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Study of enrichment of vermiculite ores of the «Tebinbulak» deposit of the Republic of Uzbekistan

Avaz Aripov, Fozil Akhtamov, Quvonchbek Bektamishov, Aslonbek Ikromov, Farxod Erkinov
Navoi State University of Mines and Technologies, Navoiy, Uzbekistan

Abstract. The mineralogical and technological properties of vermiculite raw materials are analyzed in the article, the main properties of natural vermiculite are studied. As a result of the tests, a technological scheme for dry beneficiation of vermiculite ores was developed. The output of vermiculite concentrate by fractions is 10.57%, its amount in enrichment is 85%, the separation of vermiculite in enrichment is 95.95%.

Keywords: Ore, minerals, vermiculite, air separator, grinding, settling, drying, thermal insulation, temperature, beneficiation, fractions, technological scheme.

1. Introduction cc

The production of vermiculite and materials based on it has just begun to develop in the Republic of Uzbekistan. high porosity, low density and low thermal conductivity, as well as high fire resistance and stability of the mineral content made it widely used among other heat-insulating materials. Dry building mixes are made from it, fire-resistant boards and paints are produced, it is widely used in insulation of heating devices and soundproofing of rooms, steel casting [1].

Currently, 500-600 thousand tons of vermiculite is produced annually worldwide, about 80% of which is mined in the USA and the Republic of South Africa, and the rest in Brazil, Argentina, China, India, Egypt, Kenya and Russia [2]. more than one hundred types of vermiculite products are produced in economically developed countries [3]. In most countries, the use of vermiculite is still limited due to the fact that the building materials production industry is not equipped with modern energy and resource-saving technologies. Expanded vermiculite is widely used as an effective thermal and sound insulation material, porous filler for lightweight concrete and plastering admixtures, and other purposes [4].

Vermiculite is widely used in steel casting, water filtration, as an adsorbent of smoke and toxic gases, as an anti-radiation material, in wastewater treatment, in oil spill recovery, and in reducing soil nitrate pollution [2]. Agro vermiculite is widely used in horticulture and floriculture in developed countries with high agricultural culture [5].

In the steel and iron-based alloy casting industry, the melting of any metal is always associated with high temperatures, so a reliable refractory material is required to ensure the operability of the technological processes and to protect the equipment. Vermiculite can withstand temperatures above 1300^0C and provides low thermal conductivity. Excellent adsorption properties of vermiculite are used in cases of disruption of technological processes in the production of chemical reagents, alkalis and acids.

When it comes to the use of vermiculite in the energy industry, it is primarily used in atomic energy due to its ability to reflect gamma radiation and absorb the destructive radiation of radioactive isotopes including strontium, cesium, cobalt, and others. It is also used to create fire-resistant protection for high-voltage electric cables and distribution boxes, to organize fire barriers in energy complex facilities. The process of applying vermiculite to many branches of the engineering industry began: in the automotive industry, it is one of the main components in the production of brake pads and other friction products, effectively reducing the temperature that occurs during high-speed friction allows (has high physical and mechanical properties), as a result, the service life increases [2]. In the aircraft industry, based on the fire-resistant properties of vermiculite, special coatings have been created for runways that have the ability to quickly extinguish (reduce) the temperature during braking. In shipbuilding, vermiculite is included in the coatings used for the underwater part of ships. This prevents the growth of molluscs on the ship's hull. Fire-resistant parts and thermal insulation in ships and cars are also produced on the basis of vermiculite [2].

Adsorption properties of vermiculite open a wide way for its use in the food industry. The natural origin of this material makes it possible to use it for filtering water and all kinds of suspensions (sugar syrup, starch and molasses-based products, vegetable oils, alcohol products and beer, fruit and vegetable juices). In addition, vermiculite serves as insulation in food storage in industrial refrigerators. Expanded vermiculite is used for thermal insulation of walls, floors, foundations, and sound insulation of buildings.

The purpose of beneficiating vermiculite is to separate it from loose non-expandable rock and weakly expandable micas. This process is the most complex and expensive in the production of expanding vermiculite. The next stages of raw material processing - crushing and burning are performed with less labor and costs. Their presence in the final product has almost no effect on the quality of expanding vermiculite, because currently there are methods of waste and enrichment processing that allow the complete separation of biotite and phlogopite particles directly as a result of the incineration process [2].

