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Controller-optimizer of ball mill performance

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Анотація – **This work is dedicated to regulator-optimizer ball drum mills to increase energy and economic efficiency of grinding material (coal, clinker, etc.). Developed regulatory optimizer provides continuous monitoring of key parameters of milling process (ventilation, drainage and grinding performance, load, mill, etc.), and optimization of mill grinding for maximum performance.**

Ключові слова – **Кульовий млин, розмелювання, оптимізація, енергоефективність.**

I. INTRODUCTION

The technological processes of coal grinding in ball mills are of great importance for efficient operation of heat power stations (HPS) working on solid fuel (coal). This is caused by the fact that such coal grinding mills are big power consumers at HPSs since grinding process is power-intensive. The electric power consumption for dust preparation at a HPS amounts to about 20 per cent of the total power consumption for own needs or, otherwise, about 2 per cent of the total amount of power produced [1].

The process of coal grinding in ball mills has been automated poorly, because there were no methods to measure the main parameters of the grinding process, such as quantity of coal in a mill, grinding capacity and especially there were no methods to determine the pre-failure condition in which the mill is so much overloaded that it leads to abrupt decrease in its grinding capacity and to blockage. In order to prevent the failure of a mill the operators deliberately decrease the grinding output by feeding less coal 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 grinding capacity.

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 at the mill drum and the acoustic signal of the mill. But all those systems could not ensure the maximum possible grinding capacity and they did not prevent a possible blockage of the mill.

II. AUTOMATION AND OPTIMIZATION OF BALL MILL PERFORMANCE

The maximum possible grinding capacity depends on the coal character (grain composition, grindability index, rock concentration, moisture content etc.), on the dust system characteristics (drying, ventilation and grindability) and on the amount of coal fed into the mill, on the coal 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 quantity of coal 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 and ventilation of the dust system. 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 an intellectual controller-optimizer was developed. The ball mill modeling has shown that depending on the coal and dust characteristics the maximum possible grinding capacity 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 [4].

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

When operating 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 controller-optimizer 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 controller-optimizer to avoid the temperature going out of the specified range and to avoid the exceeding of the maximum limiting value of the differential pressure at the mill drum.

Due to a specially developed algorithm the controller adjusts automatically to the existing dust system, grindability of the mill and to the qualitative characteristics of the material being ground. As these parameters vary the controller adjusts automatically to regulate the material feeding so that the grinding capacity is always maximum (see fig.1).

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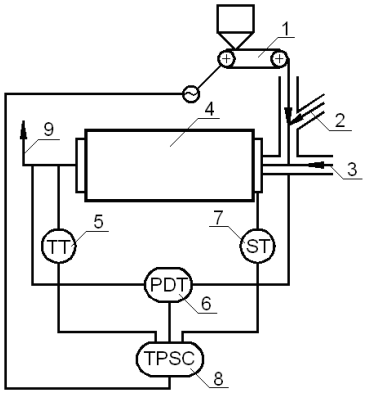

Fig.1. Structural diagram of the ball mill automation and optimization system: 1 – Raw coal feeder; 2 – back from separator; 3 – drying agent; 4 – ball mill; 5 – air mixture temperature transducer; 6 – differential pressure transducer; 7 – transducer of mill charging with material to be ground; 8 – controller-optimizer; 9 – to separator.

The piezoceramic accelerometer is mounted on the front bearing of the mill and it measures the vibration acceleration of the mill bearing which correlates directly with the mill loading with the material to be ground. The interrelation between these parameters is monitored by the controller-optimizer. A temperature transducer is applied to measure the temperature of the air mixture at the mill outlet. A differential pressure transducer is applied to measure the differential pressure at the drum of the mill.

The output signals of all the transducers are 4÷20 mA and they are attached to the appropriate analogue inputs of the controller-optimizer. A control key on the controller-optimizer switches the system to the manual control mode "Distance" or automatic control mode "Automatic". The coal is fed into the mill by means of a raw coal feeder (RCF) controlled directly by the controller-optimizer. The controlling action of the controller-optimizer is performed by regulating the rotation frequency of the RCF drive. The system is equipped with a controlling relay which is switched on by the controller-optimizer when the air mixture temperature exceeds the maximum limiting value in order to stop coal feeding and to ensure dust system safety.

The values of air mixture temperature at the mill outlet, differential pressure at the mill drum and relative values of coal loading in the mill are displayed at the front panel of the controller-optimizer. Also the limits of air mixture temperature and the information on the current condition of the controller-optimizer are displayed. The minimum and maximum values of the air mixture temperature and of the differential pressure at the mill drum (Tmin, Tmax, ΔPmin, ΔPmax) are adjusted for each mill type and specific dust preparation system individually.

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 with a 300 MW power generating unit where three ball mills were used for coal grinding. Application of the system provided improvement of grinding capacity of the mills in such a way that the capacity 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.

III. Conclusion

The developed ball mill control and optimization system provides accomplishment of the following functions:

- Measurement and calculation of the actual values of the 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 at the mill drum.
- Optimization of the grinding process including continuous search and stabilization of the ball mill loading degree by regulating the feeding into the mill in order to ensure the maximum possible grinding capacity of the mill.
- Continuous monitoring of drying and ventilation 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 at the mill drum, as well as minimum and maximum limits of the air mixture temperature and the differential pressure at the mill drum.
- Signalization of work and stops of RCF, occurrence of constraints on dust system drying and ventilation, 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 capacity 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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