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IMPROVEMENT OF THE BALL MILL AUTOMATION AND OPTIMIZATION SYSTEM FOR SOLID MATERIAL GRINDING

В статье представлена усовершенствованная система автоматизации и оптимизации шаровых барабанных мельниц, обеспечивающая непрерывный мониторинг размольной, вентиляционной и сушильной производительности и оптимизацию загрузки мельницы для достижения максимальной размольной производительности. Применение системы обеспечивает надежную работу мельницы в автоматическом режиме и снижение потребления энергии на процесс измельчения.

У статті представлено удосконалену систему автоматизації та оптимізації кульових барабанних млинів, яка забезпечує неперервний моніторинг розмелювальної, вентиляційної і сушильної продуктивності та оптимізацію завантаження млина для досягнення максимальної розмелювальної продуктивності. Застосування системи забезпечує надійну роботу млина в автоматичному режимі та зниження енергозатрат на процес розмелювання.

The improved system for automation and optimization of the ball mills performance is presented in the paper. The system provides continuous monitoring of grinding, ventilating and drying productivity and it optimizes the mill loading in order to ensure maximum possible grinding productivity. Application of the system provides safe operation of the mill in automatic mode and reduction of energy consumption for grinding.

Introduction. The technological processes of solid material grinding by means of ball mills are of great importance for efficient operation of heat power stations consuming coal as energy carrier, cement plants where clinker is grinded, ceramic plants where clay is grinded and other plants. This is caused by the fact that the grinding mills are big power consumers since grinding process is power-intensive. The electric power consumption for solid material grinding amounts up to about 20 per cent of the total power consumption for own needs of the plant [1].

A ball mill consists of a cylindrical drum and balls inside of it. The drum is being rotated by means of an electric drive. The raw material is fed into the mill at the inlet side of the drum by means of a feeder and the grinded material is taken away at the outlet side of the drum by means of the ventilation system. This is how grinding in a ball mill takes place.

The process of solid material grinding in ball mills has been automated poorly, because there were no methods to measure the main parameters of the grinding process, such as amount of material in the mill, grinding productivity and especially there were no methods to determine the pre-failure condition in which the mill is so much overloaded with the material being ground that it leads to abrupt decrease in its grinding productivity and to blockage. In order to prevent the failure of a mill the operators deliberately decrease the grinding output by feeding less material to the mill, which makes the grinding process more power-intensive and less efficient. There were no reliable methods to find the optimal loading of a mill in order to reach the maximum possible grinding productivity.

Many investigators, however, with a purpose of ball mill automation, have carried out experimental studies and established relations between the main technological parameters of the grinding process and a number of indirect indexes [2]. Based on these studies, various schemes for automation of ball mills have been proposed to regulate the outlet temperature of the air mixture, the differential pressure across the mill drum and the acoustic signal of the mill. But all those systems could not ensure the maximum possible grinding productivity and they did not prevent a possible blockage of the mill.

The aim of the paper. The aim of this paper is to present the improved system for automated control and optimization of solid material grinding by means of ball mills where one more piezoceramic accelerometer is installed at the back bearing of the mill and its signal correlates with the quality of the grinding process.

The main material of the paper. The relation between grinding productivity and loading of a ball mill by the material is proportional (see Fig. 1). The more material is fed into the mill the higher grinding productivity. But at some point there is too much material in the mill and the material is not grinded any more and mill blockage takes place. Depending on the properties of the solid material and on characteristics of the dust system the mill blockage may take place at various loadings of the mill. This is an emergency situation and it should be avoided.

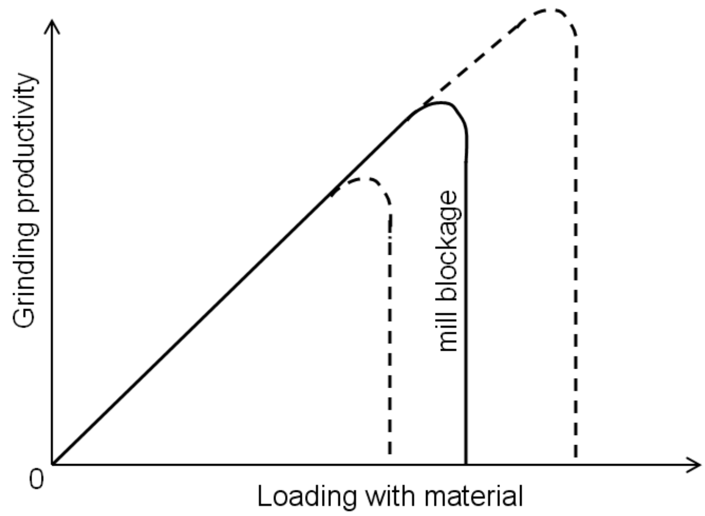

Fig. 1. Grinding productivity of a ball mill versus loading of the mill with the solid material

