Utama,

Dr. Ir. Sufriadin S.T., M.T.
NIP. 1966081720001210001

Ketua Program Studi,

Dr. Ir. Aryanti Virtanti Anas S.T., M.T.
NIP. 197010052008012026

STATEMENT OF AUTHENTICITY

The Undersigned below:

Name	:	Gabriel Wendiarto William
Student ID	:	D111 20 1033
Study Program	:	Mining Engineering
Degree	:	Undergraduate (S1)

Declared that my undergraduated thesis titled

BENEFICIATION STUDY OF COAL FROM BONEHAU, MAMUJU REGENCY OF WEST SULAWESI PROVINCE USING COLUMN FLOTATION

Is my own work of writing and is not a takeover of someone else's writing and that the thesis I wrote is really my own work.

All information written in the thesis that comes from other authors has been given credit, namely by citing the source and year of publication. Therefore, all writings in this thesis are fully the responsibility of the author. If any party feels that there are similarities in the title and or findings in this thesis, the author is ready to be clarified and take responsibility for all risks.

All data and information obtained during the process of making a thesis, which will be published by the author in the future must be approved by the supervisor.

If in the future it is proven or can be proven that part or all of the contents of this thesis are the work of others, then I am willing to accept sanctions for these actions.

Gowa, 26th June 2024

Signature

Gabriel Wendiarto William

ABSTRACT

GABRIEL WENDIARTO WILLIAM. *BENEFICIATION STUDY OF COAL FROM BONEHAU, MAMUJU REGENCY OF WEST SULAWESI PROVINCE USING COLUMN FLOTATION* (supervised by Sufriadin)

Coal is a heterogeneous organic rock with black characteristics and associated with a number of impurity mineral matters that can reduce coal quality. 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 characteristics of coal samples, analyze the effect of grain size, flotation time, and collector dosage variables on reducing ash content, and analyze the effect of grain size, flotation time, and collector dosage variables on increasing calorific value. The analytical methods used in this research are microscopic analysis and X-Ray Diffraction (XRD) analysis for coal mineralogy and proximate analysis and calorific value analysis for coal quality. The beneficiation experiment used column flotation method using flotation time, grain size, and collector dosage as research variables. The results of coal mineralogy analysis showed mineral composition consisting of quartz, pyrite, moganite, and graphite. The lowest ash content analysis results were obtained at a grain size of 60 mesh, a flotation time of 10 minutes, and a collector dose of 20 mL with an ash content value of 2.83%. The highest calorific value analysis results were obtained at a grain size of 100 mesh, flotation time for 15 minutes, and a collector dose of 20 mL with a calorific value of 5,835 cal/g.

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

ABSTRAK

GABRIEL WENDIARTO WILLIAM. *Studi Benefisiasi Batubara Bonehau, Mamuju, Sulawesi Barat Menggunakan Flotasi Kolom* (dibimbing oleh Sufriadin)

Batubara adalah batuan organik yang bersifat heterogen dengan karakteristik berwarna hitam dan berasosiasi dengan sejumlah mineral pengotor yang dapat menurunkan kualitas batubara . Benefisiasi batubara adalah proses meningkatkan kualitas batubara dengan sejumlah metode untuk menurunkan kadar abu serta meningkatkan nilai kalori batubara. Salah satu metode benefisiasi batubara adalah flotasi yang melibatkan fasa padatan berupa partikel batubara, fasa cair berupa air, dan fasa gas berupa gelembung udara sebagai faktor yang mempengaruhi proses flotasi. Penelitian ini bertujuan untuk mengetahui karakteristik sampel batubara, menganalisis pengaruh variabel ukuran butir, waktu flotasi, dan dosis kolektor terhadap penurunan kadar abu, dan menganalisis pengaruh pengaruh variabel ukuran butir, waktu flotasi, dan dosis kolektor terhadap peningkatan nilai kalori. Metode analisis yang digunakan dalam penelitian ini adalah metode analisis mikroskopik dan analisis X-Ray Diffraction (XRD) untuk mineralogi batubara serta metode analisis proksimat dan analisis nilai kalori untuk kualitas batubara. Percobaan benefisiasi menggunakan metode flotasi kolom menggunakan waktu flotasi, ukuran butir, dan dosis kolektor sebagai variabel penelitian. Hasil analisis mineralogi batubara menunjukkan komposisi mineral yang terdiri dari kuarsa, pirit, moganit, dan grafit. Hasil analisis kadar abu terendah didapatkan pada ukuran butir 60 mesh, waktu flotasi selama 10 menit, dan dosis kolektor sebanyak 20 mL dengan nilai kadar abu, yaitu 2,83%. Hasil analisis nilai kalori tertinggi didapatkan pada ukuran butir 100 mesh, waktu flotasi selama 15 menit, dan dosis kolektor sebanyak 20 mL dengan nilai kalori sebesar 5.835 kal/g.

