ADDIS ABABA INSTITUTE OF TECHNOLOGY

CENTER FOR ETHIO-MINES DEVELOPMENT

DEPARTMENT OF MINERAL ENGINEERING

Determination Of Work Index of Spodumene from Kenticha Ore, Southern Ethiopia

Graduate Project

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ABSTRACT

From Kenticha, Southern Ethiopia, granite and kenticha spodumene ore were collected and used separately as reference ores. Each test ore was weighed at 2000 grams, and the reference ore was weighed at 500 grams, and all were ground in a lab ball mill under the same conditions. Size analysis of the feed to the ball mill and the output from the ball mill was performed on both the test ore and the reference ore, with the results properly tabulated. The feed and discharge particle sizes for the samples going into the ball mill were calculated using the Gaudian Schumann formula to ensure an 80% passing rate. The work index of the Kenticha spodumene ore was then calculated using Bond's equation, and it was discovered to be 11.391 kWh/t.

Keywords: Bond’s Equation, spodumene Ore, Granite, Size Analysis, Work Index

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CHAPTER ONE

1 INTRODUCTION

1.1 Background of Study

Ethiopia's resources, including rare metals like gold, platinum, nickel, copper, iron, and chromium as well as industrial minerals and rocks like kaolin, feldspar, clay, asbestos, and talc (Tadesse et al., 2003). Common materials such as limestone, granite, and marble are also abundant in the crystalline basement of Ethiopia. The majority of Ethiopia's metallic ore deposits are gold, platinium, tantalum, nickel and iron (Tadesse et al., 2003).

The Kenticha greenstone contain lithium, beryllium, tantalum and niobium. (Emelyanov et al., 1986; Tadesse, 2001). The rare elements are associated with peraluminous granite-pegmatites. The pegmatites range in type from simple rare-element types to barren feldspar-muscovite types. The present study is carried out on the complex rare-element granitic pegmatite main body which is mineralogically complex and enriched in lithophile elements such as Be (beryllium), Cs (cesium), Li (lithium), Ta (tantalum) and Nb (niobium) (Emelyanov et al., 1986; Tadesse, 2001; Zerihun et al., 1995).

1.1.1 Kenticha pegmatites ore minerals

The Kenticha pegmatite deposit in Ethiopia contains tantalite and lithium minerals (lepidolite, spodumene) (Tadesse, 2001). The region is part of the only known rare-metal metallogenic province in the horn of Africa and is distinguished by a significant amount of intrusive activity made up of pegmatite and associated rocks. Tantalum, niobium, beryllium, lithium, Cesium, and rubidium are among the rare metals that are connected with the pegmatites (Tadesse, 2001).

1.2 Spodumene

Spodumene is colorless, transparent, gray, greenish-gray, yellowish-gray, pinkish, yellowish-greenish, light violet-pink, and very rarely blue (Ostroushko, 1962). A crucial material in the creation of vitreous products is spodumene. While acting as a bulk source of alumina and silica, it is prized for its ability to lower firing temperature and flux consumption, reduce melt viscosity, increase furnace throughput, improve forming properties, and increase product thermal shock resistance (Menéndez et al; 2004). The primary silicate mineral that contains lithium is spodumene. It frequently coexists with other silicate minerals including feldspar, mica, and quartz in pegmatite deposits (Tadesse et al; 2019). Mohs hardness scale estimates that spodumene has a hardness between 6.5 and 7.0. Pure spodumene can have a specific gravity between 3.1 and 3.2, while spodumene variations can have a specific gravity as low as 2.9 (Ostroushko, 1962).

1.3 Theoretical Consideration for Work Index (Comminution Process)

Designing comminution processes requires when the power requirements of crushing and grinding operations are taken into account (Menéndez et al., 2005).

Bond's Equation is written as the following (Wills and Napier-Mum, 2006).

$$w = 10 \times w_i \left(\frac{1}{\sqrt{P_{80}}} - \frac{1}{\sqrt{F_{80}}}\right) \text{......................... (1)}$$

$$W_r = W_t = W_{ir} \left(\frac{10}{\sqrt{P_{80r}}} - \frac{10}{\sqrt{F_{80r}}}\right) = W_{it} \left(\frac{10}{\sqrt{P_{80t}}} - \frac{10}{\sqrt{F_{80t}}}\right) \text{............ (2)}$$

1.4 Statement of the Problem

Work index of spodumene ore at southern Ethiopian pegmatite ore deposit known as Kenticha is not studied previously, lack of adequate laboratory facilities. A laboratory Determination of Work Index Using Modified Bond Index is conduct through representative samples collected from kenticha ore in which it has paramount importance for future mining progress at the area.

1.5 Objective of the research (aim and scope)

1.5.1 Main objective

The general objective of this project is determination of Work Index or comminution process of spodumene from kenticha ore of southern Ethiopia.

1.5.2 Specific Objective

- Collect and prepare samples
- Analyze particle size for test ore (Spodumene)
- Analyze particle size for reference ore (Granite)

1.6 Scope of this project work

The main concern or scope of this project work was focused on Determination of Work Index or comminution process of spodumene samples from kenticha using Modified Bond Index.

1.7 Significance of the project work

The significance of this project is in order to determine average work index and the required energy to be utilized. It will also provide important information for future processing plant of the spodumene ore deposit and the end result of this study is good resource for the Ministry of Mines, for academic researchers as well as for other explorers.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 comminution

Crushing and grinding are traditionally used in the comminution of mineral ores. In order to lower the particle size to a point where grinding may be done to produce enough liberation, crushing is typically done in numerous steps. Gyratory, jaw, and although there have been significant advancements in their control over the past few decades, cone crushers still predominate in crushing operations (Wills, 1990).

2.2 Principles of comminution

The majority of substances with regular three-dimensional atomic arrangements. The size and nature of the chemical and physical bonds that hold atoms together influence their configuration. (Wills and Napier-Mum, 2006). influenced by the loading mechanism, the comminution environment, and the material qualities (Hogg & Cho, 2000 ; Little et al; 2016).

Water reduces the energy needed for comminution, and chemical compounds that adsorb onto the material can further lower this energy requirement (Hartley et al; 1978).

2.3 Comminution theory

Energy-particle size relationship is a crucial component of the comminution of minerals, and considerable experimental and theoretical work has been put into understanding it. There are actually two distinct approaches to it that were initially perplexing and are still perplexing in practically all pertinent textbooks and published research papers (Stamboliadis, 2007).

The first method, developed by Kick in 1885, considers the energy needed to split a particle of a specific mass and size. According to this, the energy needed to break a particle of a certain substance is inversely correlated with its mass, or, to put it another way, the specific energy (energy per unit mass) needed for breakage is constant. This is only true for rather large particles, according to some recent experimental work by Tavares and King (1998), and a theoretical explanation is provided (Stamboliadis, 2005).

The second method, developed by Rittinger in 1867, connects the energy used to the distribution of product sizes. This indicates that the increased surface area is inversely related to the energy required for fracture. It has been established that Kick and Rittinger's claims are not mutually exclusive and can both be true (Stamboliadis, 2004).