In Uzbekistan, the production of vermiculite and materials based on it began to develop in the last five years. Instead of the technology of enrichment based on combustion, which is widely used in world practice, in the conditions of today's constant increase in the price of oil and gas products and their shortage, as well as increasing environmental requirements, increasing requirements for its quality, saving energy and resourcesand in the conditions of industrial safety, there was a need to develop production in new directions, vermiculite enrichments and conglomerate (from the

Latin conglomeratus - crowded, compressed, a mixture of various dissimilar things, irregular addition, assorted) sets the task of creating a new concept of processing technological systems [1]. In beneficiation of vermiculite ores, sedimentation and dry magnetic separation processes are used. At the Kovdor beneficiation plant (Russia), ore is successively beneficiated by grinding, sorting, and separated into finished product (vermiculite), waste and intermediate products. Developed a technology for extracting expanding vermiculite from under-enriched vermiculite ore by incineration in a specialized electric furnace and simultaneous separation of inert material [2].

The highest quality vermiculite enrichment is obtained from the Kovdor vermiculite mine, which is a product of hydration. Technologies for beneficiation of Potanin, Altintas, Karatas, Barchin, Sholak-Kayraktan mines (Russia) have also been developed. The ores of a number of mines were tested in pilot-industrial conditions and included in the state reserve based on the proposed solutions for their processing [2].

Vermiculite can be burned in different furnaces (gaseous or liquid-fueled tower, rotary tube, etc.). The most effective way to burn vermiculite is in a fluidized bed furnace. Tower furnaces overcome this condition, providing intensive heating of vermiculite grains and their short stay in the high temperature zone. The impossibility of separating waste rocks is an important drawback of the incineration process [3].

Based on the analysis of available works, it has been established that vermiculite ores are one of the most difficult problems to solve, since it is difficult to separate them from non-intumescent loose rocks and slightly intumescent micas during enrichment and production of various products. At the same time, the problems of improving the quality of vermiculite ores, improving technological processes aimed at the widespread use of these products in order to obtain refractory materials from them have not been sufficiently studied.

2. Objectives of the study

Enrichment of vermiculite ores and development of an effective technology for obtaining building, refractory and heat-shielding products from them. While the main process in the production of vermiculite is incineration, experience shows that it is most effective to use a set of technologies that include pre-incineration and post-processing of the material to obtain high-quality products.

Modern vermiculite processing complexes should become the main element of modern enterprises (shops, plots) specializing in the production of vermiculite and products based on vermiculite. To implement the new concept, it is necessary to model and synthesize energy and resource-saving technologies, technological processing systems aimed at solving major scientific and technical problems of great national economic importance. Among such wastes, there are up to 52% vermiculites in the composition of vermiculite conglomerates, which are a mechanical mixture of various mineral particles.

3. Method used

The scientific work used modern integrated methods, analysis of scientific and technical data on the enrichment of vermiculite ores, theoretical studies using the analytical method, experimental studies, chemical and physico-chemical methods, thermogravimetric, polarographic, spectrophotometric methods of analysis, magnetic enrichment methods, the enrichment method was applied air sorting, methods of pyrometallurgy, as well as statistical processing of experimental results.

The disadvantage of the method of processing vermiculite ores burned by exposing the processed material to an air flow and an electric field is the relatively low efficiency of the separation process. Aimed to increase the efficiency of the separation process by increasing the charge difference between mica and other rocks. The ore is heated to a temperature of 50-300^{0}C (in which the charge difference between mica and other rocks increases), then separated in an electric field and air flow [3].

4. Research results

The granulometric composition of the vermiculite ores of the Tebinbulok mine is presented in table 1. The share of particles with a size of less than 5 mm prevails (from 55 to 98%, on average 83%)

Table 1. Granulometric composition of Tebinbulok mine ores

№ examples	Fractions, мм, %				
	+10	-10+5	-5+0	Including	
				-5+0,6	-0,6+0
1	31,2	24,8	44,0	39,5	4,5
2	0,7	1,2	98,1	42,9	55,2
3	2,0	2,8	95,2	45,9	49,3
4	2,2	4,0	93,8	52,8	41,0
5	-	-	66,4	41,6	24,8
6	-	-	97,8	62,1	35,7
7	-	-	85,1	58,2	26,9
8	-	-	55,0	40,7	14,3
9	-	-	77,5	42,1	35,4
10	3,3	2,3	94,4	46,1	48,3

The main mineral in the ore is vermiculite, it also contains amphibole-$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$, carbonate, titanomagnetite-Fe_2TiO_4, iddingsite-$MgFe_2$ $Si_3O10\cdot_4(H_2O)$, montmorillonite-$(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2\cdot nH_2O$, chrysotile-asbestos $3MgO\cdot 2SiO_2\cdot 2H_2O$, gypsum- ($CaSO_4$ $\cdot 2H_2O$), there are iron oxides Fe_2O_3, FeO, Fe_3O_4 [2]. The chemical composition of the ore mainly consists of ore-forming natural rocks, %: SiO_2 - 41.13, TiO_2 - 1.11, Al_2O_3 - 6.25, Fe_2O_3 - 7.36, FeO - 3.76, MnO - 15.04, CaO - 17.7, Na_2O - 1.0, K_2O - 0.62, P_2O_5 - 0.03, SO_3 - 0.29, Cl_2O - 1.31, CO_2 - 2.55.