Kata Kunci : *Flotasi Kolom, Benefisiasi Batubara, Kadar Abu, Nilai kalori*

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

LIST OF ABBREVIATIONS AND SYMBOL MEANINGS

Emblems/Abbreviations	Meaning and Description
P	Peat
L	Lignite
SB	Sub-Bituminous
B	Bituminous
SA	Sub-Antracite
A	Antracite
MC	Moisture Content
AC	Ash Content
VM	Volatile Matter
FC	Fixed Carbon
W1	Crucible weight
W2	Crucible weight + Sample weight
W3	Crucible weight + Sample weight after combustion

LIST OF APPENDICES

PREFACE

Praise to the Lord Jesus Christ Almighty for all His grace and gifts that have been given, so that the author can complete the Final Assignment entitled Beneficiation Study of Coal From Bonehau, Mamuju Regency of West Sulawesi Province Using Column Flotation. This final assignment is intended to fulfill the requirements for study at the Mining Engineering Department, Faculty of Engineering, Hasanuddin University.

The author would like to thank all those who have helped up to the stage of preparing this final assignment, which include Dr. Ir. Sufriadin, S.T., M.T., as the supervisor and Head of the Minerals Analysis and Processing Laboratory who provided support, advice, guidance, and direction in completing this research. Dr. phil. nat. Sri Widodo, S.T., M.T., and Dr. Aryanti Virtanti Anas, S.T., M.T., as Examining Lecturers who provided advice and suggestions regarding the preparation of the final assignment. Tri Utomo Taliding who has provided samples as material for research. Combustion Motor Laboratory who helped in the analysis process using the bomb calorimeter tool. Zahran Mubarak who helped in the analysis process using the X-Ray Diffraction (XRD) tool. All students of the Department of Mining Engineering, Faculty of Engineering, Hasanuddin University, especially for DRILLING 2020 and all members of the Analysis and Mineral Processing Laboratory who have provided assistance and support in the preparation of the final project. William Djoenaidi and Martha Kallo as parents who always provide support and prayers in any form so that the preparation of the final assignment runs well.

The author humbly apologizes if there are mistakes in writing this Final Assignment, because basically the author is an ordinary human being who is not free from mistakes and needs input, suggestions and criticism to improve this research. Finally, I hope this research can be useful in providing knowledge related eneficiation using the column flotation method.

CHAPTER I
INTRODUCTION

1.1 Background

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

Coal from Bonehau district, Mamuju regency, West Sulawesi province has several characteristics from the analysis results conducted by Taliding, et al. (2023). Through the results of proximate analysis, Bonehau coal has moisture content from 3.65% to 8.42%, ash content from 5.49% to 64.96%, volatile matter from 17.69% to 62.83%, and fixed carbon from 13.70% to 46.76%. Based on Kasim (2023), the calorific value of Bonehau coal is 5,228 calories/gram with total sulfur of 1.28%.

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. Coal beneficiation can be done by using dry physical, chemical, physico-chemical and bio-beneficiation technologies (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
s. Column flotation is flotation using a column as a container for mineral
n (Haryono, et.al., 2020). There is a substance added to the coal pulp
during flotation. The substance is a flotation reagent consist of collector

and frother. Collector is a substance used to attach particles to bubbles. Meanwhile, the frother is used to increase the life of the bubble. Reagents need to be added in coal pulp to allow hydrophobic particles to float and allow hydrophilic particles to sink and be considered as impurities (Rao and Gouricharan, 2016).

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. Deashing is applied to remove polluting elements and is also an effort to increase the calorific value of the coal so that it can provide added value similar to high quality coal (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. The use of direct coal with high ash content will cause technological and environmental problems. 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.

1.2 Problems of Research

The formulation of the problems of the research are:

1. What are the quality characteristics of coal from Bonehau District, Mamuju Regency, West Sulawesi?
2. What is the effect of grain size, flotation time, and collector dosage variable on reducing coal ash content?
3. What is the effect of grain size, flotation time, and collector dosage variable on increasing calorific value?

1.3 Purposes of Research

oses of the research are:

letermine the quality characteristics of coal from Bonehau District, ıuju Regency, West Sulawesi.

2. To analyze the effect of grain size, flotation time, and collector dosage variable on reducing coal ash content.
3. To analyze the effect of grain size, flotation time, and collector dosage variable on increasing calorific value.

1.4 Benefit of Research

This research can be useful to add insight and provide information about other alternatives in reducing coal ash content using the column flotation method so that the processed coal will have a higher calorific value.

1.5 The Scope of Research

This research was conducted at the Laboratory-Based Education (LBE) Analysis and Mineral Processing, Mining Engineering Study Program, Hasanuddin University. This research was carried out to process coal from Bonehau District, Mamuju Regency, West Sulawesi using column flotation. The research carried out was limited by the analysis of ash content reduction and calorific value analysis, so that the presence of other elements was not taken into account or ignored. The coal sample conditions used in the column flotation process are 40 mesh, 60 mesh, 80 mesh, and 100 mesh, the variations of time used during the column flotation process is 5 minutes, 10 minutes, and 15 minutes, and the variations of collector dosage is 20 mL, 30 mL, and 40 mL.

