ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

CENTER FOR ETHIO-MINES DEVELOPMENT

STUDY ON FLOTATION RESPONSE OF COAL FROM GAMO ZONE SOUTHERN ETHIOPIA

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A project submitted to Addis Ababa Institute Technology Center for Ethio-Mines Development in Partial Fulfillment of the Requirements for The Degree Master of Science in Mineral process Engineering

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This is to certify that the thesis prepared by Kibru w/mariam, entitled: ‘’STUDY ON FLOTATION RESPONSE OF COAL FROM GAMO ZONE SOUTHERN ETHIOPIA” Submitted to Addis Ababa Institute Technology Center for Ethio-Mines Development in Partial Fulfillment of the Requirements for The Degree Master of Science in Mineral process Engineering complies with the regulation of the university and meets the accepted standards with respect to originality and quality.

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Declaration

I, hereby, declare that this thesis entitled: “**study on flotation response of coal from Gamo zone southern Ethiopia’’** is my original work with the guidance of my advisor. The work contained herein is my own except where explicitly stated otherwise in the text and this work has not been submitted in whole or in part, for any other degree or professional qualification.

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Witnessed by:

Name of advisor:	**signature**	**Date**
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ABSTRACT

Based on the log results of pits, geophysical results and areal coverage of coal deposits in Gamo zone, Kuccha woreda, it is roughly estimated to have 744,174.96 tons of coal. The flotation response of a coal is a critical factor in determining the efficiency of coal beneficiation processes. The study investigated the effects of collector dosage, frother dosage, and particle size on the flotation response of Gamo area coal in a 3-liter batch flotation experiment. Kerosene was used as the collector and n-octanol as the frother. Full factorial Design was applied to investigate the effect of collector dosage (10ml, 20ml), frother dosage (2ml, 6ml) and particle size (-250 µm +125µm -125 µm) on the process of flotation using Design expert® 6 software, which shows the significant influence on the value of yield and recovery. The result showed that the optimum condition for the process was 18.3ml, 4.7ml and -125 µm which resulted in 81.7% yield,90% combustible matter recovery and 37.5% flotation efficiency index. The findings suggest that careful optimization of reagent dosages and particle size can significantly improve the flotation response of Gamo area coals, with potential applications in coal beneficiation processes.

Keywords: froth flotation, collector, frother particle size, Gamo coal**.**

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LIST OF ABBREVIATION AND ACRONYMS

CIS common wealth of Independent States

PH power of hydrogen

µm micro meter

mm millimeter

Mt million tones

cal/g calori per gram

ASTM American standard testing material

g/t gram per ton

g/l gram per liter

CHAPTER1: INTRODUCTION

1.1. Background of the Study

The flotation response of coal is a crucial procedure that decides the economic worth of coal. Nonetheless, the effectiveness of this procedure can be affected by different elements, for example, particle size assortment, mineral substance, and properties of chemical reagents. Inconsistent or suboptimal flotation responses can cause economic losses due to low recovery rates, poor product quality, and increased production costs. Thus, it is essential to optimize the process parameters and analyze the relationship between collector dosage, frother dosage, particle size, and flotation efficiency to obtain a better understanding of the behavior of coal particles during the flotation process. The main reason for selecting froth floatation method is that the technique requires low capital and operating cost with low demand of plant spaces, highly efficient and effective. The project aimed to investigate the effects of these factors on the flotation response of coal from Gamo area and to determine optimal conditions for efficient and cost-effective coal beneficiation.

1.2. Objective of the Study

1.2.1. General Objective

The general objective of this project is to study the floatation response of coal from Gamo Zone kucha wereda coal deposits in south Ethiopia.

1.2.2. Specific Objective

The specific objectives of this study are to:-

- To perform sieve analysis and to determine size-by-size ash content of the sample blow 0.5mm size.
- To perform physiochemical beneficiation a coal by using froth floatation methods.
- To optimize the flotation yield of the coal and combustible matter recovery at a desired level of ash.

- To characterize flotation response (concentrate yield and ash values) of the Gamo Zone kucha wereda coal deposits.

1.3. Research question

- How do Gamo area coals respond to floatation reagents?
- How to increase the yield and combustible matter recovery of coal locally available?

1.4. Significance of the study

The flotation response of coal plays an important role in the coal preparation process as it determines the efficiency of separation between coal and its impurities. Flotation is a widely used technique for coal cleaning, and understanding the factors that affect flotation response of coal can help optimize the process and improve its efficiency.

In addition, studying the flotation response of coal can also help to develop new reagents that can enhance the efficiency of the process, minimize environmental impact, and reduce operating costs. By improving the efficiency of coal flotation, it is possible to produce a higher quality and lower ash content product, which is more valuable in the energy market.

