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U. S. BUREAU OF MINES ATTRITION TYPE GRINDER

EHB Project No. 30

Minerals Research Laboratory December 1973 Progress Report

Lab. Nos. 3199, 3438, 3686, 3710, 4050,
4108, and 4187 - Book No. 309

by
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OBJECTIVES

The objects of this project were to construct an attrition grinder of U. S. Bureau of Mines design, to test the grinder on several North Carolina minerals, and to compare the results of this test work with the results obtained by the USBM on similar materials.

PROCEDURE

Sample Description

The minerals used in this test work were samples of head feed and products used or produced during other projects at the Minerals Research Laboratory (MRL). The six minerals studied were quartz, limestone, mica, talc, feldspar, and pyrophyllite. The description of each sample is as follows:

Sand - Laboratory No. 4108. This material was used as received in scrubbing tests, and a scrubbed and sized portion, minus

14 mesh plus 28 mesh, was used as a grinding media.

Limestone - Laboratory No. (none). This material was used as received. It had been used as ball mill feed in a previous project. It was essentially pure marble.

Mica - Laboratory No. 3438. This material was used as received. It was produced by spiralling a weathered ore. It contained traces of quartz and feldspar.

Mica - Laboratory No. 4050. This sample was dry screened on 12 and 200 mesh screens after arrival at the Laboratory. It was a flotation product containing trace amounts of spodumene, feldspar, and quartz.

Talc - Laboratory No. 3686. This material had been hammer milled to pass 1/16-inch after being received at the Minerals Research Laboratory. The material was a greenish impure soapstone, but it contained about 85% colorless platy talc.

Talc - Laboratory No. 3710. This material had been hammer milled to pass 1/16-inch after receipt at the MRL. This was an impure soapstone that was greenish in color, but it contained about 70% colorless platy talc.

Feldspar - Laboratory No. 4187. This material was used as received. The material was a flotation product used for feed to a fine grinding mill. It contained some quartz and mica.

Pyrophyllite - Laboratory No. 3199. This was a flotation concentrate produced at the MRL. It was only a rougher grade of concentrate and contained a fair percentage of quartz.

The screen analyses of the minerals used as head feed to the attrition mill are shown in Table I. Also shown in Table I are the specific gravities and bulk densities of the head feed materials.

Sample Preparation

Sample preparation was limited in most cases to drying and splitting into either 250 or 500-gram samples.

After grinding and separation of ground product from grinding media and water, the product was dried and then broken up in a disc mill or by hand on a 100, 200, or 325 mesh screen.

Equipment

The equipment used in this project consisted of a U. S. Bureau of Mines type attrition grinder and auxiliary equipment used to process and test the ground products.

The batch grinding tests were made in a USBM type, 5-inch diameter, attrition grinder. This grinder is described in detail in the Bureau of Mines Report of Investigation No. 5697, "Paper-Coating Clay From Coarse Georgia Kaolins by a New Attrition-Grinding Process," by I. L. Feld, T. N. McVay, H. L. Gilmore, and B. H. Clemmons. The grinder consists of a rotor and stator fabricated of carbon steel and assembled in a vertical, cylindrical container. The container is rubber lined, 10½-inches tall, and five and three-eights-inches in diameter. The rubber liner is 3/16-inch thick. In the grinder, the cage-like rotor, with vertical bars, rotates inside the cage-like stator, which is also constructed with vertical bars. The rotor is 5-inches high and three and one-eighth-inches in diameter, and the blades are set at a 30^{o} angle

TABLE I

Object of Test - Screen Analyses, Specific Gravities, and Bulk Densities of Head Feed Samples.

Screen Size	Sand Test No. -	Limestone Test No. 1	Mica 4050 Test No. 1	Mica 3438 Test No. 2	Talc 3686 Test No. 1	Talc 3710 Test No. 6
+ 14 mesh	-	-	-	6.2	-	-
-14 + 20	14.0	-	-	13.1	-	-
-20 + 28	↓	-	-	20.1	-	-
-28 + 35	40.9	-	5.1	18.8	16.8	23.4
-35 + 48	19.9	13.5	14.7	18.9	5.1	7.2
-48 + 65	11.5	16.3	24.7	10.4	11.4	9.1
-65 + 100	6.8	19.9	26.3	6.1	12.5	8.2
-100 + 150	3.5	14.6	18.0	2.5	11.9	7.9
-150 + 200	1.9	11.1	9.2	1.3	10.6	7.7
-200 + 325	↓	12.6	↓	1.1	10.7	9.7
-325 mesh	↓	12.0	↓	1.3	21.0	26.0
(less than)	0.9	-	2.1	-	-	-
Sp. Gr. (gr/cc)		2.73	2.88	2.84	2.85	2.87
Bulk Density (lb/ft^3)		90.4	46.2	22.8	39.4	52.2

Screen-Ro-Top 20 minutes

Sp. Gr. determined with an air pycnometer.
Bulk Density determined with a Scott Paint Volumeter.