CHAPTER II
LITERATURE REVIEW

2.1 Coal

Coal is an organic rock formed from plant fossils. Coal has dark physical characteristics and has associations with some mineral content. The chemical structure of coal is believed to be a solid polymer with oxygen functional groups consisting of aromatic and polycyclic groups connected by aliphatic structures. The coal formation process consists of two stages, namely biochemical processes and dynamochemical processes and is also affected by the depositional environment (insitu or drift), temperature, pressure, and time. The chemical structure of coal is thought to be a solid polymer that cannot be dissolved in organic solvents (Pasymi, 2008).

Coal is a unique rock type in geology because it has a wide range of physical and chemical properties. Coal's wide range of physical and chemical properties have been studied over a long period of time. Coal is a traded mining material because of its primary uses in power generators, steel manufacturing, industrial use and domestic consumption. Coal trading relies on contracting and pricing mechanisms commonly used by coal producers or users (Thomas, 2013).

Coal is formed from fossilized carbon that originates from organic matter collected in low-lying areas or sedimentary basins. Coal main organic material in coal comes from trees, plants, leaves, roots, branches, pollen, and spores from plants. The main organic matter then gathers in the environment of a saturated area such as a swamp and forms part of the decaying vegetation and settles on the bottom of the swamp and turns into peat. This process is referred to as humification and refers to the decomposition of plant elements that are converted into organic residues. The presence of organic matter from peat is very important because it is the main material that forms coal, which will continue to change over time and pressure into coal (Robl, et al., 2017).

e peat that has formed will be covered through flooding or erosion called infiltration. The peat will continue to be deposited with increasing depth position process continues to a depth where the temperature and pressure continue to increase. This process will compact the peat into lignite (brown coal) and become the first step of the coalification process. As the organic matter compacts into a denser solid, the moisture of the peat decreases, while carboxylic acids and volatile matter (mainly methane) also decrease as the pressure increases during the compaction process. With time, heat and pressure, lignite matures into subbituminous coal, then into bituminous coal, and finally into anthracite. The various stages that occur over time result in chemical changes to the organic material during the process of coalification. The process of coal formation are shown in the Figure 1 (Robl, et al., 2017).

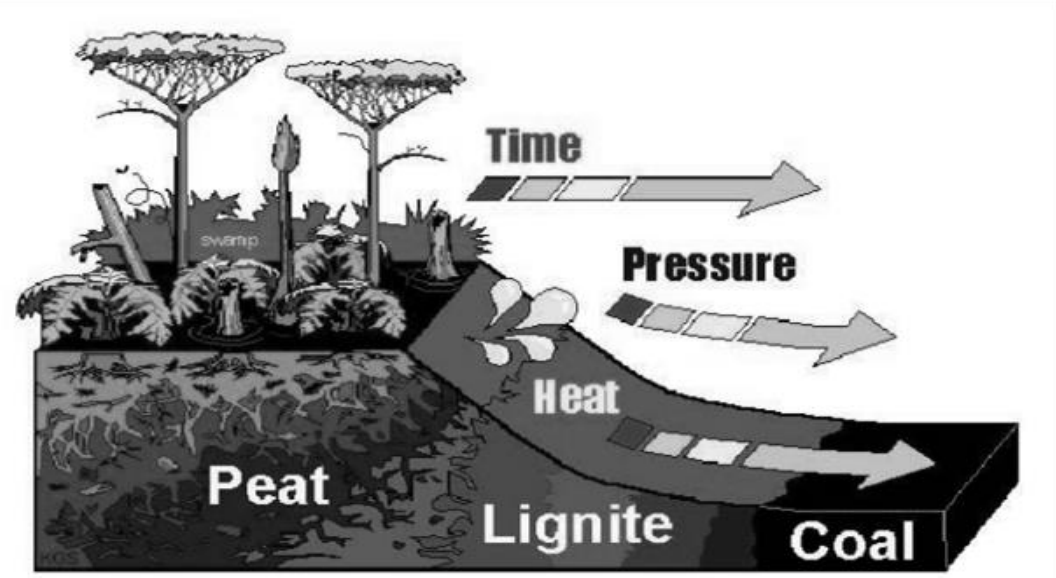

Figure 1 Coal formation process (Pasymi, 2008)

Coal rank is a term used to define the extent to which organic matter is modified through the process of coalification and each rank is determined by several physiochemical properties. One commonly used classification system uses fixed carbon, volatile matter, calorific value, and agglomeration characteristics to rank specific coals (ASTM, 2015). In this classification, fixed carbon and volatile matter are expressed on a dry mineral matter free basis (dmmf), while calorific value is expressed on a mineral matter free basis (mmf). The rank of bituminous coal is determined by calorific value and composition (fixed carbon and volatile matter). ıinous coals with high volatile matter all contain <69% fixed carbon and latile matter. The calorific value will increase with the rank of the coal, as matter is converted to fixed carbon as the process of coalification progresses. Through the continuous process of coalification, more and more volatile matter is converted into fixed carbon, as the rank increases to low volatile bituminous. Once the amount of fixed carbon increases to 86% and the volatile matter decreases to 14%, the rank is classified as Anthracite (Robl, et al., 2017).

