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THE WORKING MEDIA INFLUENCE ON THE KAOLIN VIBRODELAMINATION

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ABSTRACT
In spite of the one-hundred-years history of the vibration milling process, there are still possibilities for solving new technological tasks. An investigation on the influence of the working media elements shape to the process of fine and fine selective milling was carried out. Vibration attrition method for the delamination of the kaolin was used. The possibilities for selective milling with light working elements having density bellow 1 g/cm^3 having lens, short cylindrical and tablet shapes were examined. The frequency of the vibration was between 30 and 75 Hz, the amplitude between 0.25 and 1.8 mm. Dependence between working media elements and the degree of delamination of kaolin was established. The highest efficiency of the process of selective milling by vibration attrition was achieved by usage of lenses as working media.
KEYWORDS: Delamination, kaolin, attrition, fine particles.

INTRODUCTION

The variety of the materials being milled and consumer requirements in respect of granulometric characteristics, maximum size and shape of the particles motivate creating of different in constructions machines, as well as technical flowsheets with high complexity. Vibratory mills with horizontal placed working chamber find wide application for fine milling of ores, industrial minerals, metals, alloys, recycling of technogenic wastes and by-products.

The advantages of the vibratory mills for fine milling of traditional materials are well known and described in wide number of publications (Мадер, 1966, Вибрации в технике, 1981, Роуз, 1964, Стоев, 1979). Vibratory mills with well-defined vibration parameters and working media offers possibilities for new technological solutions for milling of materials considered as hard-milled. There are still obscurity in the process of vibration milling therefore there are unsuspected possibilities for finding of new theoretical and technological solutions.

THEORETICAL PRECONDITIONS

The requirements of the process of fine vibration milling could be generally grouped in:

- Appling of relatively small forces;
- Usage of as high frequency as possible of the vibration impact;
- Ensuring of thin-layered distribution of the material being milled between the milling media.

Appling of high-energy hit impacts for fine milling is not exculpated from economical point of view. Moreover, strong hit impacts cause destroying of the facing and corps as well as working elements surface. The milled materials are contaminated with big quantity of unacceptable impurities, when a high-intensity fine milling is applied. Therefore, in the fine milling, the amplitude is limited in the low values. Variations in the frequency of the vibrations are allowed in the interval up to 50 Hz ensuring the solidity of the mill construction. The easiest way to ensure the thin-layered distribution of the material being milled between the milling media is to be feed in as much packed as possible stricture of the working media with large contact area between working bodies.

The typical value of the vibration parameters in the vibratory mills with horizontal working chamber for producing of fine in size products are:

- Amplitude up to 6 mm.
- Frequency between 15 and 50 Hz;
- The form of the vibration – elliptic or near to the circular.

The technological possibilities of the vibratory mills with horizontal working chamber are frequently realized with fixed vibration parameters. The optimization of these parameters is limited in short interval according to the above shown limits.

The known construction Podmore Boulton Vibro-Energy Mill (Podmore,1969) has specific ring-type form which ensures compact packing of the working media represented by short cylindrical bodies. Compact package ensures the condition of thin-layered distribution of the material being milled between the milling media. The working media ensures large line and area contacts between the elements as well as working elements and vibrating surface of the ring-type chamber. Conditions for ultra fine milling, as a result mostly of the attrition action of the working media elements and hits wit low intensity between them are created in the working chamber.

The attrition is one of the base impacts applied for fine milling of mineral raw materials. Two types of efforts take action together in the attrition process – pressure and tension according to the Joazel theory. The process is schematically illustrated at Figure 1 (Мадер, 1966).

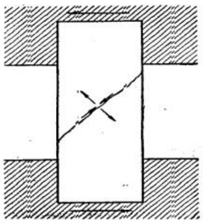

Figure 1. Attrition destroying.

Realizing of the attrition process in the vibratory mill with horizontal chamber could be achieved by 100% filling of the working chamber with working media whereupon the conditions for fine and ultra fine milling are realized. These conditions take place in the process of selective milling of layered minerals (Кузев и др. 1995).

TEST REZULTS

The process of fine and ultra fine milling was examined for delamination of kaolin, for selective milling of fine-flaked hematite, for milling of malleable metals, metal alloys etc.