The project has advantages for both the citizens of Ethiopia and the interested parties by escalating the cost of coal, thereby generating a more lucrative and competitive worldwide market.

CHAPTER 2: LITERATURE REVIEW

2.1. Application of Coal

Coal plays a vital role in various sectors worldwide; the primary purposes of coal include generating electricity, producing steel, manufacturing cement, and serving as an energy source for households, as well as a fundamental component in diverse chemical industries. Coal is an essential facilitator in the contemporary era.(Hester & Harrison, 2004)

2.2. Environmental Impacts of Coal

Mining activity places immense stress on indigenous plant and animal life, especially when forests are cleared for mining purposes. The consequences of mining on the groundwater table, sedimentation of nearby bodies of water, and terrestrial ecosystems are also highly worrisome. The mining of coal is a crucial driver of the nation's economic growth, albeit with a considerable influence on public well-being. Moreover, it significantly impacts the social fabric and cultural dynamics of both laborers and residents residing in close proximity to mining regions.(Goswami, 2015)

2.3. Recent Development and Beneficiation Techniques of Coal

Coal is regarded as one of the utmost significant energy sources globally. In the initial stages of the sector, coal was extracted and transported to its destination without undergoing any form of refinement. Mined coal is deemed as a primary substance and necessitates purification to eliminate impurities like pyrite and ash.(Bulatovic, 2015)

In the past few years, several coal advancements have been created to eliminate impurities like ash and pyrite. Certain techniques encompass: washing, gravitational concentration, and agglomeration flotation.(Bulatovic, 2015)

2.4 Froth Flotation

Flotation is a method of improving the value of small coal particles (-500µm) that has been employed for over half a century. Coal is the mineral that is most readily float due to its inherent water-repelling properties. Flotation characteristics of coal are influenced by the mineralogical and petrographic makeup, their grade, level of oxidation, and types of inorganic impurities.(Kaya & Tasdogen, 2020)

2.5. Factor influencing floatation performance

Froth flotation is a formal method utilized in the enhancement of fine coal. The flotation behavior of coal relies on numerous elements, such as macerals, grade, source, impurity quality, and level of oxidation. The coal experiences oxidation as a result of exposure to weather conditions.

Froth flotation has been widely examined in recent times, with significant focus being given to the impacts of different design and operational factors on output and recovery. Different factors like solid proportion, rotor speed, airflow rate, particle size, collector variety and quantity, frother variety and quantity, pH of coal slurry and conditioning time influence the flotation procedure.(Shahzad et al., 2017)

CHAPTER 3: MATERIALS AND METHODS

3.1. Materials

3.1.1. Apparatus and Instruments

The equipment and tools utilized in this investigation included; All-Purpose Hot Oven, Jaw crusher(RoHs53743, Deutschland), Centrifugal grinder (RETCH 56402, Deutschland), Sieve Vibrator (RETCH A200, Deutschland), Wedag flotation unit (Groppel 98, West Deutschland)

Materials

The coal samples obtained from Gamo zone kucha wereda coal mine area of southern Ethiopia were dried and ground in a laboratory mill to 80% passing a 0.5mm sieve.

Flotation test

The flotation tests were conducted in an ambient temperature water bath and a fixed airflow rate of 3 L/min. The initial coal sample weight was 100 g, which was added to 2.5L of water in 3L flotation cell, followed by the addition of desired volume of solutions for frother and collector. The pulp was agitated for 3 minutes at an impeller speed of 2800 rpm and then conditioned for a further 2 minutes with slow agitation to allow for attachment of collector on coal surface. After conditioning, air was introduced into the flotation cell to generate froth, which was removed continuously from the top of the flotation cell at 15-second intervals for a total flotation time of 3 minutes.

Ash%= $\frac{wt.of\ residues\ left\ \ after\ burning(g)}{wt.of\ feed\ coal(g)} \times 100\%$ ------------------------------- (1)

Yield (%) $= \frac{MC}{MF} \times 100\%$ --- (2)

3.2 Geology of the area

From the Geophysical survey vertical electrical sounding result, a coal layer was identified with the average thickness ranging from 0.62m to 2.62m. Based on the log results of pits, geophysical results and areal coverage of coal deposit, the study area is roughly estimated to have 744,174.96 tons of coal.(*Potential Assesment Of Coal Deposit In GAMO, Southern Nations , Nationalities and Prs.*, 2022)

Figure 1.coal mining site

3.2.1 Sampling Techniques

The techniques used to collect samples from the sampling site followed the guidelines of the International standards of coal analyses (ASTM D-2234). When collecting the samples, it is important to record the location area, the thickness of the seams, and the depth and elevation of the site. Representative samples from each layer were collected in plastic bags, with a weight of 10 to 15 kg. Lastly, the samples were transported from kucha wereda to Addis Ababa Institute of Technology for further examination.