Bituminous coal is a type of solid coal, which is usually brownish black, often dark brown color, and sometimes has stripes between light and dull material, which is used as an ingredient in steam electric power plants with considerable quantities used for heat and power applications in manufacturing and coke making. The moisture content of bituminous coal is usually less than 20% by weight. The heat content of bituminous coal ranges from 21 to 30 million btu/ton on a moist and mineral matter free basis (Speight, 2005).

Subbituminous coal is coal that has similar properties of bituminous coal and lignite coal, which is used as fuel for steam power plants. Subbituminous coal is usually dull, dark brown to black color with a soft texture and brittle at the lower end. Water content Subbituminous coal contains 20% to 30% by weight. The heat content of subbituminous coal ranges from 17 to 24 million btu/ton on a moist and mineral matter free basis (Speight, 2005).

Lignite coal is the lowest grade of coal and is commonly referred to as brown coal which is used as fuel for steam power plants. Lignite coal is brownish black in color with a high moisture content (45%) and heat content that ranges from 9 to 17 million btu/ton on a moist and mineral matter free basis (Speight, 2005).

Based on the value of moisture content, ash content, volatile matter, fixed carbon, and calorific value, coal classification can be divided in the Table 1 (Rao and Gouricharan, 2016):

Table 1 Coal classification based on coal quality (Rao and Gouricharan, 2016)

No.	Coal Quality	P	L	SB	B	SA	A
1.	MC (%)	15-25	10-30	10-20	0.5-14	3.0	2.3
2.	VM (%)	50-55	40-45	40	20-45	8.4	3.1
3.	AC (%)	3-10	3.4-7.5	-	3-8	9.7	6.9
[illegible]	[illegible]C (%)	25-30	30-35	60	-	78.9	87.7
[illegible]	[illegible]V (Kcal/Kg)	4,500-5,000	6,500-6,600	6,800-7,600	7,500-8,900	7,700	7,700

2.2 Coal Beneficiation

Coal beneficiation is the process of separating coal particles with low ash content from mine-derived coal (ROM coal) by physical or physico-chemical treatment. ROM coal has various sizes ranging from boulders to fine sand mixed with impurities and rocks. There are special treatments on ROM coal such as size reduction and screening, beneficiation, and drying. Coal beneficiation is necessary to meet market requirements related to size, ash, sulfur, moisture, and calorific value. Coal beneficiation is an activity carried out on ROM coal to prepare it as a feed material to coke ovens or coal-fired boilers as an end use by a conversion process without physically damaging the coal (Rao and Gouricharan, 2016).

The coal that feeds into the fuel will produce ash, which is formed from the mineral matter contained in the coal. When coal size reduction is performed, each coal particle formed will never have the same amount of mineral matter. Due to the different mineral content of the coal particles, the coal particles can be separated to obtain low ash coal particles and high ash coal particles as two products. The product of coal particles with low ash content is referred to as clean coal (combustibles), while the product of coal with high ash content is referred to as refuse or reject. Sometimes there is another product with medium ash content called middling (Rao and Gouricharan, 2016).

Coal ash is the part of coal that remains when coal is burned completely. Coal ash is composed of inorganic compounds such as clay, pyrite, limestone, sand etc. Coal ash content will affect the calorific value and combustion performance of coal (Pasymi, 2008). The reduction of coal ash content is referred to as deashing. The most effective deashing is chemical washing of coal using alkali and acid solutions or often known as the leaching method. Leaching is effectively used to reduce most ash-forming minerals, pyritic sulfur and organic sulfur from coal (Pratama and Fadhilah, 2021). Ash content is one of the most important indices of coal quality. The standard measurement method of coal ash content is the combustion weighing method to obtain the percentage of impurities according to the weight ratio before … combustion (Zhang et.al., 2014).

… objectives of coal beneficiation are to reduce ash content, reduce harmful … phosphorus content especially in metallurgical coals, increase calorific value, improve coking properties, increase ash fusion point by removing alkali chlorides (which are responsible for lowering the fusion point), reduce clinkering propensity, and increase utilization efficiency. Clean beneficiated coal has the following beneficial properties (Rao and Gouricharan, 2016):

1. More efficient combustion with higher heat per unit weight of coal burned.
2. Maximum use of utilized heat.
3. Lower transportation and handling costs for delivery from the coal-fired power plant to the point of consumption and for waste or ash disposal.
4. Higher level of cleanliness as it produces less ash that needs to be handled.

