ABSTRACT

dissertation for the PhD degree by specialty 6D071700 – Heat Power Engineering

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Efficiency of industrial heat and power plants in the modernization of solid fuel preparation systems (for example, CHP-2 the city of Temirtau)

Relevance of the dissertation research.

In the global consumption of organic fuel, coal is second only to oil. However, the sharp increase in the cost of oil and gas increases interest in using coal as fuel for TPP (thermal power plants).

The Republic of Kazakhstan ranks 8th in terms of confirmed coal reserves, coal reserves are about 35 billion tons (coals account for approximately 45% of the total fuel balance). Coal occupies a very large share in the generation of electric energy - about 70%, slightly less in the generation of thermal energy.

Several major coal-fired thermal power plants operate in Kazakhstan, including: Ekibastuz SDPP-1 with an installed capacity of 4,0 thousand MW, Ekibastuz SDPP-2 with an installed capacity of 1,0 thousand MW, Aksu SDPP with an installed capacity of 2,4 thousand.MW, Karaganda SDPP-1 with an electric capacity of 84,0 MW, Karaganda SDPP-2 with an electric capacity of 665,0 MW. A large number of coal - fired thermal power plants have been installed in Kazakhstan: 3 - in Pavlodar, 2 - in Almaty, 2 – in Astana, 3 – in Karaganda, 1 - in Ust-Kamenogorsk and 1 - in Ridder, as well as many other thermal power plants. Coal is burned in a crushed form with coal dust residues on a 90-micron sieve at the level of 20%; this degree of grinding is achieved in various mills and with different dust preparation schemes.

Preparation of high-quality coal dust for steam boilers is an energy-consuming process, in this regard, an urgent task in the dissertation is to find optimal solutions for fuel preparation at thermal power plants that reduce energy consumption and increase the productivity of mills.

The dissertation discusses ways to reduce the consumption of electrical energy and increase the efficiency of the coal dust preparation process of the Temirtau CHP-2. The paper proposes a pre-crushing plant for coal, which allows fractionating fuel before grinding, optimizing the process of grinding coal in a ball drum mill (BDM). The BDM model has been developed and a technique for selecting the optimal loading of the grinding balls of the mill is presented, which allows to reduce energy consumption and increase productivity. In addition, a modern automation system of the dust preparation production process has been developed, taking into account the minimization of energy consumption.

The most reliable indicators of the grinding efficiency in the BDM can be obtained at an operating mill. However, conducting experiments at an operating mill is very difficult, due to difficulties in accessing a working mill and especially if possible, changing the design or operating mode. In connection with this difficulty, the possibility of creating a reduced model of a ball drum mill was considered in the dissertation. When creating the BDM model, the preservation of geometric similarity becomes mandatory and the developed BDM model accurately reproduced the geometric shape of the drum. On the reduced model of the BDM, comparative studies of the influence of various factors on the grinding process can be conducted with great reliability of the results, especially those related to the indicators of the crushed coal. Comparative experiments with a change in the studied parameter should be conducted with an equal duration of the grinding process, since the level of grinding changes markedly with a change in the duration of the process.

Research purpose is to study the possibility of reducing the cost of electrical energy in the dust preparation system for the preparation of coal dust and to determine ways to improve the basic indicators of ball drum mills.

Research objectives. To achieve this goal, the following tasks are envisaged:

- to analyze existing dust preparation systems and review existing methods for improving the energy efficiency of dust preparation systems;
- to evaluate the thermal and thermodynamic efficiency of an individual dust preparation system of a thermal power plant (CHP);
- development of a device for preliminary crushing of coal;
- development of a methodology for modeling the coal grinding process in an unventilated ball drum mill with the required accuracy of reproducing the grinding process;
- creation of the BDM model, determination of the influence of mill parameters on the intensity of coal grinding when changing the diameters of grinding balls and the degree of filling of the drum with grinding balls;
- development of mathematical modeling of optimization of the parameters of the Sh-25A ball drum mill for coal grinding;
- to conduct a comparative analysis of theoretical and experimental studies of fuel grinding processes in a ball mill;
- development of a modern automation system for a ball mill, taking into account the thermal characteristics of the fuel.