3.2.2 Experimental Design

The complete experimental methods that were conducted in the research were outlined in Figure.7. It encompasses the gathering and arrangement techniques of the samples up to the concluding phase of analysis.

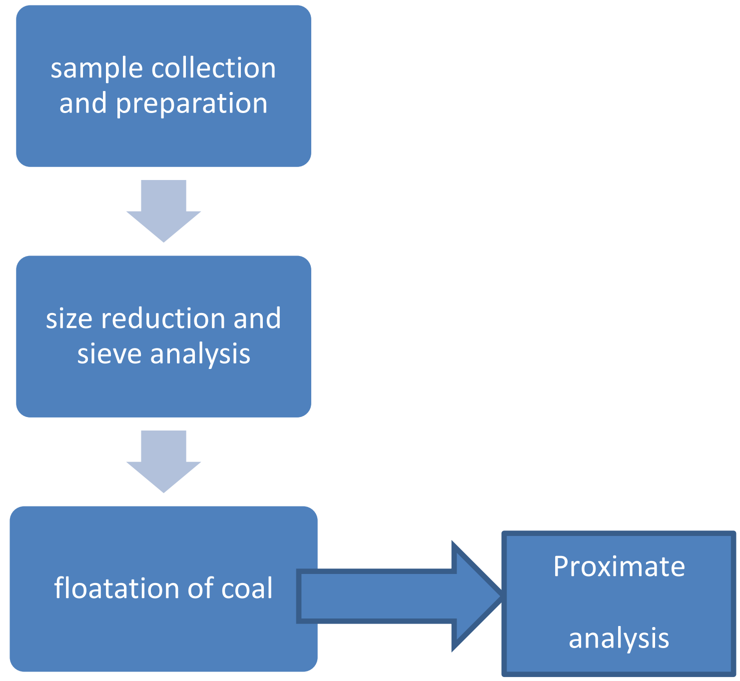

Figure 2.the overall experimental design for raw and floated coal samples

3.2.3. Sample Preparation

The gathered specimens were readied in compliance with the coal preparation techniques outlined in the ASTM D-2234 guidelines, which involved the processes of crushing, milling, and sieving. The initial step in decreasing the coal's particle size was crushing. The mass sample obtained from the crusher was then subjected to centrifugal milling, and the resulting milled coal sample was sorted based on their sizes using a sieve shaker. The size categories were -500 +250 µm, -250 +125 µm, and -125 µm. The most suitable particle sizes were collected and stored in airtight plastic bags to minimize sample oxidation during the preparation phase.(Usman et al., 2022)

CHAPTER 4: RESULTS AND DISCUSSION

4.1. Prepared coal sample

The collected coal specimens were prepared in accordance with the ASTM guidelines. The chunky coal that was obtained from the research area contains substances such as organic matter, inorganic (mineral matter), and inherent materials and has been pulverized. The large sample from the crusher was processed by a milling machine and the coal sample was made ready for sorting using arranged sieve shakers based on their dimensions. Subsequently, the coal samples were finely powdered by utilizing various sizes of sieve shakers arranged as (500-250 µm, 250-125 µm,-125 µm).

Figure 3.size reduction of coal sample

Table 1 Size, yield and ash content of coal fines used

Size fractions(μm)	Yield (%)	Ash (%)
-500+250	39	21.81
-250+125	17	21.12
-125	44	20.8
Total	100	21.2

Table 2 Proximate analysis of row coal -500 µm coal

Details	Wt %
Moisture	20.09
Volatile matter	29.09
Fixed carbon	29.01
Ash	21.81

4.2. Floatation Results

A 2^3 full complete factorial designs of experiments were utilized when examining the impact of various factors in order to ascertain the primary and combined effects.(Naik et al., 2005)

Table 3 the ash% in concentrates, % yield, %flotation index and %recovery

Run	Collector dosage(ml)	Frother dosage(ml)	Particle size (µm)	Ash% conc.	Yield (%)	Flotation Index%	Recovery (%)
1	10	2	-125	13	70	36.1	77.8
2	20	2	-125	13.14	80	40.6	88.8
3	10	6	-125	15	75	29.9	81.5
4	20	6	-125	13.14	85	43.2	94.4
5	10	2	-250 +125	17	60	16.9	63.6
6	20	2	-250 +125	20	70	7.4	71.6
7	10	6	-250 +125	20	65	6.8	66.5
8	20	6	-250 +125	18.5	75	14.5	78.2

Figure 4.coal flotation experiment

4.3 Experimental Design Analysis

To ascertain the impact of each factor on yield, recovery and flotation efficiency index,a complete factorial model was employed. The dosage of the collector (A), the dosage of the frother (B), and the size of the particles (C)was selected as main variables to create a model and enhance based on the carried out trials. The response parameter, expressed as a percentage, was the dependent variable (yield, reecovery, and flotation efficiency index). All experiments were carried out in a randomized order to minimize the effect of unexpected variability in the observed response due to extraneous factors. The experimental results shown in Table 3 were analyzed using Design-Expert v6 software.

