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SYSTEMS THINKING IN JAW CRUSHER ANALYSIS

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Abstract. *It provides information on the method of system thinking, where the analysis of the crusher for grinding solid materials shows four hierarchical structure of the object - the jaw crusher. For a particle - a piece of material at the lowest hierarchical level, the influence of the infrastructure of the material and object on the stochastic grinding process is considered, which is characterized by probabilistic mathematical models. Moving to higher hierarchical levels, computer models of deterministic processes in the material and the crusher are given. It is preliminary shown that increasing the grinding ratio increases the efficiency of the material crushing plant.*

Key words: *jaw crusher, a particle, computer models, grinding ratio*

Introduction

Shredding processes are widely used in human production activities and in the national economy. Currently, more than two billion tons of minerals are crushed and ground in the world every year, and by the number of employed people, the industries using crushing and grinding of minerals are on the second place, yielding only to agriculture.

The shredding process is accompanied by a reduction in particle size and a multiple increase in the surface of the material being shredded, which makes it possible to dramatically improve the quality of materials and products obtained from the shredded material. [1]

In industry, high steppes are required in most cases. Sometimes the sizes of pieces of an initial material reach *1500 mm* whereas in technological processes the material the sizes of which particles make fractions of micron is sometimes used. These crushing degrees are achieved when the product is shredded in several stages and it is not possible to obtain the product of a given final fineness in one go (on one machine). Grinding machines are conventionally divided into chippers for large, medium and fine crushing and mills for fine and ultrafine grinding. [1-4]

Crushing of solid materials and crushers[1,3]

The main machines are divided into the following types [1,3]: jaw crushers, gyratory (cone) crushers, hammer crushers, grinders, roller and ball mills. All crushing machines have common requirements: removal of the shredded material from the working area, minimization of dust generation, continuous and automatic discharge, possibility of regulating the degree of shredding, uniformity of parts of the shredded material, low energy consumption per unit of production.

The degree of crushing depends [2] on the design of the crushing machine, the physical and mechanical properties of the rock being processed and the absolute lump size. As the crushing rate increases, the capacity of the crushing machines decreases and energy consumption increases. For each crushing machine design, the optimum crushing degree is achieved at the maximum output. When a greater degree of crushing is required, crushing is carried out in several stages, i.e. a number of crushing machines are installed in series, with different designs and specifications.

Construction of the Jaw Crusher [5,6]

Jaw crushers are used for large and medium crushing of various materials in many industries. They are capable of destroying non-metallic materials of almost all varieties. Enterprises produce jaw crushers in various sizes: [3,4]. Classification of jaw crushers is carried out on character of movement of the moving jaw which is the basic working body of a crusher. This determines the most important technical and operational parameters of the crushers. A distinction is made between crushers with simple and complex jaw movement.

The main parameter of jaw crushers is the size of the receiving hole of the crushing chamber formed by mobile and fixed jaws [3, 4]. The unit for large crushing of material with simple cheek movement is shown in Fig. 1. The sliding jaw 3, axis 4 of which is mounted in slide bearings mounted on the side walls of bed 7, receives swinging movements through spacer plates 10 and 11 from the connecting rod 6, suspended on the eccentric part of shaft 5, driven in rotation from the electric motor through a V-belt transmission. The working surfaces of the jaws are lined with replaceable crushing plates 12 and 13, made of wear-resistant steel St110G13L. The side walls of the crushing chamber are also lined with replaceable plates 2. The working surface of the crushing plate is usually made of corrugated and less often (for primary crushing) smooth. The longitudinal profile of the boards determines the gripping conditions of the lumps and the particle size distribution of the material. During operation, it is necessary to adjust the width of the crushing chamber outlet slot. In large crushers, for this purpose, gaskets of different thicknesses are installed between stop 9 and the rear wall of the crushing bed. The guaranteed closing of the links of the drive mechanism of the moving jaw is carried out by a spring 7 and a rod 8 [6].