Delamination of kaolin

The investigations are carried out with bleached kaolin from the current production of the kaolin treatment plant Senovo, having chemical content Al_2O_3 - 32,21%, Fe_2O_3 – 1,02%, TiO_2 – 0,31%, SiO_2 – 51,62%. Two-chamber laboratory vibration mill ensuring amplitude up to 5 mm, and frequency up to 75 Hz was used. Vibration attrition was applied as delaminating process. Light delaminating media with main characteristics given at Table 1 were used. Table 2 shows the granulometric characteristics of the media. (Kuzev, 1997, Кузев, 1998).

Table 1. Characteristics of the delaminating media.

Delaminating media	Density, g/cm³	Bulk density, g/cm³		Form
		Free	Shaked	
Polyetilen HH – III group.	0.88	0.539	0.58	Tablet
Polyetilen HH – V group.	0.87	0.557	0.58	Lenses
Pollistyrol	1.16	0.707	0.737	Cylinder

Table 2. Granulometric characteristics of the delaminating medias.

Delaminating media	Yields, %		
	+ 5 mm	-5 +2.5 mm	-2.5 mm
Polyetilen HH – III group.	2.82	96.81	0.37
Polyetilen HH – V group.	1.25	98.39	0.36
Pollistyrol	-	54.93	45.07

The influence of the working elements form on the process of delamination was examined. The differences in the density of the delaminating media pollistyrol and polyetilen are small, thus it be considered that the obtained results, shown at Table 3, are resulted from the different forms of the working media. Short cylinders represent pollistyrol group whereas polyetilen group by tablet and lens forms. The results are obtained with vibration frequency of 50 and 75 Hz and constant amplitude of 0.6 mm. The density of the kaolin suspension is 15% and duration of the delaminating process 10 min.

Table 3. The obtained delamination registered by changes in the suspension viscosity

Material and media form	Vibration frequency, Hz	Viscosity			
		Parts before	Parts after	Difference	cP
Pollistyrol (cylinder)	50	9.5	10.5	1.0	5
Polyetilen III group (tablet)	50	9.5	11.0	1.5	8
Polyetilen V group (lenses)	50	9.5	13.0	2.5	13
Pollistyrol (cylinder)	75	9.5	10.9	1.4	7
Polyetilen III group (tablet)	75	9.5	11.5	2.0	10
Polyetilen V group (lenses)	75	9.5	13.0	3.5	18

The obtained delamination was proved by the variation in the suspension rheology registered with rotation viscosimeter TV (Switzerland) with measuring scale divided to 100 equal parts.

Table 4. The yields of the classes in dependence of the amplitude of the vibrations.

Class, μm	Yields of classes, % at amplitude of the vibrations, mm					
	0	0.25	0.52	0.7	1.10	1.45
+ 60	2.0	1.8	0.5	0.2	0.5	1.5
+ 50	2.2	1.9	0.8	0.2	0.7	1.6
+ 40	2.5	2.0	0.8	0.5	1.1	1.8
+ 30	2.5	2.0	-	0.7	1.3	1.8
+ 20	2.5	2.5	1.2	1.2	1.5	1.9
+ 10	5.5	6.7	4.4	2.4	4.3	6.4
+ 5	20.2	19.2	18.3	18.0	18.0	19.1
+ 4	33.0	24.6	24.0	22.2	21.7	26.0
+ 3	37.7	31.2	30.3	29.3	29.8	37.7
+ 2	42.1	40.4	38.5	37.4	38.3	40.9
- 2	57.9	59.6	61.7	62.6	61.5	59.1

Investigations for determination of the changes in the granulometric characteristics of the part of obtained in laboratory scale delaminated products were carried out. Constant conditions, only variations in the amplitude and frequency, were used for obtaining of delaminated kaolin in the laboratory. The working media was pollistyrol. The treatment duration was 10 min, the frequency of vibration - 50 Hz and the pulp density - 15 %. The amplitude was: 0.25 mm, 0.52 mm, 0.70 mm, 1.10 mm, 1.45 mm. The initial sample is marked with label Zero (0) of the amplitude at Table 4. The size of the particles is determinated as equal spherical particle whereupon the effect of the delaminating process could not be registered. The analyses were performed at "Седиментационен анализ" laboratory in СКАХП at ЦИХП, Gara Iskar with a liquid picnometer and sedimentation balance Sortarius 4610 according to БДС 10550-78.