Table 4 ANOVA for factorial model

Response	Yield					
ANOVA for Selected Factorial Model						
Analysis of variance table [Partial sum of squares]						
	Sum of		Mean	F		
Source	Squares	DF	Square	Value	Prob > F	
Model	450	3	150	6.37E+07	< 0.0001	significant
A	200	1	200	6.37E+07	< 0.0001	
B	50	1	50	6.37E+07	< 0.0001	
C	200	1	200	6.37E+07	< 0.0001	
Residual	0	4	0			
Cor Total	450	7				

Table 5 ANOVA for factorial model

Response	Recovery					
ANOVA for Selected Factorial Model						
Analysis of variance table [Partial sum of squares]						
	Sum of		Mean	F		
Source	Squares	DF	Square	Value	Prob > F	
Model	771.64	3	257.21	157.44	0.0001	significant
A	237.62	1	237.62	145.44	0.0003	
B	44.18	1	44.18	27.04	0.0065	
C	489.85	1	489.85	299.83	< 0.0001	
Residual	6.54	4	1.63			
Cor Total	778.18	7				

Table 6 ANOVA for factorial model

Response:	Flotation index					
ANOVA for Selected Factorial Model						
Analysis of variance table [Partial sum of squares]						
	Sum of		Mean	F		
Source	Squares	DF	Square	Value	Prob > F	
Model	1357.21	1	1357.21	45.54	0.0005	significant
C	1357.21	1	1357.21	45.54	0.0005	
Residual	178.83	6.00E+00	29.8			
Cor Total	1536.04	7.00E+00				

4.4 Effect of Individual Variables on the response

The Individual effect of collector doasge, frother dosage and particle size on the level of responses (yield, recovery and flotation efficiency index) were evaluated to select the best operation conditions for beneficiation of a coal using full factorial model. The range of tested process variables were: collector dosage (10ml, 20ml), frother dosage (2ml, 6ml) and particle size (-250 +125µ, -125µ).

4.4.1 The effect of collector on flotation yield

Figure 5 illustrates the impact of the quantity of collector on the coal yield. As depicted in the figure, as the dosage of collector begins to increase from 10ml, the coal yield also increases. The findings suggest that augmenting the collector dosage enhances the yield.

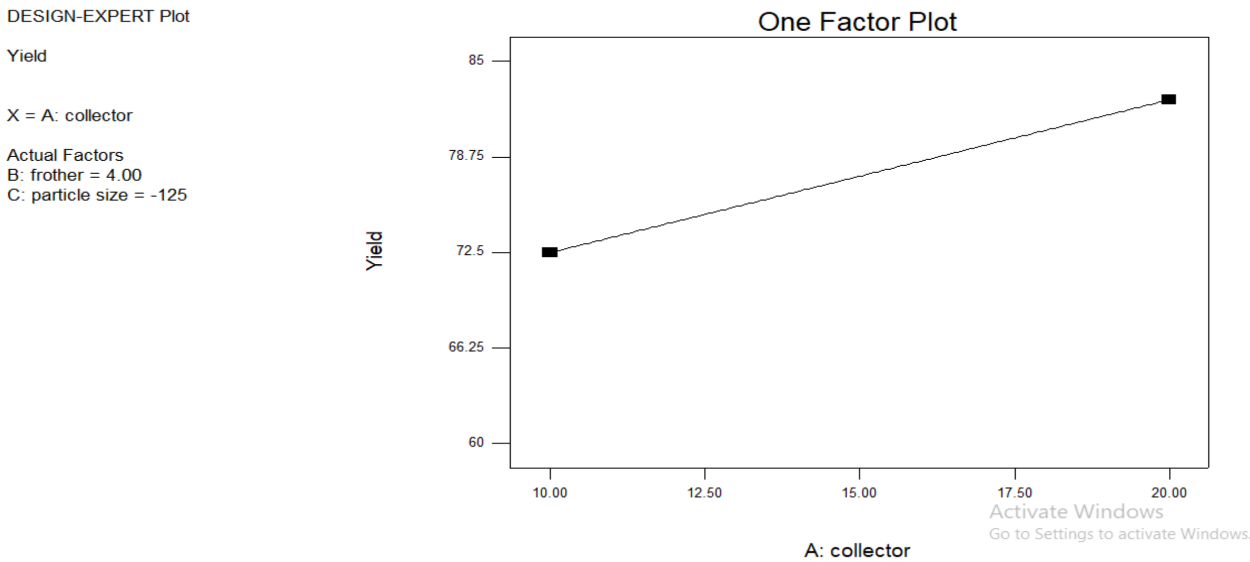

Figure 5.the effect of collector dosage on yield of a coal.