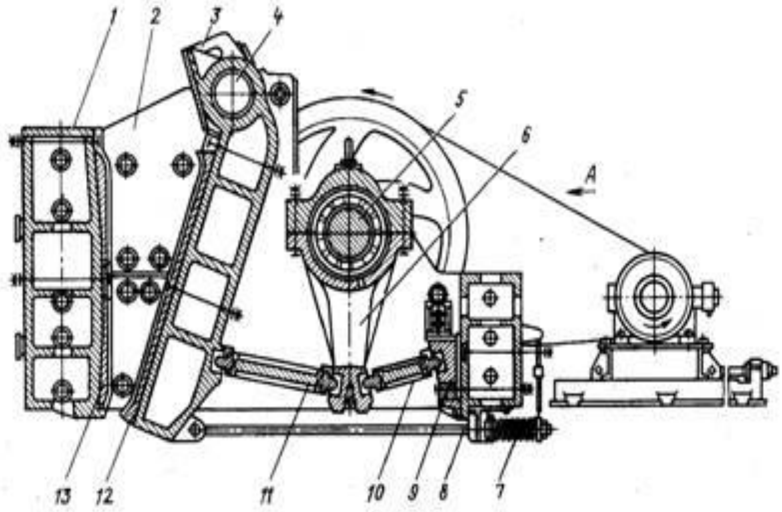


Fig. 1 Construction of the jaw crusher with simple jaw movement

The questions of development and concretization of concepts of system thinking, system approach, system analysis and multistage analysis and their sequence and interrelation are defined.

Systemic thinking and crusher analysis.

The method of system thinking that we offer [7-9], developing the existing methods [10-15], allows analyzing the system without any difficulties. According to the proposed method, initially determined indicators - input, output parameters of the object, in this case the crusher, consisting of the system (the body of the crusher) and the process occurring in the system. Then, the system (element) under consideration is divided into constituent elements, parameters for each selected element and process in the element are specified and so on. It is carried out according to the degree of necessity and possibility of research for decision making. In general, the system analysis and synthesis of the crusher is carried out in the following sequence:

First stage (system thinking and analysis)

- the crusher object is pre-selected and studied in the selected crusher (object consisting of elements) - systems and processes. The requirements are formed;
- In each subsystem (crusher element) there are many processes. From set of processes those processes which are necessary for correct decision-making of the given problem are chosen;

- The input and output parameters of the subproject, both the system and the process under study, are determined. Determining the interrelation of parameters, in most cases, requires to delve into the system under study, then,
- the elements - subsystems of the subobject - are determined. The considered system (element) of a subobject is divided into making elements, process and its parameters for each chosen element are specified, etc. Deepening into the system - the division of the element (system) into subsequent systems is not limited. It is carried out according to the degree of necessity and possibility of research to make the best decision.

Second stage (Determining the relationship of parameters)

Here by the type of object - crusher and the content of the task can be used a large arsenal of methods of the industry in which the study is conducted. Determination of the quantitative ratio of parameters requires the use of mathematical expressions, which leads to mathematical or computer models.

The third stage (Choice of the optimal solution)

The crusher requirements are specified and defined here based on systematic thinking and analysis. The optimization criteria are selected for both the primary object and the subobjects of each hierarchical step. The way to find the optimal solution is chosen. The optimal solution is determined.

A multi-step analysis of the system is as follows:

