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Control system of roll crushes in emergency situations

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Abstract. The system of emergency control of a roll crusher is developed, which allows the hardness of the crushed material to be evaluated indirectly estimating the current strength of the unit, or directly by swing of the deflecting the crusher jaw, and the pieces with the increased hardness to be recrushed, increasing compression, reducing the motor rotation frequency. This system reduces the number of emergencies and provides less downtime for equipment in the event of an accident than crushers using conventional safety elements: toggle plates and restraining spring or hydraulic fuses. Besides, this system is extensible, i.e. it does not interfere with the inclusion of additional devices (for example, mechanical breakers such as toggle plates), sensors (for example, angle protractor to improve the accuracy of measurements). With the combined use of direct and indirect evaluation of the crusher condition the accuracy and efficiency of the crusher control increases improving the reliability of a crushing unit as a whole.

1. Introduction

Many industrial manufactures, including mining, process and use large quantities of bulk solid materials of various coarseness classes. In most cases the required coarseness is achieved by grinding larger pieces on crushers, including single-roll ones. Improvement of crushers productivity operating within the crushing and screening complexes is an important task.

The materials provided for crushing, as a rule, differ in significant variations in physical and mechanical properties, thus, the main requirement for controlling the crushing process is to obtain the specified size of the final product, to maximize the efficiency of electricity supplied to the crushers. Since the crushing and screening process is continuous, stopping of one element inevitably leads to a shutdown of the whole complex.

The accident-caused failure of a single-roll crusher can be caused by the non-crushable body in the crushing chamber. To prevent such accidents that lead to a long stop of crushers various safety devices are used. It is possible to use toggle plates consisting of two parts, which are interconnected by bolts.

Bolts are the main element of a safety device, as they are cut off when the non-crushable object is fed into the crushing chamber. However, this technical solution is not reliable enough, as the toggle plates often break without visible overloads, and not only when non-crushable bodies get into the crushing chamber. The imperfection of toggle plates caused the development of safety devices of non-destructive type [1], for example, spring or hydraulic ones.

For example, there is a crusher [2] in which the movable jaw is supported by the lower part on the toggle plate, connected with the back stop (movable traverse) interacting with the wedge-like locking mechanism. A hydraulic cylinder serves for a prompt change change in the size of the output gap. The disadvantage of the crusher is the complexity of the mechanism design providing fixation of the jaw

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and a large number of technological operations necessary to changing the dimensions of the output gap.

There is also a crusher [3] which includes a hydraulic system that is equipped with a block of hydraulic cylinders connected by a piston cavity with a throttle, hydraulic lock, a pressure switch and hydraulic relief valves, and also contains a control line connected via a time relay to a crusher drive and a hopper. Such safety devices are used in most crushing machines on the market [4, 5].

The functioning of the protective device on the jaw allows the dimensions of the crushing machine to be reduced and the size of the output gap to be changed; also the block of hydraulic cylinders is more reliable than a single hydraulic cylinder. However, this arrangement worsens the repairability of the crusher due to the position of the control unit above the hydraulic cylinders, and the use of the protective device with a hydraulic cylinder block significantly increases the cost of the crushing machine.

In addition, the block of hydraulic cylinders itself can cause an emergency situation, in the event that the hydraulic cylinders do not work simultaneously (this can lead to a skewing of the toggle plate and its failure even under small loads on the movable jaw).

Also to improve the reliability of crushers, control systems are used based on the analysis of main parameters of a electric drive [6], which are effective for determining the parameters of the state of an electric motor, but do not allow the overall state of the unit to be evaluated, including its mechanical parts.

2. Results of research and discussion

A system of combined automatic control over parameters of the crusher state alongside with the system of parametric control of electric drive has been developed to solve the problem of increasing the reliability and speed of crushers control.

The controlled object under consideration (in this case a roll crusher) is described by the following set of characteristics:

- current frequency;
- the state of the jaw breaker from the restraining spring;
- hardness of the crushing material;
- current strength;
- inclination angle of a jaw.

After describing the characteristics of the object it is necessary to select a control system in which the object will be operated.

The most reliable and easy in use object control system is a feedback system [7], that is, a closed system in which the controlled object acts on the control device, and the control device depending on the deviation of the controlled quantity from the prescribed value, in turn, acts on the governing body and, therefore, on the object so that the regime of the latter satisfies certain conditions. The presence of feedback underlies operation of any automated system working on the principle of inclination.

In a system with feedback the parameters are distributed as follows: input parameters (operated by the technological process) and output parameters (generated in the technological process). Input parameters are divided into input controlled ones, i.e. their values are currently known, and the input uncontrolled parameters with values that at the current moment cannot be directly estimated.

After describing the selected control system, it is necessary to perform decomposition, i.e. distribute the object characteristics dividing them into groups according to the structure of the chosen control system.