Feldspar Test No. 1	Pyrophyllite Test No. 1	Grinding Sand Test No.-	Grinding Nylon Test No.-	Grinding Alumina Test No.-
-	-	-	100.0	100.0
-	-	29.6	-	-
1.1	-	70.2	-	-
6.7	0.1		-	-
13.3	0.8		-	-
19.5	4.0		-	-
19.9	13.4		-	-
17.4	21.9		-	-
12.7	23.2		-	-
	19.2		-	-
	17.4		-	-
9.5	-	0.1	-	-
2.62	2.79	2.65	1.15	3.91
89.8	65.7	-	-	-

from the radial direction. The stator is seven and one-eighth-inches high and 5-inches in diameter, and the blades are set in a radial direction. The clearance between stator and rotor is 1/8-inch. The rotor turns at a speed of 1600 rpm, or 1400 fpm.

In batch testing, the feed is placed in the grinder from the top. After grinding, the pulp, which consists of the ground material, water, and the grinding media, is discharged by washing it through the central opening at the bottom of the container.

Some of the other pieces of equipment used to recover, separate, and test the ground products include: Tyler series screens; a Denver vacuum filter; a Galigher pressure filter; an electric oven; an Abbe jar mill; a high-intensity scrubber; a Scott Volumeter; an Eriez magnetic separator, model HIW, style 7.4.1.; a Warman Cyclosizer, model M 4; a Beckman Air Comparison Pycnometer, model 930, a Wemco 1 + 1 batch flotation machine; and a Photovolt reflectance meter.

Type of Testing

The grinder was assembled for operation by (1) placing the stator inside the rubber-lined container and (2) fixing the container with the stator into position so that the rotor was free to turn inside the stator. Water with dispersant and the mineral to be ground were placed in the container. Unless otherwise noted, 6.6 pounds of tetrasodium pyrophosphate (TSP) per ton of head feed was added as a dispersant. The container lid was put in place, and the grinder was turned on a few minutes to pre-mix the pulp. After the pre-mix period, the grinding media was added. The grinder was then turned on and allowed to run the specified length of time. The grinder was then turned off and the plug removed from the bottom. All the contents were removed by washing into a bucket. The material was then screened to recover the grinding media and any oversize or unground mineral.

The ground mineral, or product, was then either filtered as is; settled, decanted and filtered; or further processed to upgrade the mineral contents. These products were dried, and the dry filter cakes were broken apart. The end products were then subjected to bulk density determinations.

RESULTS

The results of the tests carried out on each mineral are covered in the following tables. As a comparison, some results of grindings performed by the USBM in a 10-inch grinder, reported in RI 7641, are also shown in some tables. Although the tests were carried out on different material, the results are significant.

TABLE II

Results of Scrubbing Sand, Lab. No. 4108

Type of Scrubber	Wt of Head Feed	(Min) Time	% Solids	% Fe_2O_3 in Head Feed	% Fe_2O_3 in Product	% Product
3-Tier Wemco	10 lbs	30	70	0.4	0.037	19.6*
3-Tier Wemco	500 gr	5	75	0.4	0.13	93.2**
USBM Grinder	2500 gr	30	70	0.4	0.13	90.5**

No reagents used in any tests.

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* Sized product at plus 28 mesh to be used as a grinding media.

** Sized product at minus 16 plus 140 mesh by washing and decantation.

TABLE III

RESULTS OF GRINDING LIMESTONE (NO LAB NUMBER)

Location of Test Work	Grinding Media	Size of Media	Time of Grind (Min)	% Solids Total	Ratio of Media:Mineral	% of Head Fd. to -325	Product Bulk Density ($lbs/ft.^3$)
MRL	Sand	-14+28	30	75	2 : 1	61.6	29.0
MRL	Sand	-14+28	60	75	2 : 1	83.2	20.8
USBM	Sand	-14+28	30	75	2 : 1	98.5	22.8

