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ON OPTIMAL CONTROL OF THE CRUSHING PROCESS

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ABSTRACT

In industry, in most cases, high grinding steppes are required. The automatic control of solid particulate material crushing is a prerequisite for maximizing equipment productivity. A more voluminous task, which must be solved in the automation of crushers, is related to the optimization of the entire process of multi-stage crushing, the effect of using separate units taking into account the requirements of automatic control, rather than by increasing the number of controlled parameters, allowing, as is often the case in practice, not only receive comprehensive information about the process, but also insure against possible malfunctions in the operation of unreliable devices. An automatic crusher performance control system control circuit has been developed. The following tasks are solved: construction and description of functional diagram of automatic crusher performance control system; defined mathematical and computer models of the automatic control system; optimal control scheme is defined.

KEYWORDS: *Crushing; Performance; A control circuit; Automatic control system; Process; electric motor power consumption.*

INTRODUCTION

In industry, in most cases, high grinding steppes are required. Sometimes the sizes of the pieces of starting material reach 1500 mm, while in technological processes, a ma material is sometimes used, the particle sizes of which are fractions of microns. Such steps of grinding are achieved by grinding in several stages, since in one take-up (on one machine) it is not possible to obtain a product of a given final size. According to their purpose, grinding machines are conditionally divided into crushers of large, medium and small crushing and mills of fine and ultra-fine crushing. [1, 2, 3-5]

The main machines are divided into the following [1,2]: cheek, cone, hammer crushers, roller and ball mills, wipers. All crushing machines have general requirements: a minimum of dust generation, continuous and automatic unloading, the ability to control the degree of crushing, the uniformity of the size of the ground material, and a small energy consumption per unit of production. The difficulty of controlling the degree [6] of grinding consists in determining the degree of grinding, concentration and dispersion of the ground product. Each crushing machine design at maximum capacity corresponds to an optimal degree of crushing. When a large degree of grinding is required, crushing is carried out in several stages that is, a number of crushing machines, different in design and technical characteristics [1, 3], are sequentially installed.

The main object of direct optimal control is a crusher - a grinding apparatus. If at the first stage of multistage system analysis [7] the installation, then the grinding apparatus is divided into a number of quasi-devices. This is the crusher body, crushing elements and solid material. In turn, the solid material consists of particles of the first, second, third, etc. sizes of the milled end product.

Input parameters of object for modeling of target product cone grinder object are: consumption of solid material G_0, concentration of ground target product at inlet Co, particle sizes δ_1, energy consumption N. Output parameters: material consumption G_m, concentration of tested components at the output C.

Material with certain concentration of particles and dispersion of ground product is fed into crusher. The material balance equation for the selected component (for example, for particles in grinder a_1) is compiled:

One of the main indicators of crushing machines is the degree of grinding, which depends on the design of the crushing machine, the physical and mechanical properties of the processed stone rock and the absolute size of the pieces. With an increase in the degree of grinding, the productivity of crushing machines decreases, and the energy consumption increases. Each design of the crushing machine at maximum productivity corresponds to an optimal degree of crushing: for example, for cheek and cone crushers of large crushing i=3-5. When a large degree of grinding is required, crushing is carried out in several stages, i.e., a number of crushing machines, different in design and technical characteristics, are sequentially installed. At the same time, they gradually move from large to medium and then fine crushing so that the crushing efficiency in subsequent stages is higher, and the energy consumption is less.

The crushing process is characterized by high energy consumption and rapid wear of machine parts in contact with the crushed material. Such parts are mostly made of expensive alloyed steels. Before crushing, fractions of the finished product should be removed from the starting material, since, distributing among larger pieces, they increase the elasticity of the ground mass. When processing non-solid construction materials, machines can work in open and closed cycles.

When crushing in an open cycle, the material passes through the crushing machine only once, while the pieces of the final product are obtained in different sizes.

When crushing in a closed cycle, large fractions of the remaining material on the screen after sorting are returned for repeated crushing. Since the material repeatedly passes through the crushing machine, the load (circulation) on it increases, however, the machine operates at a higher capacity than with an open cycle and produces a more uniform product. With a closed crushing cycle, the material is not re-ground and energy consumption is reduced, as well as wear and tear of the machine working elements. The disadvantage of a closed cycle of crushing is that as the number of machines and transporting mechanisms increases, the height of buildings and capital costs increase. Single-stage, two-stage, three-stage and less often four-stage crushing schemes are used. When determining the number of crushing stages, the capacity of the plant, the size of the pieces of the initial and final product, as well as the design of the crushers should be taken into account. The number of crushing stages is the main indicator that determines the scheme of the crushing and sorting plant.

The most important means of electrification, mechanization and automation, the basis for increasing the productivity of machine equipment is an automated electric drive, which accounts for more than 65% of the country's public electricity consumption.

Extensive theoretical and experimental material has been accumulated on the mathematical description of the crushing complex, and crusher, in particular. At the same time at automation several mathematical models of crushers are proposed, depending on different channels of passage of input impact [8].