The micrometer, through which 80% of particles pass, is the recognized particle size for computations. P stands for the micron diameter, F for the size, and K for the work input per short ton through which 80% of the product, 80% of the feed, and respectively (Wills and Napier-Mum, 2006).

2.4. Sieve Analysis

Size analysis is the process of classifying a sample according to its size, regardless of the technology employed to measure particle size. The bulk of mineral processing applications only require particles of a certain size (Gupta and Yan, 2016).

2.4.2 Gaudin – Schuhmann Distribution

When the distribution is skewed it can occasionally provide a linear plot. Gaudin-Schuhmann plots are those kinds of plots (Gupta and Yan, 2016). The Gaudin–Schuhmann distribution is given as the following (Gupta and Yan, 2016; Alabi et al, 2015).

$$\text{size}_2 = \frac{(\text{percentage passing size}_2)}{(\text{percentage passing size}_1)^2}^2 \times \text{size}_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(6)}$$

CHAPTER THREE

3 MATERIALS AND METHODS

3.1 Materials

The jaw crusher, electronic weight balance, ball mill, sieve shaker and different sizes sieves available at Addis Ababa Institute of Technology laboratory are used.

Figure 3.1 materials used for laboratory work

3.1.1 Sample Collection

kenticha spodumene and granite were collected by random sampling method from the deposit.

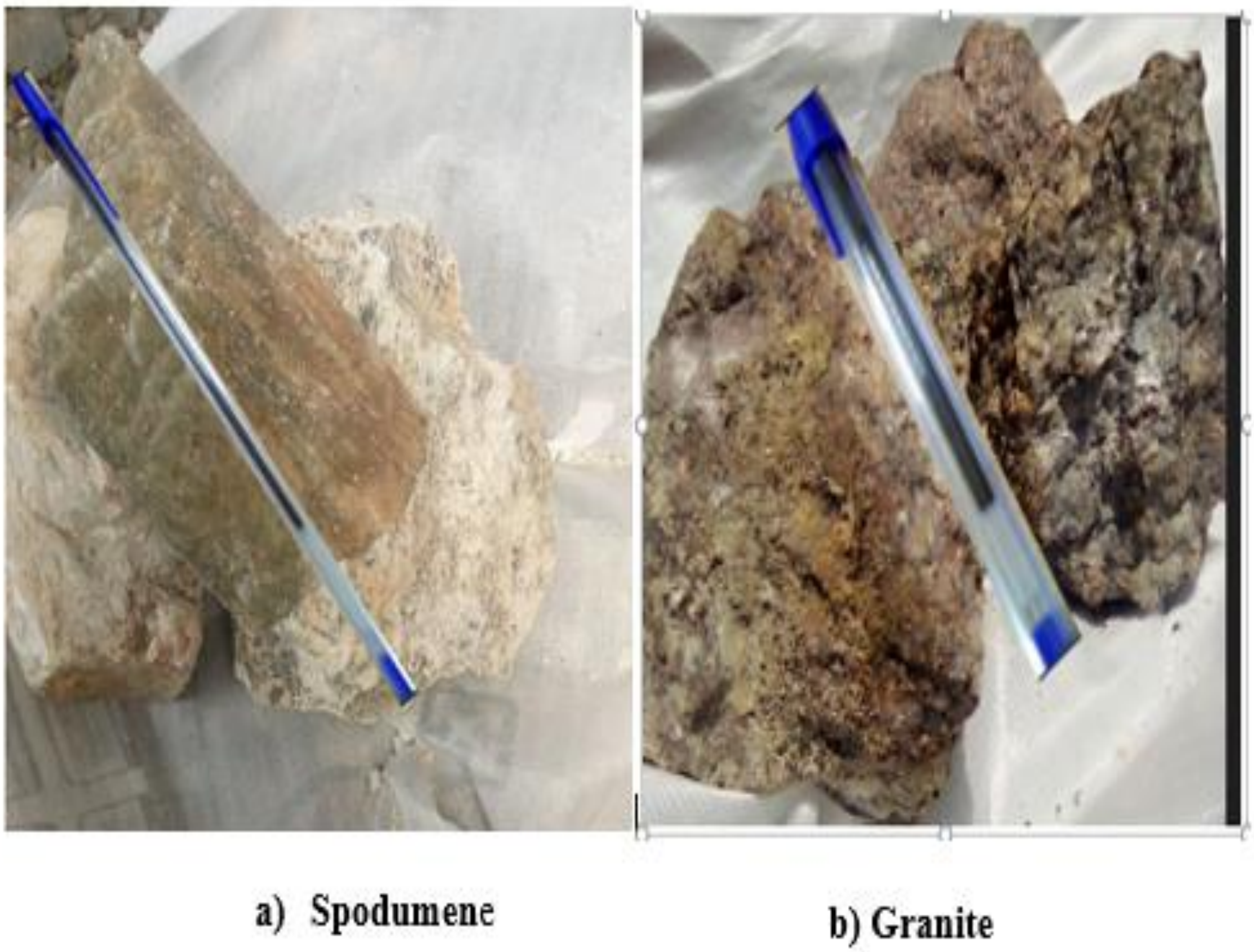

Figure 3.2 reference sample and test ore collected

3.1.2 Sample Preparation

The lump-sized samples were manually broken into the necessary size for the laboratory jaw crusher using a sledge hammer. The materials were broken down and pulverized.