The object of the study is a dust preparation system with a ball drum mill of CHP-2 JSC "ArcelorMittal Temirtau".

Research methods. In the field of solid fuel grinding in a ball drum mill, theoretical, analytical and experimental research methods were used. The use of ALTAIR EDEM programs allows you to simulate the grinding process and analyze the impact of changes in the solid fuel grinding process. In experimental studies, data were obtained on the process of grinding solid fuel in stationary mills.

The subject of the dissertation research is the laws of fuel grinding, the laws of the energy of destruction of solid fuel and ways to reduce the consumption of specific energy for grinding, analysis of the structure and parameters of a ball drum mill, evaluation of the efficiency of grinding in the mill.

Scientific novelty of the results of the dissertation:

- an installation has been developed for pre-crushing, formation of a solid fuel fraction before SHBM;
- a method of physical modeling of the operation of an unventilated ball drum mill has been developed;
- a physical model of a ball drum mill has been developed in which the grinding process with a change in the main parameters of the mill is reproduced with the required reliability;
- the influence of changes in the main parameters of the mill on the grinding process is determined;
- the influence of changes in the parameters of the crushed coal on the intensity of the grinding process is determined;
- a mathematical model of a ball drum mill has been developed, providing efficient dynamics of mill operation with the best performance and energy consumption;
- a modern automation system has been developed to effectively control the operation of the BDM, taking into account the thermal characteristics of the fuel being burned with the use of computer modeling.

The practical value of the work. The modernization of the system for the preparation of roofing with a ball mill is proposed, in which the consumption of electric energy for grinding a unit of volume (weight) of coal has decreased to the level characteristic of hammer and medium-speed mills, which allows us to recommend the expansion of the use of BDM at thermal power plants. The practical significance of the research is reflected in the use of the results obtained in the educational process and implementation into production.

Reliability of the work. The reliability of the results obtained is ensured by the use of high-precision instruments and modern research methods, and by matching the results of numerical modeling and experiments with the results of other authors in the studied range of parameter changes.

Provisions submitted for defense:

- development of a new device for crushing coal, allowing solid fuel to be fractionated before crushing;
- a technique for creating a reduced model of an unventilated ball drum mill;
- methods of grinding coal: changing the size of grinding balls, changing the degree of filling the drum with grinding balls, changing the degree of filling the drum with crushed coal;

- the results of the study of the influence of the parameters of crushed coal on the grinding intensity: characteristics of coal (different coals), particle sizes of incoming coal;

- results of experimental studies and mathematical modeling of the grinding process in the mill;

- development of an automation system for effective control of the BDM operation, taking into account the thermal characteristics of the fuel being burned.

Approbation of the results of the dissertation. The main results of the dissertation work have been tested at international scientific-practical and scientific-technical conferences and symposiums:

- X International Scientific and Practical Conference «Competitiveness of the nation - the main condition for improving the welfare of the people» (Temirtau, 2019);

- Days of Scientific Science - Sofia XXIV Scientific Conference with international participation EMF 2019 (Sofia, Bulgaria, 2019);

- International Educational Blending Conference «Education is the foundation of Eurasian Cooperation» dedicated to the 85th anniversary of Shakarim University (Semey, 2019);

- IX International Scientific and Practical Conference «Science and Education in the modern world: Challenges of the XXI century» (Nur-Sultan, 2021);

- XV International Scientific and Practical Conference «Global science and innovations 2021: CENTRAL ASIA». 2021 (Nur-Sultan, 2021);

- International scientific and practical online conference «Integration of science, education and production - the basis for the implementation of the National Plan» (Karaganda, 2022);

- International scientific and practical conference «XV Saginovsky readings. Integration of education, science and production» (Karaganda, 2022).