A more voluminous task, which must be solved in the automation of crushers, is related to the optimization of the entire process of multi-stage crushing, the effect of using separate units taking into account the requirements of automatic control, rather than by increasing the number of controlled parameters, allowing, as is often the case in practice, not only receive comprehensive information about the process, but also insure against possible malfunctions in the operation of unreliable devices.

The Purpose of the Study is: Development of control circuit of automatic crusher performance control system.

RESEARCH OBJECTIVES

1. Construction and description of functional diagram of automatic control system (ACS) of crusher capacity.
2. Definition of mathematical-computer model of ACS.
3. Determine the optimal control.

Prior to the development of the Automatic Crusher Performance Control System (PCS) control device, it is appropriate to consider a simplified crusher arrangement, in particular a coarse crusher cone crusher.

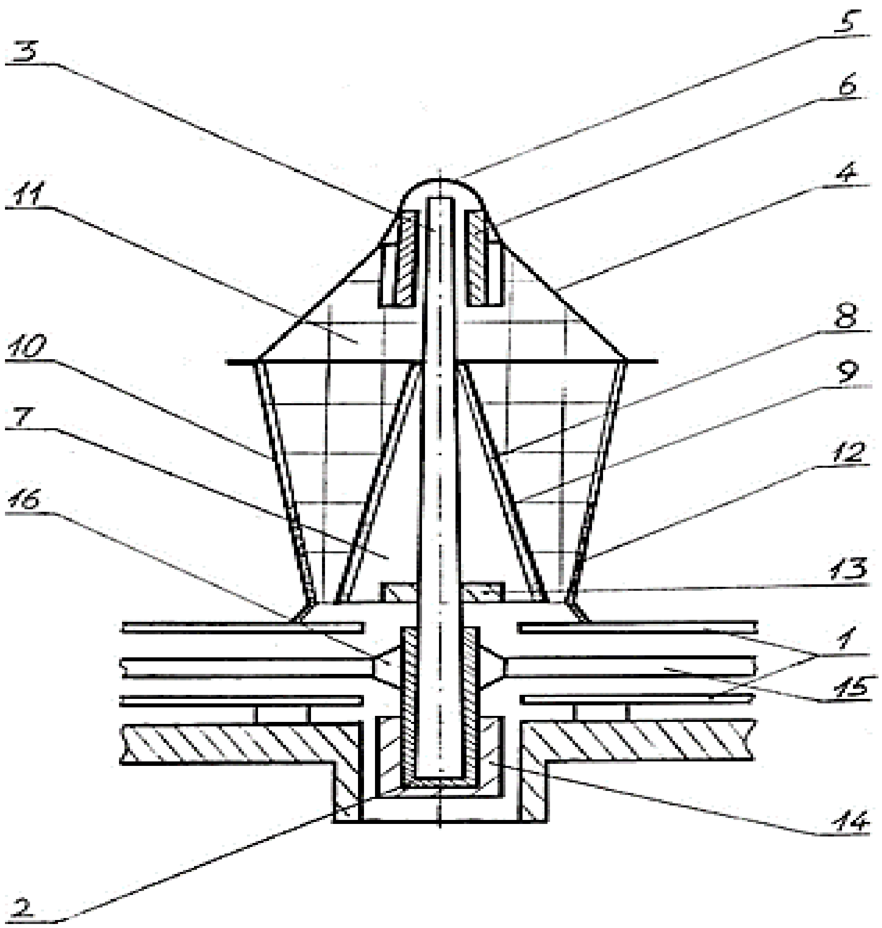

Fig. 1. Cone Crusher Diagram

1-whole-cast bottom part of crusher; 2-eccentric shaft; 3-vertical shaft; 4-crossbeam; 5-cap; 6-suspension; 7-movable cone; 8-stitching; 9-crushing plates; 10-middle part of the housing; 11-shift armor; 12-cement pouring; 13-seal; 14-cup eccentric shaft; 15-drive shaft; 16-cone wheel

The capacity of a large crusher cone crusher is determined by the volume of crushed stone V_0 leaving the machine in one run-in of the inner cone, and the number of runs-in per calculated time, that is:

$$P=V_0\cdot n$$

The volume of crushed stone falling out of the crusher during one rolling of the cone will be equal to the volume of the ABCD ring (see Fig. 2).