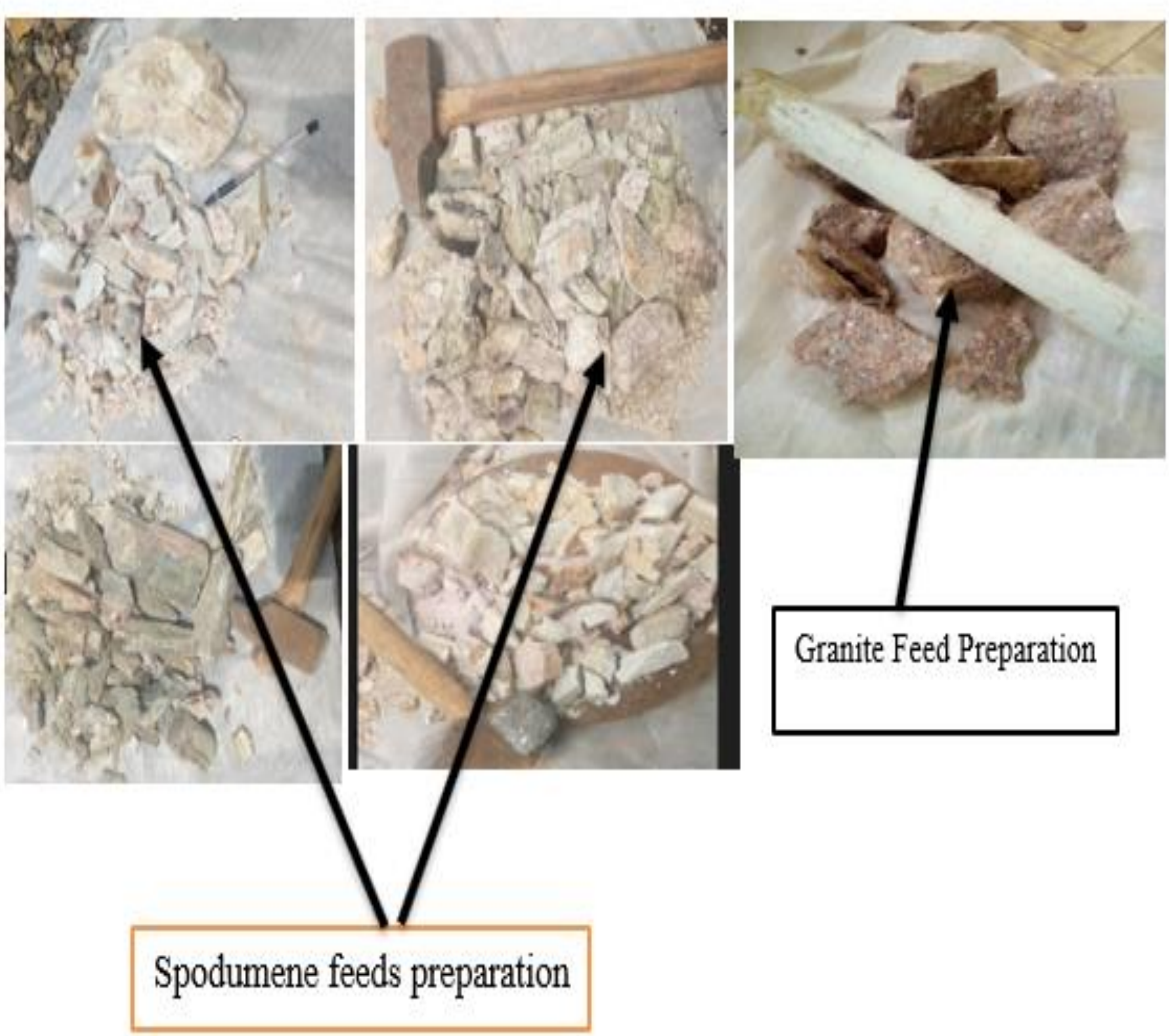

Figure 3.3 Samples preparation to feed into laboratory jaw crusher

3.2 methods

1) 2kg (2000 gram) (divided in four equal each with 500g) and the reference ore (500g) were crushed in ball mill.

2) The spodumene ore and r (granite) sieving for 5 minutes.

3) The weights of the spodumene and granite in each size fraction were recorded as "feed" values.

4) The “feed” test (feed1, feed 2, feed 3 and feed 4) and ground for 1 hour (feed 1 for 20 minutes, feed2 for 15 minutes, feed3 for 10 minutes and feed 4 for 5 minutes) and reference sample granite for10 minutes.

5) The laboratory ball mill equipment was used to size the test and reference samples.

6) using sieve size fractions ranges which are available

Note that the negative sign (-) show particle size passes sieve and plus sign (+) show particle size retain on sieve.

CHAPTER FOUR

4 RESULTS AND DISCUSSION

4.1 Results

4.1.0 Chemical Analysis Results

The chemical analysis result of the kenticha spodumene in pegmatite are presented on Table 4.1 according to analytical method AAS (acid attack and fusion) done on four samples. From these results, kenticha spodumene ore contains on the average 66.88% SiO_2 (silicon oxide), 21.83 % Al_2O_3 (Aluminium oxide), 0.51CaO % (Calcium oxide), 0.54% MgO (Magnesium oxide), 3.58% Na_2O (Sodium oxide), 1.06 % K_2O (Potasium oxide), 0.60% Fe_2O_3 (Iron oxide) and 2.34% Li_2O (Lithium oxide).

Table 4.1 Chemical Constituents (oxides) of the Test Ore (spodumene)

	Oxides constituents (%)									
	Field no.	SiO_2 %	Al_2O_3 %	CaO %	MgO %	Na_2O %	K_2O %	Fe_2O_3 %	Li_2O %	LOI
Kenticha spodumene	KSD-01	66.25	21.45	0.65	0.68	5.25	1.5	0.32	3.21	3.26
	KSD-02	65.12	22.13	0.62	0.67	4.25	1.31	0.51	2.04	6.05
	KSD-03	66.25	22.13	0.53	0.56	3.98	1.1	0.89	1.86	5.23
	KSD-04	69.28	21.69	0.29	0.32	1.36	0.47	0.69	1.88	2.56
Minimuim		65.12	21.45	0.29	0.32	1.36	0.47	0.32	1.86	2.56
Maximum		69.28	22.13	0.65	0.68	5.25	1.5	0.89	3.21	6.05
Average		66.88	21.83	0.51	0.54	3.58	1.06	0.60	2.34	4.29

4.1.1 Sieve Analysis Results

4.1.1 Test Ore (spodumene) and (Granites) as Feeds to the Ball Mill

Products from laboratory jaw crusher as feed for spodumene and granite were described as following.

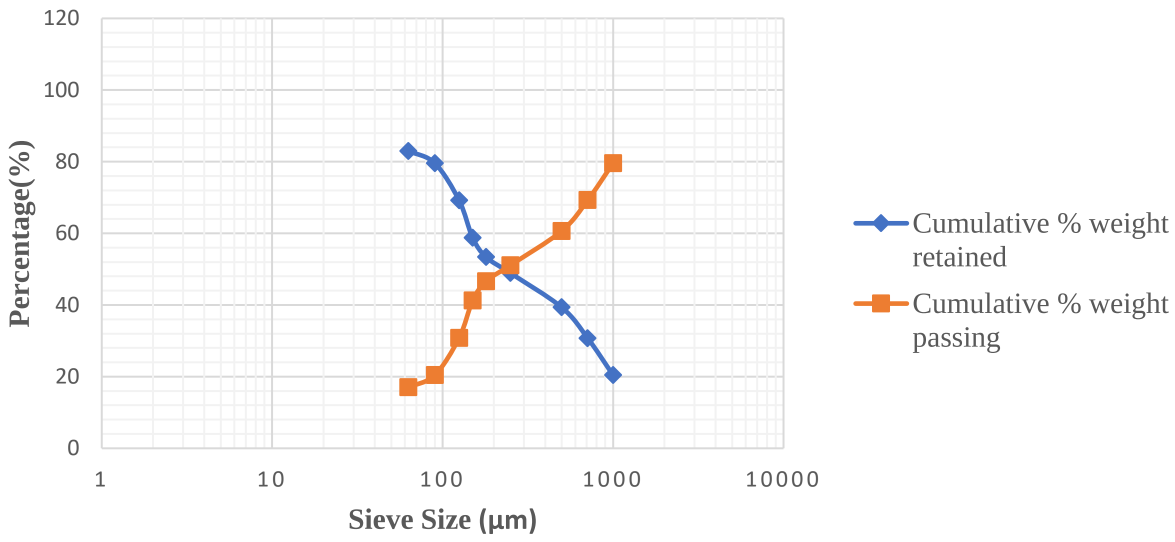

Figure 4.1 Semi logarithm Plot of the Cumulative Percentage Weight Retained and Passing against Sieve size of the Feed 1 to Ball Mill for Test Ore (spodumene)

