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Comparison of typical control laws of crushing unit on the example of a jaw crusher

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Comparison of typical control laws of crushing unit on the example of a jaw crusher

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Abstract. To control the jaw crusher in a constantly changing input conditions, various types of typical regulators are used. It is necessary to take into account the fact that a modern jaw crushing machine is not only an element of the crushing and screening complex, but is also a system per se. Each element of this system has a certain isolation, up to the presence of an independent safety device in each subsystem. Safety devices are, for example, a toggle plate belonging to the protection devices of the mechanical subsystem, or a crusher drive control system based on monitoring the basic parameters of the electric drive belonging to the protection devices of the electrical subsystem. When controlling the mechanical subsystem, the values change proportionally, but in the control system of electric drive parameters their values change according to the type of controller used. When using the P-controller, the amount of correction to the control action is proportional to the deviation. The PI-controller provides a change in the magnitude 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. The PID-controller takes into account not only the accumulated value of the controlled variable, but also the rate of its change. The parameters of the regulators were adopted by the method of Ziegler- Nichols. It is shown that each of the model regulators has its drawbacks, which may be insignificant during operation.

1. Introduction
Many industrial productions process and use bulk materials of various size classes in large quantities. In most cases, the desired size is achieved by grinding larger pieces on crushers. Crushing machines (including jaw crushers) are used in crushing and screening complexes consisting of feeders, pre-screens, crushing section and screens to separate the fractions of the product [1,2]. Since the crushing and screening process is continuous, stopping a single element inevitably leads to a halt of the entire complex as a result of the process control systems actuation.

2. Characteristics of the studied object
When designing crushing machines, it is necessary to take into account that a modern crusher is not only an element of the crushing and screening complex [3], but is also a system per se [4]. Each element of this system has a certain isolation, up to the presence of an independent safety device in each subsystem. The choice of the structure that provides the best control in terms of speed, the interaction of these elements is an urgent task.

Mandatory, and therefore the most common element of the crushing machines protection is the toggle plate [5], belonging to the protection devices of mechanical subsystem. This device often breaks without visible overload, and not only when non-crushable bodies gets into the crushing

chamber [3]. The protection element of the electrical subsystem is the crusher drive control system based on monitoring the main parameters of the electric drive [6], which changes the frequency of the current in accordance with the change in the current value proportional to the moment developed by the drive, which creates feedback.

3. The structure of the unit in terms of control

In terms of control a crushing machine is also a feedback system (figure 1) that functions as follows: when the input value changes – the strength of the material, the force changes proportionally, and, consequently, the torque required to crush it.
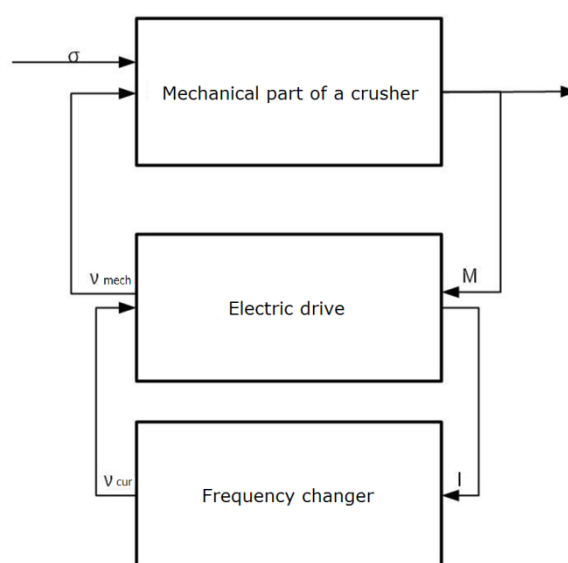

Figure. 1. Block diagram of a crushing unit: σ – the strength of the material, M – the moment, I – the current of the electric drive stator, υ_{cur} – current frequency, υ_{mech} – shaft rotational speed.