Table 5. Medial diameter and particle shape defined by microscopic observation.

Sample №	Counted particles, μm						Form of the particles
	- 2 μm	2 - 5μm	5 – 10 μm	+ 10 μm	Sum, numb.	Medial diam,μm	
Bleached k	336	64	39	22	451	2.62	Bulk
Sample 13	2464	338	54	10	2866	1.27	Lenses
Sample 1	3312	336	21	8	3677	1.29	Lenses
Sample 18	1104	584	223	73	2984	1.29	Lenses
Sample 22	3152	228	103	49	3532	1.50	Lenses
Sample 50	1136	496	55	9	1696	2.01	Lenses
Sample 48	848	208	16	14	1086	1.75	Lenses
Sample 52	928	320	102	18	1368	2.25	Lenses
Sample 38	3860	768	99	-	4727	1.54	Lenses

The medial size of the particles in the kaolin suspension before delamination as well as after the delamination in different statistically defined conditions was measured by microscopic observations. In result of the counting of the particles, at Table 5 are shown classes with size -2 μm, 2 – 5 μm, 5 – 10 μm, and +10 μm. The medial diameter is estimated according to the dates of observed sample.

Table 6 shows the conditions for delamination of the samples represented at Table 5.

Table 6. Experimental conditions for delamination.

Sample №	Delamination conditions				
	Frequen, Hz	Amplitud mm	Time, min	Pulp, % density	Medial diam, μm
Bleached kaolin	0	0	0	-	2.62
Constant amplitude					
Sample 13	40	0.25	15	15	1.46
Sample 1	50	0.25	15	15	1.29
Sample 18	60	0.25	15	15	1.29
Sample 22	75	0.25	15	15	1.50
Constant frequency					
Sample 50	50	0.31	10	10	2.01
Sample 48	50	0.70	10	10	1.54
Sample 52	50	1.10	10	10	1.75
Sample 38	50	1.445	10	10	2.25

DISCUSSION

As a result of vibration attrition process, fine dispersed particles with different forms, according to the physical-mechanical properties of the material been milled, could be obtained. The correct definition of the vibration parameters and working media, leads to obtaining of particles with predominantly plate forms from layered minerals such as kaolin, graphite, specular hematite etc. From the same raw material, at different conditions - parameters of the vibrations and working media could be predominantly obtained particles with isometric forms.

For obtaining of kaolin particles with flake forms it is necessary the force in direction of "c" axes ($E = 644 \times 10^{-6}$ cal/cm^2), which keep different crystals in one kaolin stack, to have smaller value, then the attrition force between the slithered surfaces of the working bodies. (Conly,1987, Davis and Dawson, 1989).

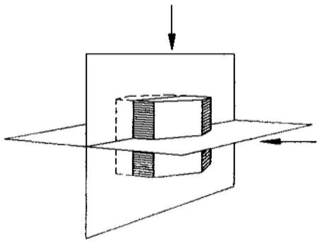

Figure 2. Bonds energy of the kaolin crystals.

The obtained in the investigation results, shown at Table 3, for the viscosity of kaolin suspensions after delamination with different delaminating medias shows:

- The highest value of viscosity increasing is obtained by usage of polyetilen lenses as working media.

- Downstream climax of the efficiency of working elements with different forms is lenses, tablets and cylinders. Arrangement of these forms corresponds to the contact area decreases between the elements. In the case with lenses as working media, contact area is the largest. Contact area is smaller with usage of tablets (or combination between tablets and cylinders) because there are line and area contacts. The smallest contact area is with usage of cylinders as working media, because the contacts between the elements are predominantly lines.

