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N. Pryadko, L. Muzyka, O. Pryadko

DATABASE FOR NUMERICAL SIMULATION OF GAS FLOWS IN A GAS JET GRINDER

Annotation. The process of material jet grinding is analyzed from the point of view of the granulometric material composition changing in the main elements of the grinding plant. A database of dependencies connecting the technological parameters of the process and the acoustic signal characteristics of the mill operating zones has been created. The advantage of the approach to building mathematical models and creating an automatic control system based on the developed database is the ability to accurately describe most of the factors affecting the grinding efficiency, the possibility of describing with the necessary details for specific material grinding and obtaining the required size of the ready product. The use of connections between acoustic signals and technological parameters makes it possible to take into account the patterns of changes in the material particle size distribution during the passage of the flow in the grinding plant channels and respond to changes in the product quality or the grinding mode on-line, without wasting time on transport delays.

Keywords: jet grinding, acoustic signal, database, productivity, amplitude.

Introduction. Grinding processes in ore processing technology are the most energy intensive. The costs of these processes amount to 30-50% of the cost of mining and processing. The performance of all subsequent stages of material processing, and ultimately the efficiency of the entire factory, depends on the quality of grinding.

The current level of the mathematical apparatus development, simulation methods allow us to expand our understanding of the grinding processes essence, to build more advanced mathematical models of grinding plants as a control object. These models help to solve technological problems of grinding while stabilizing the yield of the ready product of a given size class without increasing energy consumption.

Existing automatic process control systems allow solving only one of the tasks: either stabilizing the mass yield of the ready product, or reducing the energy consumption of the grinding plant. Therefore, the task of complex automation of the grinding process in order to stabilize the ready product and at the same time reduce the energy intensity of the process is relevant.

The Institute of Technical Mechanics of the NASU and SSAU has developed a method for monitoring jet grinding based on the acoustic signal analysis of operating areas. For further development of the automatic control system and mathematical modeling of the process, it is necessary to establish the main patterns, the connections technological parameters with acoustic characteristics.

Purpose of the work – development of a database for numerical simulation of gas flows in a jet mill based on the results of process acoustic monitoring.

To conduct the grinding process in the most efficient mode, it is necessary to ensure maximum productivity, the demanded product quality and minimize the specific energy costs. Studies have shown [1] that the jet mill productivity depends on the filling of the jets with material. Moreover, incomplete loading reduces productivity, and overflow of the chamber leads to an emergency and stop the mill operation. Therefore, this process must be controlled and kept at the desired level, which is proposed to be implemented based on the analysis of the acoustic signals of the operation zones of the mill: the chamber and the zone behind the classifier.

Main research. Fig. 1 shows a functional diagram of an automatic control system (ACS) for a jet mill, where the designations are used: B - a loading hopper, GCh - a grinding chamber, C - a classifier, Qc - a ready product bin with quality control, Aav - signal processing and filtering in the grinding chamber, Acav - signal processing in the zone behind the classifier.

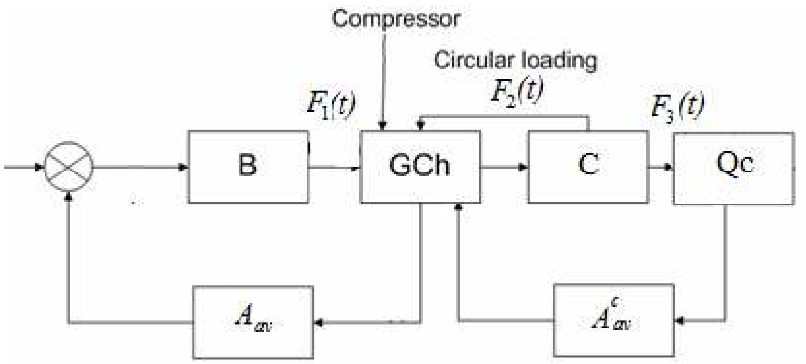

Figure 1 - Functional diagram of the ACS of the jet mill

By analyzing the characteristics of acoustic signals [2], the dependences of the magnitude of the signal amplitude on the grinding mode were established, i.e. from loading the camera. This allows you to create a base of main parameters for model-

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ing the grinding process and creating an automatic control system for the operation of the mill.