4.4.2 The effect Frother Dosage on flotation yield.

Figure 6 represents the effect of frother dosage on the yield level of coal. As shown in the figure, when the frother dosage starts to rise from 2ml, the coal yield increase with the rise of frother dosage. The results indicate that increasing frother dosage leads to improved yield, beyond which efficiency begins to decline due to oversaturation of the froth layer.

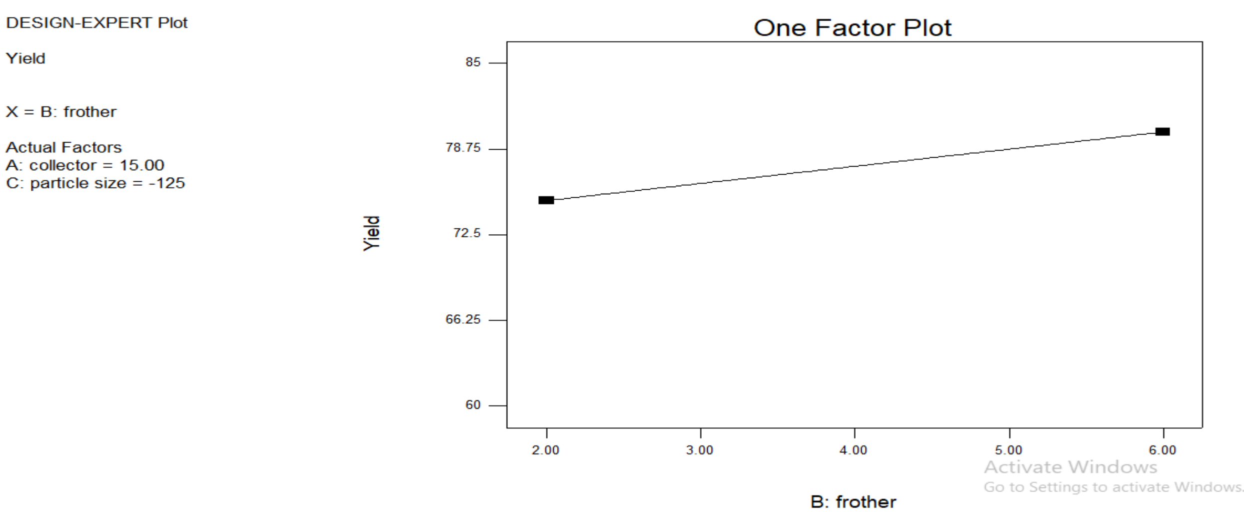

Figure 6.the effect of frother dosage on yield a coal

4.4.3 The effect of Particle Size on flotation yield

Figure 7 represents the effect of particle size on the yield level of coal. As shown in the figure, smaller particles exhibit higher rates of yield than larger particles. This behavior is likely due to the greater surface area of smaller particles, which provides more opportunities for adsorption of collector and frother reagents.

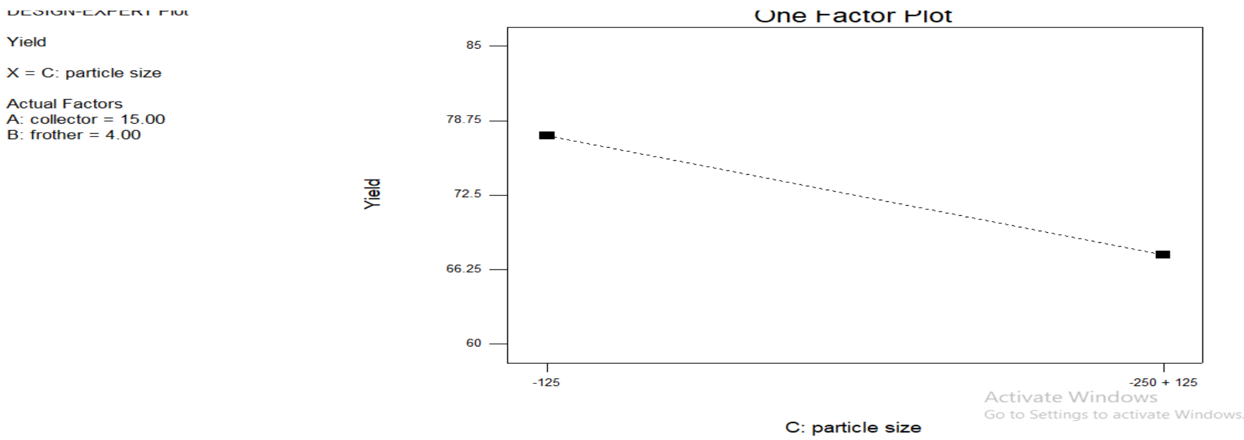

Figure 7.the effect of particle size on flotation yield of coal

4.4.4 The effect of collector on combustible matter recovery

Figure 8 represents the effect of collector dosage on the combustible matter recovery level of coal. As shown in the figure, when the collector dosage starts to rise from 10ml, combustible matter recovery increase with the collector dosage. The results indicate that increasing collector dosage leads to improved recovery.