Based on the theory of automatic control and system analysis [7], the parameters characterizing the crusher can be distributed as follows:

- input parameters

input controlled (U): supply voltage, current frequency;

input disturbance (W): size of a piece, material hardness;

- output parameters (Y)

- current strength;
- size of the output piece;

In accordance with the above structure of parameters the crusher can be represented in the form of a control circuit with feedback as follows (figure 1):

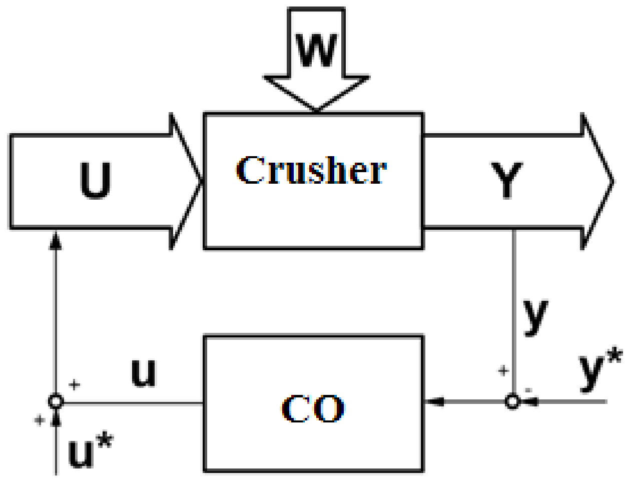

Figure 1. Crusher control ciruit.U – vector of input controlled values; W – vector of input disturbance values; Y – vector of output values; u – generated input value; u* - base values of the generated input value; y – measured output values; y* – basic values of output values; CO – controlling object.

The principle of operation of this circuit is as follows. The vector of input values U enters the crusher a which is known and is controlled. In this case, the frequency and voltage are included into this vector. Also a vector of disturbance parameters W enters into the crusher, which displays the properties of the crushed material that are not predetermined in advance – the size of the the fed pieces and its hardness. As a result of the materials processing by the crushing machine the input vectors U and W are converted into the output vector Y consisting of the current and the size of the fed piece. For direct measurement only the current signal is available which is the measured value y. This value is compared with the baseline y*, determined by the technologist or operator on the basis of the technology, personal experience, etc. If a significant (for example, above 5% of the base) deviation of the measured value is detected, the controlling object generates a change in the input value u (in this case the current frequency) or, in the event of a pre-emergency situation activates the crusher safety device.

The emergency control system for the crusher (figure 2) operates as follows. From the receiving hopper through the feeder *2*, the raw material enters the crusher. In the crusher the material is crushed by roller compression *13* and jaw *4*. The processed material along the guide *8* enters the conveyor 10 for further transportation.

If a material falls into the crusher with a strength exceeding the calculated one, the force developed by the roll increases.

The increase in force is characterized by an increase in the current in the roll drive *14*. The evaluation of the current signal is made according to the formula of the consumed electric power (P_{el}). Due to the rigid kinematic connection between these components the mechanical power (P_{mech}) produced by the electric motor can be considered equal to the power consumed by the crusher.

$$3 \cdot U_f \cdot I_f \cdot \cos\varphi = M \cdot \omega. \qquad (1)$$

It is known [8] that the rotational speed of the motor shaft (ω) is proportional to the frequency of the electric current. When using frequency converters, the frequency of the current is a known quantity, thus, the rotational speed of the shaft is also known.

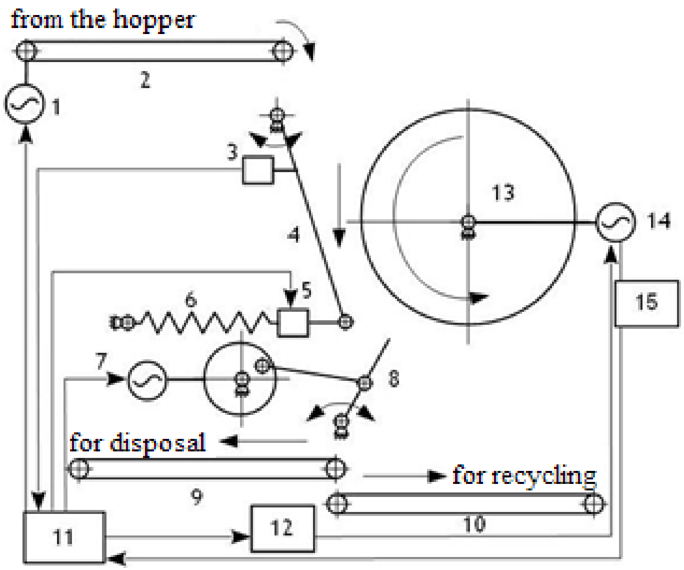

Figure 2. Schematic diagram of a crushing plant with a joint assessment of the state. 1 – feeder drive; 2 – feeder; 3 – sensor of the jaw position; 4 – jaw; 5 – fixing device; 6 – safety device; 7 – drive of the guide; 8 – the guide; 9 – conveyor "for disposal"; 10 – conveyor "for processing"; 11 – controller; 12 – frequency converter; 13 – roll; 14 – crusher drive; 15 – current sensor.