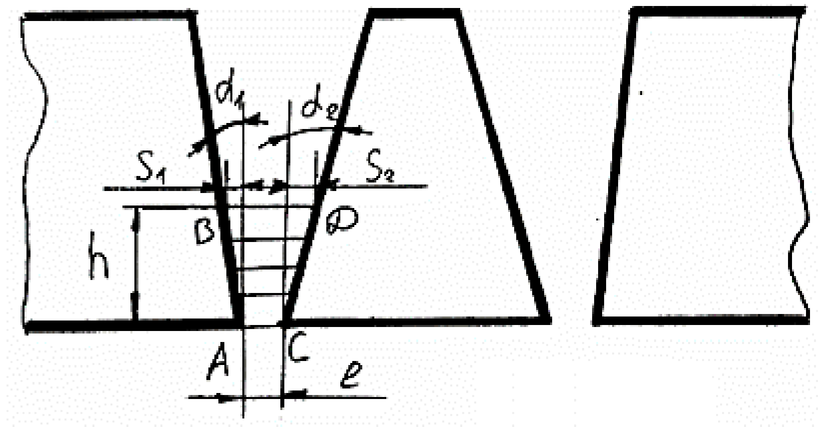

Fig. 2. Stone crushing scheme in cone crusher

The volume of crushed stone V_0 exiting the machine in one run-in of the inner cone is determined by:

$$V_0 = PD_{av}\frac{2l + S_1 + S_2}{2}h$$

Where D_{av}- average diameter of crushed stone ring, m.

Knowing that:

$$S_1 + S_2 = 2r, \qquad h = \frac{2r}{tg\alpha_1 + tg\alpha_2}$$

we get:

$$P = 3600\frac{nD_{av}2r(l + r)}{tg\alpha_1 + tg\alpha_2}n\mu$$

where n-number of inner cone rolls, sec; μ-coefficient of loosening of a ready-made product (0.35-0.6); the l-size of an unloading crack of the crusher at rapprochement of cones; r-eccentricity of swing of a cone, m; h-distance from upper unloaded pieces to lower edge of crusher slot, m.

Before proceeding with the development of the functional diagram, it will be appropriate to consider the simplified crushing process diagram (Fig. 3).

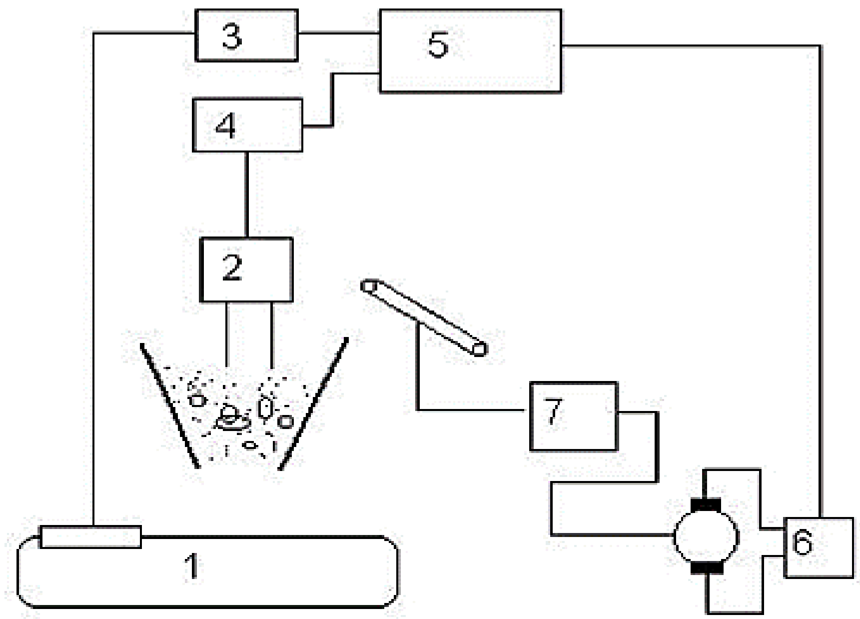

Fig. 3. Simplified Crushing Process Diagram

The main controlled parameters are the moments of resistance on the shaft of the crusher motor and the output conveyor (1), the control parameter is the angular speed of rotation of the input feeder motor shaft or the feeder capacity. Two control circuits including level (3) and output (4) regulators through intermediate unit (5) act on bias current of single-phase power magnetic amplifiers (6). Rectified voltage is supplied to the feeder motor armature winding. If the adjustable values exceed the limits set for them, then a signal is transmitted to the unit (5) and the feeder (2), which acts as an actuator, will reduce its performance until the signal disappears.

In this case, we need to ensure that the crusher capacity is displayed and that the crusher capacity can be changed.

The performance control window contains a functional process diagram as a substrate, as well as two forms such as dynamic text, to display performance. These forms are intended for displaying and entering information. This property can be used to allow the operator to specify the desired mill capacity.