Increase in the required torque leads to an increase in the current value of the electric drive stator. By changing the frequency of the current with the help of a frequency converter, such rotation frequency of the motor shaft is achieved at which it develops the moment needed for crushing the material.

During transients that occur when changing technological parameters (for example, when the strength of the crushed material changes), overshoot can occur in the feedback circuits – the signal is exceeds the target or specified value determined by the process conditions, which, in this case, leads to overloads in the crusher, causing the destruction of the safety element. The occurrence of overshoot can be determined by the regulator structure.

When the crusher operates in the normal mode, the dependencies between the quantities in the mechanical part and inside the electric drive are linear and proportional [3,7]. Other laws are used in frequency converters. There are several typical control laws used in modern frequency controllers [8,9]: P, PI, and PID.

4. Results and discussion

In the process of operation of the crusher, in which the P-controller is used, the magnitude of the correction to the control action is proportional to the magnitude of the deviation. The PI controller provides a change in the magnitude 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. The PID controller takes into account not only the accumulated value of the regulated value, but also the rate of its change.

If the change in the input value (in this case, material strength) occurs in steps, then the change in output value (torque on the motor shaft) will depend on the type of regulator used (figure 2). The parameters of the regulators were adopted by the method of Nichols-Ziegler [10].
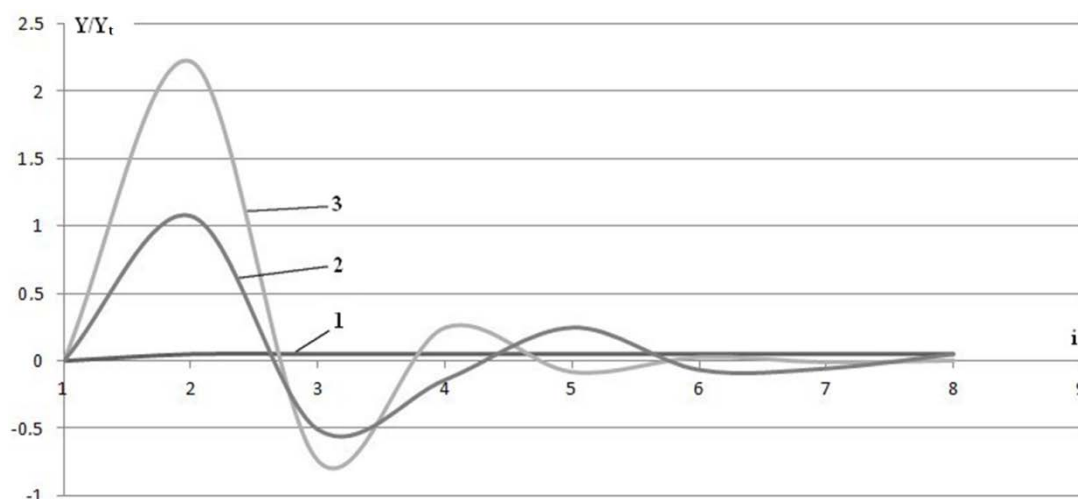

Figure 2. Deviation of the output value when using different regulators: 1 – P-controller, 2 – PID-controller, 3 – PI-controller, Y/Y_t – the ratio of the input value to the target value, i – discrete timings.

The considered regulators have the following properties: the P-controller responds quickly to changes in the input value, but leads to regulation errors, which results in increased loads on the drive; the PI-controller reacts quickly enough to changes in the input value, allows its short-term increases to be ignored, but causes significant change in the output value, which negatively affects the performance; the PID-controller responds to changes in the input value with minimal impact on the equipment and allows short-term changes in the input value to be ignored, but the transition process lasts a considerable time.

5. Conclusion

The use of various types of regulators ensures the operation of the crushing machine in the conditions of a constant change in the material strength, which does not allow the use of a P-regulator. A PID-controller with significant transient time is also not optimal in terms of monitoring speed. Thus, the best solution for the control circuit of a crusher is a PI-controller.

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