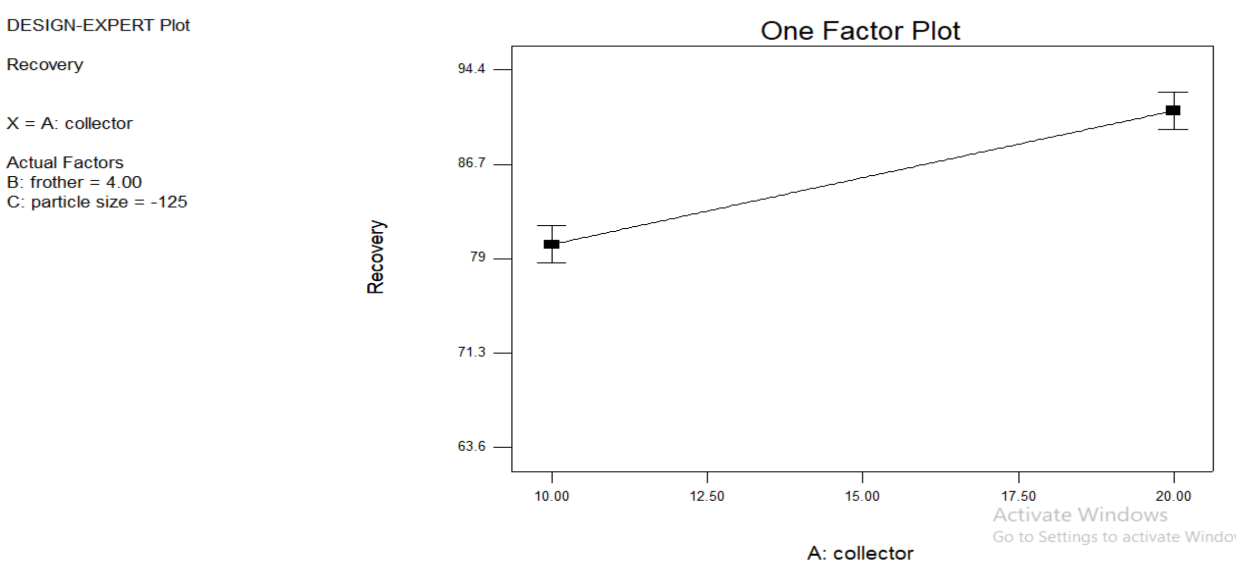

Figure 8.the effect flotation recovery of coal.of collector on

4.4.5 The effect of frother on combustible matter recovery

Figure 9 represents the effect of frother dosage on the combustible matter recovery level of coal. As shown in the figure, when the frother dosage starts to rise from 2ml, the recovery increase with the rise of frothe dosage. The results indicate that increasing frother dosage leads to improved coal recovery, beyond which efficiency begins to decline due to oversaturation of the froth layer.

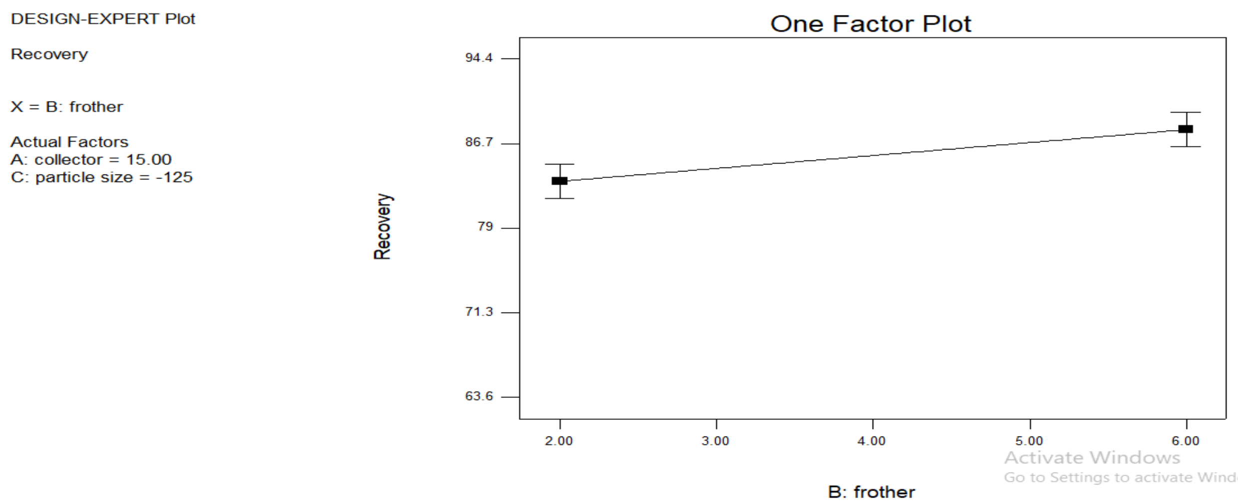

Figure 9.the effect of frother on flotation recovery of coal.

