LOADING LEVEL DETERMINATION FOR CONE CRUSHER

Horobets V., Assistant

Kryvyi Rih National University

Abstract. The importance of accurate measurement and control of the loading level of cone crusher was shown. The review of existing measurement systems was done and their disadvantages were shown. The method of measuring loading level in the crusher based on consumed power of its engine was proposed. The factors were determined on the basis of which the task for loading level in the crusher is formed and the structural scheme of the control system was designed.

Keywords: cone crusher, loading level, control system.

Introduction. For the creation of modern control systems of 3rd – 4th crushing stage tract and directly crushers of medium and fine crushing it is important to determine the level of filling the crushing chamber of the crusher. The greatest attention should be paid to cone crushers of fine crushing (CCF) because they are usually much more loaded. Whereas cone crushers of medium crushing (CCM) are often underloaded due to unadjusted activity of sieve crusher located before them, or due to its absence. Domestic and foreign researchers determined that for each type of crusher there is an optimum filling level that allows achieving maximum efficiency at a given quality. In most cases, for best performance CCF crusher must be filled by 70 - 90 % [8 - 13].

Materials and methods. Maintaining a high filling level of crusher is a challenging task due to the large inertia of the process and the possibility of crusher overload.

In ore mining and processing combine of Krivoy Rog iron ore region crushers of "KMD – 2200" type produced by "Uralmash" plant have been mainly used so far. Their outdated design allows only installation of relay switches for measuring the ore level in the crusher. Of course, these sensors cannot be used as a feedback and serve only to prevent the crusher overloading and obstruction.

Foreign researchers face fewer difficulties solving such problem, because of the built-in sensors measuring the filling level of crushers and controlled feeders [1 - 5].

Satisfactory way to measure the loading level of CCF is needed to be defined, which doesn't require significant investment and modification of crusher and fully exploits the possibilities of modern industrial automation. Criteria, that state more clearly the desired loading level of crusher for optimal tract operation and offer automated system of control (ASC) structure, are needed to be defined as well.

Results. Gamma-relays or radioactive and ultrasonic level gauges are used for measuring the filling level of the crusher, if there is a constructive possibility of installation. Such arrangement protects the crusher from the emergency overflow, and also from possible accidents if oversized pieces happen to enter the crusher. However, it does not allow to adjust the productivity of the combination the feeder - the crusher in required flow range for technological process. The disadvantages of this scheme should also include the fact that even installing of multiple sensors on different heights of the crusher's receiving chamber for productivity adjustment does not give the desired effect as depending on the size of pieces (large or small) of input material at the same level, different productivity can be achieved: an increased producrivity while processing the smaller pieces, a reduced one while processing the larger pieces.

Obviously, even if the sensor is installed, it is always a danger that it will be destroyed by input ore stream.

Also, the practice of setting ultrasonic level meter at PJSC "Pivnichny GOK" crushing plant, which initially did not have an installation spot, showed that input ore stream (or even individual pieces of relatively large size) can lead to false impressions of the sensor which will respond to instant bursts of output signal.

So it is an opportunity to measure the filling level in the crusher is the basis for the creation of the functioning circuit for loading of the crusher. Such circuit is also possible to set up on existing

crushers CCF. But there filling level can be measured only by indirect methods. Accuracy, in this case, depends on the strength and viscosity of ore and may vary with a change of the specified parameters. So functioning of the circuit will be unstable and, in some cases, crusher overload may occur.

Most of these disadvantages have been taken into account in the method of determining loading level in the crusher, which was developed by researchers of SIHE "Kryvy Rih National University" [11]. There active spectral analysis of the crusher body from vibration control devices located in its upper part was used. As an informational parameter that characterizes the filling of the crusher was adopted the level of one of the components of the spectrum of the shell vibration. Experimental studies were conducted in the environment of crushing plants of Pivdeny GOK and Poltava GOK. The overall level of vibrations in a wide frequency band (10 Hz to 10 kHz) does not give any information about the level of loading due to the influence of various factors (barriers of different mechanisms, wear of mechanical equipment elements, etc.). Characteristics were taken from an empty crusher and as well as from loaded by 75%. Evaluation of load was carried out by the filling level. The analysis shows that the informative frequency bands for determining the level of loading are those, which comply with the active bandpass filter of medium frequencies of 1000 and 2000 Hz.