Assuming that the supply-line voltage remains unchanged and the angular velocity is known, the current of the motor load is functionally dependent on the torque on the shaft [9]:

$$I_f = f(M). \tag{2}$$

If the material is not crushed under the action of this force it is transmitted to the jaw. Due to the presence of the safety device 6 the jaw starts to deviate from the initial position which is fixed by the position sensor 3 [10].

The signal about the deviation is sent to the controller 11 which with the frequency converter *12* changes the current frequency at the drive of the crusher *14* to increase the crushing force, while stopping the drive of the feeder *1*. In this case it is possible to crash the material with increased hardness exceeding the calculated one.

In the event that the strength of the crushed material is greater than the values of the increased hardness, there is jamming, that is, a piece of material is fixed in the crusher fracture zone. When the piece is jammed the jaw deviates from its original position. When the inclination of the jaw is fixed the controller starts the drive the guide *8*. After changing the position of the guide *8* a signal is sent to the fixing device *5* (figure 3) which results in a weakening of the piece clamping, and it falls on the conveyor to the disposal *9*.

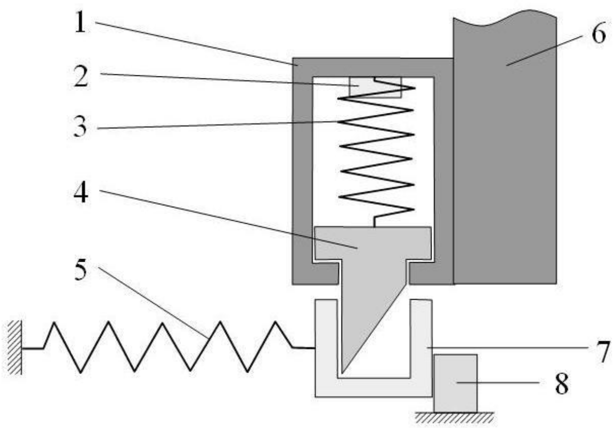

Figure 3. Schematic diagram of the fixing device. 1 – body of the fixing device; 2 – electromagnet; 3 – spring; 4 – retainer; 5 – spring; 6 – jaw; 7 – groove; 8 – stop.

The fixing device works as follows (figure 3): when the non-crushed body gets into the fracture zone, the jaw deviates from its original position, which is fixed by the angle sensor directing the signal to the controller, which generates a signal aimed at turning on the electromagnet.

When a signal from the controller is received the electromagnet *2* is activated, which drives the retainer 4 breaking the kinematic connection between the jaw and the safety device, which reduces the clamping of the non-crushed body allowing it the fracture chamber to be left when the roll rotates.

After removing the non-crushed body from the crushing chamber the electromagnet is disconnected and the retainer under the action of the spring *3* returns to its original position. In this case the torque that develops under the weight of the jaw returns it to its original position.

After removing the non-crushed body from the working chamber the jaw returns to its working position and the crusher continues to operate in the nominal mode.

3. Conclusions

A method for joint evaluation of the mechanical and electrical parameters of a crushing unit is developed, which makes it possible to use the combined object control by joint analysis of the measured signals in order to recognize characteristic informative signals describing the pre-emergency or emergency state of an object.

References

[1] Klushantsev B V, Kosarev A I, Muizemnek Yu A 1990 *Crushers. Construction, Calculation of Operation Features* (Moscow: Mechanical Engineering) p 320
[2] Pavlov N A et al 2009 *Grinding by Crushes with Reciprocating Motion of Working Elements* Patent of the Russian Federation 2345837 Bul 7 p 8
[3] Kulikov A A and Degtyarenko V A 1995 Patent of the Russian Federation 2043788 V02S1/04
[4] Sandvik – Roller Crushers www.mining.sandvik.com/en/products/equipment/crushing-and-screening/hybrid-crushers
[5] Maekawa-kogyosho – Roller Crushers www.maekawa-kogyosho.com/product/single/index.html
[6] Petukhov V S 2005 *News of Electrical Eng.* **1** 54–61
[7] Tsypkin Ya Z 1977 *Fundamentals of the Theory of Automatic Systems* (Moscow: Nauka) p 560
[8] Ilyinsky N F et al 2008 *Electric Drive: Energy and Resource Saving* (Moscow: Academiya) p 208
[9] Makarov A V and Tagiltsev-Galeta K V2014 *Ferrous Metallurgy* **6**
[10] Nikitin A G and Tagiltsev-Galeta K V 2014 *Ferrous Metallurgy* **8** 34–6