According to the content of vermiculite, ores can be conditionally divided into 3 types: poor, medium (10-20%) and rich ores (more than 20%) containing 5-10% vermiculite. Taking into account the relatively low amount of vermiculite in the ore, laboratory tests were conducted to determine the possibility of preliminary beneficiation in a sedimentation machine. Tests were conducted on samples with vermiculite content of 8.12% and 11.62%. The amount of vermiculite in the obtained enrichments (in light fractions) was 18.49% and 28.35%, respectively, the yield of enrichment was 25.7% and 27.6%. The degree of separation of vermiculite into enrichment is 58-67%, the volume density of expanded vermiculite is 166-178 kg/m^3.

The large amount of titanomagnetite in the ores allows enrichment by magnetic separation at the initial stage of the technological process. According to laboratory tests, the amount of magnetite Fe_3O_4 is 24.7-50%, and they can be used as an iron additive in cement production. During the beneficiation process in precipitators, beneficiation rates are low. In order to develop the scheme of optimal beneficiation of vermiculite ore of Karauzyak mine, ore containing 10.16% vermiculite was tested.

The ore is crushed to separate the +4 mm fraction, the fraction larger than 4 mm is fed to the crusher for grinding, and then the crushed product is returned to the smelter. Vermiculite grains are easily opened along the cracks along the cleavage planes under mechanical action, forming very soft, weakly swollen layers. Therefore, excessive fragmentation of vermiculite during grinding should be avoided.

According to its structure and properties, vermiculite is significantly different from other natural rocks, which can be effectively crushed in hammer, jaw and jaw crushers. The ability of vermiculite to separate into thin layers and high viscosity do not allow using existing grinders to grind it in some cases. Physical properties of vermiculite, the above requirements for crushed material require vermiculite to be crushed by cutting or simultaneous cutting and impacting rather than by impact or crushing action. in the process of crushing vermiculite ore from Karauzyak mine, it was carried out in order to study the crushing parameters in jaw, jaw and hammer crushers.

Studies on vermiculite grinding showed good results using hammer mills with cutting blades [1]. Their use allows to reduce the degree of crushing, to increase the thickness of crushed vermiculite grains, thereby increasing the specific crushing efficiency. It is dried in cyclone drying drums at a temperature of 150^{0}C to remove moisture. the removal of non-ferrous metals is carried out using a separator-sorter in an electromagnetic field, from where the vermiculite product is classified in sieves for sorting into -4+2 mm, -2+1 mm and -1 mm fractions.

In addition, dry sorting of vermiculite ores was carried out in air separators. each size class was separated separately to improve the enrichment performance and the efficiency of the separator. The experiments were carried out in a CAD-4 air separator with changes in the air flow rate. In the separation of vermiculite ores, minerals were separated by specific gravity. minerals with a high specific gravity fall into the first receiving hopper, while vermiculite has a low specific density. Compared to other minerals in the ore, it is carried away by air currents and enters a distant receiver. research results show that the initial speed of the main air flow should be in the range of 25-30 m/s to separate the vermiculite particles from the waste rock. The results of the conducted experiments are presented in Table 2.

Table 2. Distribution of vermiculite enrichments by fractions

Fraction	Output of enrichment, %	Amount of vermiculite in the inrechment, %	Separation of vermiculite into enrichment, %
-4+2 мм	4.0	85.0	33.46
-2+1 мм	3.97	85.0	33.21
-1+0 мм	3.50	85.0	29.28
Total	11.47	85.0	95.95

During the research, methods of beneficiation of vermiculite ores were studied, X-ray phase analysis, grinding, magnetic sorting, incineration, air sorting, propagation of vermiculite ores based on the study of various methods and modern granulometric composition, chemical analysis, physicalchemical roentgenometric research methods were used. The roentgenogram of vermiculite ore from Tebinbulok mine is shown in Figure 1.

According to X-ray diffractometric analysis, mica in the intermediate stage of hydration, represented by mixed-layer formations with alternating layers of hydrobiotite and vermiculite, plays a key role in the composition of vermiculite. Vermiculite itself is sometimes only composed of small pieces of mica. According to the nature of exchangeable cations, magnesium vermiculite, magnesium-calcium vermiculite, sodium vermiculite hydrobiotites are noted. In large mica pieces of vermiculite, their sodium varieties dominate, and in small pieces, their calcium varieties prevail.