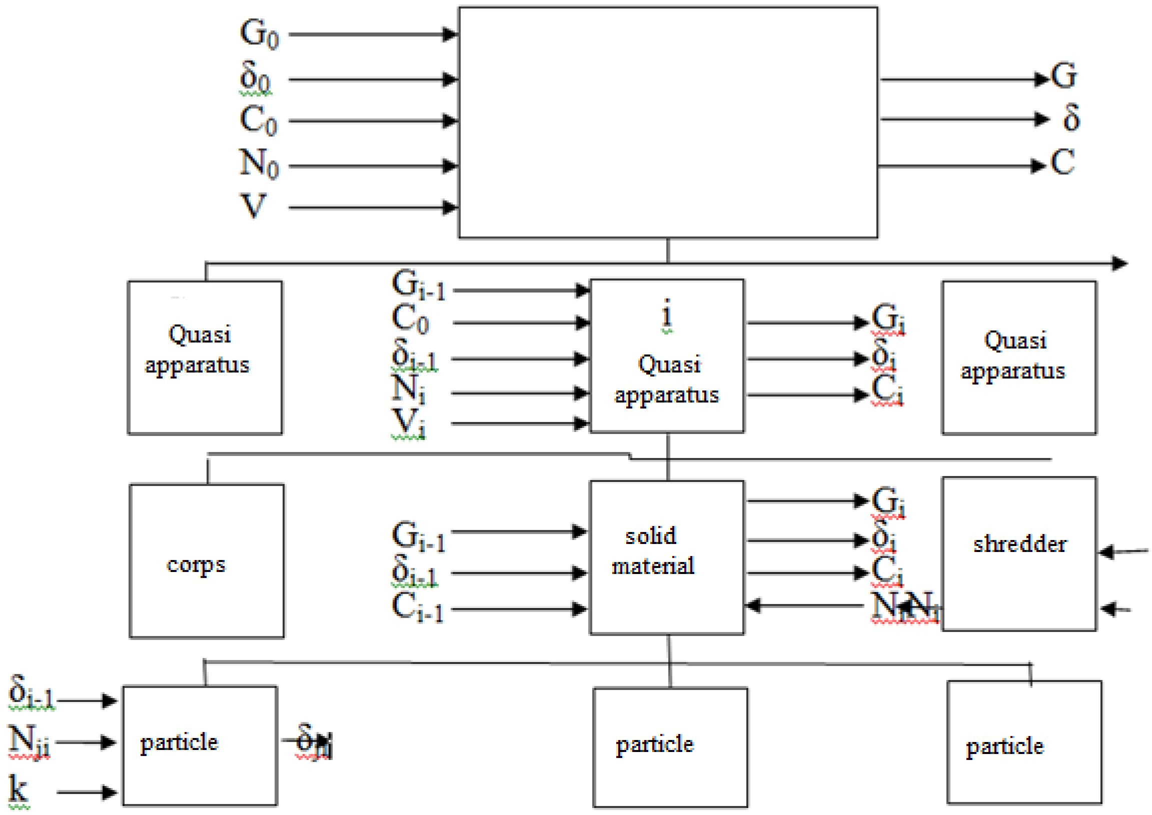
1. The crusher under study is taken as a primary large object (first hierarchical level). A cumulative process takes place in it. Studying the system and the process under study in it, the input and output parameters are determined for both the system and the process under study. Determining the relationship between output and input parameters allows for more accurate analysis and better decision making. However, making a decision at a limited level of research without moving deep or up the system is sometimes insufficient. It is possible to go up or down deep in the system. Let's consider the case of moving into the depth of the system, then, step by step, we can go deep into the selected object.

2. The main crushing system is broken down into elements. Each of its elements is called a second hierarchical level system. In each element, a second hierarchical level system, a specific process is considered and the system parameters are defined. We have developed the definition of the importance of each subsystem on a common background, based on static and dynamic coefficients of information movement [6].

3. The second hierarchical level system is also broken down into constituent elements. Each element of the second level system is called a third hierarchical level system. Each element of the third hierarchical level system has its own specific processes that define the parameters of the system of this hierarchical level.

4. Further on, the division into subsystems continues up to a possible deep level.

Let's consider the system thinking on the analysis of the crusher grinding object, Fig. 2. The main object is considered as a multistage multi-element system. Here the material part of the object is a body and another part of the object is a process taking place in this body.



The object being investigated - the jaw crusher is taken as a primary large technological system (first hierarchical level). In it the cumulative process takes place. Indicators are determined - input, output parameters of the object - system and the process occurring in the system.

Determining the relationship between output and input parameters allows for more accurate analysis and better decision making. For the examined object of the cone crusher the input parameters will be G_0 - material consumption, δ_0 - diameter of the input particle of material, C_0 - concentration of the crushed material, V - volume or index of geometric dimensions of the device, N - energy supplied to the device.

Output parameters of the apparatus - the crusher is G-flow of the crushed material, δ-sizes of the crushed material particles and C - concentration of the crushed substances corresponding to the requirements of the grinding.

In the second stage, the main unit is divided into quasi-elements. Each of its elements is called the second hierarchical level system. In each element - the system of the second hierarchical level, a specific process is considered, and the parameters of the quasi-apparatus are defined. For each quasi-apparatus there are input and output parameters and corresponding parts of the apparatus.

Means to each quasi device there corresponds a part of the device case a part of an element of crushing, in this case the cheek is them. For the selected i of that quasi-apparatus the input parameters are G_0 - material consumption, C_{i-1}- concentration, δ_i - particle size, N_i - energy supplied to that quasi-apparatus and V_i - quasi-apparatus volume.

The quasi-apparatus outputs material with its G_{iJ} flow, C_i concentration, crushed material, with its lump size δ_i.