In general, the ACS scheme has the form:

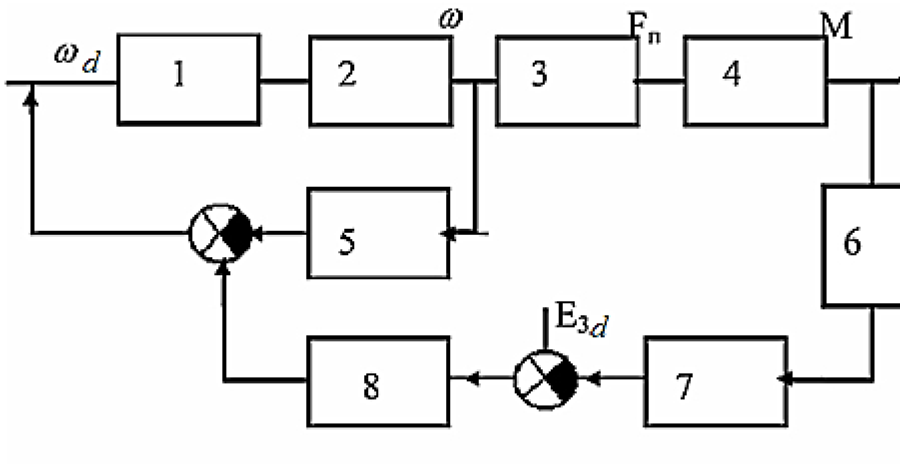

Fig. 4. General view of ACS diagram

Elements included in the control device (Fig.4): 1-electronic control device in the motor shaft speed ACS; 2-Feeder motor; 3-Feeder; 4-Crusher receiving chamber; 5- Speed sensor, ¼ d-maximum speed of shaft rotation; 5-Speed sensor, M-maximum shaft rotation speed; 6-Electric motor converting the mass of material at the moment of resistance, and then at the moment on the engine shaft; 7-Sensor converting M1 into an electric signal; 8-electronic control device to the crusher motor load ACS.

The complex should be considered as an in-line transport complex. This complex should include an automatic start-up system, with the first to include a receiving conveyor, then a crusher and only then a feeder.

Based on the above diagram of the complex control system, a computer model is developed, which consists in cascading control of the crusher performance and dependency graphics (Fig. 5, a, b, c).

The first part of the control is to control the supply of material to the crusher. Such a control part is to control the power of the electric motor. The control problem is that if the crusher is overloaded, it will be loaded with a large amount of materials, and the load on the electric motor will increase. The power consumed by the electric motor will increase, and it can change to the limit power. Therefore, such a scheme is created - a kind of cascade scheme for controlling the operation of the crusher. To do this, in both cases we used proportional adjustment - the curves show changes in the transient characteristics of such a system. In both cases of proportional regulators, changing the proportionality coefficient, we will try to obtain a more acceptable characteristic of the object. As you can see from the number of selected options, the system with a coefficient of 0.1 is most suitable for the case of material supply. The object is an integral system, and for power control the gain is 0.5. In the future, we can draw up such a scheme and further create a computer control ofPCS material crushing. At coefficient 1, for the first system and 1 for the second system, as can be seen from the graph, the system has a larger oscillation coefficient. And for case 0.1 and the second coefficient 2, the fluctuations are also relatively large. Therefore, we have chosen the best case of optimal work configuration.

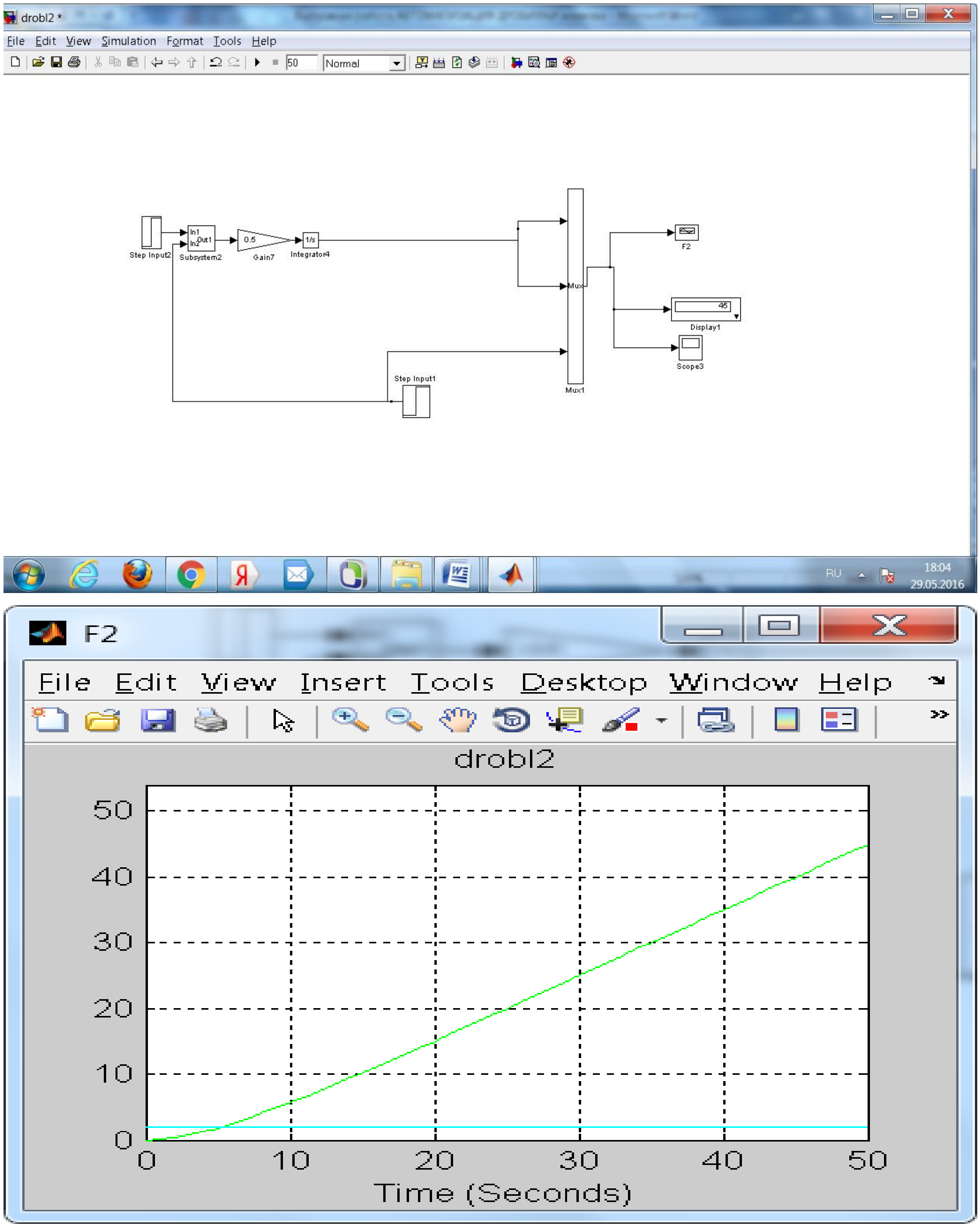
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Fig. 5, a.

