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Multifunctional centrifugal grinding unit

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Abstract. The article presents scientific and engineering developments of multifunctional centrifugal grinding unit in which the selective effect of grinding bodies on the crushing material is realized, depending on its physical and mechanical characteristics and various schemes for organizing the technological process

1. Introduction

At the present stage of development of the economy and production, development of energy-saving equipment and technologies for the production of highly dispersed composite mixes is becoming an actual task.

One of the ways of improving physical and mechanical properties of composite materials, including dry construction mixes, is the input of highly disperse mineral additives. In this case, the strength and deformation characteristics of the materials are not only improved, but also the possibility of directional formation of the macro- and microstructure of the composite appears [1-3].

However, as the dispersion of the finished product increases, energy costs increase sharply, while the productivity of grinding equipment decreases. One of the effective ways to reduce energy costs is the rational organization of the step-by-step process of grinding and use of energy-saving grinding units.

Centrifugal mills are a type of vibrating mills used for fine and ultrafine grinding in the production of binding building materials (cement, lime, gypsum), fine ceramics, glass, refractory and other products. A distinctive feature of centrifugal mills is the principle of providing grinding bodies motion as a result of complex plane-parallel displacement of the grinding drum [4-6].

Crushing materials passing through the grinding chambers is subjected to intensive impact of vibro-impact, abrading and crushing loads, which ensures high productivity of the installation with low energy costs.

However, an analysis of different types of vibratory mills shows that the law of motion of the grinding drum for all grinding stages is the same. The difference is only in the shape and size of grinding bodies, as well as in the length of the chambers (with a multi-chamber grinding drum) [7,8].

2. Development of construction of the grinding unit

In this regard, it is evident that one of the directions of extending the application of centrifugal mills and increasing the grinding efficiency can be a combination into single machinestages of middle, fine and superfine grinding. Moreover, this combination should be determined not only by the shape and size of grinding bodies, but also by different trajectories of the motion of the chambers to provide



appropriate modes of operation for medium grinding-intensive impact loading and partial abrasion; for fine grinding - impact load with increasing rate of abrasion; for ultrafine grinding - intensive abrasion.

The task of providing various trajectories of grinding chamber motion and reducing dynamic loads can be solved by creating a mechanical system consisting of parallel crank-slider mechanisms with coordinated motion of the input links [9,10] (Fig. 1).

Cranks 1 and 1' are connected to stand 0 by rotational kinematic pairs A and A', respectively; connecting rods 2 and 2' are connected to cranks 1 and 1' by rotational pairs B and B', with sliders 3 and 3' - rotational pairs C and C'; sliders 3 and 3' are connected with the stand with translational pairs D and D'.