2.3 Coal Analysis

Coal analysis has several reporting or standards when the basis for coal analysis are shown in the following explanation (Thomas, 2013):

1. As received basis (a.r.), or commonly referred to as sampled. This basis will state the percentage data of the coal including the total moisture content, which is the surface moisture content and air-dry moisture content of the coal.
2. Air dried basis (a.d.b.) is a basis that states the percentage of coal that is air dried including air moisture but excluding coal surface moisture.
3. Dry basis (dry) is a basis that expresses the percentage of coal after all moisture has been removed.
4. Dry ash-free basis (d.a.f.) is a basis where the coal is considered to consist of volatile matter and fixed carbon from recalculation by removing moisture and ash. It should be noted that this does not allow for the volatile matter derived from minerals present in the air-dried coal. This basis is used as the easiest way to compare organic fractions of coals.
5. Dry, mineral matter-free basis (d.m.m.f.) is a basis that determines the total amount of mineral matter rather than ash is determined, so that the volatile matter content can be eliminated.

Coal can be considered to consist of moisture, pure coal, and mineral matter ...uents of coal. Moisture is found on the surface and in chemically bound ... Pure coal is the amount of organic matter present in coal, while mineral ... the inorganic matter that forms ash when coal is burned. During the combustion process, the composition of ash and mineral matter may not be the same, or not all of the mineral matter is reduced to ash. Coal analysis that is often reported is proximate analysis and ultimate analysis. Proximate analysis is an analysis that determines the amount of moisture, volatile matter, ash content, and fixed carbon. Proximate analysis is the most basic of all coal analyses and is highly dependent on the procedure used. It is important to know the procedure used when conducting the analysis because the results obtained can be different if different times and temperatures are used. Ultimate analysis is an analysis that determines the amount of chemical elements in the coal, namely carbon, hydrogen, nitrogen and sulphur that have a direct link to the required utility of the coal. Ultimate analysis also includes sulfur, chlorine, phosphorus, as well as elements that make up the mineral content of coal and selected trace elements (Thomas, 2013).

2.3.1 Proximate Analysis

Coal proximate analysis is the analysis of moisture content, ash content, volatile matter and fixed carbon based on predetermined methods or standards. This analysis method was developed in a simple way to determine the distribution of products obtained when a coal sample is heated under certain conditions. The proximate analysis conducted will produce four groups of products, namely water vapor, volatile matter consisting of gases and vapors wasted during the pyrolysis process, ash or inorganic residue remaining after combustion, and fixed carbon which is the non-volatile fraction of coal. The test method for proximate analysis uses ASTM D-3172 which includes analytical methods related to proximate analysis of coal and coke (Speight, 2005).

Proximate analysis is an analysis that has no absolute significance, but can be decisive if carried out under certain conditions, the results of which can be used as material for coal classification. Research has shown that proximate analysis can be used to estimate certain physical, chemical, and thermal properties of the coal being analyzed. The following are parts of proximate analysis (Thomas, 2013):

isture content

ere are many terms to describe the moisture content of coal, such as surface isture, as received or as delivered moisture, total moisture, and air dried moisture. Surface moisture is moisture that does not naturally occur with the coal and can be removed using low temperature air (around 40^{o}C). As received or as delivered moisture is the total moisture in the coal when the coal is shipped or received in the laboratory and usually the coal sample is air dried to obtain loss on air drying. Total moisture is the moisture removed by using a temperature of about 150^{o}C in a vacuum. While air dried moisture is the moisture that remains after air drying and can be removed using aggressive drying.

2. Ash content

   Coal ash is the inorganic residue that remains when coal combustion has been carried out. Coal ash content is not equivalent to the entire mineral content of coal, but ash content can represent most of the mineral matter contained in coal when losing volatile gas components such as carbonate, sulfide, and clay minerals. High ash content will reduce the calorific value of coal, such as in steam coal. The maximum ash content for steam coal to be used as pulverized fuel is about 20%, but for some stoker-fired boilers, much lower ash content values are preferable. In the case of coal, a maximum of 10%-20% is recommended because the higher the ash content the less efficient the blast furnace will be.

3. Volatile matter

   Volatile matter is a component of coal that evaporates at high temperatures in the absence of air. Volatile matter comes from the organic matter of the coal with a small amount can come from the mineral matter present. In pulverized fuel combustion for power generation, boilers are designed to accept volatile matter in the range of 20%-25%. In stoker-fired power plants, the recommended volatile limit is 25%-40%.

4. Fixed carbon

   The fixed carbon content of coal is the carbon that is present in the residue after combustion and removal of volatile matter. Fixed carbon is determined ng the difference in air-dried coal and the total percentage of other nponents, which are moisture content, ash content, volatile matter, and)%.

2.3.2 Ultimate Analysis

Coal ultimate analysis is performed to determine the weight percent of carbon as well as sulfur, nitrogen, and oxygen estimated by the difference method. Trace elements are also often determined using the ultimate analysis method. Coal carbon determination includes organic carbon and carbon present as carbonate minerals. Hydrogen determination includes organic hydrogen and water hydrogen in coal. Nitrogen is assumed to be present in the organic matrix of the coal. Meanwhile, sulfur exists in three forms in coal, namely organic sulfur compounds, inorganic sulfur (iron sulfide pyrite and marcasite), and inorganic sulfate (Na_2SO_4 and $CaSO_4$). The value of coal sulfur determined through ultimate analysis depends on the coal and the previous coal cleaning method (Speight, 2005).