The maximum possible grinding productivity depends on the properties of the solid material (grain composition, grinding ability index, rock concentration, moisture content etc.), on the characteristics of the dust system (drying ability, ventilation ability and grinding ability),on the amount of material fed into the mill and on the feeding system and its regime [3]. The experience of using the systems developed earlier has put forward the task to improve them and to create new algorithms for calculation of actual values of the main technological parameters of the grinding process, including a new method to measure the amount of material in the mill. Another task was to develop new algorithms in order to optimize mill performance both under standard conditions and under constraints on drying ability and ventilation ability of the dust system [4]. It was also necessary to take additional measures to provide safe operation of the mill and to try out failure situations. In order to fulfill all the above tasks a ball mill automation and optimization system was developed (see Fig. 2).

Depending on the properties of material and characteristics of the dust system the maximum possible grinding productivity of the mill is reached at the level of 80 to 95 per cent of the maximum possible loading of the mill with the material being ground [5].

The maximum grinding productivity in operating conditions is sometimes constrained by drying ability and ventilation ability of the dust system. The deficiency of these abilities may take place due to large moisture content in the material being ground relative to the nominal value or due to decrease of temperature of drying agent. Low drying ability of the dust system is usually characterized by air mixture temperature decrease at the mill outlet below the minimum limit. Deficiency of ventilation ability may be caused by blockages of the inlet and outlet throats of the ball mill (the differential pressure across the mill drum exceeds the maximum limiting value).

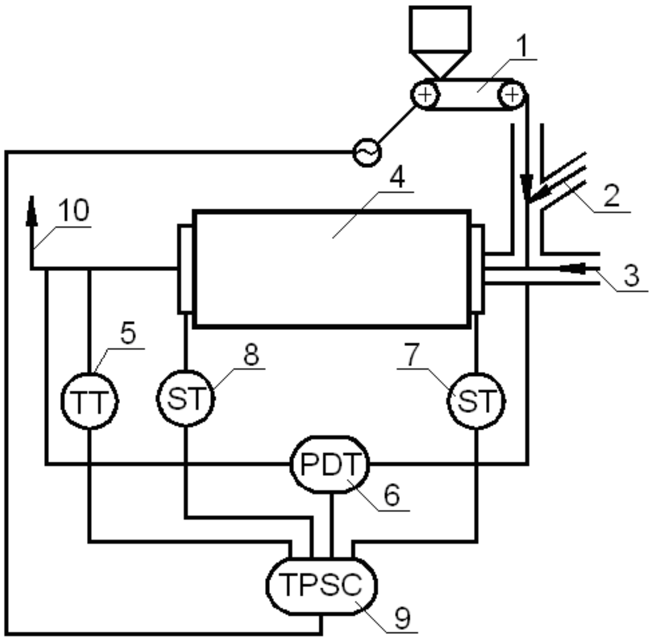

Fig. 2 Structural diagram of the ball mill automation and optimization system: 1 – raw material feeder; 2 – from separator; 3 – drying agent; 4 – ball mill; 5 – temperature transducer; 6 – differential pressure transducer; 7,8 – piezoceramic accelerometers; 9 – controller-optimizer; 10 – to separator

During operation of a ball mill it is especially important to avoid the exceeding of the maximum limiting temperature of the air mixture, which can result in an explosion of the dust system. Therefore the developed ball mill automation system provides a mechanism to prevent overheating of the air mixture. Additionally a sound alarm is provided to give a signal of a pre-failure situation with a possibility to interrupt the supply of a heating agent. In order to safeguard the dust system the precautionary measures are taken by the automation system to avoid the temperature going out of the specified range and to avoid the exceeding of the maximum limiting value of the differential pressure across the mill drum.