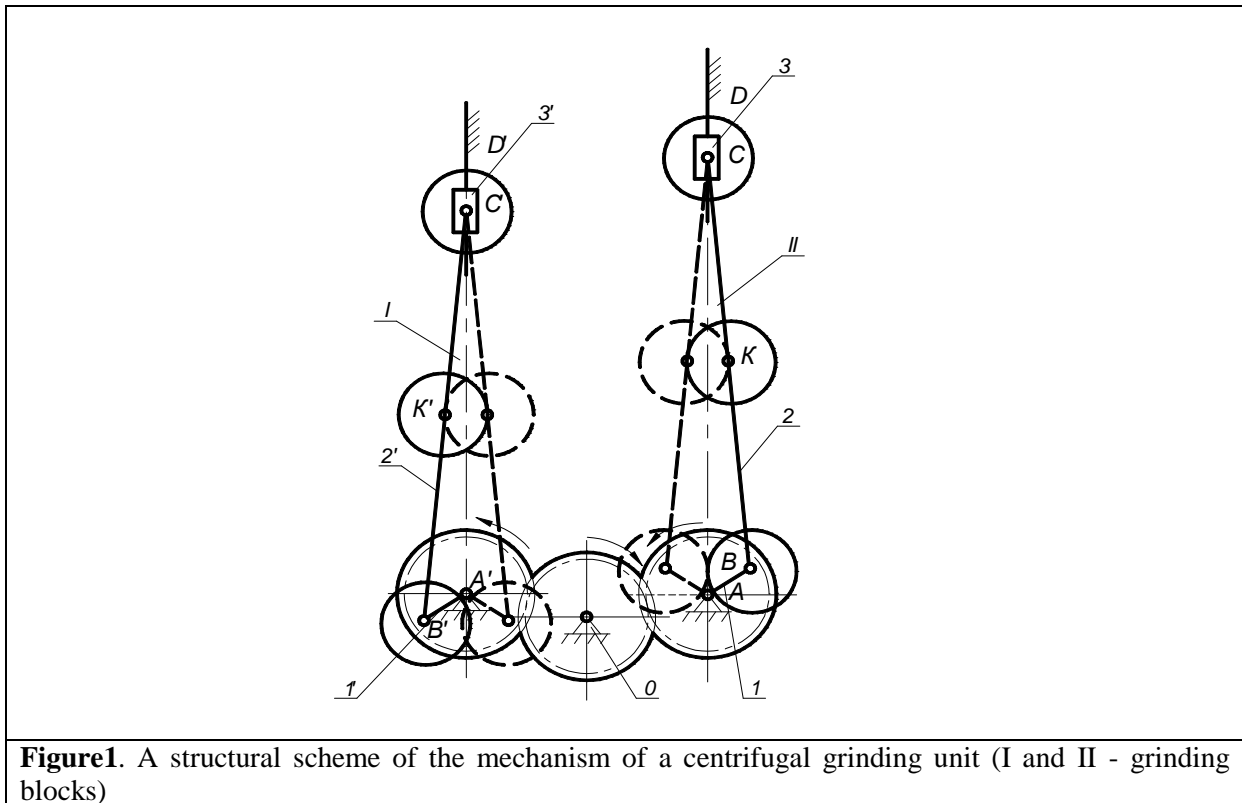


Figure1. A structural scheme of the mechanism of a centrifugal grinding unit (I and II - grinding blocks)

Points B and B' of the mechanism move along the circumference when links 1 and 1' are rotated; Points K and K' located on links 2 and 2' move along an elliptical trajectory; points C and C' perform reciprocating motion.

The centrifugal unit with parallel grinding blocks (CUwPGB) (Figure 2) consists of bed 4 comprising two pairs of vertical cylindrical guides 2 and 3 with sliders 15, 16 and support stands 21 and 22. In each pair of support stands, there are eccentric shafts 19 and 20. Each shaft is provided with adjustable counterweight 27 and 28.

The unit also has two movable frames 17 and 18 of rectangular shape made of channels, provided with brackets for articulation with eccentric shafts 19, 20 and sliders 15, 16. The frames serve as connecting rods in crank-slider mechanisms formed from a frame, eccentric crankshafts, ram-rods and sliders, which is necessary to provide the required trajectories of movement of the grinding chambers fixed to the frames. The upper 9, middle 10 and lower 11 grinding chambers are connected to each other with connecting pipes 12.

