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ACOUSTIC PRINCIPLES OF JET GRINDING MONITORING

An urgent problem of fine disperse powder production is an efficiency increasing of fine grinding. Parameters of grinding efficiency are specific productivity of a mill and an energy expense for unit of the formed surface or weights of a ready product.

The purpose of this article is the principle establishment of acoustic information analysis about jet grinding plant for estimation of fine grinding efficiency.

The scientific approach to the decision of this problem includes generalization of new physical laws of destruction and crushing in their connections with acoustic parameters of process. Destruction is the nonequilibrium process initiated by acoustic waves after achievement of a critical (limited) level of voltage and deformations, at crossing which the autoresonant liberation mechanism of the saved energy acts. Studying crack formation processes, destructions and grinding with full information is realized by a method of acoustic emission [1-3]. It is experimentally established, that intensive development of dispersion area at laboratory samples loading with volumetric compression is accompanied by increase of acoustic emission activity on 2...4 order. The estimation of rock ability to grinding and expected dispersion effects at destruction is possible on the basis of the following functional and correlation dependences [3]:

– connection between a relative share formed fine fractions and specific acoustic radiation $N_V = N_\Sigma / V$ (summary count N_Σ of acoustic signals (AS) for the unit of sample volume);

– connection of peak distribution of acoustic emission signals and granulometric characteristics of the grinded particles;

– connection of a specific surface and quantity of fine fractions with share of low amplitudes acoustic signals;

Check of conclusions is made at jet grinding by acoustic monitoring of a grinding zone. Thus the special attention was given to regularity of AS amplitude changes during grinding as at load particles by compression or impact the size of AS amplitude is proportional to the size of destruction [1].

On fig. 1 the generalized dependences of acoustic signal amplitude (AS) from the destruction size are shown at compression [2] as $\lg A = 1,66 \lg d - 2,98$, $R=0,88$ and during jet grinding various heterogeneous materials in a range 0,04-2 mm [4-7] as $\lg A = 1,72 \lg d - 0,97$, $R = 0,86$. The fig. 1 shows, that there is a correlation connection of AS amplitude with the destruction size at compression of laboratory samples and impacts of particles during jet grinding. Thus, change of the particle sizes

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during grinding can be controlled by AS peak distributions during acoustic monitoring of a grinding zone.

For other equal conditions the dispersion effects are intensified in "rigid", pulse modes of loading with high frequency, about own frequency of a self-oscillatory resonance of destroying particles, and high speed of dynamic deformation ($\dot{\epsilon} = V/d \cong 10^5 \text{ c}^{-1}$; where V, d are speed of impacts and particle size accordingly). Application in technology of crushing high dynamic and rating modes of processing provides significant loosening of substance structures, high specific surface $\Delta S/V$ and a new power state of new formed surface, describing superficial activity, i.e. mechanoactivation of fine products. The mechanoactivation degree of fine fractions is estimated experimentally by a potentiometric method [2-3].