The task signal is formed on the basis of modeling mass flows, taking into account technological conditions (energy carrier parameters, classification mode), properties and fineness of the source material, as well as the results of the acoustic signal analysis from the operation zones of the grinding plant. In particular, for grinding slag, it was found that the optimal operation mode of the grinding plant was achieved when the signal level from the acoustic sensor was A = 1.2 V, for quartz - 0.9 V. The lower limit of the allowable range of signals during the implementation of grinding is A_{min}=0.003 V, with these signals (the state of an empty chamber), grinding does not occur. Based on this, a task signal is formed at the input of the ACS. Fig. 2 shows the change in the amplitude of acoustic signals in the grinding chamber during the grinding of quartz. The operating mode of grinding is observed from 40 s to 140 s, and then the chamber is slowly unloaded.

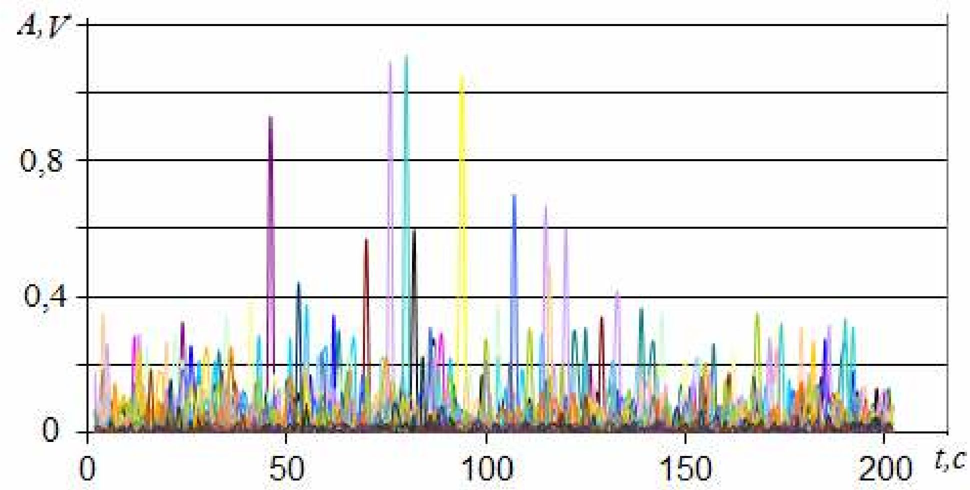

Figure 2 - Changes in the signal amplitude at the grinding process

From the standpoint of control, the most difficult process is the continuous ore grinding. The complexity of control lies in the fact that the optimal mode is in close proximity to the stability limit, which is associated with uneven circulation loads. The process of jet grinding has a number of specific features [2 - 3]. For simulation it is necessary to take into account the changes in the properties of the supplied ore, technological parameters, changes in the circulation load, and the yield of the ready product.

One of the most important factors determining the kinetics of grinding is grindability, which characterizes the propensity of the material to destruction. The strength properties of ores vary over a wide range and manifest themselves differ-

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ently under various grinding conditions, so the first block of the database consists of the characteristics of ores, their tendency to grind. The second block of data, closely related to the first, includes the technological parameters of grinding established during preliminary test grinding of a particular material, namely the pressure and temperature of the working medium (gas, air, steam), classification mode (speed of the classifier rotor), size of the initial and ready material . The functional dependence of the acoustic signals amplitude of the grinding zone on the mill productivity, the mill load factor, the speed of the classifier rotor is derived [3].

The database includes dependencies that connected material flows in the main blocks of the grinding plant and the characteristics of acoustic signals.