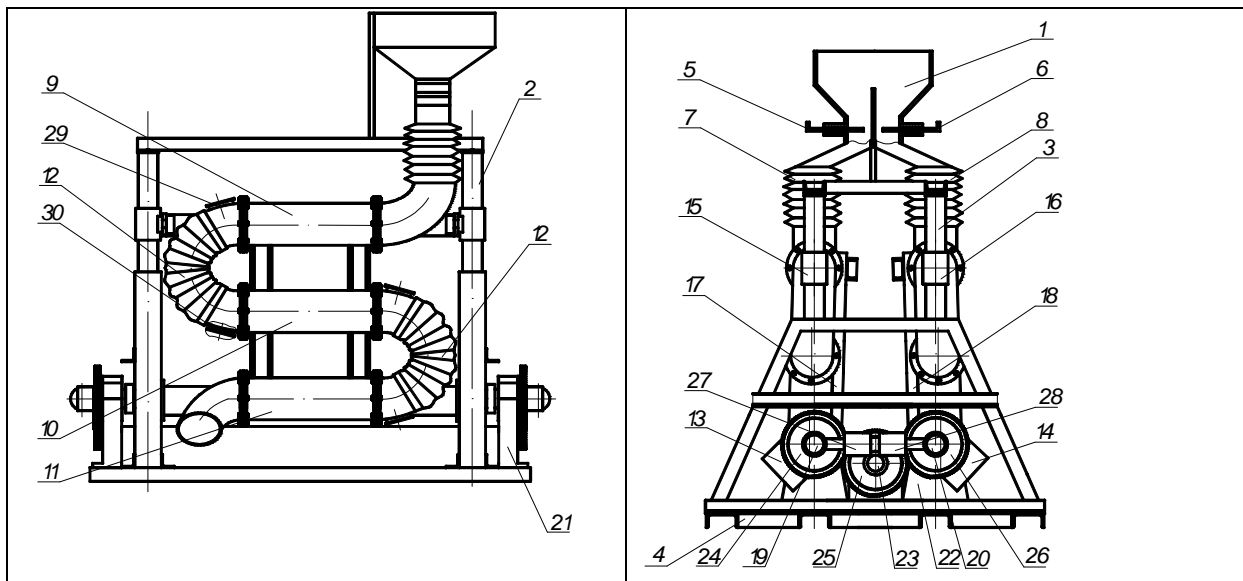


Figure 2. A scheme of the centrifugal unit with parallel grinding blocks: 1 - charging bunker; 2, 3 - cylindrical guides; 4 - bed; 5, 6 - dampers; 7, 8 - flexible connecting pipes; 9 - upper grinding chamber; 10 - medium grinding chamber; 11 - bottom grinding chamber; 12 - connecting branch pipe; 13, 14 - unloading pipes; 15, 16 - the sliders; 17, 18 - mobile frames; 19, 20 - eccentric shafts; 21, 22 - support stands; 23 - an intermediate shaft; 24, 25, 26 - gearwheels; 27, 28 - adjustable counterweights; 29 - loading window; 30 - unloading window.

The material is fed through bunker 1, equipped with horizontal shutters 5, 6 and working as a vibration bunker. With the feed pipes of the upper grinding chambers, the bunker is connected by flexible connecting pipes 7 and 8.

The principle of operation of the unit is following. The raw material through feed bunker 1 installed on cylindrical guides 2 and 3 fixed on bed 4, with equally open dampers 5 and 6, evenly flows along flexible connecting pipes 7 and 8 into the loading ports of upper grinding chambers 9. As the material moves through the upper 9, middle 10 and lower 11 grinding chambers, connected by connecting pipes 12, provide intensive impact and abrasive action of milling bodies on the material. This is due to the different trajectories of the motion of the grinding chambers and, accordingly, to the different dynamic effects of the milling bodies on the initial material, namely, the combination of shock and abrasive loads. The material unloading is carried out through discharge pipes 13 and 14, where the restrictive grating is installed.

The movement of sliders 15 and 16 of frames 17 and 18 hingedly connected to the pairs with the grinding chambers fixed to them is carried out from the rotation of respective counter-directional eccentric shafts 19 and 20 located in support stands 21 and 22.

The eccentric shafts are set at required angle α (in this case $\alpha = 180^\circ$) and their rotation is coordinated through intermediate shaft 23 and gearwheels 24, 25 and 26 mounted on the eccentric and intermediate shafts. In this case, the dynamic loads that arise when moving parts of two parallel lever mechanisms are balanced. Thus, simultaneous grinding of the material in parallel grinding blocks is ensured, which substantially increases its productivity.

Longitudinal movement of the material inside the grinding chamber is provided by the natural support of the feed material. As a grinding load, steel balls of various diameters, $d = (4 \text{ } 20) \cdot 10^{-3} \text{ m}$, are used.