TABLE IV

RESULTS OF GRINDING MICA, LAB. NO. 4050

Test Location	Grinding Media	Size of Media	Grind Time (Min)	% Solids Total	Ratio, Media : Mineral	% of Hd.Fd. Ground to -325 Mesh	Product Bulk Den. (lb/ft^3)	Remarks
MRL	Sand	-14+28 m.	60	61	1.6:1	59.4	11.0	All -325 m. filtered together. Reflectance colors on prod., G = 78, B = 73, A = 81.
MRL	Sand	-14+28	30	75	2:1	10.4	11.9	All -325 m. filtered together.
MRL	Nylon	-8+10	60	50	2:1	74.5	10.0	Minus 325 m. settled & deslimed. Prod. = 51.4% of hd. fd. Reflectance colors of products, G = 75, B = 68, A = 76.
MRL	Alumina	-10+12	30	50	2:1	93.8	12.6	-325 m. settled & deslimed. Prod. = 67.7% of hd. fd. Reflect., G = 74, B = 67, A = 76.
MRL	Nylon	-8+10	30	50	2:1	52.1	10.6	-325 m. settled & deslimed. Prod. = 29.8% of head feed.
MRL	-	-	60	62	-	6.9	10.5	Scrubbed in 3-tier Wemco scrubber at 1250 rpm. No T.S.P. added.
MRL	Alumina	1¼"X1¼"	60	88	9:1	9.7	10.8	Ground in Abbe jar mill. % solids, mineral to water = 43%. No T.S.P. added.

(Table continued)

TABLE IV

RESULTS OF GRINDING MICA, LAB. NO. 4050

(Continued)

Test Location	Grinding Media	Size of Media	Grind Time (Min)	% Solids Total	Ratio, Media : Mineral	% of Hd.Fd. Ground to -325 Mesh	Product Bulk Den. (lb/ft^3)	Remarks
MRL	Alumina	1¼"X1¼"	60	95	9:1	9.2	10.8	Ground in Abbe jar mill. % solids, mineral to water = 65% No T.S.P. added.
MRL	Alumina	1¼"X1¼"	60	71	9:1	7.3	14.4	Ground in Abbe jar mill. % solids, mineral to water = 20% No T.S.P. added.
USBM	Sand	-14+28 m.	30	75	2:1	60.2	17.1	6 lbs/ton. T.S.P. added.
USBM	Sand	-8+10	30	70	2.5:1	99.7	10.5	6 lbs/ton. T.S.P. added.

TABLE V

RESULTS OF GRINDING MICA (LAB. NO. 3438), FELDSPAR (LAB. NO. 4187), AND PYROPHYLLITE (LAB. NO. 3199)

Type Mineral	Test Location	Grinding Media	Size of Media	Grind Time (Min)	% Solids Total	Ratio, Media : Mineral	% of Hd.Fd. Ground to -325 Mesh	Product Bulk Den. (lb/ft^3)	Remarks
Mica	MRL	Nylon	-8+10 m.	60	50	2:1	90.6	8.5	-325 mesh settled & deslimed. Product = 74.2% of head feed. Reflectance colors of products, G = 71, B = 63, A = 72.
Mica	MRL	Nylon	-8+10	30	50	2:1	59.8	7.4	-325 mesh settled & deslimed. Product = 52.5% of head feed. Reflectance color of product, G = 69, B = 57, A = 70.
Mica	USBM	Sand	-8+10	30	56	2:1	100.0	12.7	6.0 lb/ton T.S.P. added.
Feldspar	MRL	Sand	-14+28	60	72	2:1	33.3	-	Considerable sand in -325 m. product.
Feldspar	MRL	Sand	-14+28	30	50	2:1	44.7	-	Considerable sand in -325 m. product.

(Table continued)

TABLE V

RESULTS OF GRINDING - MICA (LAB. NO. 3438), FELDSPAR (LAB. NO. 4187), AND PYROPHYLLITE (LAB. NO. 3199)

(continued)

Type Mineral	Test Location	Grinding Media	Size of Media	Grind Time (Min)	% Solids Total	Ratio Media : Mineral	% of Hd.Fd. Ground to -325 Mesh	Product Bulk Den. (lb/ft^3)	Remarks
Pyrophyllite	MRL	Nylon	-8+10 m.	30	50	2:1	73.5	11.1	6.6 lb/ton T.S.P. added.
Pyrophyllite	MRL	Nylon	-8+10	30	50	2:1	81.8	12.4	No T.S.P.
Pyrophyllite	MRL	Nylon	-8+10	15	50	2:1	57.8	14.2	No T.S.P.
Pyrophyllite	USBM	Sand	-8+10	30	56	2:1	100.0	10.9	6.0 lb/ton T.S.P. added.