Table 4.2 Sieve result feed 1 sample of kenticha spodumene ore.

size(μm)	Ret.Weight	Ret. % Weight	Cummulative % Retained	Cummulative % Passing
+1000	102.15	20.43	20.43	79.57
−1000 + 710	51.55	10.31	30.74	69.26
−710 + 500	42.95	8.59	39.33	60.67
−500 + 250	47.85	9.57	48.9	51.1
−250 + 180	22.3	4.46	53.36	46.64
−180 + 150	27.1	5.42	58.78	41.22
−150 + 125	52	10.4	69.18	30.82
−125 + 90	51.95	10.39	79.57	20.43
−90 + 63	17.1	3.42	82.99	17.01
−63	85.05	17.01	100	0

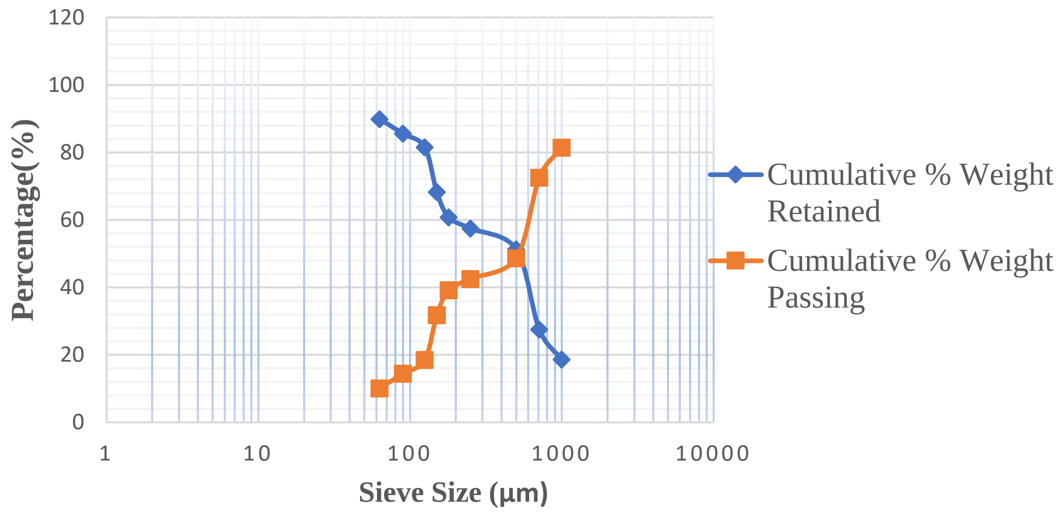

Figure 4.2 Semi logarithm graph for Feed 2 to Ball Mill for Test Ore (spodumene)

Table 4.3 Sieve result of feed 2 sample of kenticha spodumene ore

size(μm)	Weight Retained	Ret.% Weight	Cummulative % Retained	Cummulative % Passing
+1000	92.85	18.57	18.57	81.43
−1000 + 710	44.75	8.95	27.52	72.48
−710 + 500	129	23.8	51.32	48.68
−500 + 250	30.8	6.16	57.48	42.52
−250 + 180	50.55	3.33	60.81	39.19
−180 + 150	37.1	7.42	68.23	31.77
−150 + 125	66.5	13.3	81.53	18.47
−125 + 90	20.15	4.03	85.56	14.44
−90 + 63	21.65	4.33	89.89	10.11
−63	6.65	10.11	100	0

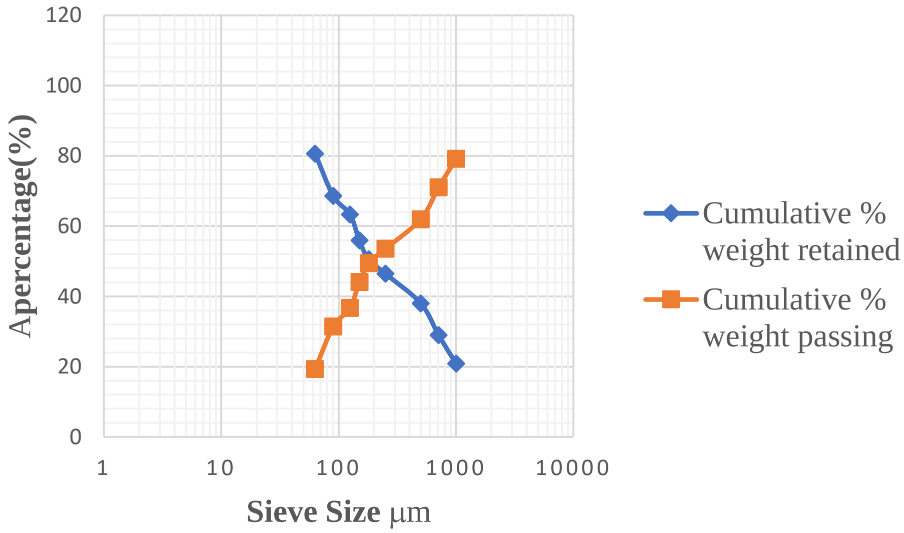

Figure 4.3 Semi logarithm graph for Feed 3 to Ball Mill for Test Ore (spodumene)

Table 4.4 Sieve result of feed 3 of kenticha spodumene ore.

size(µm)	Mass Retained	Ret% mass	Cummulative % Ret.	Cummulative % Pass.
+1000	104.35	20.87	20.87	79.13
−1000 + 710	40.5	8.1	28.97	71.03
−710 + 500	45.35	9.07	38.04	61.96
−500 + 250	42.15	8.43	46.47	53.53
−250 + 180	20.3	4.06	50.53	49.47
−180 + 150	26.9	5.38	55.91	44.09
−150 + 125	37	7.4	63.31	36.69
−125 + 90	26.35	5.27	68.58	31.42
−90 + 63	60.3	12.06	80.64	19.36
−63	96.8	19.36	100	0

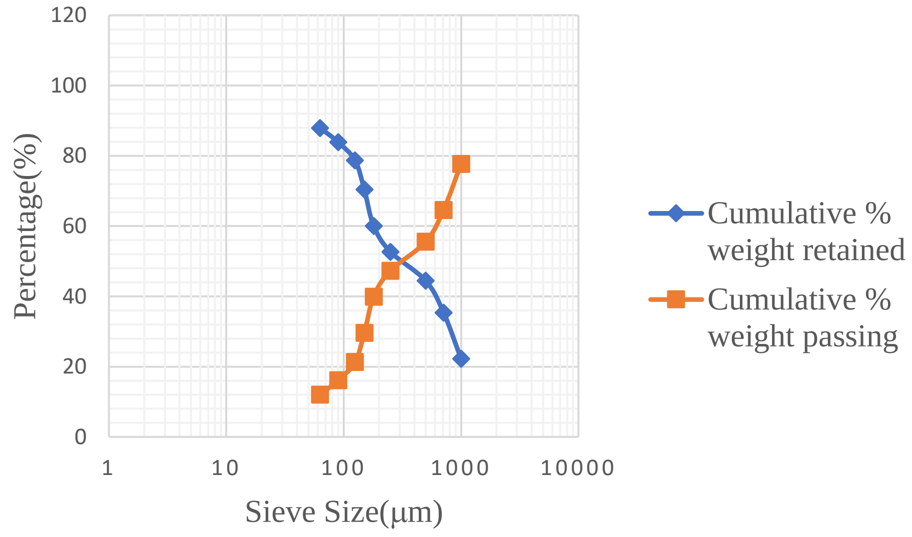

Figure 4.4 Semi logarithm Plot graph for Feed 4 to Ball Mill for Test Ore (spodumene)