In addition to the self-balancing of the mechanical system for balancing the linkage mechanisms of individual grinding blocks at the ends of the eccentric shafts, adjustable counterweights 27 and 28 are installed. Execution of counterbalances of the eccentric shafts by adjustable enables the organization of various schemes of the grinding process of the material in the grinding unit, which significantly

expands its technological capabilities, open or closed grinding cycles, when grinding materials of different grindability in separate grinding blocks, with the realization of other technological functions (classification, mixing, granulation, etc.).

To ensure the possibility of material selection at different stages of grinding, loading and unloading windows 29 and 30 are provided.

The result of the complex research is the development and creation of a new design of a centrifugal grinding unit with parallel grinding blocks (Fig. 3), the technical characteristics of which are presented in the table.



Figure 3. A general view of the centrifugal grinding unit with parallel blocks

Table 1. Technical characteristics of the grinding unit

№	Characteristics	Dimension	Designation	Value
1.	Diameter of the grinding chamber	m	D_{ext}	$150 \cdot 10^{-3}$
2.	Length of the grinding chamber	m	L_k	$500 \cdot 10^{-3}$
3.	Coefficient of loading of cameras		ψ	0,25–0,35
4.	Productivity	kg/h	Q	50–250
5.	Eccentric shaft speed	min^{-1}	n	350– 420
6.	The magnitude of the eccentricity	m	e	$(5– 25) \cdot 10^{-3}$
7.	Drive power	kW	$P_{\Sigma dr} P_{\Sigma m}$	2,2
	Dimensions:			
8.	-length	m	L	$2340 \cdot 10^{-3}$
	-width		B	$1400 \cdot 10^{-3}$
	-height		H	$1286 \cdot 10^{-3}$
9.	Weight	kg	m	950

3. The study of the structure of the modified lead-tin-base bronze. Experimental research

This aggregate allows one to grind loose materials of various strengths such as portland cement ($S_{sp} \leq 600 \text{ m}^2 / \text{kg}$), quartz rocks ($S_{sp} = 600\text{-}800 \text{ m}^2 / \text{kg}$), waste of perlite and vermiculite manufactures, cullet, etc. Using a grinding unit, modified binder, which is used in the composition of insulating foam gas-concrete, was received. The analysis showed that, in comparison with the heat-insulating foam gas-concrete on Portland cement (CEM I 42.5 N), an optimal pore structure was obtained on the

samples with the modified binder; the samples were not subjected to shrinkage deformations. Using such astringent, the setting time is significantly shortened, the water requirement is reduced and the strength characteristics are increased.

Table 2 shows the comparative characteristics of the modified binder, which confirm the conclusions drawn about the significant improvement in the technological properties of products.

Table 2. Comparative characteristics of binders

Binder	Grinding fineness		Setting time, min				Strength					
	Pass through a sieve №008, %	Surface area, m ² /kg	NG				bending (days)		compressive (days)			
			Start	End	3	28	TVO (1 day)	3	28	TVO (1 day)		
BHB-100 Melflux	97.9	623	21.1	23	76	7.3	8.6	6.5	49.4	63.8	54.9	
BHB-100 Melment	97.1	620	21.2	25	80	7.1	7.9	6.1	44.1	63.1	51.4	
TMC-100	97.3	510	25.8	30	78	6.5	8.3	6.0	38.2	57.4	48.7	
CEM I 42,5 N	91.1	310	24.7	67	167	5.3	8.3	5.7	34.2	53.5	39.4	

4. Conclusion

The use of the developed unit in various technological lines allows reducing energy costs by 15-20%, eliminating stagnant zones in the grinding load, and consequently, by including "inactive" previously grinding bodies to reduce their mass by 15-20%. The design of the unit ensures the production of an ultrafine product due to the high energy intensity of the unit because of the application of several types of mechanical action on the crushing material.

The design of a multifunctional centrifugal unit with parallel working chambers developed by us is the basis for the implementation of other technological operations in it: dry and wet grinding of materials in both open and closed grinding cycles (including periodic operation), homogenization of various composite mixes, granulation of polydisperse materials, etc.

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