4.4.6 The effect of Particle Size on combustible matter recovery

Figure 10 represents the effect of particle size on the combustible matter recovery level of coal. As shown in the figure, smaller particles exhibit higher rates of recovery than larger particles. This behavior is likely due to the greater surface area of smaller particles, which provides more opportunities for adsorption of collector and frother reagents.

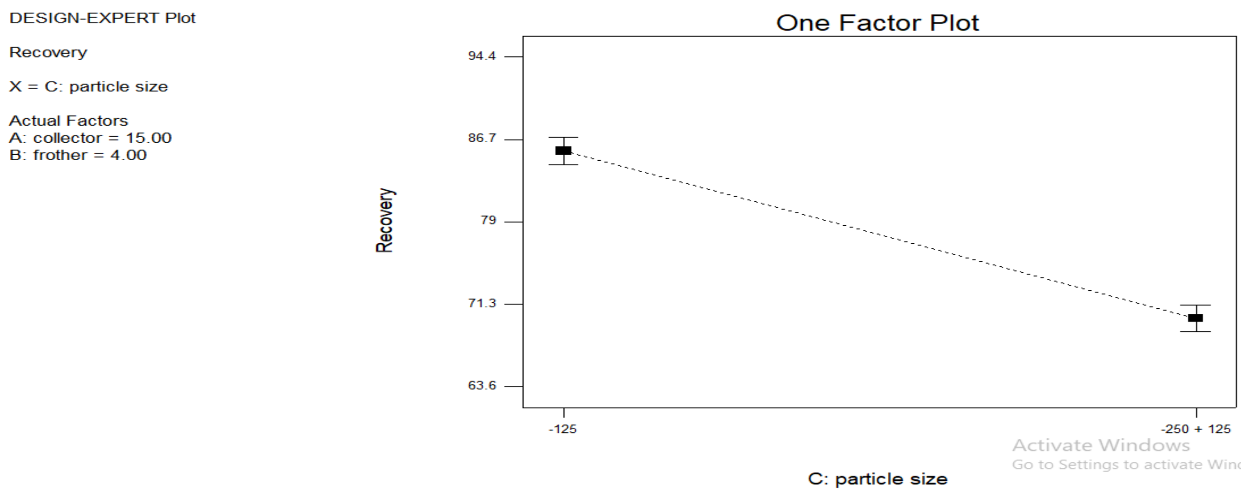

Figure 10.the effect of size on flotation recovery of coal.particle

4.4.7 The effect of particle size on flotation efficiency index

Figure 11 represents the effect of particle size on the flotation efficiency index of coal. As shown in the figure, smaller particles exhibit higher rates of flotation efficiency index than larger particles. This behavior is likely due to the greater surface area of smaller particles, which provides more opportunities for adsorption of collector and frother reagents

