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Mobile Crushing and Screening Machine Control System

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Abstract: The study research the problem of automating the mobile crushing and screening plant as a complex multi-level system. The analysis of the characteristics of the technological equipment and individual aggregates of the mobile crushing and screening plant is performed. A software implementation of an automated cone crusher control system is proposed that allows to integrate a set of interconnected technological units in the control of one hardware and technical complex in the controller and human-machine interface on the touch panel in the operator station. The results of research in automation processes for automated crushing and screening production of fractionated building material are a practical basis for selecting the structures of automated process control system of crushing and screening plant which ensure maximum productivity in accordance with the specified consumption of grain size.

Key words: Automation processes, Automated Process Control System (APCS), Crushing and Screening Plant (CSP), cone crusher, mnemonic scheme, Cone Crusher Control System (CCCS), Industry Internet of Things (IIoT), Industry 4.0, Human Machine Interface (HMI)

INTRODUCTION

Modern crushing and screening production of stone materials is a complex technological equipment with a set of operations including the delivery of raw material, its cleaning and pre-sorting, crushing in several stages, sorting the required commodity fractions into stages of crushing, storing and transporting to the final consumer. The technological processes of crushing and screening are among the most important processes in the technology of construction materials but are not highly effective.

To increase the efficiency of technological processes of stone crushing and screening, the development of new multi-level automated process control systems for Crushing and Screening Plants (CSP) is required which have become increasingly mobile over the past few years, i.e., moving from one site to another.

Modern Automated Process Control Systems (APCS) unite heterogeneous elements, combined to achieve some final aim with the help of branched interconnected links (Ostroukh and Yuan, 2013a-c; Ostroukh and Tian, 2014). Taking into account the evolving modern concepts of Industry Internet of Things (IioT) and Industry 4.0, a growing number of industrial devices, machines and aggregates are equipped with modern automation systems developed using modern industrial controllers (Maksimychev *et al*., 2016a, b; Ostroukh *et al*., 2015a-e).

Industrial devices, machines and aggregates have a permanent connection to the global network via wireless communication channels. Control is carried out through the Human Machine Interface (HMI), software implemented on interactive touch panels (touchscreens).

Research object: A set of technological equipment of a crushing and screening plant is a branched flow-transport system consisting, for example of screens, a crushing plant and several belt conveyors and in a more complex version having in its composition several dozen pieces of equipment linked into a single technological process and working in automatic mode (Ostroukh *et al*., 2015a-e, 2016a-c).

The choice of the technological scheme CSP depends on the type of processed raw materials, its physical characteristics, quality requirements and the purpose of the finished product. In addition, the technological scheme of the crushing and screening plant depends on the required ratio of cubed grain, planned capacity and the willingness of the owner of the CSP to bear a certain share of the cost of restoring the working capacity of its working bodies.

Mobile crushing and screening machine Metso NW220GPD with cone crusher Nordberg GP220 and screeners DS was selected for research (Fig. 1).

Cone crushers are most effective for medium and fine crushing of strong and highly durable rocks. In them,

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crushing is carried out continuously due to the rotation of the eccentric conical rotor the “crushing cone” inside the outer stationary cone.

Cone crushers use continuous rotation and not simultaneously along the entire width of the slit but alternately by its variation along the length. The working clearance in the cone crusher varies continuously along a circle, contributing to an improvement in the quality of crushing. The entrance and exit slots in the cone crusher are in the form of concentric rings. The maximum and minimum size of the output slit is set by the adjusting device.

The size of the product of crushing cone crushers depends mainly on the size of the output gap and the strength of the rock. The weighted average size of the crushing product z_{cB} for soft, medium and strong rocks in the fractions of the output slit b^z of the cone crusher is determined by Eq. 1:

$$Z_{CB} = K_p b^z \quad (1)$$

Where:
K_p = 2.2÷2.8 (for soft rocks)
K_p = 2.6÷3.6 (for medium rocks)
K_p = 3.0÷5.0 (for strong rocks)

The technical productivity of cone crushers is determined in m^3/sec by volume of a batch of material per one crushing cycle:

$$Q_t = 0.45\pi n b^z l D \quad (2)$$

Where:
n = The frequency of rotation of the cone, s^{-1}, b^z width of the output slit (m)
l = The length of the parallel zone of the exit slit (m)
D = The diameter of the base of the crushing cone (m)

Fig. 1: Mobile crushing and screening machine Metso NW220GPD with cone crusher Nordberg GP220 and screeners DS

MATERIALS AND METHODS

Electrical power supply and automation system: The electrical power supply and automation system (Fig. 2) include some module which provides the possibility of reconstruction or modernization of production.

Commands for controlling the drives of the crusher, the size of the output slit, conveyor feeder, screen, conveyor of the finished product are formed on the operator’s automated workstation where the program is executed in accordance with the specified algorithm for optimal control of the crushing process.

Local control during automation is provided by information channels with the necessary number of sensors controlling the relevant parameters.

For the crusher are the sensors of the speed of the drive (frequency), the size of the output gap, the force (moment) of crushing and the energy consumed.

The process of crushing, regardless of the type of crusher is controlled by changing the size of the output slot and the speed of the drive (by adjusting the speed of the crusher drive) (Gimadetdinov and Ostroukh, 2014; Ostroukh and Wai, 2014; Wai and Ostroukh, 2014; Ostroukh *et al*., 2015a-e).

Simultaneous control and size of the output gap of the crusher and the speed of the drive can be defined as two-dimensional in which along with ensuring the required fractional composition of the product at the output, the required value of the crusher capacity is achieved.

