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Selection of a structure of jaw crusher regulator

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Abstract. To control a crushing machine at various industrial enterprises, including the mining industry, different types of typical regulators are used. It should be taken into account that a modern jaw crushing machine is not only an element of a crushing and screening complex, but it is also a system in itself. Realizations of various typical regulators for the electrical protection subsystem are shown.

1. Introduction

The current raw material requirements of many industrial enterprises are covered by crushed materials of various size classes, which are produced by various technical means. One of the most common types of such devices is jaw crushers, which act as the primary material processing unit. As in any technical means, directly involved in the production of semi-finished products, as well as the finished product, the crushing machine must be able to control various parameters, for example, fluctuations in the physical and mechanical properties of materials supplied to crushing [1], compliance with a given size of the output material.

Crushing machines (including jaw ones) are used as part of crushing and screening complexes, consisting of feeders, preliminary screens, crushing department and screens for separating fractions of the crushing product [2,3]. Since the crushing and screening process is continuous, the shutdown of one element inevitably leads to the shutdown of the entire complex as a result of the operation of the process control systems.

The design of modern crushing machines should take into account the systemic nature of not only the crushing and screening complex as a whole [4], but also the crusher itself [5]. Each element of this system has sufficient independence, up to the presence of a separate safety device for each subsystem. The choice of a structure that provides the best in terms of control efficiency, the interaction of these elements is an urgent task.

2. Overview of safety devices

An obligatory and, therefore, the most common safety element of crushing machines is a toggle [6], which belongs to the protection devices of the mechanical subsystem. However, for the destruction of such devices, the presence of an uncrushable body in the crushing chamber is not always necessary – they can be destroyed without visible overloads [4]. Another element of the crusher protection is the crusher drive control system based on the control of the main parameters of the electric drive [7], which controls the current frequency depending on the current value associated with the torque developed by the drive to destroy the material in the crushing chamber, which leads to feedback.



From the point of view of control, the crushing machine is also a feedback system (figure 1), which functions as follows: when the value of the input quantity, the strength of the material, changes, the force changes proportionally, and, consequently, the moment required for its crushing.

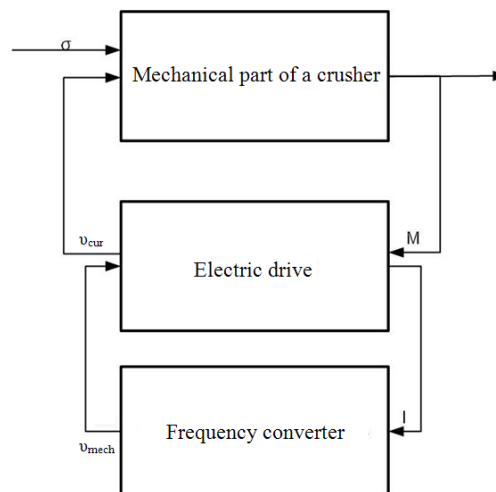


Figure 1. Block diagram of the crushing unit (σ – material strength, M – moment, I – electric drive stator current, v_{cur} – current frequency, v_{mech} – shaft rotation frequency).

An increase in the torque developed by the drive leads to an increase in the stator current of the electric drive. With the help of a frequency converter, such a change in the frequency of the current is achieved, which ensures that the crusher drive reaches the torque indicators sufficient for crushing the material.

3. Regulation of the electric drive

When the crusher is operating in the normal mode, the relationships between the values in the mechanical part and inside the electric drive are linear [4, 8-10].

Transient processes that arise, in particular, when the characteristics of the material in the crushing chamber change, can lead to an excess of the output signal level relative to the target value of the technological process (overshoot) in the control system of the parameters of the electric drive, which leads to overloads in the crushing machine and destruction of a safety element. However, overshoot occurs not only due to a change in the output signal, but also due to the regulator structure.