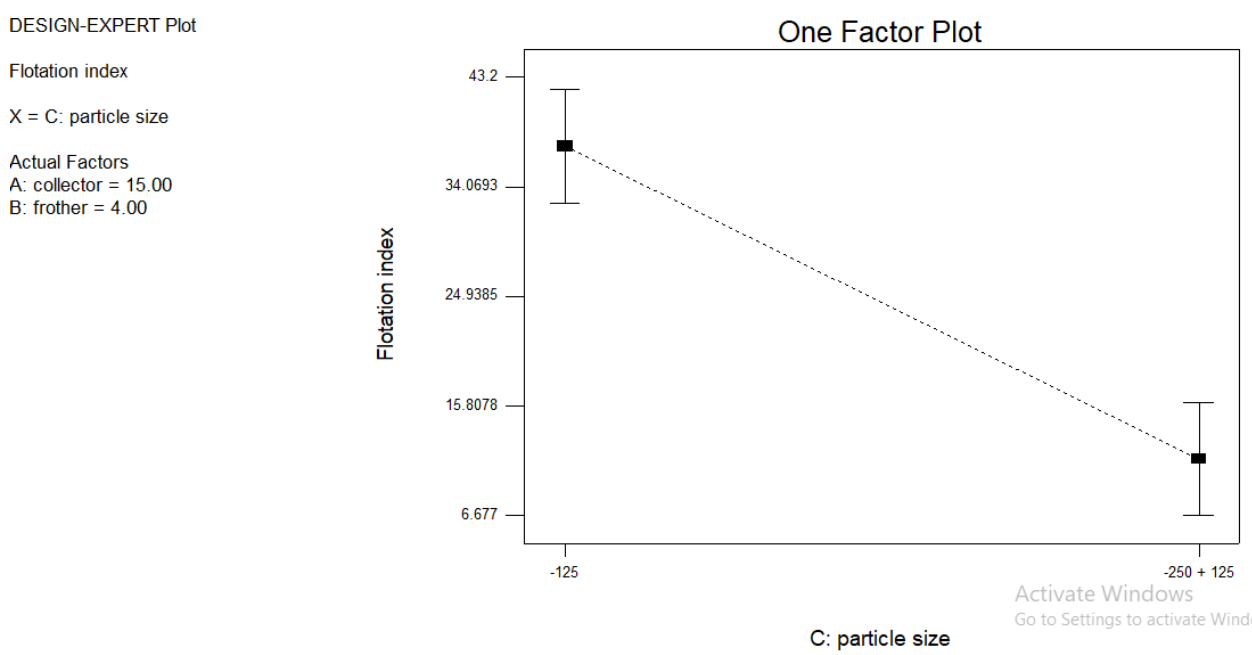

Figure 11.the effect of particle size on flotation efficiency index of coal.

4.5 Optimization of flotation Parameters

The optimum process parameters of coal flotation (collecter dosage, frother dosage and particle size) were obtained by full factorial Design optimizer. Optimization was performed to determine the optimum dosage points needed to produce high yield and recovery at suitable particle size. One solution was found and the first result with the highest desirability was chosen (Table 7). The predicted optimal conditions of flotation process occurs at a collector dosage 20ml, with a frother dosage of 6ml, and particle size of -125µm, which may result in 85% yield, 93% combustible matter recovery and 37.5% flotation efficiency index.

Table 7 Optimization constraints of flotation variables using design expert program

Constraints								
Lower	Upper	Lower	Upper					
Name	Goal	Limit	Limit	Weight	Weight	Importance		
collector	minimize	10	20	1	1	3		
frother	minimize	2	6	1	1	3		
particle si:	is in range	-125	-125	1	1	3		
Yield	maximize	80	95	1	1	3		
Recovery	maximize	60	95	1	1	3		
Flotation i	maximize	30	55	1	1	3		
Solutions								
Number	collector	frother	particle si:	Yield	Recovery	Flotation i	Desirability	
1	18.37	4.69	-125	81.7324	90.1094	37.45	0.275	Selected

Table 8 Point of prediction

Factor	Name	Level	Low Level	High Leve	Std. Dev.		
A	collector	20	10	20	0		
B	frother	6	2	6	0		
C	particle si:	-125	-125	-125	N/A		
	Predictior	SE Mean	95% CI lov	95% CI hig	SE Pred	95% PI lov	95% PI hig
Yield	85	0	85	85	0	85	85
Recovery	93.425	0.9	90.92	95.93	1.57	89.08	97.77
Flotation i	37.45	2.73	30.77	44.13	6.1	22.51	52.39

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Based on the test carried out on the flotation response of a Gamo region; southern Ethiopia coal using varying amounts of collector and frother, as well as particle size, the following deductions can be made.

The findings indicated that the amount of collector, quantities of frother, and size of particles had a notable impact on the flotation outcome of Gamo region coal. As a result, it is advised to meticulously optimize these variables in order to enhance the overall efficiency of the process.

Optimization was carried out to identify the best dosage points required to achieve a high yield and recovery at an appropriate particle size. One solution was discovered and the initial solution with the greatest desirability was selected, consisting of a collector dosage of 18.4ml, frother dosage of 4.7ml, and particle size of -125µm. This combination could potentially lead to a yield of 81.7%, recovery of 90% for combustible matter, and a flotation efficiency index of 37.5%.

5.2. Recommendation

Based on the result derived from test on the flotation response of coal from Gamo region, southern Ethiopia, the following suggestions can be put forth to enhance flotation efficiency:

- Optimize the amounts of reagents to achieve an ideal value for maximum flotation effectiveness.
- Use particle size reduction methods to improve exposure of hydrophobic surfaces.
- Monitor and control mineral content in coal mining processes to prevent unnecessary loss of coal due to contamination with undesired minerals.

- Further research should be conducted on different types of collectors and frothers to investigate their impact on flotation efficiency. This may involve testing new chemical compounds or optimizing existing ones to enhance their performance.
- Further studies can be conducted to examine other factors such as pH, temperature, and airflow rate that may alter flotation response and recovery rate.

In general, the results reveal significant understandings into the intricacy of the coal flotation procedure and establish a foundation for subsequent investigations in this field. The effective execution of these suggestions may potentially yield substantial economic advantages for coal enterprises and promote environmentally friendly coal mining methods.

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