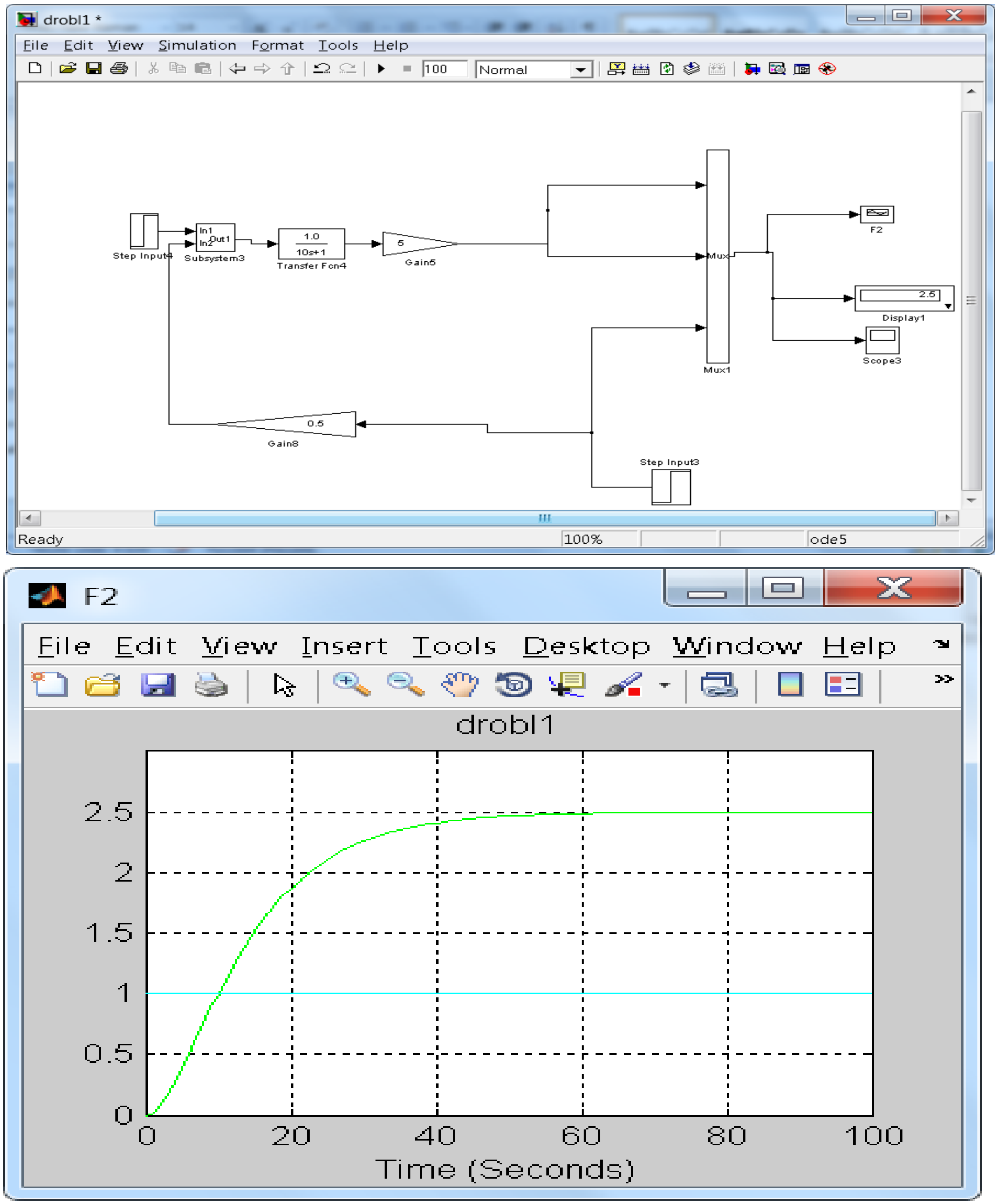
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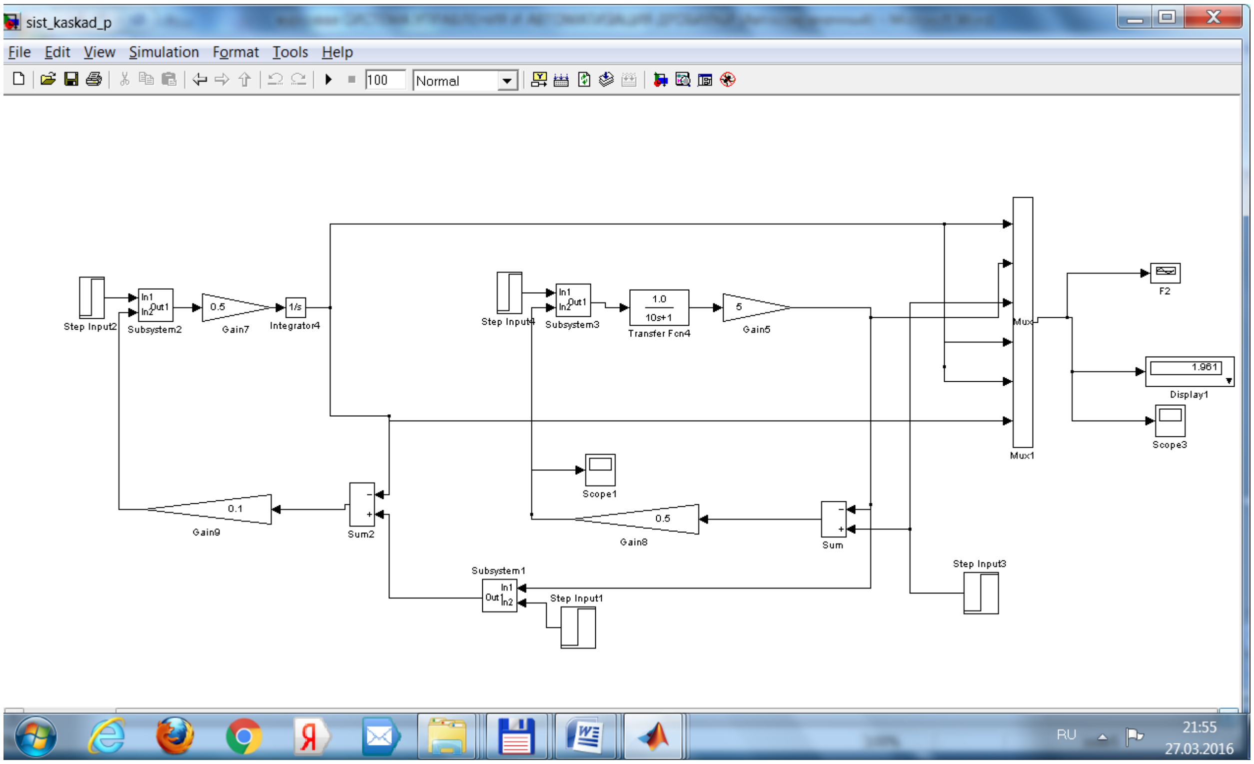