Controlling the size of the output slit alone is the main way of obtaining the output of the required fractional composition can be defined as one-dimensional. One-dimensional way of controlling the process of fragmentation is basically, the subject of research in this dissertation work. The use of this control method does

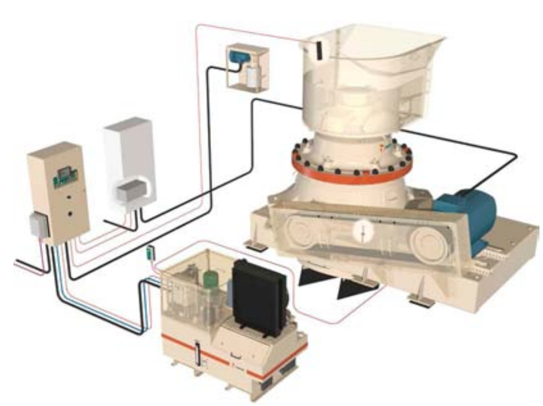

Fig. 2: Electrical power supply and automation system of cone crusher Nordberg GP220

not impose any limitations on the performance of the crusher, considering that the required fractional composition is the main indicator for the effectiveness of the CSP.

The choice of the method for controlling the crushing process depends also on the design features of the crusher, the chosen process, the operating conditions of the CSP (planned production of crushing products or production under conditions of random demand).

The communication functions can perform a wired connection with high interference immunity of reception and transmission based on fiber optics and in some cases also wireless communication, coupled with modern network industrial interfaces.

RESULTS AND DISCUSSION

Cone crusher control system: Cone Crusher Control System (CCCS) (Fig. 3) developed on the basis of SCADA (Ostroukh *et al*., 2016) provides a simple and safe use of the CSP. The system allows you to control the feeder, crusher and conveyors with a single touch screen.

CCCS automation solutions are designed to meet the customer's needs and the requirements of crushing plants for continuous productivity, safety and easy monitoring of the crusher's parameters. Thanks to the optimized start, stop and workflow algorithms that form the basis of the CCCS, customers can be assured of the proper functioning of the crusher and minimal downtime under all operating conditions.

CCCS allows you to optimize the performance of crushing equipment. This is achieved through clearly defined safety control parameters such as oil temperature and pressure and drive power which are indicators of the actual working load of the crusher. The CCCS monitors the crusher's condition and identifies faults and problems in advance. Thus, it is possible to eliminate the problem without waiting for serious and costly consequences.

Integration of automation system components: The upper level of automation (Ostroukh and Pomazanov, 2014; Ostroukh *et al*., 2013, 2014) CSP represents an automated system for the technological preparation of crushing and screening production for the automation of all production control processes.

The main task of automation of the lower level is to organize the optimal control of the crushing process, the purpose of which is to provide the required fractional composition of the crushing product. The task of automation of the lower level is a particular task of the general problem of automation of production. At the same time, the lower level of automation of CSP can be considered as an automated control system for the technological process of crushing.

The CCCS can easily be connected to any plant-wide automated control system used for crushing and screening equipment (Fig. 4).

Fig. 3: Touchscreen and remote control of the cone crusher

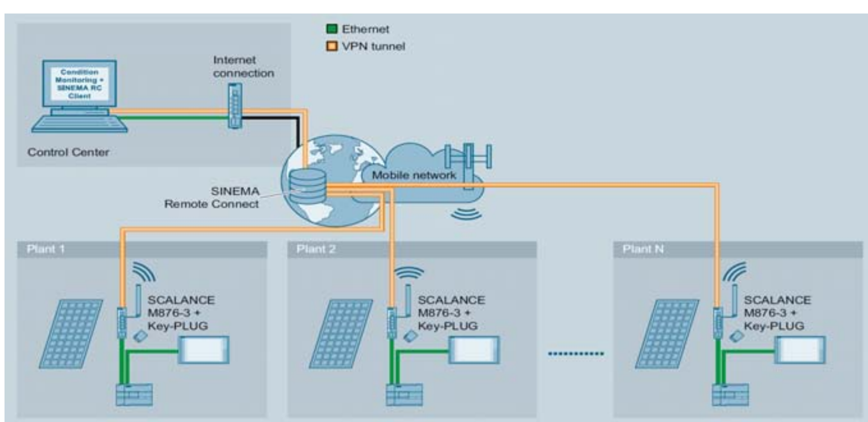

Fig. 4: Integration of automation system components

Such integration will provide the possibility of centralized management of the crusher and the whole enterprise and will also allow the operator to safely monitor and regulate the operating parameters of the crushing equipment from one operator's console.

CONCLUSION

Thus, the features of the functioning of the elements of the CSP scheme are determined due to the need for automation of crushing and sorting production. On the basis of the design parameters of the crushers, it is shown that the size of the crushing product which is a certain weight-average diameter of the grain of the crushed product is its main stochastic characteristic.

It is established that the task of automatic regulation of the crushing process is to maintain the specified size of the final product and to maximize the energy supplied to the crushing aggregates by optimally loading the crushers as well as to obtain the greatest possible productivity of the crushing aggregates and to maximize the energy supplied to the crushing aggregates due to the optimal load of crushers as well as the greatest possible productivity of obtaining the final product at the highest loading crusher chamber crushers.

IMPLEMENTATIONS

The program implementation of an automated control system for the technological process of crushing stone materials is proposed which makes it possible to integrate a set of interconnected technological units in the management of one hardware and technical complex, the efficiency of their joint operation is largely determined by the degree of agreement and the speed of two-way information exchange.

The developed system ensured a significant increase in the comfort of the operator, providing him with a single user interface for managing various technological units from one operator station and an additional volume of information and services.

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