The system of hierarchical level i of that quasi-apparatus is also broken down into constituent elements. In this case, you can see that the body of the device, shredder - cheek and solid material, they make up the systems with their input and output parameters. The main part of this hierarchical step is the hard material, which is crushed into separate pieces. The input parameter of solid material is its flow into the quasi object, the size of the material, the dispersibility of dimensions, they will vary within certain limits, and the concentration among the dispersibility of the size of the cheek, the energy supplied through the cheeks. From this zone the output parameters are the flow rate of solid material, size and dispersion of the crushed material, the concentration of the crushed material. In the hard material, the energy supplied by the cheeks is used to grind the material.

Then the hard material is also divided into elements, and these elements are particles of material, sometimes they can be called pieces of crushing. On this quasi-project of the hierarchical level the input parameters for the particles are its conditional diameter, the mass of the piece, the energy acting through the cheeks, and the coefficients, in particular, characterizing the hardness of this particle of material. The output parameters are the mass and size of the shredded material, the correspondence of the shredded material to the required size. The above analysis allows us to move on to the question of mathematical modeling.

About statement of mathematical modeling of crushing process. The sequence of modeling analyses and search for optimal solutions can take place in the following order of system thinking and analysis.

1. We are referring to a thorough study of the object of study - the crusher, presenting it as a system, as well as the processes occurring in the system (in the body of the crusher).
2. Determining the input, output, system and process parameters completes the preliminary analysis.
3. Subsequently, the relationship of the parameters is defined. In most cases, the definition of the relationship between the output and input parameters is a more complete analysis of the object of study.

In this way, the analysis and modelling of the crushing process of solid material can be started with the particle level - the shredded lump, which is the deep level at the particle level of the crushing of the lump, for this purpose energy is supplied, i.e., the cheek squeezes it, and under the impact of the particle-bite of the material is crushed. The degree of crushing depends on the particle size and the grinding ratio.

Recently, researchers [14] have been assessing the grain (lumpy) composition through the coefficients of the Rosin-Rambler equation (grain distribution parameters), in the form:

$R = lOOe^{-(x/Xi)\ \wedge n}$,

R is the total class output, larger x, %;

e - the basis of the natural logarithm;

X - particle diameter, µm;

Xi - characteristic particle size (particle size above which the material contains);

n - coefficient of uniformity of the dummy composition characterizing particle size scattering.

Transition to change of properties of the crusher is connected with change of lump composition of the received material. Or the selective function P(δ) determines the probability of destruction of particles of size δ and is numerically equal to the mass fraction of destroyed particles of class δ. A similar dependence has been proposed to describe the selective function P(δ) [15].

The stochastic process of grinding at the level of pieces of material will be characterized by probabilistic mathematical models. At small dispersion of lump sizes from the average value it will be possible to pass to deterministic mathematical models at the level of quasi-hardware grinding process using computer model [16].

Analyzing incoming solid material and from material balance it is possible to make mathematical model for process of crushing of a solid particle, and then we already pass to drawing up the equation of process i of that quasi-apparatus, uniting mathematical models i of that quasi-apparatus and mathematical models of process of all system (crusher), the big object are made.

On the basis of the received mathematical model, for continuous process, computer models on the basis of works [6-9] with use of MATLAB software package were received [16]. Using the analysis of solid material crushing process and mathematical description of single cell continuous process, the single cell computer model using MATLAB software package was obtained (Fig.1). The following input parameters are entered into the computer model input unit: total material mass m_0, grinding factor k and initial concentration of the ungrinded component, as part of the total material mixture x_0. The output parameter is the change in concentration of the crushed component in the total material mixture.