Fig. 5, b.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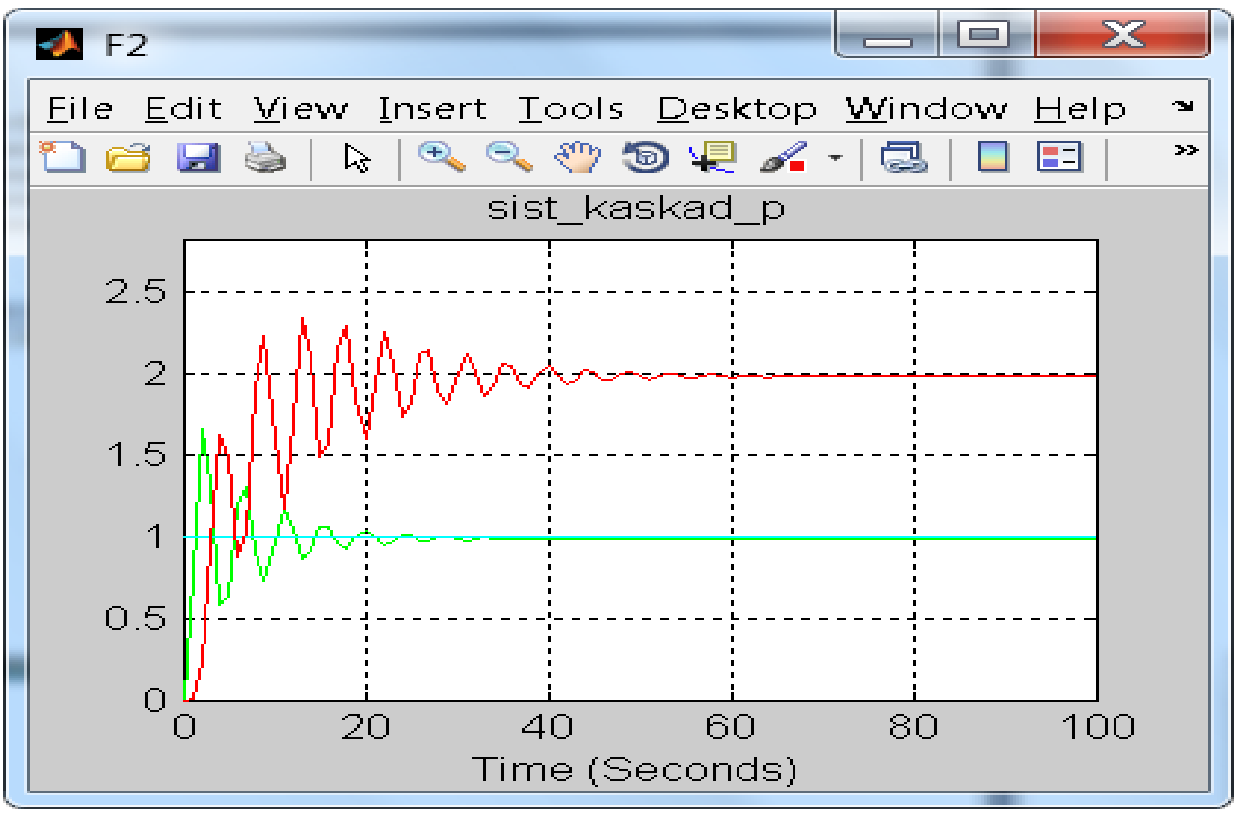