Table 4.5 Sieve result of feed 4 sample of kenticha spodumene ore.

sieve size(µm)	mass Ret.	% mass Ret.	Cummulative % Ret.	Cummulative % Pas.
+1000	111.35	22.27	22.27	77.73
−1000 + 710	65.6	13.12	35.39	64.61
−710 + 500	45.35	9.07	44.46	55.54
−500 + 250	41.15	8.23	52.69	47.31
−250 + 180	36.9	7.38	60.07	39.93
−180 + 150	51.7	10.34	70.41	29.59
−150 + 125	41.5	8.3	78.71	21.29
−125 + 90	25.85	5.17	83.88	16.12
−90 + 63	20.3	4.06	87.94	12.06
−63	60.3	12.06	100	0

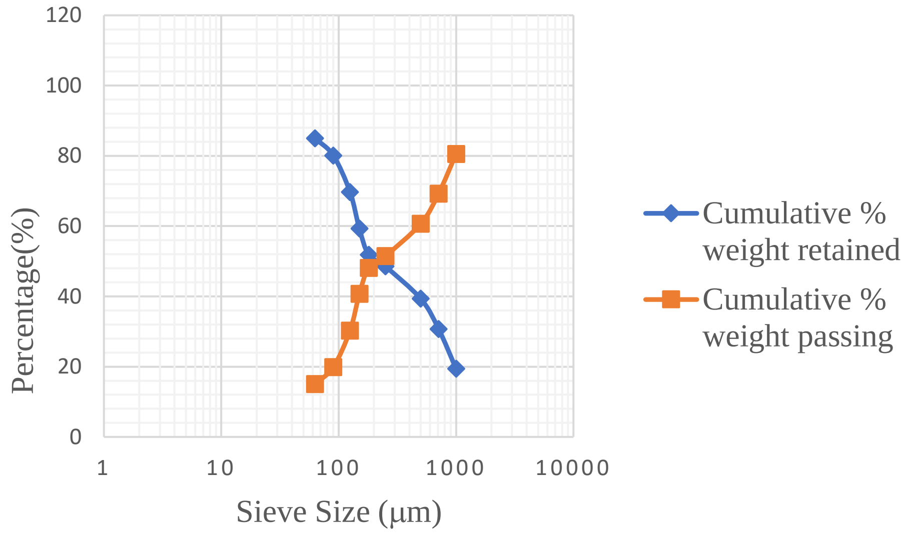

Figure 4.5 Semi logarithm Plot graph Feed to Ball Mill for Reference Sample (granite)

Table 4.6 Sieve result of sample granite (feed to the ball mill).

size(µm)	mass Ret.	% mass Ret.	Cum. % Ret.	Cum. % Pass.
+1000	97.15	19.43	19.43	80.57
−1000 + 710	56.55	11.31	30.74	69.26
−710 + 500	42.95	8.59	39.33	60.67
−500 + 250	45.95	9.19	48.52	51.48
−250 + 180	16.75	3.35	51.87	48.13
−180 + 150	37.2	7.44	59.31	40.69
−150 + 125	52	10.4	69.71	30.29
−125 + 90	51.95	10.39	80.1	19.9
−90 + 63	24.3	4.86	84.96	15.04
−63	75.2	15.04	100	0

4.1.1.1 Test Ore (spodumene)/Reference (Granite) out put

products results from laboratory for spodumene) & sample (granite) described as following.

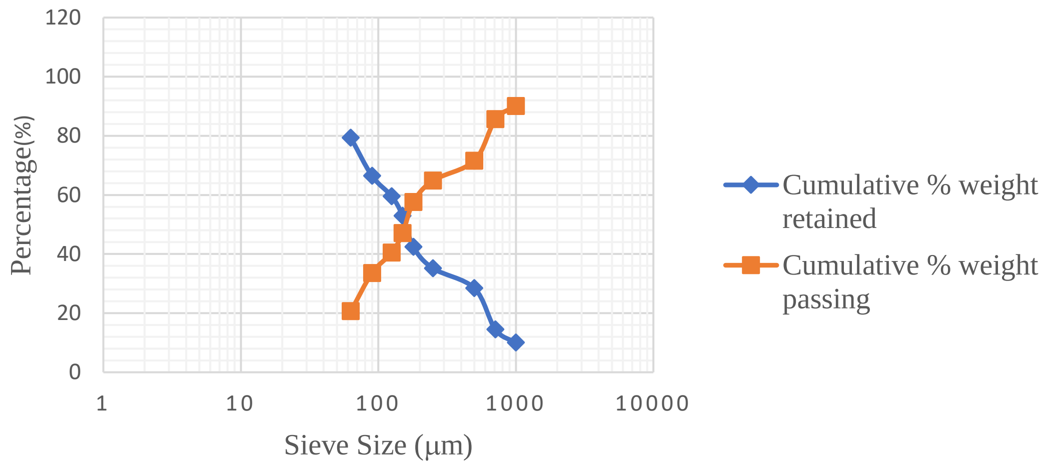

Figure 4.6 Semi logarithm graph Product1 from Ball Mill for Test Ore (spodumene)

Table 4.7 Sieving result of sample of spodumene (product1 of feed1).

sieve (micro)	Retained mass	% mass Ret.	Ret. Cummulative %	Passing Cummulative %
+1000	50	10	10	90
−1000 + 710	22.2	4.44	14.44	85.56
−710 + 500	69.9	13.98	28.42	71.58
−500 + 250	33.6	6.72	35.14	64.86
−250 + 180	36.2	7.24	42.38	57.62
−180 + 150	52.85	10.57	52.95	47.05
−150 + 125	33.05	6.61	59.56	40.44
−125 + 90	34.25	6.85	66.41	33.59
−90 + 63	64.85	12.97	79.38	20.62
−63	103.1	20.62	100	0