The ore undergoes crushing, screening, drying, incineration and air screening processes. during burning, vermiculite particles do not swell uniformly: small ones heat up faster and expand more strongly, and large ones heat up more slowly and expand smaller in size.

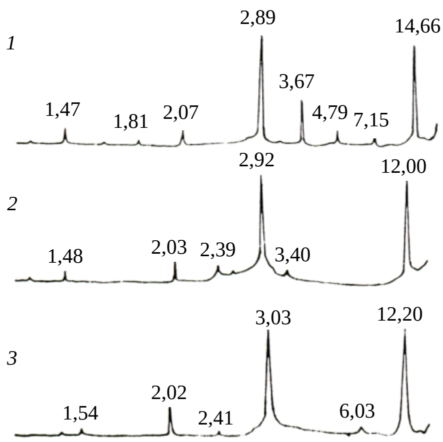

Figure 1. Roentgenogram of Tebinbulok mine vermiculite ore: 1 – ore sample 1; 2 – ore sample 2; 3 – ore simple 3

The derivatogram obtained as a result of preliminary analysis in labsys evo setaram derivatograph is presented in Figure 2, which consists of 4 curves. Analysis of the dynamic thermogravimetric analysis (DTGA) curve (curve 2) shows that the DTGA curve mainly occurs in the 2 intensive decomposition temperature ranges. The 1st decomposing interval corresponds to the temperature of 103-257°C, and the 2nd decomposing interval corresponds to the temperature of 260-900°C.

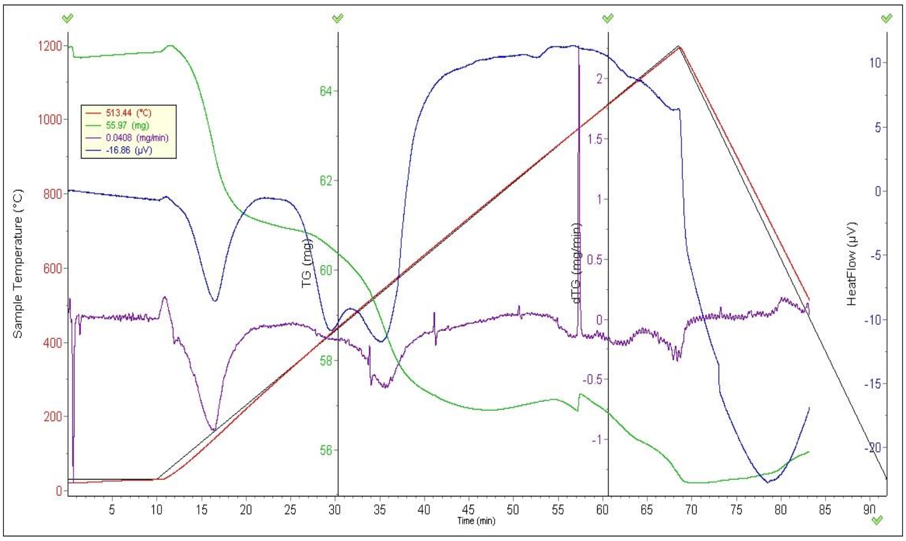

Figure 2. Vermiculite derivatogram**:** 1-Temperature curve; 2- dynamic thermogravimetric analysis curve (DTGA); 3- dynamic thermogravimetric analysis curve derivative (DTGP); 4-DSK curve

Analyzes show that, intensive decay occurs in the 2-degradable interval. In this interval, the amount of decay, i.e. 5.3% of the decay takes place. A detailed analysis of dynamic thermogravimetric analysis curve and DSK curve is presented in table 3.

Table 3. Analysis of vermiculite DTGA and DSK curve results

№	Tempereture, ºC	Lost mass, %	The rate of decomposition of the substance, mg/min	The amount of energy consumed (µB*s/mg))
1	50	0.125	0.137	1.45
2	100	0.985	0.465	2.88
3	200	1.025	0.453	2.01
4	300	1.235	0.087	3.02
5	400	1.985	0.147	1.02
6	500	2.569	0.455	2.03
7	600	3.215	2.499	1.59
8	700	4.021	2.125	1.69
9	800	5.012	1.265	1.89
10	900	6.258	2.698	3.02
11	1000	7.541	1.235	2.05
12	1100	8.014	0.235	3.02
13	1200	8.126	0.356	1.25

From these derivatograph studies, it appears that the main mass loss occurs in the range 150-1180^{0}C, where 8.2% of the main mass, i.e., 5.6 mg of mass, is lost. After 1180^{0}C, no change is observed, the mass remains unchanged. Thermogravimetric, DSK, DTG analysis of vermiculite is presented in Figures 3 and 4.

