ANNOTATION

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

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Development of technical solutions for reduction of harmful emissions of TPP at SGP

Research rationale

The trend of high energy development leads to the development of new, efficient, energy-intensive installations. Also, new power plants should meet annual tightening environmental requirements. It is known that the main sources of electricity in Kazakhstan are thermal power plants using traditional fossil fuels - coal.

According to the Concept for the development of the fuel and energy complex of the Republic of Kazakhstan until 2030, it is envisaged to increase electricity generation due to the use of natural gas, using maneuverable power plants, in particular gas turbine ones, and the need to use modern fuel combustion methods is noted.

The generation of electricity using gas at thermal power plants with steam and gas plants for Kazakhstan, especially in the southern and western regions where there is main gas, is the most promising. First, the capital cost per unit of electricity is lower than the cost of coal-fired thermal power plants and they can be built faster. Secondly, the economy of SGT is higher than that of individual STP or GTP. We all know that SGT allow to achieve electric efficiency of about 60%, when the efficiency of steam power plants is 33-44%, and GTP - 25-35%. Thirdly, the SGP in the GTP is maneuverable, that is, it quickly gains the assigned power. SGP is operated in such cities of Kazakhstan as Aktobe, Uralsk, it is planned to build new PSUs in Kyzylorda, Shymkent, Turkestan, Taldykurgan, Nur-Sultan.

Research purpose is to develop and study technical solutions for reducing harmful emissions in fuel-burning devices of thermal power plants (TPP) with steam-gas plants (SGP), and more specifically, to develop technical solutions for creating a low-toxic GTP and a heating chamber of exhaust heat boiler (EHB) SGT.

Research objectives. In accordance with the goal and taking into account a wide range of areas for research, the following objectives have been set:

- literary analysis and assessment of the environmental impact of existing TEPs on the environment;
- development of anticipated technical solutions (a - two-tier burner for GTU combustion chamber; b - recovery boiler heating chamber on echelloned angle stabilizers) to reduce harmful emissions into the atmosphere of SGP fuel-burning plants;

- theoretical and experimental study of the two-tier burner device of the EHB SGT and echoloning of the corner stabilizers of the recovery boiler;

- development of mathematical model of microfracking of gaseous fuel in MFU using ANSYS software complex;

- Issuing recommendations on the use of micro-flare burners and developing a methodology for calculating nitrogen oxide formation;

- development of an analytical procedure for calculating NO_x during gas combustion in a blocked air flow at $14\% > \alpha > 20\%$.

Comparison of the results obtained with similar works by other authors.

Research methods. The dissertation used theoretical, analytical and experimental research methods. Theoretical studies suggested the use of modern modeling methods using programs such as ANSYS Fluent. Experimental studies were used to analyze and determine the characteristics of the created front-line devices. Experimental studies were carried out using modern instrumentation, in particular an anemometer, a gas analyzer, flow meters, etc.

Description of the main investigation results. Within the framework of the investigation work, the following results were obtained:

1. As a result of the analysis of literary sources and patent searches, the possibility of reducing emissions of nitrogen oxides in the GTP CC and EHB SGT during microfactive combustion of natural gas in them is justified;

2. On their basis, a new front-end device with a two-tier burner for the GTU CC was developed, implemented in the design and investigated, which is confirmed by the patents of the Republic of Kazakhstan and EAPO;

3. As well as for the pre-heating chamber, the EHB SGT was developed, implemented in the design of microfake devices from angle stabilizers and investigated in assembly during echeloning;

4. Independent theoretical and experimental studies confirmed the effectiveness of the proposed method of reducing nitrogen oxides, that is, when burning a "poor" preliminary fuel-air mixture in a two-tier burner.