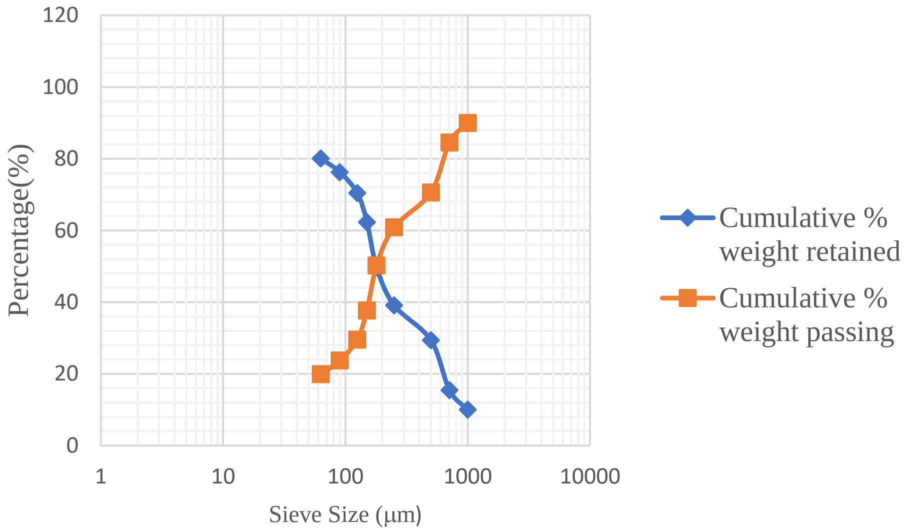

Figure 4.7 Semi logarithm graph Product2 from Ball Mill for Test Ore (spodumene).

Table 4.8. Sieve analysis of spodumene ore (product of feed 2) from the ball mill

size(micro)	Mass Ret.	% mass Ret.	Cummulative % Ret.	Cummulative % Pass.
+1000	50	10	10	90
−1000 + 710	27.2	5.44	15.44	84.56
−710 + 500	69.9	13.98	29.42	70.58
−500 + 250	48.6	9.72	39.14	60.86
−250 + 180	53.1	10.62	49.72	50.28
−180 + 150	62.85	12.57	62.33	37.67
−150 + 125	40.5	8.1	70.43	29.57
−125 + 90	29.25	5.85	76.28	23.72
−90 + 63	24.05	4.81	80.09	19.91
−63	94.55	18.91	100	0

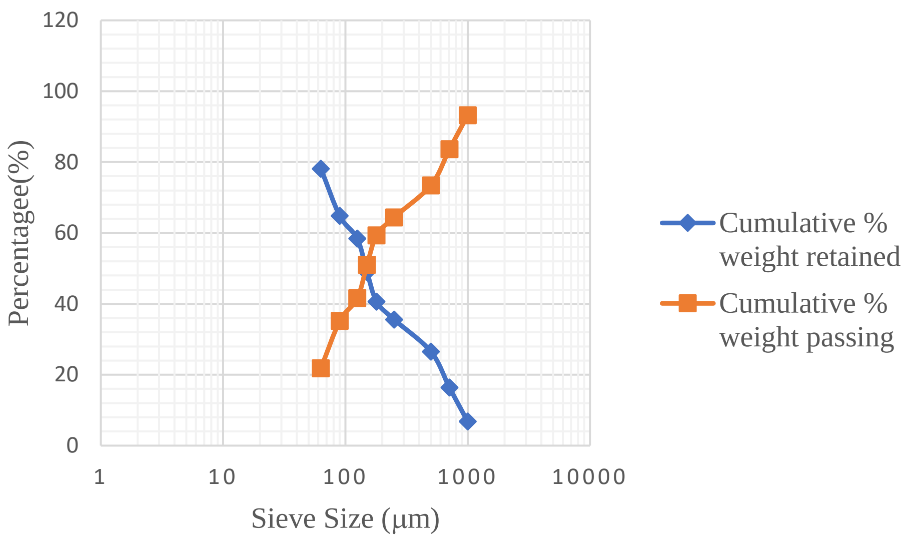

Figure 4.8 Semi logarithm graph discharge for feed 3 from Ball Mill for Test Ore (spodumene)

Table 4.9 Sieve analysis of spodumene ore (product of feed 3).

size(micro)	Mass Ret.	% mass Ret.	Cummulative% Ret.	Cummulative % Pass.
+1000	33.9	6.78	6.78	93.22
−1000 + 710	47.85	9.57	16.35	83.65
−710 + 500	51	10.2	26.55	73.45
−500 + 250	45.15	9.03	35.58	64.42
−250 + 180	25.3	5.06	40.64	59.36
−180 + 150	41.9	8.38	49.02	50.98
−150 + 125	47	9.4	58.42	41.58
−125 + 90	31.95	6.39	64.81	35.19
−90 + 63	66.75	13.35	78.16	21.84
−63	109.2	21.84	100	0

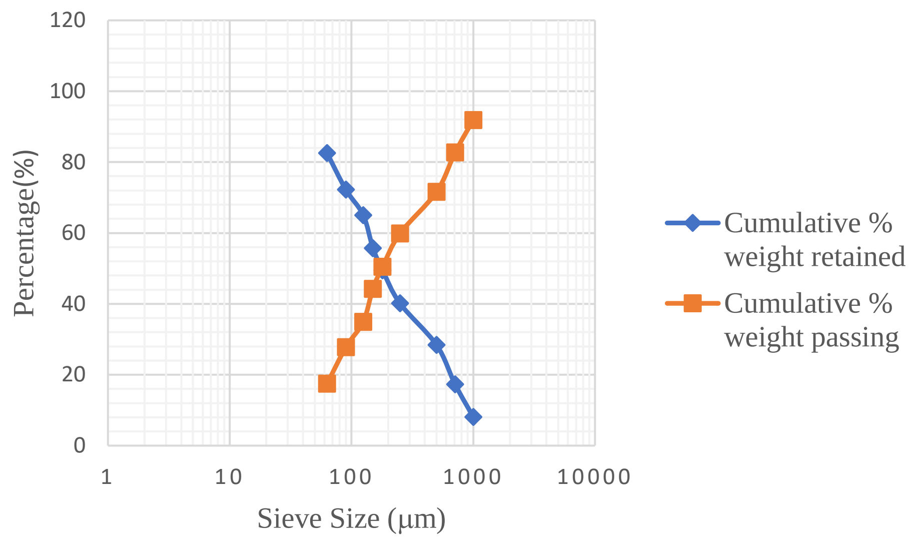

Figure 4.9 Semi logarithm graph discharge feed 4 from Ball Mill for Test Ore (spodumene)

Table 4. 10 Sieve analysis of spodumene ore as product of feed 4

size(micro)	Mass Ret.	% mass Ret.	Cummulative % Ret.	Cummulative % Pass.
+1000	40.55	8.11	8.11	91.89
−1000 + 710	45.8	9.16	17.27	82.73
−710 + 500	55.6	11.12	28.39	71.61
−500 + 250	58.85	11.77	40.16	59.84
−250 + 180	46.75	9.35	49.51	50.49
−180 + 150	31.2	6.24	55.75	44.25
−150 + 125	46.5	9.3	65.05	34.95
−125 + 90	35.85	7.17	72.22	27.78
−90 + 63	51.6	10.32	82.54	17.46
−63	87.3	17.46	100	0