Location of the sensors on the most movable parts of the crusher and the corresponding significant impact of vibration is another disadvantage of this method. It is also an ambiguity in measurement amends corrections to mass of moving parts, depending on the crusher armor, quality of mechanical connections and other physical parameters

It is proposed to improve this method with informative parameter of active power value consumed by the crusher's motor. Obviously, the power consumption is proportional to the amount of work done by crushing, and hence on the amount of ore mass, which has been moved by the cone of the crusher inside its case. To assess the fine crusher loading level it is advisable to use interpolation in the form: y = $y = b_1 x + b_2 \cdot x^2$, where x - the level of active power, y - ore filling level in the crusher, $b2$, $b1$ - interpolation equation coefficients, that should be found for each crusher. For crushers "KMD - 2200T" values of the coefficients $b_1 \approx -2 \cdot 10^{-3}$, $b_2 \approx 35 \cdot 10^{-6}$, and the corresponding dependency is presented in Figure 1. Taken into account the structural similarities crushers CCM and CCF, we can conclude that the use of this method for determining the filling level of CCM crushers gives a similar result in condition of finding the correct equation coefficients interpolation. .
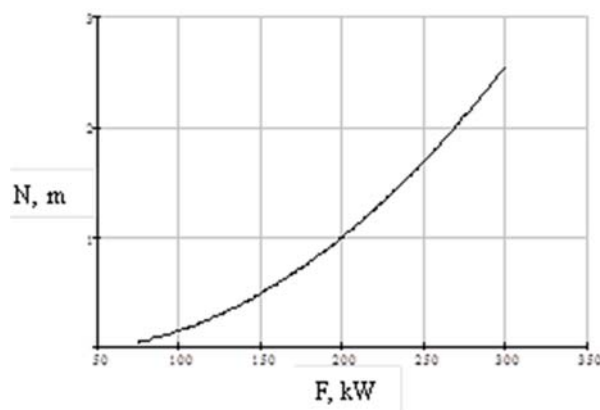

Figure 1. Dependency of the filling level from the crushing chamber from power consumption of the crusher

By increasing load crushing units to match the calculated values (providing "overload power" of crushing unit), content of large classes S can be significantly reduced, and a minimum average piece in the outcoming product can be provided, Figure 2 [7].

Shown reduction depends on the characteristics of the product, which is being crushed, on the mode of crusher, conditions of service. So while counting load sizes for crusher "KMD – 2200" in environment of crushing plant Poltava GOK, it is needed to remember that decreasing the average diameter of the piece in the mass of outcoming crashed product by the value Δd_{avrg} causes a decrease the product coast by the value ΔS_{coast} comparatively with the initial coast, i.e. an increase in income, Fig. 3. Increasing the load of crushing unit reduces the value of the specific discharge of lining armor. On the other hand, analyzing the level of "overload performance" at different values of discharge gap, it can be concluded that the provision of such a performance

makes use of the drive operating not at the maximum values of efficiency and cos(φ). Extreme values were observed when loads are 20-30% less then calculated values. This would result in additional energy consumption for crushing.
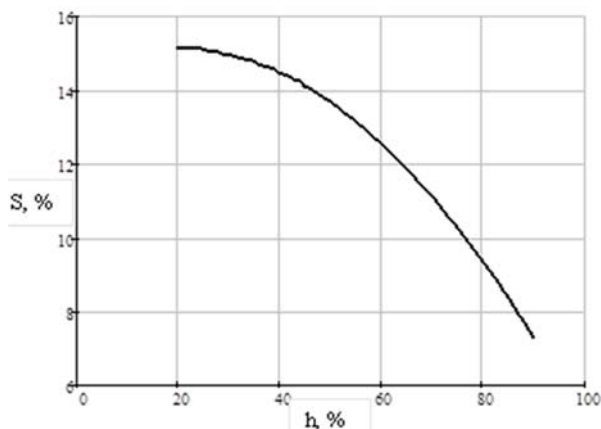

Figure 2. Dependency of large fractions from the filling level of the crusher

It is known that the frequency of wear of variable parts of the crusher's equipment can be practically determined by consumed active power [9]. Thus, the increase in energy consumption increases the frequency of wear of fuel variable components, significantly affecting the durability of the crushing unit, i.e. it is pointless to force the modes of crushing basing on such indicator.