A real effect of grinding could be observed browsing over the numeric data at Table 4, in the columns showing the yields of the different classes. After the delamination with different amplitudes, the number of particles with size over 20 μm decreases. Taking into account the size of classes from 20 to 2 μm a character minimum could be observed with the amplitude of 0.7 mm. The yields of these classes increase with the variations of the amplitude up and down from 0.7 mm. There is an anomaly at first view, but it could be easily explained with the changed attrition conditions. Namely, the glide plane remains constant at different amplitudes and remains independent of the different speed of the working media caused by the vibrations, while the speed of the suspension movement in the contact area of the working elements depends on the amplitude. That is way, at higher suspension speed than the glide speed increases yields of the fine classes. At the equation of the speeds, there is an optimum of the milling, whereupon the finest products are obtained. After the passage of the speed equation, the increases of the amplitude could not increase the fine classes yield. The absolute values for the different classes at Table 4 are small but the quality of the delaminated kaolin could be visualized by Scanning Electron Microscope (SEM) pictures. A general view of the bleached kaolin is shown at Figure 3. Figure 4 shows delaminated kaolin.

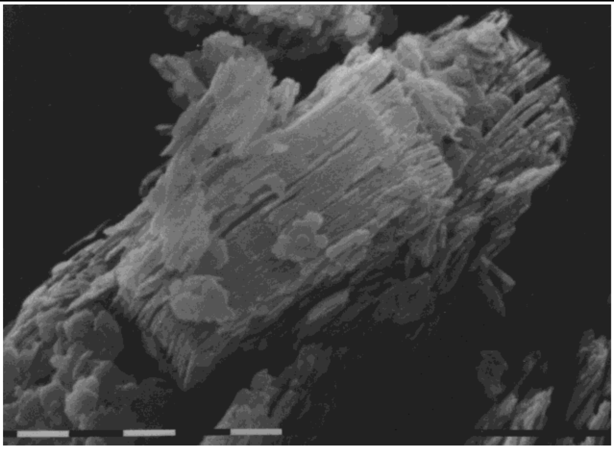

*Figure 3. SEM picture of kaolin stack.
Magnification 10 000 times and Marker 1 μm.*

Interesting results for changes of the medial size of the particles are perceived by microscope observation of the initial and delaminated in the following conditions samples:

- Constant amplitude 0.25 mm and frequency of 30, 40, 50, 60, 75 Hz.
- Constant frequency 50 Hz and amplitude of 0.31 mm, 0.7 mm, 1.10 mm, 1.45 mm.

Results are shown at Table 6.

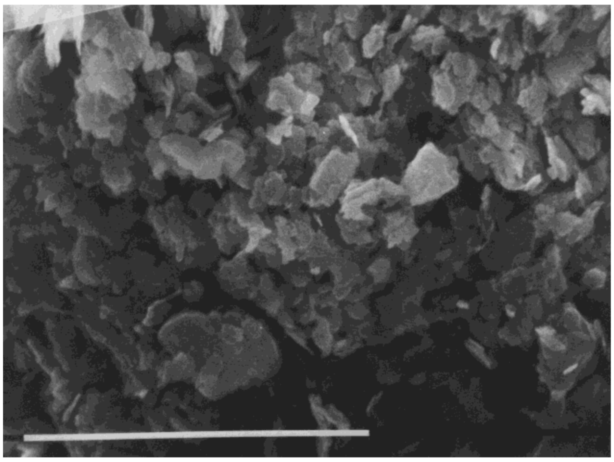

*Figure 4. SEM picture of kaolin particles (flakes)
Magnification 6 200 times and Marker 1 μm.*

The medial diameter of the bleached kaolin 2.62 μm was decreased to 1.29 μm after the delaminating process by applying of different vibration parameters, duration of the treatment and density of the slurry. The data for the received medial diameter of the kaolin particles at constant frequency and amplitude from 0.31 to 1.45 mm, completely correspond and confirm the data shown at Table 5.

CONCLUSION

An investigation on the influence of the working elements form to the fine selective milling – delamination of kaolin under conditions of vibration milling in the mill with horizontal working chambers was performed. The investigated light working bodies are with inconsiderable differences of the density. The size is between 2.5 to 5.0 mm. Usage of light working bodies as milling media excludes the hit impacts between the bodies and crushing of the material being milled. Under these extremely conductive conditions, the influence of the working elements form on the process of selective milling was investigated. The increasing of contact area between the working elements of the milling media, which is a direct result from the working bodies form, accelerates the process of delamination. The most appropriate form of the working bodies is lenses, followed by tablets and cylinders.

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