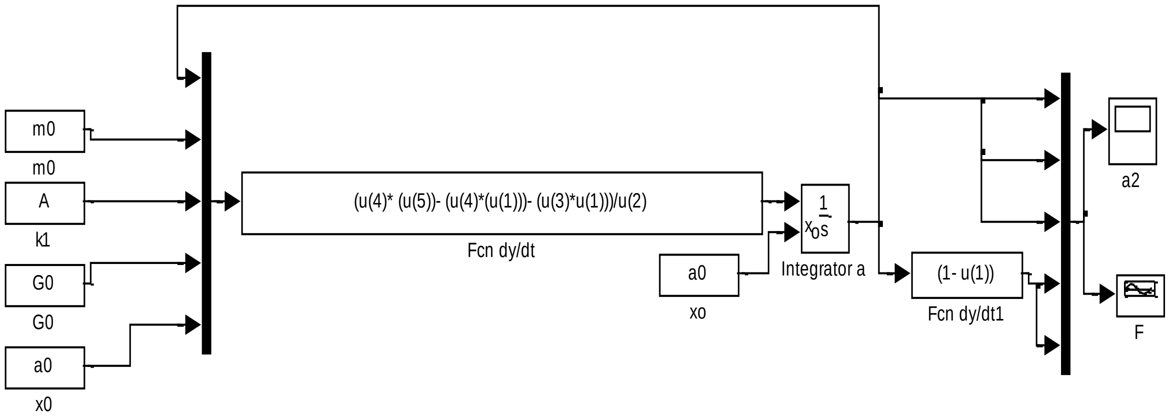


Fig.1. Computer model of the material grinding process for selected (in this case the first) quasi-hardware cone crushing.

The computer model consists of the following blocks:

The computer model, as shown in Figure 1, consists of the following blocks:

Input blocks 1.2, 3, 4;

Signal collection units 5;

Combination units 6.8;

4. Integrator 7;

5. Blocks of signal acquisition and time charts 9, 10, 11.

In the input unit of single cell computer models input parameters are entered, presenting on MATLAB computer program the initial conditions for the process of crushing the material in the cone crusher: Initial consumption of the mixture of crushed material G=500/3600=0.14 kg/s, the concentration of not crushed component x_{10} =1, the total mass of the material in the quasi-apparatus m=23 kg. The output parameter is the concentration of not shredded component in the total material mixture.

One quasi-hardware computer model works as follows: after entering the input parameters in the input blocks 1,2,3,4 signals are collected in the signal acquisition unit 5 and further the calculation of parameter values in blocks 6,8 and in the integrator 7 through the signal acquisition unit 9. The calculation results are displayed as time graphs. In time schedule 9 the results of the mass change of the crushed component with respect to the heavy substance are obtained. The obtained results are fed back into the signal acquisition unit 5 and calculated in the calculation unit. The results of the calculation can be seen on the digital screen and as time graphs in units 10 and 11.

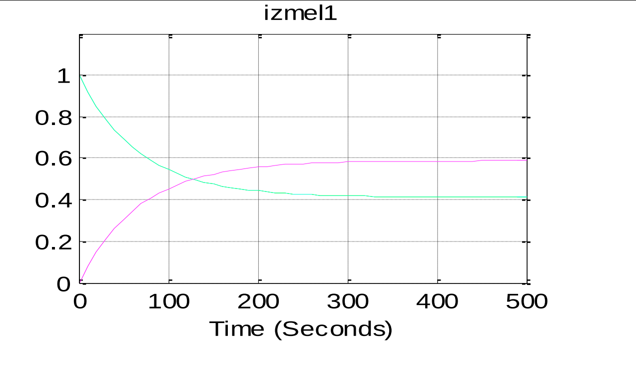


Fig.2. Plots of change in concentration of not ground and ground material relative to total mass of the substance at, k = 0.2

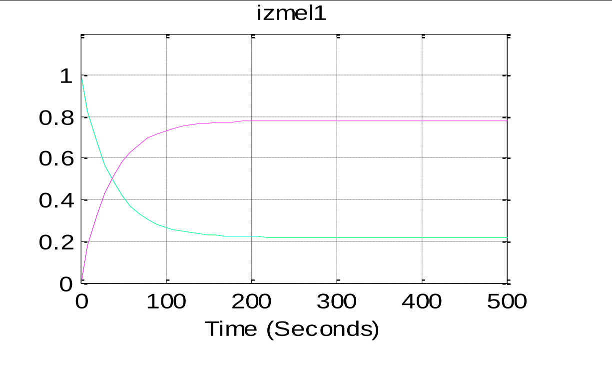


Fig.2. Plots of change in concentration of not ground and ground material relative to total mass of the substance, at k = 0.5

The time graph shows graphs of changes in concentration of not ground and ground component relative to total mass of substance.

As can be seen, depending on the coefficient of material properties and installation, the degree of material shredding increases. For example, at the shredding ratio k = 0.2 the concentration of the shredded component reaches 60%, at the shredding ratio k = 0.5 the concentration of the shredded component reaches 79%, at the shredding ratio k = 1 the concentration of the shredded component reaches 88%. Thus, an increase in the shredding ratio significantly increases the efficiency of the material shredding unit.

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