ANNOTATION

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

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Development and investigation of burner devices for burning microfaceting the basis for the decision of ecological problems

Research rationale

The contemporary development of the energy sector and any industry of the state is associated with the satisfaction of the permanently growing demand for electric and thermal energy with the constant growth of requirements for environmentally safe applications in fuel-burning devices. This is shown by all the fundamental documents, including the Program for the transition to a "Green Economy", the Program for the Development of the Fuel and Energy Complex of the Republic of Kazakhstan until 2030 and the new Environmental Code of the Republic of Kazakhstan.

Renewable energy sources are becoming increasingly relevant in the above documents and in a number of others. Moreover, considering the Kazakhstan 2050 program, the increase in renewable energy is planned to be much more significant. The essential growth is observed in Solar and wind energy.

At the moment, gas turbine technologies are widely used in the western regions of Kazakhstan where there is a fairly large base of gaseous fuel, but there are projects to bring out gas turbine plants in the southern regions, in particular, the construction of steam-gas cycles. In metallurgy, the main consumers of fuel are fuel combustion devices that are used in the main and auxiliary processes of various high-temperature furnaces.

In general, the share of traditional fuel is significant, therefore, the issues of reducing the formation of harmful substances remain relevant, in particular in industries where fuel consumption is considerable.

Considering all of the above, it is meaningful to develop technologies that allow burning gaseous fuels of various compositions, under various loads and in a wide range of excess fuel and low emissions of toxic substances.

A promising method to meet the requirements stated above is the use of zone combustion in a small number of flares - "microflame" combustion. This method can significantly reduce the formation of toxic substances, and the use of this technology will improve the environmental safe devices applied in various industries.

Research purpose is to develop and research burners appling microflame combustion (MFC) for environmental safety in the following industries: for combustion of waste gases in petrochemical plants (flare burners), in mechanical engineering for uniform heating of metal products (MFC).

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

- Carrying out literary and patent analysis of flare burners in the petrochemical industry and burners for metal's heat treatment.
- Development of new flare burners for waste gases of petrochemical and micromodular burners for metal's heat treatment.
- Experimental study of microflame stabilizers in the form of triangular prisms for diffusion combustion of gases in flare burners.

Theoretical study of microflare elements with the application of numerical simulation ANSYS Fluent.

- Carrying out experimental studies of a microflame burner for heating metal products.

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

Research methods. Theoretical and experimental research methods are used in the given investigation work. Theoretical studies involved the use of modern modeling methods using programs such as ANSYS Fluent and COMSOL Multyphysics. Experimental studies were used to analyze the created burners. In experimental studies, a modern instrument park was used, in particular an anemometer, a gas analyzer and flow meters.

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

- A literature review and patent analysis of burners for waste gases of the petrochemical industry, as well as burners used for heat treatment of metal products, has been carried out.
- A new flare burners for waste gases from the petrochemical industry have been developed . New micro-modular burners for heating metal products with efficient combustion of natural gas (propane) have been developed. All developments received patents and applications.
- Experimental studies of multifunctional devices in the form of triangular prisms were carried out in order to select the size and method of fuel supply to the multifunctional devices, and there was shown the efficiency of reducing harmful emissions .
- Calculations of the main characteristics of the combustion process of a mixture of gases (waste gases of a petrochemical production) have been performed and the results have been compared with experiments on corner multi-function devices using numerical simulation on the ANSYS Fluent software product.

A series of experiments was carried out on the developed stand for the investigation of heating processes for metal products with different thickness with micromodular burners. Measurements of temperature fields and concentration of toxic substances were carried out. Comparison results with other authors are presented. Numerical modeling was carried out using the ANSYS Fluent software package.

- Comparison of the obtained results with the works of other authors shows that microflame burners have 20% lower values of nitrogen oxide concentrations.

Comprehensive studies have shown the efficiency of microflame combustion of gaseous fuel for environmental safety (CNO ≤20 ppm, CCO ≤1%).

The main idea and internal unity of work. The fundamental idea of investigation work is the possibility of creating devices with relatively high environmental parameters on the basis of micro-flare combustion while maintaining high technical and economic indicators and also stably operating in a wide range of changes in the composition of gaseous fuel.

All chapters are devoted to the main investigation idea and have internal unity, because they are interconnected.

Scientific novelty lies in the development and investigation of new fuel-burning devices, in particular:

- An efficient method of fuel supply when using stabilizers in the form of triangular prisms for the application in gas flares has been determined;
- An efficient method for heating metal products with a microflame burner and emissions of toxic NO and CO has been investigated;
- A new design schemes of flare burners, as well as burners based on microflame fuel combustion devices, providing low emissions of toxic substanceshas been developed.