Moisture and ash in the proximate analysis are not determined as part of the data generated through the ultimate analysis, but should still be determined so that the analytical values obtained can be converted to a comparable base other than the analytical sample. When appropriate work-up is done for carbon, hydrogen, and sulfur to inorganic matter, and ash to mineral matter, then the ultimate analysis will represent the elemental composition of organic matter in the coal in terms of carbon, hydrogen, nitrogen, sulfur, and oxygen (Speight, 2005). The following are parts of the ultimate analysis (Thomas, 2013):

1. Carbon and hydrogen

   Carbon and hydrogen materials are liberated as CO_2 and H_2O when coal is burned and are therefore most easily determined together. However, CO_2 can be liberated from carbonate minerals present, while H_2O can come from clay minerals or from moisture present in the coal.

2. Nitrogen

   The nitrogen content of coal is related to atmospheric pollution when burning coal, as nitrogen will help form oxides that can be released as flue gas, polluting the atmosphere. Coal that is low in nitrogen will be preferred by industry with a content of no more than 1.5%-2.0%.

fur

with nitrogen, coal sulfur levels can cause pollution and problems with l utilization. Sulfur can cause corrosion and impurities in boiler tubes, as well as cause atmospheric pollution when released in flue gases. Sulfur in coal can be categorized in three forms, namely organic sulfur found in coal organic compounds, pyritic sulfur found as sulfide minerals in coal such as iron pyrite, and sulfate minerals resulting from oxidation of the sulfide fraction in coal. In the ultimate analysis of coal, only the sulfur content is determined, but the amount of sulfur in all forms is required.

4. Oxygen

   Oxygen is a component found in coal's organic and inorganic materials including moisture content. When coal is oxidized, oxygen will take the form of oxides, hydroxides and sulfate minerals, as well as oxidized organic matter. Keep in mind that the presence of oxygen will be important as a ranking indicator in coal. Oxygen is usually determined by subtracting the amount of other elements, carbon, hydrogen, nitrogen and sulfur from 100%.

2.3.3 Calorific Value

Calorific value is the heat formed from the combustion of a number of parts of coal in a bomb calorimeter with oxygen under specified conditions (ASTM D-121; ASTM D-2015; ASTM D-3286; ISO 1928). Calorific value is determined using a bomb calorimeter by either the static (isothermal) method or the adiabatic method, with corrections made if a net calorific value is desired. The unit of calorific value is calories per gram, which can be converted to alternative units (1.0 kcal/kg = 1.8 btu/lb = 4,187 kJ/kg). Calorific value is a direct indication of the thermal energy value of coal and represents the combined heat from the combustion of carbon, hydrogen, nitrogen, sulfur, and is the gross calorific value with corrections applied if a net calorific value amount is desired (Speight, 2005).

Calorific value is usually expressed as the gross calorific value (GCV) or the higher heating value (HHV) and the net calorific value (NCV) or lower calorific value (LHV). The difference between the gross calorific value and the net calorific value is the latent heat of condensation of water vapor formed during the on process. The gross calorific value assumes that all the vapor formed e combustion process is fully condensed. Whereas the net calorific value that water is removed with the combustion products without being fully condensed. To equalize the value of the results, the calorific value must be compared to the net calorific value basis. The calorific value of coal is highly variable, compared to the ash, water content and grade of coal, whereas the calorific value of fuel oil is much more consistent (Speight, 2005).

The calorific value of coal is the amount of heat per unit mass of coal during the combustion process and is often referred to as specific energy. The calorific value of coal can be determined in two ways, namely the gross calorific and the net calorific. The gross calorific is the amount of heat liberated during laboratory testing, when coal is burned under standard conditions with a constant volume, so that all water in the product remains in liquid form. During combustion in a furnace, the gross calorific value is never reached because some products such as water are lost with their latent heat of combustion. Meanwhile, the net calorific value is the maximum calorific value expressed under constant pressure conditions and can be calculated through the gross calorific value with units of absolute joules, calories per gram, or btu per ton (Thomas, 2013).

2.4 Coal Flotation

Flotation is a mineral processing technique based on the physical and chemical properties of mineral surfaces. In the preparation of mineral flotation, the sample will be mixed with water to form a slurry. While during the flotation process, air will form bubbles and then will affect hydrophobic minerals to rise up to the surface of the flotation cell due to differences in mineral surface properties. Mineral particle size is one of the factors that determine the flotation process because it can determine the flotation of a particle. In addition to particle size, the type of reagent that binds the particles will also affect the flotation process because each type of chemical reagent used will be different from one another. Chemical reagents will be used to create conditions for the desired minerals to float and rise up to the surface of the flotation cell (Drzymala, 2007).