Publications. According to the results of the research, 28 publications were published: 6 works were published in publications recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Education and Science of the Republic of Kazakhstan, 1 scientific work in the journal Scopus, which was included in the international abstract database Scopus, 4 works in foreign journals, 22 works in international conferences, 1 patent for a utility model.

The author's personal contribution consists of: setting research objectives, analyzing and generalizing literary data; developing new technical solutions, as well as developing a ball drum mill model in which the grinding process is reproduced with the required reliability; conducting experiments on a ball drum mill model to determine the influence of mill parameters and crushed coal on grinding efficiency; conducting mathematical modeling the grinding process.

Scope and structure of the dissertation: The dissertation consists of a definition, designation and abbreviation, introduction, five sections, conclusion, list of references and appendix.

The introduction presents the main data, including the relevance of the research work, and specifies the problem under study. The main idea, scientific novelty, reliability of the work is shown, the personal contribution of the author is presented, as well as the approbation of the results and publications.

In the first section, the analysis and review of existing fuel preparation systems of CHP-2 JSC "ArcelorMittal Temirtau. The characteristics of the fuel economy and thermal power characteristics of solid fuel preparation systems are given. The analysis is conducted, the main characteristics of the dust preparation system are revealed, the indicators of various mill devices are determined and their advantages and disadvantages are noted. Based on the generalization of experimental data and calculations, the operating characteristics of a ball drum mill are determined.

In the second section, measures are proposed aimed at improving the energy efficiency of the CHP-2 dust preparation systems, obtained on the basis of an exergetic analysis of the operation of the coal-grinding system. To achieve energy efficiency, an analysis of each structural block was conducted and the input and output flows of the exergetic balance system were determined. Based on the results of calculations, the exergetic efficiency of individual units and the fuel preparation system itself are determined, characterizing the thermodynamic efficiency of the dust preparation system for predicting equipment modernization or the introduction of new technologies at the station.

In the third section, the influence of the parameters of a ball drum mill on the intensity of coal grinding is considered. With the use of modern software products for modeling the grinding process, the influence of changes in the parameters of the BDM and the crushed coal on the efficiency of the grinding process is determined. A series of experiments were conducted to determine the level of optimal loading with balls and crushed coal for an unventilated BDM, an analysis of a numerical experiment performed in the Altair EDEM software environment was conducted. It is established that the optimal degree of ball loading for the grinding process in the BDM is in the range of 0.30–0.35 of the volume of the mill drum.

In the fourth section, a method for selecting optimal parameters for the solid fuel grinding process under conditions of its combustion at the Temirtau CHP-2 of JSC ArcelorMittal Temirtau has been developed. For this purpose, experimental models of a ball mill were used on the basis of the Almaty University of Energy and Communications named after G.Daukeev and on the basis of the Karaganda Industrial University. Recommendations are given for effective improvement of the mill loading process with grinding balls and feed fuel.

For mathematical modeling of the solid fuel grinding process, the theory of a full-factor experiment was applied, which establishes the influence of all possible combinations of the main experimental factors on the target response function in the form of optimization parameters. Regression equations are obtained that take into

account the dependence of the energy performance of the mills on the operating parameters of the grinding process.

The fifth section presents a modern system of automatic control of the technological process of the dust preparation system (APCS) for the preparation of coal dust at the Temirtau CHP-2. A system for monitoring the operation of mill equipment, collecting and analyzing data on the progress of the grinding process, maintaining the specified grinding parameters, ensuring safe and economical operation of the dust preparation system has been created.

Such a system allows you to automatically adjust the parameters of the mill and maintain optimal modes, which helps to increase production efficiency and reduce the occurrence of emergencies.

The conclusion reflects the main results and provides conclusions on the dissertation work.