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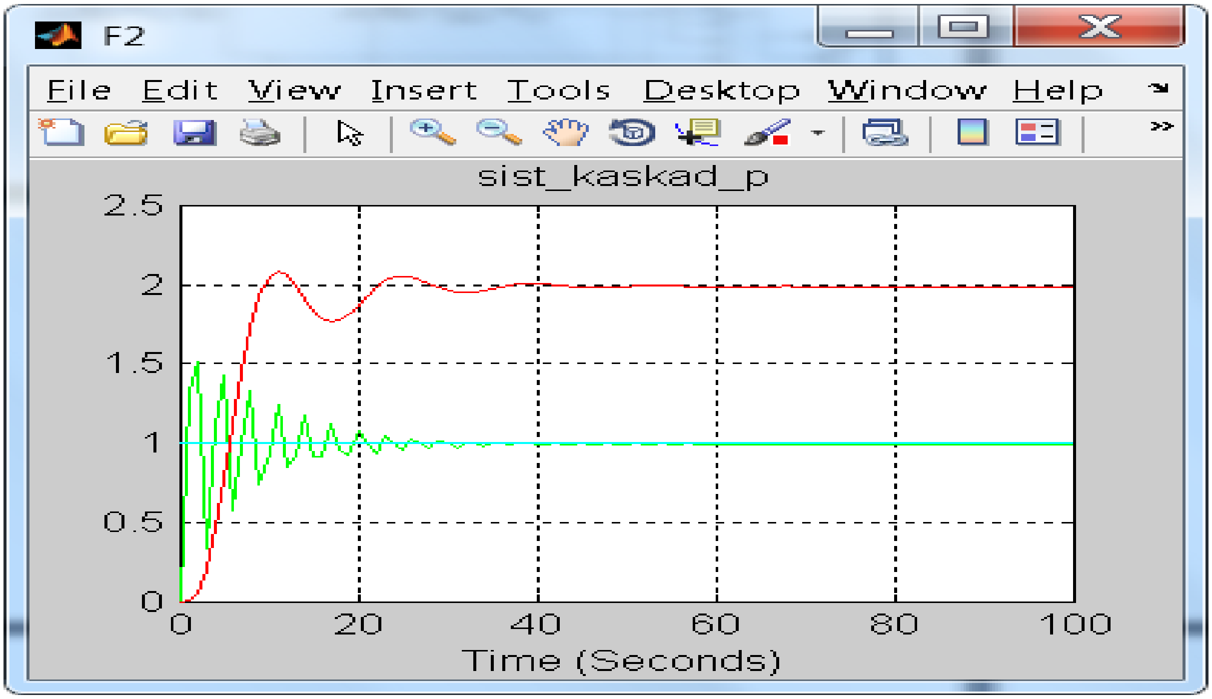
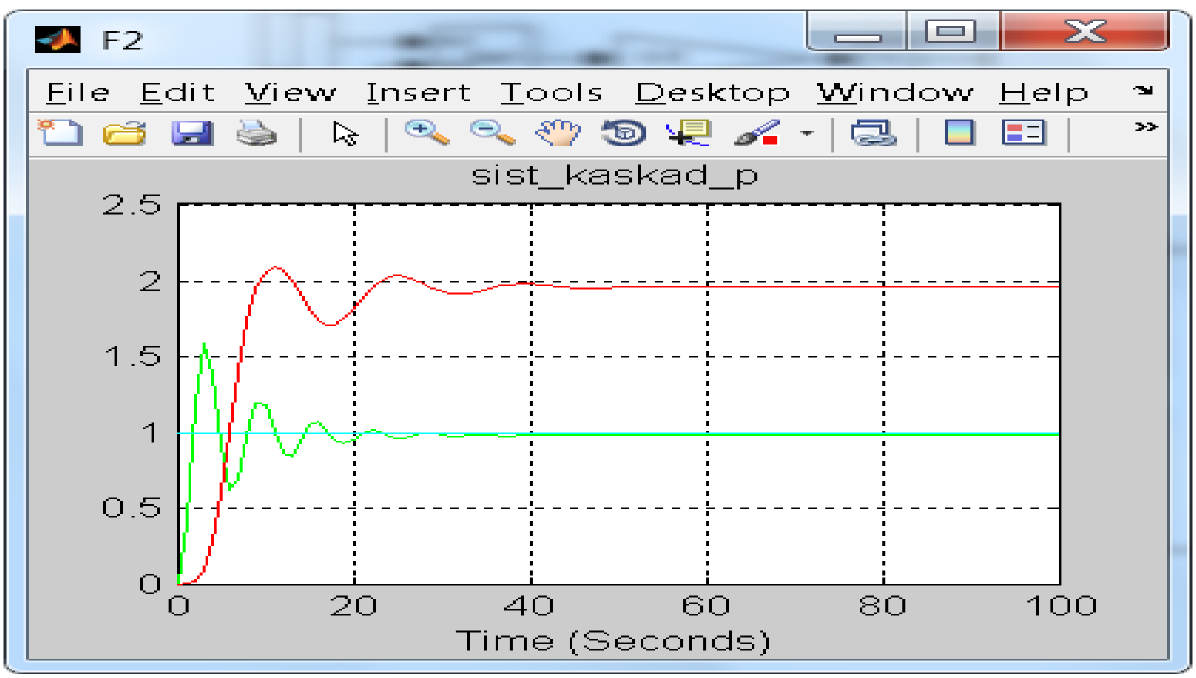
К1=1 к2=1