TABLE VI

RESULTS OF GRINDING TALC LAB. NO. 3686 AND TALC LAB. NO. 3710

Talc Lab No.	Test Location	Grinding Media	Size of Media	Grind Time (Min)	% Solids Total	Ratio Media : Mineral	% of Head Feed Ground to:	% of Product +10.7	Bulk Den. Product (lb/ft^3)	Remarks
3686	MRL	Nylon	-8+10 m.	30	59	2:1	-325 mesh 76.9	-	10.7	
3686	MRL	Nylon	-8+10	60	58	2:1	-325 mesh 93.1	-	9.0	
-	USBM	Sand	-8+10	30	56	2:1	-325 mesh 100	86	12.0	
3710	MRL	Nylon	-8+10	15	50	4:1	-400 mesh 84.3	95.4	-	-400 mesh magnetically separated, then filtered. -400 mesh nonmag = product.
3710	MRL	Nylon	-8+10	30	50	4:1	-400 mesh 95.2	97.4	-	-400 mesh magnetically separated, then filtered. -400 mesh nonmag = product.
3710	MRL	Nylon	-8+10	45	50	4:1	-400 mesh 96.5	98.6	-	-400 m. magnet. sep. & filtered. -400 mesh nonmag = product.
3710	MRL	Nylon	-8+10	30	50	4:1	-200 mesh 96.5	95.0	11.0	-200 mesh magnetically separated, floated, cleaned once, then filtered. Cleaned F.P. = product = 44% of head feed. Reflectance colors, G = 82, B = 78, A = 83

DISCUSSION

The minerals used in this test work were not from the same locations as the minerals used in the Bureau of Mines work (RI 7641). However, a check of the mineral descriptions, screen analyses, specific gravities, and bulk densities indicates the minerals ground were very similar. The grinding media used by the Bureau of Mines was Ottawa sand, which is essentially spherical in shape. The grinding media used at Minerals Research Laboratory were screened sand from a North Carolina deposit, not spherical; nylon pellets, oval in shape; and alumina beads, almost round. Some of the differences between Bureau of Mines and Laboratory data could possibly be attributed to the differences in grinding media.

The Bureau of Mines work reported in RI 7641 was performed in a 10-inch diameter grinding unit. Conversations with Bureau of Mines personnel at Tuscaloosa, Alabama indicate that they had found larger units to be more efficient than their smaller units.

The attrition grinder had originally been designed as a scrubber unit, so it was put to that use (Table II). When sand containing an appreciable amount of clay and Fe_2O_3 was scrubbed for five minutes in a standard laboratory scrubber, most of the clay and Fe_2O_3 was removed. But a 30-minute scrub in the attrition mill could produce no better reduction in iron values.

The grinding tests performed on limestone show a greater size reduction in the USBM 10-inch grinder than in the MRL 5-inch grinder. But the bulk density of the final product of the MRL work is lower than any produced by the Bureau of Mines.

Mica, Lab. No. 4050, is a product from a spodumene beneficiation plant. The mica is known for its high white color and its extreme difficulty to grind. The time necessary to reduce the particle size to minus 325 mesh in the attrition mill was surprisingly short. The attrition mill reduced the particle size of the mica at a rate far greater than did a jar mill or a scrubber. This wet attrition ground product had a very good color and showed a good amount of sheen. This same mica is presently being dry ground, producing a product with little or no sheen. No wet grinding methods are commercially being used to produce a high sheen product from this mica.

Mica, Lab. No. 3438, is produced from a weathered ore body by spiralling. Although this mica is very coarse, it grinds at a much faster rate than mica No. 4050. The bulk density of this product is lower than that of No. 4050, but the color reading is also lower.

The feldspar No. 4187 is considerably harder than the other minerals ground. When sand was used as a grinding media, it was found, by chemical analysis, that considerable sand was ground into the fine fractions. Another grinding media might be used to produce an uncontaminated product.

The pyrophyllite No. 3199 was an impure concentrate that had been produced at the Minerals Research Laboratory by flotation. The sand that was in the head feed did not grind as easily as the pyrophyllite; therefore, much of it could be removed from the ground product by screening.

The samples No. 3686 and 3710 were interesting to work with in that the grinding took place so fast and the particle size reduction was very great. When some of the ground talc was treated by screening,

magnetic separation, and froth flotation, a product was obtained which was equal in quality to the best products obtained in the Laboratory's major soapstone project. The yield of final product was twice as great as in the previous work, and the color was just as good.

This method shows great promise in upgrading soapstone talcs.

CONCLUSIONS

The Laboratory's USBM-type attrition mill will grind minerals in a manner comparable to the machines used by the Bureau of Mines.

The high density grinding media needs to be further tested, but it seems to grind at a higher rate than quartz.

Grinding soft minerals, such as talc, limestone, and mica, in the attrition mill is fast and very effective. Grinding harder minerals may prove to be a problem.

The unit is not very suitable as a scrubber of coarse sand.

The unit seems better than a jar mill for grinding minerals such as tough mica.