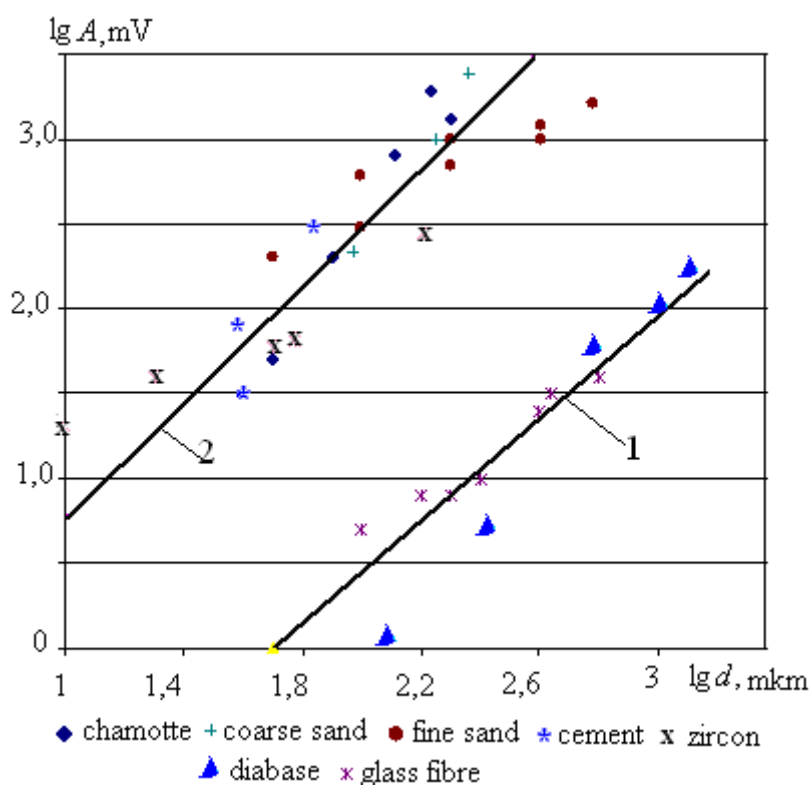


Fig. 1. Function between the AS amplitude and destruction size:
1 – compression (0,1 – 2 mm) and break (0,1-2 mm);
2 – jet grinding (0,04 – 1,1 mm)

In this work the following technique is used. AS parameters were measured in a grinding zone with the help of detector faced with the end of a brass wave guide. Other wave guide end was placed inside a mill chamber. The detector was connected with the analog-digital converter of AS and a computer. The frequency registration of AE signals was 400 kHz, an interval of measurement was 10-60 c. The minimal AS amplitude value (less than 0,02 V) was accepted as a zero readout level of amplitudes. On all modes a level of acoustic activity \dot{N} (number of AS in unit of time) and values of amplitudes (mean A_m and maximal A_{max} ones) in the grinding zone are registered.

A counterflow jet installation of a laboratory standard size by 2-30 kg/h productivity was used for grinding. The granulometric structure definition of an initial material (zircon, chamotte, slag, quartz sand, cement, coal) was carried out by a clothing analysis method, dispersion of a ready product – by a method of air permeability on V.V. Tovarova's T-3 device. At experiments the specific powder surface lies in the range of $S_c = 0,6-2,1 \text{ m}^2/\text{g}$.

Researches have shown that the mode of jets loading for other equal conditions (product dispersion, the energy carrier parameters, a classification mode, fineness and properties of loaded material) determines a mill productivity level and grinding efficiency accordingly. Grinding process proceeds with peak efficiency at the certain values of optimum concentration and speed of firm particles. In case of a deviation of these parameters from optimum values the grinding efficiency is decreased.

On fig. 2 the AS amplitude sizes kinetic records are resulted at grinding researched materials: fine-grained zircon 1 (the mean size is 0,1 mm), fine sand 2 (the sizes of particles are 0,1-0,3 mm, the mean size is 0,2 mm), coarse sand 3 (the sizes of particles are 0,2-0,5 mm, the mean size is 0,3 mm).