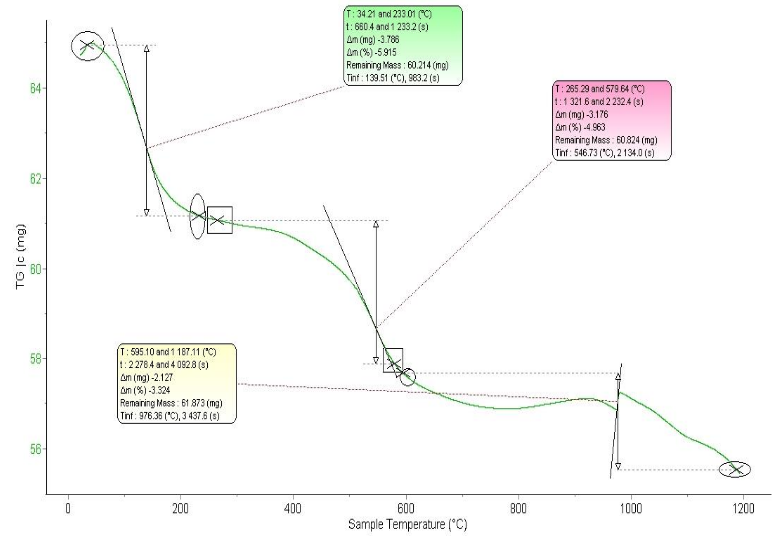

Figure 3. Thermogravimetric curve of vermiculite

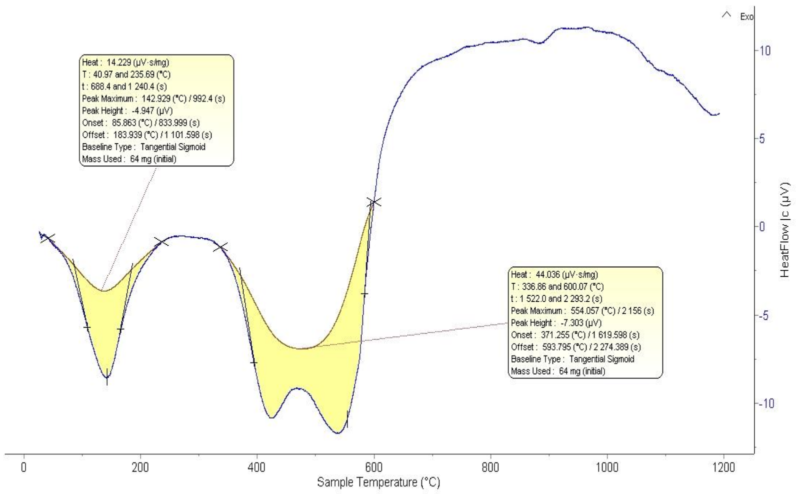

Figure 4. DSC analysis of vermiculite

5. Major findings

On the basis of theoretical and experimental studies carried out in the scientific work, the following results were obtained:

(1) The composition and properties of vermiculite ore have been fully studied and it contains SiO_2-38.1%, MgO-23.4%, Al_2O_3-12.2%, Fe_2O_3-9.5%, FeO-1.2%, K_2O-5.1%, TiO_2-1.5%, H_2O-5.2%.

(2) Vermiculite ore is granular, of various shapes, with relatively large pieces up to 20 mm, since the swelling process is associated with the size of vermiculite, it was determined that before enrichment, vermiculite ore must be crushed to a size of -4 mm.

(3) Due to the high content of titanomagnetite in the ore, a magnetic concentrate was obtained by magnetic separation at the beginning of the technological process by magnetic separation. The content of Fe_3O_4 in the magnetic concentrate from 24.7% to 50% makes it possible to use it in the cement industry as an iron additive.

(4) As a result of the tests, an effective technological scheme of dry beneficiation of vermiculite ores was developed. The yield of vermiculite enrichment by fractions is 3.5-4%. As a result of the studies carried out according to the developed scheme of vermiculite enrichment, the output of vermiculite enrichment for fractions -4+2mm, -2+1mm and -1mm was 11.47%, the amount of vermiculite in enrichment was 85%, and the degree of separation of vermiculite in enrichment was 95.95% organized. From the results of the conducted experiments, it was found that the dry beneficiation of vermiculite ores according to the proposed scheme is effective enough.

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