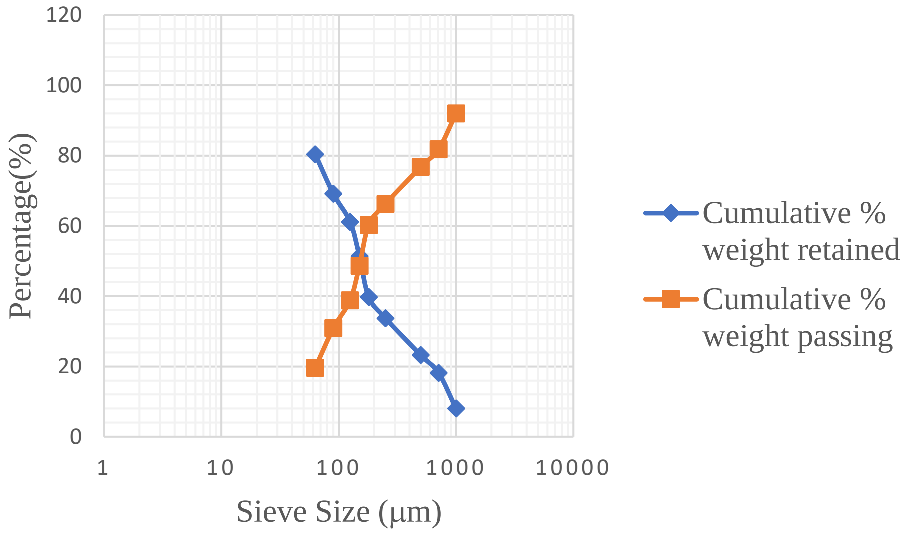

Figure 4.10 Semi logarithm graph Product from Ball Mill for reference sample (granite).

Table 4.11 Sieve analysis of sample of granite (product)

Size (micro)	mass Ret.	% mass Ret.	Cummulative % Ret.	Cummulative % Pass.
+1000	40	8	8	92
−1000 + 710	50.75	10.15	18.15	81.85
−710 + 500	25.35	5.07	23.22	76.78
−500 + 250	52.55	10.51	33.73	66.27
−250 + 180	30.15	6.03	39.76	60.24
−180 + 150	58.15	11.63	51.39	48.61
−150 + 125	48.8	9.76	61.15	38.85
−125 + 90	39.8	7.96	69.11	30.89
−90 + 63	56.3	11.26	80.37	19.63
−63	98.15	19.63	100	0

4.2 Calculation of kenticha spodumene.

The work index of the spodumene ore (test ore) was calculated using the Bond's equation (Equation 3) which is as following.

$$W_{it} = W_{ir}\left(\frac{10}{\sqrt{P_{80r}}} - \frac{10}{\sqrt{F_{80r}}}\right) \div \left(\frac{10}{\sqrt{P_{80t}}} - \frac{10}{\sqrt{F_{80t}}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

granite is reference sample and spodumene is test ore.

Granite work index was obtained from literatures while the values of P_{80r}, F_{80r}, P_{80t}, and F_{80t} for all four feeds were obtained using Gaudian Schumann's expression and data obtained from tables 4.2 - 4.11. Gaudian Schumann expression can be represented as follows if size 1 is the size determined by the sieve analysis results and size 2 is the 80% passing size (Alabi et al, 2015):

$$\text{size}_2 = \frac{(\text{percentage passing size}_2)}{(\text{percentage passing size}_1)^2}^{2} \times \text{size}_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

By using this equation, we can find F_{80r} (80% of feed of reference sample), $P80_r$, F_{80t1}**,** P_{80t1}, F_{80t2} P_{80t2} , F_{80t3}, P_{80t3} , F_{80t4} and P_{80t4} as following.

To get F_{80r} (80% of feed of reference sample) Granite feed: calculate $size_2$

$$\text{size}_2 = \frac{(\text{percentage passing size}_2)}{(\text{percentage passing size}_1)^2}^{2} \times \text{size}_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$X\ \mu m = \frac{(\frac{80}{100})}{(\frac{80.57}{100})^2}^{2} \times 1000\mu m = 985.90\mu m \text{ at } 80\%$$

P_{80r} was obtained **after granite feed was ground in a ball mill for 10 minutes and discharged as granite product.** calculate $size_2$

$$X\ \mu m = \frac{(\frac{80}{100})}{(\frac{81.85}{100})^2}^{2} \times 710\mu m = 678.26\mu m \text{ at } 80\%$$

To get F_{80t1} (80% of feed 1 test ore passes**)**: calculate $size_2$

$$\text{size}_2 = \frac{(\text{percentage passing size}_2)}{(\text{percentage passing size}_1)^2}^{2} \times \text{size}_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

X µm = $\frac{(\frac{80}{100})^2}{(\frac{79.57}{100})^2} \times 1000\mu m = 1010.83$ µm at 80%

P_{80t1} was obtained **after feed1 was ground in a ball mill for 20 minutes and discharged as product of feed1**. calculate $size_2$

$$size_2 = \frac{(\text{percentage passing } size_2)^2}{(\text{percentage passing } size_1)^2} \times size_1$$

X µm = $\frac{(\frac{80}{100})^2}{(\frac{85.56}{100})^2} \times 710\mu m = 620.72$ µm at 80%

P_{80r} (µm) = 678.26µm,F_{80r}(µm) = 985.90µm, p_{80t1}(µm) = 620.72 µm and F_{80t1}(µm) =1010.83 µm

The work index reference sample granite is 15.13 Kwh/t (Wills and Napier-Mum, 2006).

$$W_{it1} = W_{ir}\left(\frac{10}{\sqrt{P_{80r}}} - \frac{10}{\sqrt{F_{80r}}}\right) \div \left(\frac{10}{\sqrt{P_{80t}}} - \frac{10}{\sqrt{F_{80t}}}\right)$$

$$W_{it1} = 15.13Kwh/t\left(\frac{10}{\sqrt{678.26}} - \frac{10}{\sqrt{985.90}}\right) \div \left(\frac{10}{\sqrt{620.72}} - \frac{10}{\sqrt{1010.83}}\right)$$

$15.13 \times \frac{0.06}{0.086}$ = 10.5558 Kwh/t

To get F_{80t2} (80% of feed 2 test ore passes): calculate $size_2$

$$size_2 = \frac{(\text{percentage passing } size_2)^2}{(\text{percentage passing } size_1)^2} \times size_1 \text{.................................(6)}$$

X µm = $\frac{(\frac{80}{100})^2}{(\frac{81.43}{100})^2} \times 1000\mu m = 965.18$µm at 80%

P_{80t2} (80% of discharge feed 2 test ore passes) was obtained **after feed2 was ground in a ball mill for 15 minutes and discharged as product of feed2**. calculate $size_2$

$$size_2 = \frac{(percentage\ passing\ size_2)^2}{(percentage\ passing\ size_1)^2} \times size_1 \text{................................. (6)}$$

X μm = $\frac{(\frac{80}{100})^2}{(\frac{84.56}{100})^2} \times 710\mu m = 635.49$ μm at 80%