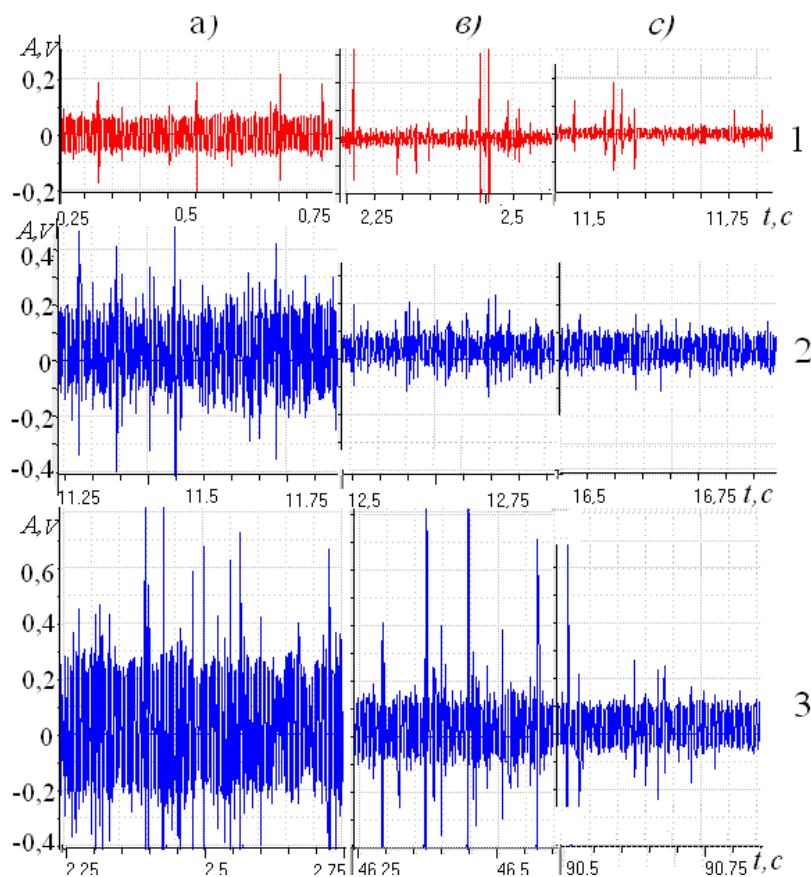


Fig. 2. Records of AS amplitude at grinding:
1 – fine-grained zircon; 2 – fine sand; 3 – coarse sand

It is possible to make a conclusion that kinetic of the jets containing finnier particles is characterized mainly small AS amplitude in comparison with grinding of coarse particles.

It was proved, that distribution of AS amplitudes at a initial loading stage can serve as the initial material fineness characteristic [4, 5]. Acoustic signals from the

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most fine firm particles at jets unloading stage characterize the sizes of circulating loading particles (it's a return of sub-standard particles from the qualifier to grinding zone).

1. The analysis of the experimental data of acoustic monitoring jet grinding installation has allowed formulating the following acoustic principles and criteria for a grinding efficiency estimation:

– criterion of grinding efficiency K_e is the ratio of a mill productivity to acoustic activity;

– criterion of circulation K_c is the ratio of the current acoustic activity to initial;

– criterion of grinding process approach to optimum jet mill operating conditions K_{opt} is a product of the maximal amplitude on signal activity of a grinding zone for the testing period;

– criterion of grinding power intensity and dispersion power intensity, which are \mathcal{E}_{gr}^N calculated as a reciprocal value to K_e and \mathcal{E}_{disp}^N calculated as a reciprocal value to product K_e and a specific surface of the grinded products;

– the parameter $N_{-\beta}$ which is carrying out the control of the crushed product dispersiveness and taking into account signal activity of corresponding small amplitude and simultaneously size of their amplitude.

2. Leading acoustic characteristics in the forecast of destruction and grinding effects are AS amplitudes and activity kinetics at a stage of over-limited deformation of rock loaded samples. The size of AS amplitude is proportional to the destruction size at compression, impacts and during grinding.

3. The basic characteristics of acoustic monitoring grinding technological process are changes in time of AS activity and amplitude. Process optimization is necessary for carrying out on the basis of three criteria control: efficiency K_e , circulation K_c and optimality K_{opt} .

Efficiency of jet grinding is estimated in [6, 7] by conditional factor $K_e = Q / \lg \dot{N}$ (g/imp), describing the ratio of a mill productivity Q to corresponding AS activity (as the logarithm of \dot{N}) in the grinding zone. In an operating conditions of a jet mill ($G = 1,6-5,5$ g/c) factor K_e changes in the range of 0,3-1,5. Connection of factor K_e with mill productivity at processing various materials (zircon, chamotte, limestone, slag, lignite and coal) is shown on fig. 3.