The equation describing the flow of the initial material from the loading hopper depends on the shape of the hopper [4], its outlet area *S* and the velocity *v(t)* of the material flow

$$F_1 = f(S, v(t)). \qquad (1)$$

The relationship between the amplitude of the acoustic signals of the grinding zone and the productivity of the jet mill is described by the equation:

$$Q(t) = 8{,}741\, A_{av}(t) + 0{,}074 \qquad (2)$$

where *Q(t)* - product output, kg/h, A_{av} – average amplitude, V.

The circulating load has a great influence on the grinding process. The experimental dependence of the value of the average circulation load C_{ch} from the degree K_{ch} chamber filling (Fig. 3).

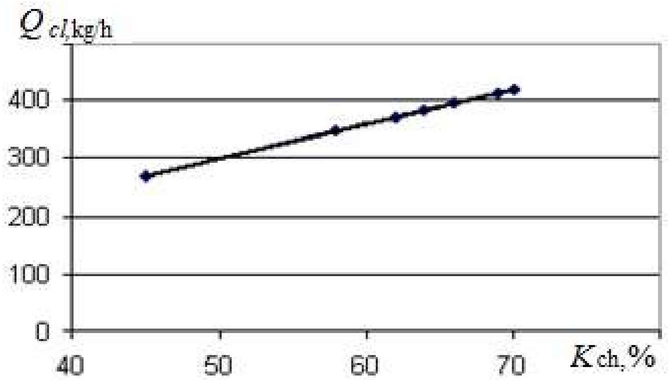

Figure 3 - Dependence of the circulating load on the grinding chamber filling

For acoustic quality control of the ready product it is necessary to know the dependence of the maximum amplitude on the particle size of the material. The general form of this dependence has been established, which has a linear character, however, the dependence coefficients are different and determined for all the study-

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ing materials. For example, for slag and quartz, the dependence has the form, respectively:

$$\overline{A} = 6{,}32\ d - 0{,}84,\ R=0{,}98; \qquad (3)$$

$$\overline{A} = 1{,}6\ d + 0{,}023,\ R=0{,}98;$$

The scheme of the developed database of the jet grinding process, which takes into account the connection of technological and acoustic parameters, is shown in fig. 4.