P_{80r}(μm) = 678.26μm, F_{80r}(μm) =985.90μm, P_{80t2}(μm) = 635.49 μm and F_{80t2}(μm) = 965.18μm

$$W_{it2} = W_{ir}\left(\frac{10}{\sqrt{P_{80r}}} - \frac{10}{\sqrt{F_{80r}}}\right) \div \left(\frac{10}{\sqrt{P_{80t}}} - \frac{10}{\sqrt{F_{80t}}}\right)$$

$$W_{it2} = 15.13Kwh/t\left(\frac{10}{\sqrt{678.26}} - \frac{10}{\sqrt{985.90}}\right) \div \left(\frac{10}{\sqrt{635.49}} - \frac{10}{\sqrt{965.18}}\right)$$

$15.13\times\frac{0.06}{0.08}$ = 11.3475Kwh/t

To get F_{80t3}(80% of feed 3 test ore passes): calculate $size_2$

$$size_2 = \frac{(percentage\ passing\ size_2)^2}{(percentage\ passing\ size_1)^2} \times size_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(6)}$$

X μm = $\frac{(\frac{80}{100})^2}{(\frac{79.13}{100})^2} \times 1000\mu m = 1022.11$ μm at 80%

P_{80t3} (80% of discharge feed 3 test ore passes) was obtained **after feed3 was ground in a ball mill for 10 minutes and discharged as product of feed3**. calculate $size_2$

$$size_2 = \frac{(percentage\ passing\ size_2)^2}{(percentage\ passing\ size_1)^2} \times size_1$$

X μm = $\frac{(\frac{80}{100})^2}{(\frac{83.65}{100})^2} \times 710\mu m = 649.39$ μm at 80%

P_{80r}(μm) = 678.26μm, F_{80r}(μm) = 985.90μm,p_{80t3}(μm) = 649.39 μm and F_{80t3}(μm) = 1022.11μm

$$W_{it3} = W_{ir}\left(\frac{10}{\sqrt{P_{80r}}} - \frac{10}{\sqrt{F_{80r}}}\right) \div \left(\frac{10}{\sqrt{P_{80t}}} - \frac{10}{\sqrt{F_{80t}}}\right)$$

$$W_{it3} = 15.13Kwh/t\left(\frac{10}{\sqrt{678.26}} - \frac{10}{\sqrt{985.90}}\right) \div \left(\frac{10}{\sqrt{649.39}} - \frac{10}{\sqrt{1022.11}}\right)$$

$15.13\times \frac{0.06}{0.079}$ = 11.4911Kwh/t

To get F_{80t4} (80% of feed 4 test ore passes): calculate $size_2$

$$size_2 = \frac{(percentage\ passing\ size_2)}{(percentage\ passing\ size_1)^2}^2 \times\ size_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (6)$$

$$X\ \mu m = \frac{(\frac{80}{100})}{(\frac{77.73}{100})^2}^2 \times 1000\mu m\ = 1059.26\ \mu m \text{ at } 80\%$$

P_{80t4} (80% of discharge feed 4 test ore passes) was obtained **after feed4 was ground in a ball mill for 5 minutes and discharged as product of feed4**. calculate $size_2$

$$X\ \mu m = \frac{(\frac{80}{100})}{(\frac{82.73}{100})^2}^2 \times 710\mu m\ = 663.91\ \mu m \text{ at } 80\%$$

$P_{80r}(\mu m)$ = 678.26μm,$F_{80r}(\mu m)$ = 985.90μm,$p_{80t4}(\mu m)$ = 663.91 μm and $F_{80t4}(\mu m)$ = 1059.26 μm

$$W_{it4} = W_{ir}\left(\frac{10}{\sqrt{P_{80r}}} - \frac{10}{\sqrt{F_{80r}}}\right) \div \left(\frac{10}{\sqrt{P_{80t}}} - \frac{10}{\sqrt{F_{80t}}}\right)$$

$$W_{it4} = 15.13Kwh/t\left(\frac{10}{\sqrt{678.26}} - \frac{10}{\sqrt{985.90}}\right) \div \left(\frac{10}{\sqrt{663.91}} - \frac{10}{\sqrt{1059.26}}\right)$$

$15.13\times \frac{0.065}{0.0808}$ = 12.171Kwh/t

Wtest = $(w_{it1} + w_{it2} + w_{it3} + w_{it4}) \div 4$

Wt = (10.555 + 11.347 + 11.491 +12.171)Kwh/t ÷ 4 =11.391 Kwh/t

4.3 Discussion

The results of the four samples' use of the analytical method AAS (acid attack and fusion) displayed in Table 4.1. According to these findings, the typical composition of kenticha spodumene ore is 66.88% silicon dioxide, 21.83% aluminium oxide, 0.51 calcium oxide, 0.54% magnesium oxide, 3.58% sodium oxide, 1.06% potassium oxide, 0.60 percent iron oxide, and 2.34% lithium oxide. give the results from tables 4.2 - 4.11 and Figures 4.1 – 4.10 graphical distribution for sample (granite) and test ore (spodumene) 80% passing for all the four feeds and four products sieves size fractions for the references sample (granite) and the spodumene ore samples. The particle size fraction 80% passing for all feeds (feed 1, feed 2, feed 3, feed 4) and the products (product 1, product 2, product 3 product 4) of the spodumene ore sample was found to be (1010.83,965.18,1022.11,1059.26) µm and (620.72,635.49,649.39,663.91) µm respectively while the total work index of the spodumene ore sample was computed to be 11.391 kWh/ton on the average which when compared to the work index of spodumene ore, the result obtained lies favorably within the work indexes of 10.4 - 11.5 kWh/ton for spodumene ore sighted in the literatures (Michaud, 2022). The 11.391 kWh/ton work index obtained for the spodumene ore sample means that about 11.391 kilo watt hour of energy is needed to decrease one ton of the a spodumene ore at lab scale.

4.4 Limitations of Project

Factors which impacted the results of this study were limitations of laboratory equipment and constraints of time. Equipment’s like sieves and ball mill are not in standard condition, this resulted in not achieving the desired particle size for conducting a test on the mineral. The sieve shaker is damaged and unable to handle several sieves and inability of existing ball mill to mill more than 500 grams of sample at once. These limitations of equipment were noted and taken into account in the analysis of results. One of the biggest constraints of this study is shortage of time which hinders repeated measurements and laboratory analysis (test) which enable to ensure correct value of work index. Taking into account these limitations, the results achieved were satisfactory.

5. Conclusion and Recommendation

5.1 Conclusion

Work index of kenticha pegmatite spodumene ore was determine by the Berry and Bruce method and the following conclusions were drawn: The work index for feed1, feed 2, feed3 and feed4 of test ore spodumene is (10.555,11.347,11.491 and 12.171) Kwh/t and obtained average work index for kenticha spodumene ore is 11.391 kWh/t at laboratory scale, this means that 11.391 kWh/t energy is needed to comminute kenticha spodumene ore from infinite feed size to 80% passing 100µm. This will further ensure that a proper choice of comminution equipment in future mining progress at the area which enable to save energy and to take cost-effective measures. The parameter obtained in this project is very significant.

5.2 Recommendation

Following points are recommended.

- Determination of comminution process by using another method should be applied to further work on kenticha spodumene work index.
- Determination of comminution process by using another reference samples on kenticha spodumene.

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