K1=0.1; к2=2



K1=0.1; к2=0.5

Fig. 5, c.

Fig. 5. Computer model consisting in cascade control of crusher performance and dependency graphics

Select a control device. Structural diagram of automated process control system (APCS)of crushing is given in Fig. 6.

The crushing process control system is provided as hierarchical in a three-level design. The lower level is implemented by instruments and hardware in place and on local boards. It includes regulation, parameter monitoring and alarm. The second level is organized in operator stations with access to the common network via the interface. The principle of APCSconstruction is adopted locally, for each building and department with transmission of information to the common information network. At the APCS software control level, the controller's task is to generate control actions on actuators by mathematical processing of information on the process progress, logical processing of signals on the position of controls and the state of actuators, as well as displaying the operating state of the control system on the screen. From the software control layer controller, all Ethernet information is transferred to the upper layer of the management system. At the upper level of APCSore crushing, data processing, visualization of main process parameters at terminals, generation of schedules and reporting process documentation for process control and monitoring are performed. A GENESIS-32 system is used to manage and visualize, diagnose and track the process at a centralized control point that provides quick access to all data and allows for global settings. GENESIS-32 is a software package designed to develop, configure and start real-time process control systems. The software complex includes an ACSdevelopment mode and a run-time mode. The entire ideology of GENESIS-32 construction is based on the OPC standard - OLETM *forProcessControl* (a mechanism for linking and implementing objects for data collection and control in industrial automation systems), which is the most common way to organize interaction between various data sources and receivers, such as devices, databases and systems for visualizing information about a controlled automation object.

Fig. 6. Structural Diagram of Automated Crushing Process Control System

CONCLUSION: The task of describing the control device of the automatic crusher performance control system was performed at a sufficient level.

A more comprehensive task, which should be solved in the automation of crushers, is related to the modeling and optimization of the entire crushing ACS process. It has been more acceptable to control the level of material supply by controlling the load on the electric motor of the equipment.

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