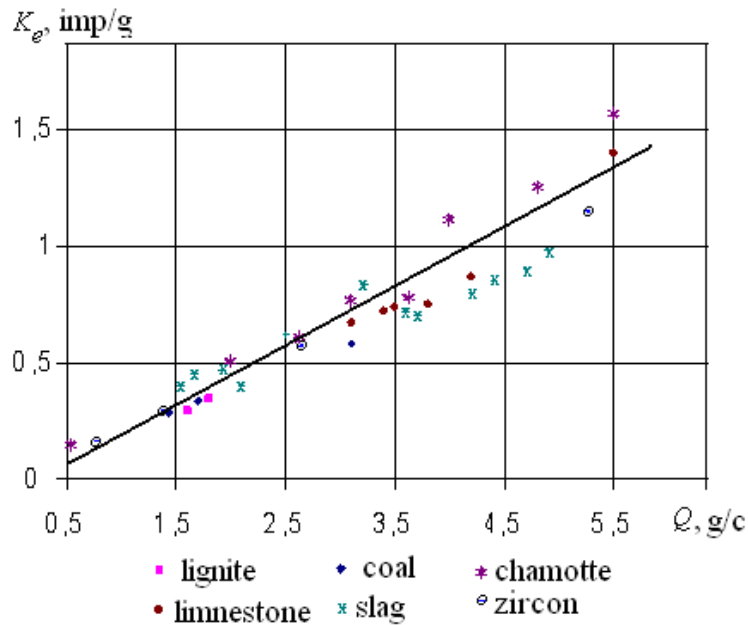


Fig. 3. Function of jet grinding efficient factor K_e from mill productivity Q

It is experimentally established, that the optimum acoustic activity level of the grinding zone with process efficiency for $K_e \geq 0,4 \text{ g/imp}$ makes a range of $\dot{N} = 10^{3,5} - 10^{5,3}$. And for all that getting of higher dispersion product is characterized by increasing of acoustic activity index $\lg \dot{N}$ level.

The important technological parameter of jet mill operating is a rate of material circulation in system, i.e. size of mill circulating loading. It's supposed, that ratio $K_c \approx N / N_{load}$ which means that ratio of acoustic signals amount during definite moment of grinding process (N) to one during initial moment of material loading in jets (N_{load}) can characterize size of acoustic circulation factor. In case of optimum mill operation with the maximal productivity this factor is close to unit; in conditions of material overflow of jets it lies in range of $K_c = 2 - 4$ and for excessive unloading jets it becomes less than unit (fig. 4 e).