Thus, on one hand, the parameters of crusher loading (medium size piece of crushed product and wear of lining armor) along with increase of its size result in increased profits. On the other hand, the increase of load leads to increase of wear of changeable components, increasing maintenance costs, reducing profits.

Such kind of dependencies forms extreme dependency type in summation. Given the extreme dependence on electricity consumption, in general case, minimum point of various functionals do not match for studied criteria. Therefore important to establish order relation in the set of vectors, i.e. choose the scheme of compromise [6]. The simplest is to get ΔS_{load} in the function of productivity (due to the amount of the individual components) and assessment of functioning regimes of crushing units according to this value. In general, this will determine the size of ΔS_{load} as extreme dependence of random type, and dependencies from both: operating conditions and terms of service.
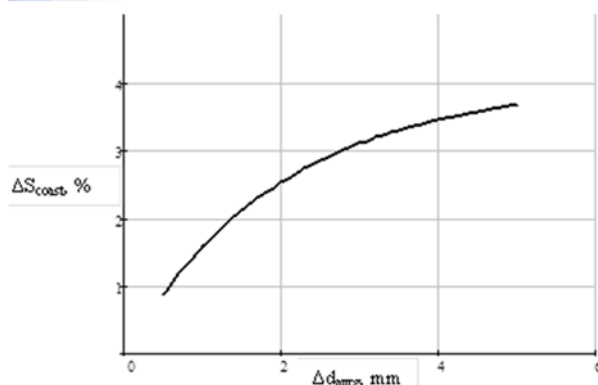

Figure 3. Dependency of reducing of the production cost of the crusher from reducing of the medium-size-piece diameter in the end of a crushing cycle

The use of devices diagnosing operational parameters of the crushers (discharge gap size, grain size of crushed product) allows you to intervene in the management of change quickly and compensate the change of grain size of the final product with respect to the required size. Increase of the gap in one cycle (shift) by the value of Δh would affect the change of the average piece by the value Δd_{avrg}, which, consequently, will reduce the cost of 1 ton of crushed product in the value ΔS_n.

It becomes possible to implement the tracts management system for medium and fine crushing on mining crushing factory based on the proposed methods, standard means of automation and computer engineering. This allows to load crushing and screening equipment efficiently, ensuring minimal costs of fragmentation.

Rational productivity of CCF crusher, size of discharge gap and load amount by filling level can be determined in ASC based on the planned budget productivity of the factory planned physical and mechanical characteristics of the input material and the technical and economic parameters. To ensure the minimum cost of production process with feeder it is needed to load CCM crushers rationally. Tracts put into work are usually refined and corrected based on the actual value when the current plant productivity is known. Thus, the value of rational load cycles of the CCF crushers is defined in the ASC program, based on the physical and mechanical properties of input batch of ore and the size of the task of unloading gap of the CCF crusher, which is determined by loading level for CCF crasher of "KMD-2200" type.

