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Analysis of Methods for Controlling Ball Drum Mills at Hard Materials Grinding

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***Abstract* — The technological process of grinding hard materials with application of ball drum mills has been analyzed. The advantages and disadvantages of ball drum mills application for grinding hard materials have been determined. The analysis of methods for ball drum mills control has been conducted based on the vibration acceleration signal from the mill's input support, the differential pressure across the mill drum, the temperature of the air mixture at the mill's outlet and the active power signal of the mill drive.**

***Keywords* — ball drum mill; automatic control; protection; algorithm; productivity**

I. Introduction

The technological processes of material grinding with application of ball drum mills (BDM) play a key role in many industries [1]. Ball drum mills are used for grinding clinker at cement plants, clay at ceramic plants, ore at mining enterprises and other. Grinding processes are of particular importance for thermal power plants that operate on solid fuels, i.e. coal.

The significant energy consumption associated with the grinding of hard materials drives the development of new approaches to the automated control of ball drum mills. The improvement of automatic control algorithms is also aimed at enhancing the reliability of BDM operation and preventing emergency situations such as mill blockage (overflow), air mixture explosions, blockages and failures in dust pipelines [2].

II. Technological Process

Grinding is the process during which the size of material particles is reduced by means of the mechanical action. It is widely used in various industries for different purposes. As a result of grinding, the surface area of the processed materials increases, which significantly accelerates processes like dissolution, chemical interaction and the release of biologically active substances from the material being ground. Depending on the size of the initial material chunks and the final product, grinding can be divided into crushing (coarse, medium, and fine) and milling (fine and ultra-fine). During medium and fine crushing, brittle substances are ground in rollers, crushers and mills.

A ball drum mill consists of a drum partially filled with grinding bodies, such as balls, rods or sometimes pebbles. During the rotation of the drum, the grinding bodies are lifted by the centrifugal force and by the mutual friction between themselves and the drum lining, which helps them rise to a certain height, fall and grind the material inside the mill. Steel balls are often used as grinding bodies.

The ball drum mill has many advantages, making it one of the leading machines for grinding:

- it is used for grinding both soft and hard materials;
- it can operate for a long time without repair, ensuring high operational stability;
- the ability to adjust the fineness of grinding within the limits required for a specific task;
- the ability to work with heated air provides high drying efficiency, even when working with high-moisture materials;
- metal impurities entering the mill with the material do not damage the mill itself.

However, the ball drum mill also has some disadvantages:

- the construction of the mill requires significant material costs and occupies a large space;
- if the mill operates at less than full capacity, its efficiency decreases significantly.

Despite the mentioned disadvantages, the ball drum mill is widely used for grinding hard materials.

The technological diagram of the process for grinding the hard materials includes the following equipment: raw material hopper, raw material feeder (belt conveyor), ball drum mill, separator, cyclone (dust removal from the air), dust hopper and mill fan. The raw material flows from the raw material hopper to the feeder, which transports it to the rotating ball drum mill. Additionally, the inlet of the BDM receives the drying agent, i.e. a mixture of flue gases and ambient air. After grinding, the material and the drying agent form the air-mixture that exits the BDM and enters the separator, where particles are classified according to their size. Larger particles that were formed during grinding are returned to the BDM for re-grinding (return from the separator). The air-mixture after the separator enters the cyclone, where the drying agent and dust are separated. The dust is then directed to the dust hopper.

III. Automatic Control Methods

During the setup of automatic control systems for the BDM, mill calibration is usually performed. This involves recording the static characteristics of the mill's load dependence on the raw material feeder productivity [3]. The mill's load is also an indicator of its grinding productivity. When the productivity of the raw material feeder increases, the grinding productivity of the mill increases too. But after reaching some maximum value, the grinding productivity of the mill may decrease. This may lead to a blockage of the mill. Such a situation may occur due to changes in the quality characteristics of the raw material, such as moisture content and granulometric composition.

After calibrating the mill, its control is carried out according to the obtained static characteristics. Blockage protection is provided by measuring the vibration of the bearing supports at the mill's input and output, as well as the differential pressure across the mill. If the vibration levels of the bearing supports fall below the allowable values (each bearing has its own allowable limit), the protection system should activate stopping the material feed to the mill and preventing a blockage. The mill's blockage protection also involves monitoring the differential pressure across the drum. If the differential pressure exceeds the allowable limits, the raw material feed to the mill must be immediately stopped.

During the start-up of the mill from the off mode, the coal supply is carried out gradually to avoid potential blockage. In case of the pulse feed mode, when the productivity of the coal feeder is twice or three times higher than the working productivity of the mill, the duration of pulses gradually increases, and in case of the continuous feeding, the productivity of the coal feeder increases gradually.

When the raw material feeding is suddenly stopped, there is a risk of blocking and failure of the dust pipelines. This happens because the material becomes evenly distributed along the mill drum, leading to a significant increase of the coarse dust fraction amount in the mill and the air mixture. This increase in the coarse dust fraction leads to an increase in the differential pressure across the mill to a certain maximum level, after which the differential pressure may decrease. If the differential pressure increases to a critical value, blockage and failure of the dust pipelines may occur. Therefore, during operation of BDM, it is important to maintain conditions when the differential pressure does not reach the critical value. The mill is stopped by gradually reducing the duration of the pulses (in case of the pulse feeding of the raw material) or by gradually decreasing the feeder productivity (in case of the continuous feeding of the raw material).

In addition to the threat of blocking and failure of the dust pipelines, another emergency situation may arise in a coal mill, i.e. explosion of the air mixture at the outlet. This explosion can be triggered by the combustible components contained in the coal dust, if the temperature of the air mixture exceeds the permissible limits. To prevent such explosions, a protection loop should be provided in the automatic control system. This protection loop should change the temperature of the drying agent by increasing the supply of air from the environment. However, this can create a new hazard because of the increased amount of oxygen in the drying agent, which can increase the risk of explosion. Therefore, the ratio of ambient air flow rate and flue gases flow rate should be maintained within the strictly defined limits.

Today, there are several control algorithms for BDM [1] – [4]: pulse raw material feeding with fixed duration of pulses and pauses between them; continuous raw material feeding with fixed productivity of the feeder; control based on the measured vibration signal of the front bearing support with pulsed or continuous feeding of the raw material; control based on the measured differential pressure signal across the mill with pulsed or continuous feeding of the raw material; control based on the measured air mixture temperature signal at the mill outlet with pulse or continuous feeding of the raw material; control based on the measured active power signal of BDM drive with pulsed or continuous feeding of the raw material.

The condition of the dust pipelines can be a limitation for increasing the grinding productivity of the BDM. If the dust pipelines are not airtight, this leads to reduction of the ventilation productivity and overall efficiency of the mill. Another limitation is an insufficient or too high level of the ball charge in the mill. This level depends on the characteristics of the coal and the type of the mill.

IV. Conclusion

This work presents an analysis of the technological process of grinding hard materials with application of the ball drum mills. The advantages and disadvantages of using ball drum mills for grinding hard materials have been identified. Methods for controlling the ball drum mills based on the vibration acceleration signal from the mill's input support, the differential pressure across the mill drum, the air mixture temperature at the mill's outlet and the active power signal of BDM drive have been analyzed.

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