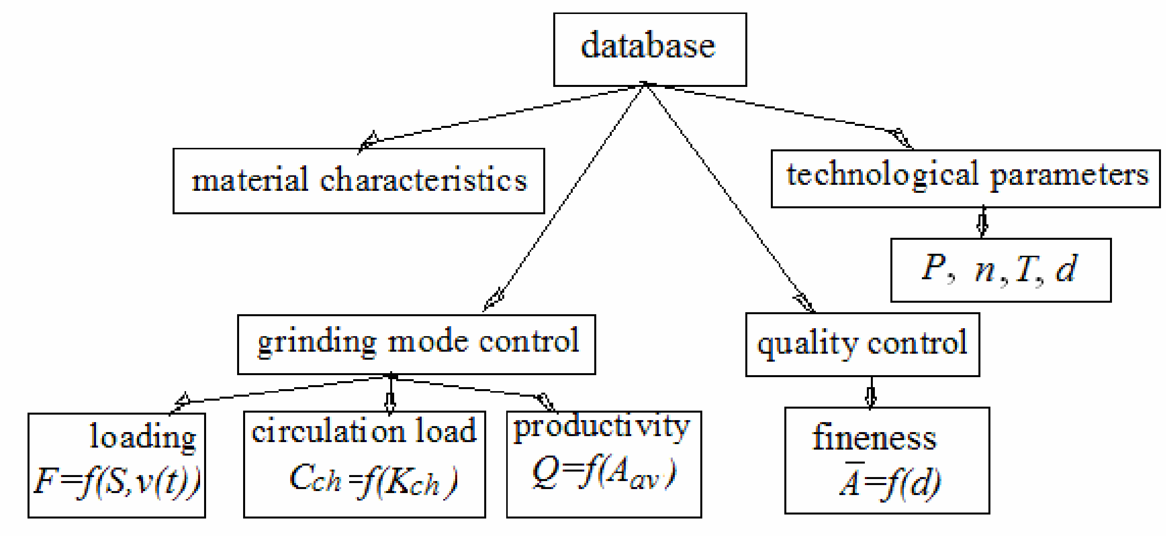

Figure 4 - Database schema

The developed database provides the creation of an automatic control system to maintain a rational grinding mode, in which the maximum productivity is realized for a given fineness class of the ready product, which leads to a reduction in the mill energy consumption. The main advantage of the approach to building mathematical models and creating an automatic control system based on the developed database is the ability to accurately describe most of the factors affecting the grinding efficiency, the possibility of describing with the necessary detail for grinding a specific material and obtaining the required size of the ready product.

Conclusions. A database of the jet grinding process based on the relationship between technological and acoustic parameters has been developed. This makes it possible to take into account the patterns of changes in the granulometric composition of the material during the passage of the flow in the channels of the grinding plant and respond to changes in the quality of the grinding product in the on-line mode, without wasting time on transport delays.

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База даних для чисельного моделювання потоків газу в газоструминній подрібнювальній установці

Процеси подрібнення в технології переробки руди є найбільш енергоємними. Витрати на ці процеси становлять 30-50% вартості видобутку та переробки. Від якості подрібнення залежить продуктивність усіх наступних етапів обробки матеріалу, а в кінцевому підсумку і ефективність роботи всього заводу. Для максимально ефективного проведення процесу подрібнення необхідно забезпечити максимальну продуктивність, необхідну якість продукції та мінімізувати питомі енергетичні витрати. Дослідження показали, що продуктивність струминного млина залежить від заповнення струменів матеріалом. Тому цей процес необхідно контролювати і підтримувати на необхідному рівні.

В роботі проаналізовано процес струминного подрібнення матеріалу з точки зору зміни гранулометричного складу матеріалу в основних елементах подрібнювальної установки. Для акустичного контролю якості готового виробу необхідно знати залежність максимальної амплітуди від розміру частинок матеріалу. Дослідженнями встановлено загальний вигляд цієї залежності, що має лінійний характер, однак коефіцієнти залежності різні і визначені для всіх

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досліджуваних матеріалів. На основі досліджень створено базу даних залежностей, що зв'язують технологічні параметри процесу та характеристики акустичного сигналу робочих зон млина. Перевагою підходу до побудови математичних моделей та створення системи автоматичного керування на основі розробленої бази даних є можливість точного опису більшості факторів, що впливають на ефективність подрібнення, можливість опису з необхідними деталями для подрібнення конкретного матеріалу та отримання готового матеріалу необхідного розміру. Використання зв'язків між акустичними сигналами та технологічними параметрами дає можливість враховувати закономірності зміни гранулометричного складу матеріалу при проходженні потоку в каналах подрібнювальної установки та реагувати на зміну якості продукції або режиму подрібнення on-line, не витрачаючи час на транспортні затримки.

Прядко Наталія Сергіївна – провідний науковий співробітник Інституту технічної механіки НАН України і ДКА України, д.т.н., с.н.с.

Музика Лев Володимирович –науковий співробітник Інституту технічної механіки НАН України і ДКА України, к.т.н.

Прядко Олександр Валерійович – інженер 1 категорії Інституту технічної механіки НАН України і ДКА України.

Pryadko Nataliya Sergiivna – Leading Researcher, Institute of Technical Mechanics of the National Academy of Sciences of Ukraine and State Space Agency of Ukraine, Doctor of Technical Sciences.

Muzyka Lev Volodimirovich –Researcher, Institute of Technical Mechanics of the National Academy of Sciences of Ukraine and State Space Agency of Ukraine, Candidate of Technical Sciences.

Pryadko Oleksandr Valeriiovych - 1st category engineer of Institute of Technical Mechanics of the National Academy of Sciences of Ukraine and State Space Agency of Ukraine.