5. Based on the use of mathematical modeling of the Ansys fluent program, the dependencies of the NO_x output on the degree of swirling of the air flow in the combustion zones on the aerodynamic parameters of the flow and geomet are established;

6. The method of calculation of excess air coefficient in ballasted combustion products for CP with LPG in the form of angle stabilizers is proposed, which allows preliminary estimation of emissions of nitrogen oxides depending on aerodynamic and geometric parameters for CP CP with layered LPG;

7. Experimental and theoretical studies show the possibility of creating an effective two-tier front-line devices of the GTU CC, satisfying the promising standards of harmful emissions of combustion products during microfactive combustion of pre-prepared FAs (natural gas, propane) in a wide range of $\alpha\_\Sigma=1{,}5\div12$ while maintaining other characteristics at a high level;

8. On the basis of theoretical and experimental studies of microfrake fuel-burning devices, ways to improve them have been proposed and a number of new patents protected by copyright certificates have been developed.

The obtained results of the calculation-experimental study for TCS PSU TPP can be used in the training process and in the works of Technoservice LLP during the implementation of MFIs (the possibility of implementing the results of the study is confirmed by the Act and Certificate)

The main idea and internal unity of work. Using the methods of system analysis, the theory of combustion of gaseous fuel and the principles of greening thermal power plants, develop technical solutions in the designs of the burner of the GTP and EHB combustion chamber to reduce the formation of nitrogen oxides.

All chapters are devoted to the basic idea and have internal unity, since they are interconnected.

Scientific novelty lies in the development and investigation of new fuel-burning devices, in particular: 1. Comparative ecological assessment of the operating thermal power plants with technical training college, GTU, the CCGT is executed and the analysis of microtorch combustion of fuel and technology, constructive solutions on increase in eco-friendly safety of operation of the CCGT is made. 2. Generalized experimental characteristics on emissions of nitrogen oxides in GTP combustion chambers and CP burners were obtained. 3. A mathematical model of microfake combustion of gaseous fuel in the GTU combustion chamber with a two-tier burner and in the afterburning chamber of the CP with angle stabilizers has been developed. 4. The method of calculation of nitrogen oxides in the superheating chamber taking into account microfiltration in burners of SGP and blockage of combustion products has been developed.

And also, the novelty of the work is confirmed by the Eurasian patent for the invention and seven patents for the invention of the Republic of Kazakhstan.

Reliability of work. The results obtained during the experiments have the necessary degree of reliability, for the following reasons: 1) during the investigation of microfake combustion of two-tier burners and angle stuin-diffusion stabilizers, certified instruments and tested methods were used; 2) results of experiments and numerical modeling were consistent with results of foreign authors; 3) the results have the necessary degree of reliability, since they are confirmed by the convergence of calculated and experimental data.

The practical value of the work and the importance of the results lies in the development and obtaining of:

New frontline combustion devices can be used for combustion of gaseous fuel in GTP combustion chambers and EHB in afterburning chambers, which improves its characteristics, improves combustion completeness and efficiency, significantly reduces harmful emissions into the environment and reduces the length of the combustion chamber.

The procedure for calculating nitrogen oxide concentrations can be used at the design stages of the GTP and STP and will make it possible to make optimal design solutions and mode parameters during the modernization of combustion chambers.

The textbook Steam and Gas Plants and the monograph Combustion Chambers and Microfix Devices, which include the results of dissertation work, can be used in the training process for training engineers at universities.

Provisions for Defense:

- results of numerical modeling and experimental studies of combustion processes, formation of toxic substances when using a two-tier burner and echelloned angle stabilizers;
- developed designs of gas burners operating on the principle of microfrake combustion, which have high environmental and technical characteristics;
- formulae, dependencies of "poor" breakdown and stable combustion of the front-end device, as well as emission of nitrogen oxides of the GTU CS and the CP heating chamber when using experimental burners, taking into account developed, new designs;
- short-length video videos of combustion processes in different modes.