There are several typical laws of current frequency control – regulator structures used in modern frequency controllers [11, 12]: P – proportional, PI – proportional-integral and PID – proportional-integral-differential.

During the operation of the crusher, which uses a P-controller, the value of the correction to the control action is proportional to the value of the deviation. In turn, the PI controller provides a change in the value of the correction to the control action not only in proportion to the magnitude of the deviation, but also depending on the accumulated action of the deviation of the controlled variable, and the PID controller takes into account not only the accumulated value of the controlled variable, but also the rate of its change.

If the change in the input value in the model of the system (in this case, the strength of the material) occurs stepwise, then the change in the output value (torque on the motor shaft) depends on the type of controller used (figure 2).

It should be noted that the existing methods of analytical calculation of controllers [13] for such object lead to a P-controller, which is optimal from the point of view of performance, however, if we take into account the reliability of the equipment, only the performance criterion becomes insufficient,

therefore the parameters of the controllers were determined by the Ziegler-Nichols method [14], which allows the settings of typical control laws to be calculated for any structure of an object.

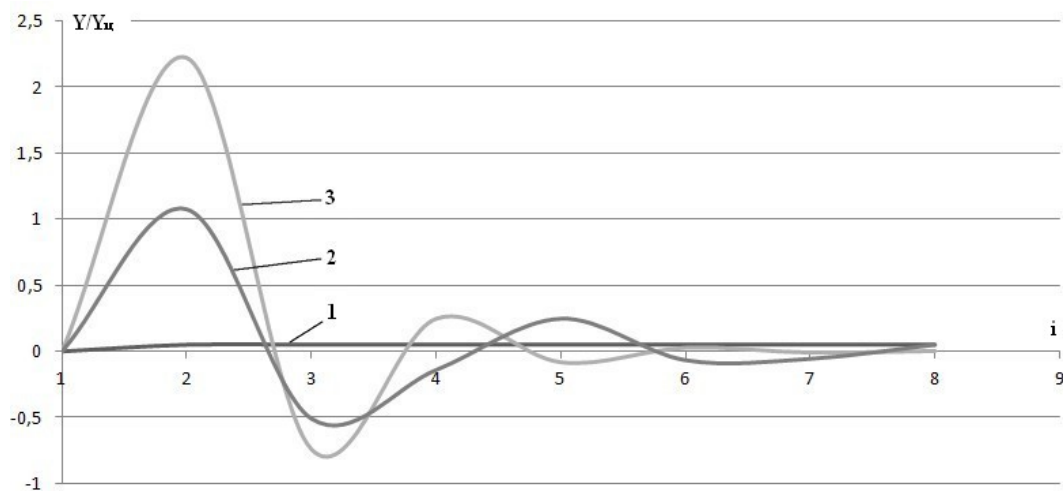


Figure 2. Deviation of the output value when using different regulators (1 – P-controller, 2 – PID-controller, 3 – PI-controller, Y/Y_t – the ratio of the input value to the target value, i – discrete time samples).

Thus, from the analysis of the obtained dependencies, it follows that the controllers have the following properties: the P-controller quickly responds to a change in the input value, but leads to control errors and increased loads on the drive, the PI-controller quickly responds to a change in the input value, allows its short-term increases to be ignored, but causes a significant change in the output value, which negatively affects performance, the PID controller reacts to changes in the input value with minimal impact on the equipment and allows short-term changes in the input value to be ignored, however, the transient process occurs during a significant period of time.

4. Conclusion

In conditions of contradictory requirements for current frequency controllers, which affect the torque developed by the crusher motor, there is no standard law that can satisfy all the criteria for implementing a stable crushing process, however, as a result of the performance characteristics analysis of various regulators, it is possible to minimize the risks of contradictory (in the case of a regulator) factors – reliability and speed. Thus, for the control loop of the crushing machine, the optimal solution is the use of a PI controller, which provides the best combination of reliability and speed.

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