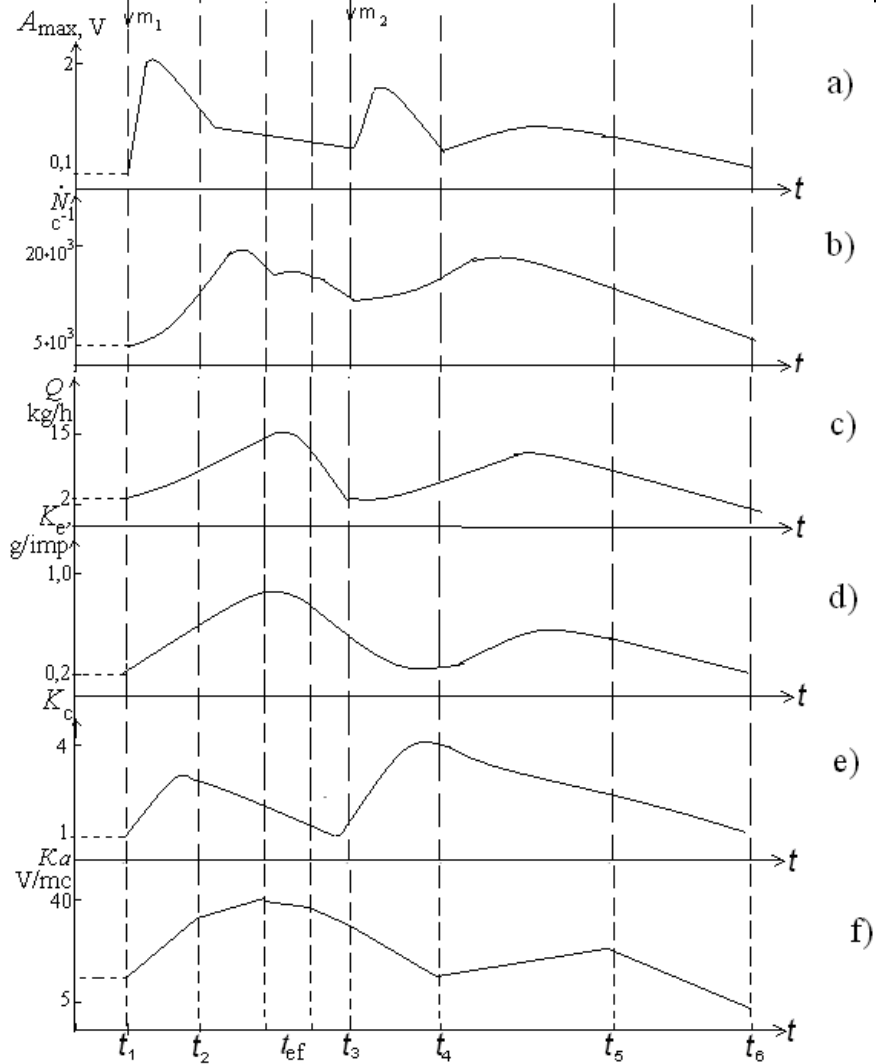


Fig. 4. The circuit of basic interrelations of acoustic and technological jet grinding parameters of slag, chamotte and quartz sand grinding

Next important factor of jet grinding is frequency of the effective particle impacts characterized by acoustic activity. In this connection for an estimation of optimum mill operation an acoustic criterion K_a is offered in this work. Its size is characterized by product of maximal amplitude A_{max} on the general amount \dot{N}_{Σ} or particular one of acoustic activity: $K_a(\dot{N}_{\Sigma}) = A_{max} \cdot \dot{N}_{\Sigma}$; $K_a(\dot{N}_{A_{max}}) = A_{max} \cdot \dot{N}_{A_{max}}$.

From physical positions of destruction the offered criterion characterizes acoustic effect of kinetic energy transformation of the particles accelerated by jets in acoustic energy of crack formation at particle destructions by impacts. Thus, the size of criterion is theoretically proportional particle destruction tension during jet grinding. Processing of experimental data has shown that it is more preferable to use the first formula because of wider change range of criterion in various grinding modes.

The analysis of the acoustic monitoring data of various materials jet grinding has allowed to designate K_a change borders (allowable and inadmissible ones from positions of process optimality) for single operating cycle of grinding (loading of one portion, grinding, jet unloading). There is good reason to believe that the admissibility

border of the criterion should correspond to transition of an optimum grinding mode to not optimum one. It helps to exclude inadmissible operating mill modes with smaller productivity.

Optimum size K_a lies in a range $(19-35) \cdot 10^3$ V/c, allowable one is $K_a^+ = (6-17) \cdot 10^3$ V/c and inadmissible one is $K_a^- = (0,4-6) \cdot 10^3$ V/c. Research has shown, that the recommended level of values K_a depends from observed ready product dispersity: for $S_c = 0,6-0,7m^2/g$ (sand, chamotte, slag) there is $K_a = (23-35) \cdot 10^3$ V/c, whereas for $S_c \approx 0,98m^2/g$ (coal) there is $K_a = (12-15) \cdot 10^3$ V/c.

The size of acoustic criterion of an grinding process optimality depends on physicommechanical properties of a crushed material, in particular, its density and particle size. So, increase of material density results in appreciable decline of grinding productivity. Accordingly the optimality criterion size decreases at grinding materials of higher density. For example, grinding of zircon and quartz sand: for zircon $K_a = 16 \cdot 10^3$ V/c, for quartz sand $K_a = 35,5 \cdot 10^3$ V/c. For an inadmissible grinding mode the criterion size is comparable for products of an identical specific surface. The criterion kinetics is kept identical for various loose materials. For a loading mode it increases typically, and for mill unloading the reduction of criterion size is compared with its value for an optimum operating conditions of grinding process (fig. 4 f).

Thus jet grinding process management should found on the information given by acoustic monitoring about a jets loading condition. Then on the basis of the received information analysis it's needed to provide duly submission of material portions for achievement of grinding process maximum efficiency [8, 9].

The conclusion

The idea of an optimization consists in constant monitoring values of acoustic signal amplitude and activity of a grinding and qualifier zone, their processing and comparison of the established criteria with control values. At a significant deviation of criteria there can be carried out additional material loading or classification mode changes. Testing this optimization for laboratory and industrial jet grinding has shown satisfactory result concurrence that has proved the revealed principles of grinding optimization.

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