The personal contribution of the author consists of:

- in a literary review and patent search on the technical solutions of the dissertation;
- in the preparation and execution of applications for proposed patents;
- in the manufacture of a physical model of a two-tier burner for the GTU combustion chamber and angle stabilizers for the afterburner chamber of the recovery boiler;
- calculation using the ANSYS fluent software system for micro-flare combustion processes;
- in conducting the experiment of a two-tier burner and an angle stabilizer;
- in the processing of experimental data and in the analysis of results;
- in writing dissertation work.

Approbation of the investigation work results. The main results of the work were presented and discussed at international scientific and practical conferences and forums: V international scientific and practical conference "Global science and innovations2019: Central Asia" (Astana, 2019); VIII International Scientific and Practical Conference "Topical Problems of Transport and Energy: Ways of their Innovative Solution" (ENU named after L. N. Humilev, Nur-Sultan, 2020); Scientific and practical conference "Coal energy in Kazakhstan: problems, solutions and development prospects" (NURIS, Nur-Sultan, 2020);

Publications. Basic provisions of work are presented in 20 publications, including in the Bulgarian Chemical Communications magazine entering the Scopus database, in 3 editions recommended KKSON to MAUN RK in 4 international academic and research conferences and forums, in 7 patents for the invention of RK and in 1 Evrazian patent for an invention, in the monograph "Combustion Chambers and Microtorch Devices" and the manual "Steam Gas Plant". The results of the dissertation work were also included in the report of grant financing of the Ministry of Education and Science of the Republic of Kazakhstan on the topic of IRN AR05134025 "Research and development of micro-glass front-line devices, complex technical solutions in order to improve the environmental safety of gas turbine plants in Kazakhstan."

Volume and structure. The dissertation consists of an introduction, 4 sections, a conclusion, a list of literature and an appendix.

The introduction considered the existing situation regarding energy, TPP, revealed the relevance of scientific work, specified the problem under study. The purpose and tasks of the work, scientific novelty, personal contribution of the author, reliability, as well as publications and testing of the results are given.

The first section of the dissertation presents an overview and analysis of the environmental impact of existing thermal power plants and a comparative environmental assessment of existing thermal power plants with SGT, GTP and STP. Mechanisms of nitrogen oxides formation are considered. Design and technological methods of solutions for suppression of harmful emissions into the environment and for improvement of environmental safety of PSU operation have been dismantled. The processes of fuel combustion were investigated and the structures of the microfrake device (MFU) in the fuel-burning devices of SGP were analyzed. The task of the study is formulated.

In the second section describes the experimental installation and bench for the MFU and the micro-flare front device (MFFD), i.e., the installations for studying the two-tier burner of the GTU combustion chamber and for the echelloned angle stabilizers of the heating chamber are described. The hot experiment was carried out on natural gas and propane. Proposed new technical solutions to reduce harmful emissions. Method of conducting experiments and processing of results, assessment and accounting of errors of measurement results are considered.

In the third section provides analysis of theoretical models of nitrogen oxides formation in GTP combustion chambers. A mathematical model for new MFIs has been developed. Results of calculations using ANSYS fluent software are given. Calculations were made for both natural gas and propane. Temperature fields, velocity fields of combustion products, swirling of flow after two-tier front-line devices and angle stabilizers are presented. Analytical is calculated for NO_x in the GTP combustion chamber during microfracking of lean fuel-air mixture. Method of calculation of CGP EHBheating chamber with determination of C_{NO_x}.

The fourth section presents the results of the study of environmental safety of PSU operation and reduction of nitrogen oxides formation in fuel-burning devices. There are presented analyses of experimental studies of the designs of micro-flare devices of the GTP combustion chamber with a two-tier burner and the results of testing the model of the superheating chamber with layered angle stabilizers of the EHB recovery boiler. Dependencies of nitrogen oxides concentration on temperature of exhaust gases, air excess coefficient, etc., are shown. New technical solutions for nitrogen oxide concentration reduction were analyzed. There are presented new two-tier front-end devices that burn fuel more efficiently compared to the prototype, and these burners also work effectively on gaseous and liquid fuels at the same time..

The conclusion reflects the main results and conclusions of the given investigation work.