Flotation is the process of separating valuable materials from their impurities the surface properties (hydrophobic and hydrophilic) of the materials. , the flotation process will release bubbles at the bottom of the flotation ıydrophobic particles will follow to the top of the flotation. Gravity and buoyancy forces will influence the particles to move downward and air bubbles to move upward, so there is a place for interaction between bubbles and particles. The result of this interaction causes particles that have hydrophobic properties to stick to air bubbles, forming aggregates of bubble particles and carried to the top of the flotation cell and separated from impurity particles (in the case of coal flotation) which are left in water because they are hydrophilic (Warjito, et. al., 2015).

Based on the flotation process and cell, flotation consists of several types, namely based on the process and based on the flotation cell. The following are types of flotation based on the process, namely (Alfredo and Fadhillah, 2021):

1. Bulk flotation, flotation is carried out on ores that have a group of valuable minerals, resulting in a concentrate consisting of a group of valuable minerals with a higher grade than before. So the concentrate formed is only one type.
2. Differential flotation, this type of flotation is an advanced process of bulk flotation. After obtaining a concentrate in bulk flotation, the flotation process is carried out again which will then produce a concentrate containing one type of valuable mineral whose level is higher than the bulk concentrate. For example, there are three groups of valuable minerals in the bulk concentrate, then the concentrate produced in differential flotation consists of three types with the content of one valuable mineral each.
3. Selective flotation consists of the same group of valuable minerals, but the difference with bulk flotation is in the resulting concentrate. The valuable minerals in selective flotation are already separated in each concentrate, just like in the concentrate produced in differential flotation.

Based on the flotation cell, the flotation process can be divided into three types, which are as follows (Alfredo and Fadhillah, 2021):

1. Mechanical flotation, the shaft and impeller are located in the center of the machine, air will be introduced through the shaft and dispersed to the surface through the impeller. This type consists of two types based on the aeration process, namely induction and blower. It is said to be induction if the water ers manually without the help of a machine by utilizing the pressure erence between inside the cell and in the air. While the aeration process he blower type utilizes blower media.

2. Pneumatic flotation, no impeller and works by compressing air for agitation or the pulp aerator.
3. Column flotation, flotation is carried out inside a column, while the conditioning process is carried out outside the cell. There are no moving parts in column flotation. Air is blown in from the bottom.

The important aspects of the flotation process include engineering, physical and chemical aspects. Engineering aspects include flotation system design, bubble manufacturing and particle release systems. Physical aspects include the geometry and dynamics of particles and bubbles, while chemical aspects include the mechanism of particle attachment to the bubble surface which involves reagents to change the surface properties of particles. Flotation is determined by the probability of interaction, the probability of particle attachment to the bubble surface, and the formation of stable aggregates of particle bubbles. The process of particle interaction with bubbles is divided into a collision process, particles attached to the bubble surface and followed by the formation of bubble particle aggregates or detached from the bubble surface in two beneficiation products (Warjito, et al., 2015).

Flotation is the process of separating valuable minerals from their impurities by using the surface properties of minerals. Based on the nature of the mineral, the minerals can be separated from one another with air bubbles. Factors that affect flotation, are (Kuntaarsa and Subagyo, 2020):

1. Particle size

   Large particle sizes make the particles tend to settle, making it difficult to flotation. The deposition of these particles will make it difficult for bubbles to lift large particles. Conversely, a fine particle size will make the flotation process easier.
2. pH of solution

   The optimum pH for coal beneficiation by flotation is 4.5-6.5.
3. Surfactant

   e function of a surfactant is a collector that is a reagent, which has polar ups and non-polar groups at the same time. The collector will change the ticle properties from hydrophilic to hydrophobic.

Coal flotation is a complex process involving several phases (particles, oil droplets and air bubbles). These phases simultaneously form interactions with each other and with other substances such as propelling reagent molecules and ions dissolved in water. Physical and chemical interactions between fine coal particles can lead to aggregation, especially for high-rank coals. Non-selective particle aggregation can be said to be the main cause of selectivity problems in coal flotation. The problem must be overcome by physical or chemical (reagent) preparation before or during flotation. The interaction between oil droplets and coal particles is actually hydrophilic so stabilization of oil droplets by a small number of fine hydrophobic particles can lead to decreased selectivity and increased oil consumption. These problems can be overcome by using reagents that modify the coal surface for the relationship between particles, reagents and particles, and particles and bubbles during oil droplet feeding. The role of the reagent may be different for different types of coal, but it can be used as a modifier to improve the hydrophobicity of low rank coal while the main role is to control aggregation for high rank coal (Polat, et.al., 2003).