To means described above it is necessary to add another one: active power sensors that can create a high-quality anti-crash system of tract. The greatest threat to tract operations is a continuous work overload of the sieve crusher and CCF crasher. Both are accompanied by a sharp increase in the power of the mechanism, that can be detected by the first derivative and comparing it with some nominal value. If such situation happens - stop of the feeding path should immediately be done. If the engine's power of the sieve crucher is not reduced, it can be an effective to start the engine in reverse. If there is no possibility of automatic control of emergency system, then personnel must be at least informed about the situation with appropriate alarm. The block diagram of system based on the above parameters is shown in Fig. 4.
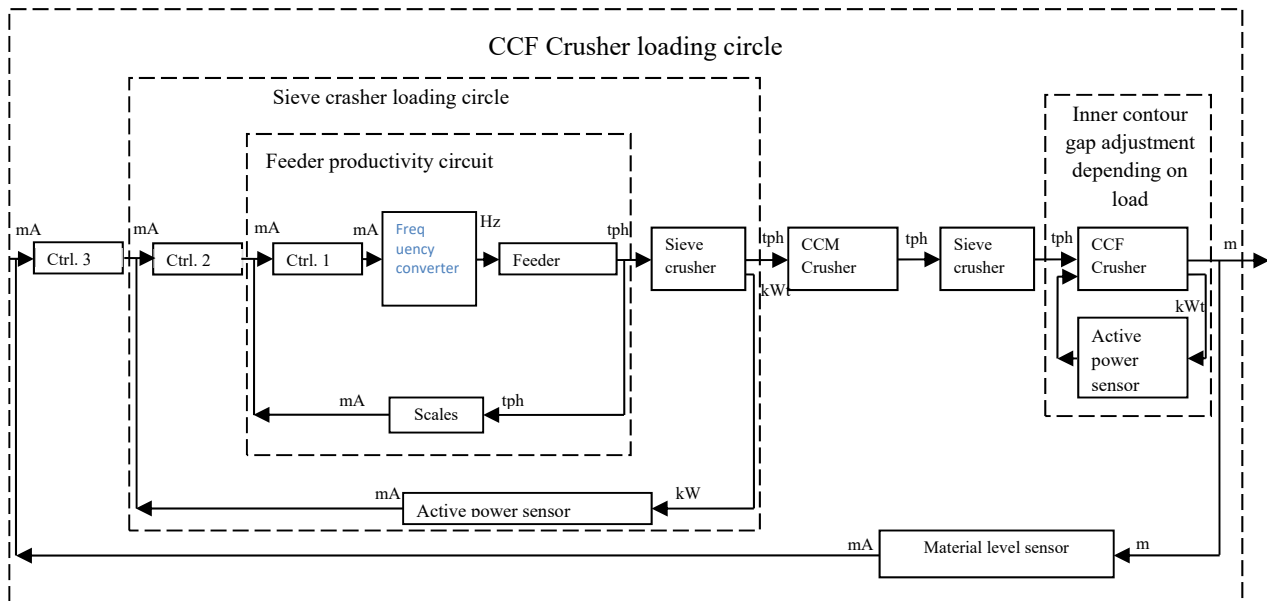

Figure 4. ASC structural graph

It shows four closed circuits. Power stabilization circuit ensures supply of a relatively uniform load stream to the tract. Loading circuit of the sieve crusher works on relay scheme. When a certain level of active power of the sieve crusher is reached, then a signal to limit the load should go from the regulator. The only function of the circuit – demolishing compression prevention of the mechanism. Internal circuit of crusher's unloading gap adjustment is required for optimal adaptation of the crusher mode to the input material. The main circuit is the one for loading CCF crusher.

The described system can be implemented on modern PLC of average class. It is convenient for use in small systems, systems that can be quickly reconfigured, and if the conditions of the production process need reliable functioning, which is especially important for the continuous operation of crushing plant. In combination with other means of automation, PLC additionally allows to build system diagnostic of equipment and alarm emergencies. All subsystems are built at its base, using centralized control, can be easily integrated into a single global system of crushing factory control. The use of universal TCP / IP protocol is the key to the integration of the controller in all types of communications. The maximum number of input and output signals, regulators and internal memory are enough for building control system of the tract.

Conclusions. This paper contains an overview of existing measurement systems of crusher loading level. The most common of them at the Krivoy Rog ore processing plants are gamma relay or radioactive and ultrasonic level gauges. Some disadvantages of these sensors and features of building the systems based on them were given.

As the best way to determine the crusher loading level, it was accepted the method of determining the loading level based on power consumption by the crusher motor. Power consumption is proportionally depended on the amount of work done by crusher, and hence

depends on the amount of ore mass that moved by the cone of the crusher inside the case. To assess the level of load in fine fraction crusher it is advisable to use interpolation in the form: $y=b_1 x+b_2 \cdot x^2$, where x - the level of active power y - filling level of ore in the crusher, b_2, b_1 - interpolation equation coefficients those are for each crusher. For crushers "KDD-2200T" values of the coefficients $b_1 \approx -2 \cdot 10^{-3}$, $b_2 \approx 35 \cdot 10^{-6}$.

Determination of rational load of the crushers is based on the following factors: physical and mechanical parameters of the input ore stream, unit costs of lining armor, energy consumption for crushing and integral characteristic as the cost of the product.

In further studies it is advisable to consider modeling the system of controlling the whole tracts of 3rd – 4th stages of crushing with developed subsystems for determination of the filling level in the crusher.

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