According to a specially developed algorithm the controller of the automation system adjusts automatically to the existing dust system, grinding ability of the mill and to the qualitative properties of the material being ground. As these parameters vary the controller adjusts automatically to regulate the material feeding so that the grinding productivity is always maximal. When there are constraints in the dust system on drying ability, ventilation ability or maximum temperature of the air mixture at the mill outlet the material is fed in such a way that the temperature of the air mixture at the mill outlet is maintained within the specified limits and the differential pressure across the mill drum does not exceed the maximum limiting value.

A piezoceramic accelerometer is mounted on the front bearing of the mill and it measures the vibration acceleration of the mill bearing. This signal correlates directly with the mill loading with the material to be ground. Another piezoceramic accelerometer is mounted on the back bearing of the mill and its signal correlates with the quality of the grinding process (fineness of grinding). The interrelation between these parameters is monitored by the controller-optimizer. The controlling action of the controller-optimizer is performed by regulating the rotation frequency of the feeder drive.

The values of air mixture temperature at the mill outlet, differential pressure across the mill drum and relative values of mill loading by the material are displayed at the front panel of the controller-optimizer as well as limits of these parameters.

The task of the main operation mode of the controller-optimizer is to ensure such a feeding of raw material into the mill at which the maximum possible grinding productivity is reached. The controller-optimizer switches to other modes when there are constraints on the mill's drying ability or ventilation ability, as well as when pre-failure situations occur. When the system goes outside of the limiting conditions, the controller-optimizer switches to the dynamic optimization mode in search for an optimal loading of the mill by the material.

When there are no constraints on the drying ability and ventilation ability of the mill and when there is no pre-failure situation the controller-optimizer operation mode is determined by the relative degree of mill loading. So when the relative degree of mill loading is less than 40%, the material is fed into the mill continuously at the maximum possible productivity of the feeder. In other cases the material is fed into the mill according to a special algorithm until the maximum value of loading degree is reached. As soon as the optimal value of the mill loading is reached, when the dust system operates at the maximum possible productivity, the controller-optimizer maintains this value as long as the technological process conditions do not change.

The productivity of raw material feeder should be 1.5 - 2 times higher than the mill's grinding productivity. This is the main condition to ensure normal running of the technological process of material grinding in the mill. When the feeder productivity is insufficient, the controller-optimizer operates in a non-standard mode which is characterized by a lower degree of mill loading. This, in turn, results in an inefficient operation of the dust system.

Insufficient drying ability and ventilation ability of the mill are also limiting factors for reaching the maximum possible grinding productivity of the mill. When such constrains occur optimization of mill operation is possible within the specified constraints.

The developed automation and optimization system was installed at a number of ball mills at heat power stations for grinding the coal, at cement plants for grinding the clinker and at ceramic plants for grinding the clay. One of the systems was installed at a heat power station where three ball mills were used to grind the coal for a

300 MW power generating unit. Application of the developed ball mill automation and optimization system provided raising of grinding productivity of the mills in such a way that the productivity of two mills was enough for preparation of the fuel for the power generating unit and the third mill was turned off. This is how energy saving by 30 % at coal grinding was reached.

Conclusions. New ball mill automation and optimization system is developed and it provides accomplishment of the following tasks:

- Measurement and calculation of three main technological parameters: loading degree of the ball mill with the material being ground, air mixture temperature at the mill outlet and the differential pressure across the mill drum.
- Optimization of the grinding process including continuous search and maintaining of the ball mill loading degree by regulating the feeding of solid material into the mill in order to ensure the maximum possible grinding productivity of the mill.
- Continuous monitoring of drying ability and ventilation ability of the dust system, and in case of decrease of these parameters down to critical values – optimization of mill operation within allowable constraints.
- Visualization of controller operation modes, current values of the mill loading degree, the air mixture temperature at the mill outlet and the differential pressure across the mill drum, as well as minimum and maximum limits of the air mixture temperature and the differential pressure across the mill drum.
- Signalization of work and stops of raw material feeder, occurrence of constraints on dust system drying ability and ventilation ability, exceeding of the maximum limiting temperature value of the air mixture, existence of pre-failure situations.
- Prevention of mill blockage by the material being ground.
- Guarantee of safe operation of the dust system in automatic mode.

Implementation of the system ensures a considerable increase in grinding productivity of a ball mill irrespective of the quality characteristics of the material being ground and the dust system condition. It also consumes less power per unit weight of the material being ground.

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