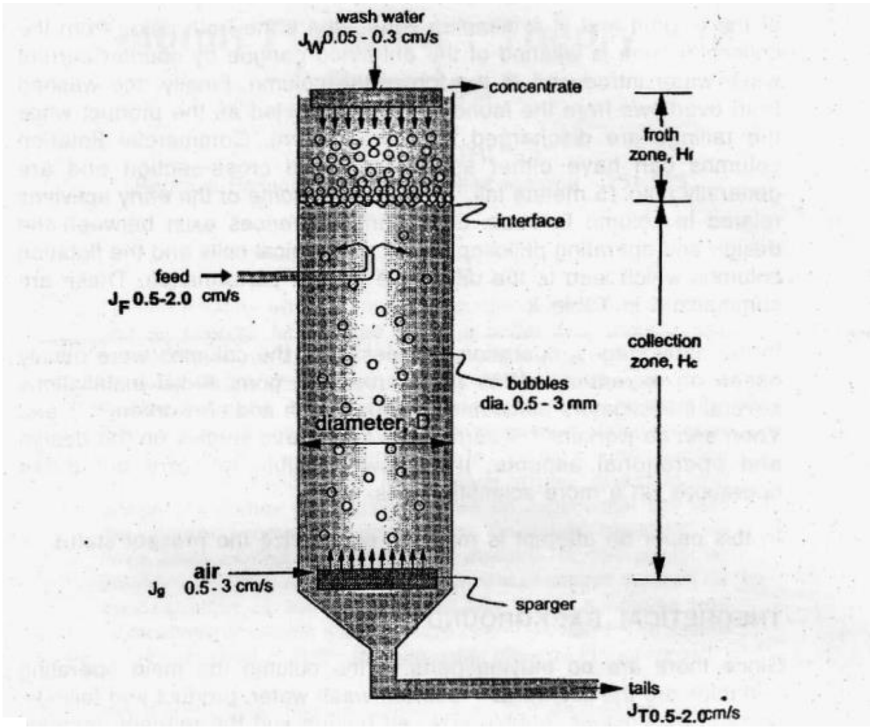

Figure 2 Column flotation scheme (Sastri, 1998)

umn flotation is flotation using a column as a container for mineral n. Ore is introduced from the top, while bubbles are blown through the sparger at a certain rate from the bottom of the column. There is interaction between ore and bubbles, so the separation using column flotation is very good, therefore the use of column flotation is usually carried out at the cleaner stage (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). To obtain maximum results of coal deashing by flotation, this process needs to be carried out under optimum parameter conditions. The flotation process needs to find optimum conditions for particle size variables, column dimensions (L/D), and pH. In general, clean coal removal is obtained at relatively large column dimensions (L/D) (Jaya, 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. A decrease in the hydrophobicity of the coal surface can occur due to oxidation, forming hydrophilic carbonyl, carboxyl, and ester groups. Coal consists of a number of different organic entities called macerals. Maceral groups with different physical and chemical properties will control the overall behavior of the coal including its hydrophobicity. The influence of macerals on the wettability and floatability of coal particles has been investigated by studying their critical surface tension (Ding, 2009).

2.5 Flotation Reagents

Flotation is a process of separating a substance from other substances in a liquid or solution based on differences in the surface properties of the substances to be separated, where hydrophilic substances remain in the water phase, while hydrophobic substances will be bound to air bubbles and will be carried to the surface of the solution and form froth, so that they can be separated from the liquid. The difference in the nature of the material surface (hydrophobic and hydrophilic), emical reagent is needed to change the mineral surface for the flotation Chemical reagents used in the flotation process, are (Kuntaarsa and 2020):

1. Collector

   An organic chemical reagent useful for changing the surface properties of minerals from hydrophilic to hydophobic, such as diesel and soap.

2. Modifier

   An inorganic chemical whose function is to affect the working of the collector. The general effect is to strengthen or weaken the hydrophobicity of a particular mineral surface, such as activators.

3. Frother

   A hydrocarbon organic substance consisting of polar and non-polar. The function of this reagent is to stabilize air bubbles so that they can reach the surface. The substance envelops the air bubbles so that the surface tension of the water will become lower, so that air bubbles will arise, such as methyl isobutyl carbinol.

Reagents are the most important part of the flotation process. In the early stages of flotation process development, major advances in flotation treatment were due to improved flotation reagents. Modern reagent classification is based on specific reagent functions and reagents are divided into collectors, frothers, modifiers and depressants. Collectors are a fairly large group of organic chemical compounds, which differ in chemical composition and function. The basic purpose of collectors is to selectively form a hydrophobic layer on the surface of certain minerals in the flotation pulp and thereby provide conditions for the attachment of hydrophobic particles to air bubbles and the recovery of such particles in the froth product. According to the ability of collectors to contact in water, they can be divided into several groups. Ionic collectors consist of heteropolar organic molecules and anionic collectors which are classified into oxhydryl collectors (Bulatovic, 2007).

Frothers are heteropolar surface-active compounds that lower the surface tension of water and have the ability to interact at the surface of air and water bubbles. Its presence in the liquid phase can increase the strength of the air bubble ıs providing better attachment of hydrophobic particles to the bubble. ension also affects the size of air bubbles. The effectiveness of some s highly dependent on the pH of the pulp. Their performance is optimal when the froth is molecular. Modifiers can be considered the most important chemicals in mineral processing, which control collector interactions between minerals. With the use of modifier reagents, the selective adsorption of collectors on certain minerals can be increased or decreased to achieve mineral separation. The use of modifiers makes it possible to isolate sulfide minerals of lead, zinc and copper from complex sulfide ores (Bulatovic, 2007).