Also within the framework of the investigation work: 3 patents for an invention, 1 patent for a utility model and one positive decision for the grant to a patent for an invention were received.

The getting scientific novelty corresponds to the priority direction "Energy and Mechanical Engineering" approved on April 20, 2020 by the minutes of the meeting of the Supreme Scientific and Technical Commission of the Republic of Kazakhstan.

Reliability of work. The experimental results and numerical experiments have a sufficient degree of reliability for the following reasons:

- when planning, preparing and conducting experiments, the calculations of the errors of obtained data were carried out;
- during the experiments, verified and certified modern high-precision instruments and equipment were applied;
- the results of the experiments were compared with the closest analogs and with the results obtained by foreign authors;
- the numerical modeling results were compared with the obtained experimental data and works of other authors.

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

- use of bluff micro-flame devices in the form of triangular prisms, providing high flame stabilization, relatively low hydraulic losses and low emissions of toxic substances;
- a flare burner that provides high technical and environmental indicators in the entire range of loads, protected by an author's patent for an invention;
- a flare burner protected by the inventor's certificate for utility model.

The obtained experimental data on microflame devices allow us to create a new class of fuel-burning devices with high environmental, technical and

economic indicators. The obtained patents for inventions and a utility model can be used to develop burners that will reduce emissions of harmful emissions into the environment.

Provisions for Defense:

- the results of numerical modeling of combustion processes, taking into account various options for fuel supply, as well as heating of metal products at microflame combustion;
- the results of experimental studies of combustion processes, taking into account various options for fuel supply, as well as heating metal products with microflame combustion;
- burner designs have been developed that have high environmental and technical indicators;
- developed flare burners for use in various industries and with acceptable environmental performance.

The materials used in the investigation work were obtained independently and in co-authorship with the staff of the Department of Management in Engineering, NJSC Almaty University of Power Engineering and Telecommunications named after Gumarbek Daukeev.

The personal contribution of the author consists of:

- in the analysis and generalization of literature data;
- in carrying out numerical modeling;
-in planning, organizing and conducting experimental research, processing and summarizing the results of experiments;
- in the development of new technical solutions;
- in writing and preparing the investigation work.

Approbation of the investigation work results. The main results of the work were presented and discussed at the V international scientific and practical conference "V International scientific and practical conference" Global science and innovations 2019 Central Asia ", Astana, Kazakhstan, 2019; XXIV scientific conference with international participation EYF 2019, Sozopol, Bulgaria, at the international scientific and technical conference "I Anniversary Readings of F.K. Boyko", dedicated to the 100th anniversary of F.K. Boyko, PSU named after S. Toraigyrova, Pavlodar, 2020.

Publications. The main provisions of the work are presented in 14 publications, including in editions, two articles in journals recommended by the KKSON MES RK, two articles in the journal "Thermal Science" included in the Web of science database, in the journal "Bulgarian Chemical Communications" included in the database data from Scopus, in 4t international scientific and practical conferences and forums, 3 patents for an invention, 1 patent for a useful model of the Republic of Kazakhstan. Based on the results of the work performed, 1 textbook was published on the environmental aspects of energy.

Volume and structure. The investigation work contains an introduction, 5 chapters, a conclusion, a list of used literature, annexes. The thesis is presented on 101 pages of a computer set, including 52 figures and 14 tables, a bibliography of 111 titles.

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

The first section analyzes the emissions of harmful substances that are products of combustion processes in various industries. It is shown how the pollution index of different cities changed. The main pollutants and their impact on the environment and human health are presented. The analysis of flare devices used in the oil production sector is carried out, the main types and the principle of their operation are determined. The section also analyzes burners used in the metallurgical sector to ensure the technological process of metal preparation. The corresponding conclusions are drawn. The formulation of the goal and objectives of the study is presented. The development and research of microflame front-line devices based on triangular stabilizers for flare burners, as well as a new multifunction device for processing metal products is proposed.

In the second section of the investigation work, the results of numerical modeling of combustion behind triangular prisms, analysis of the effect of different locations of the fuel supply holes, and calculation of emissions from the multifunction device in the form of a gas flare burner are presented. The results of numerical simulation of combustion in a new microflame flat burner for processing metal products, the formation and concentration of nitrogen oxides are presented. The analysis of the thermal conductivity of the metal is carried out depending on the type of burner used. Comparison with the results of foreign authors is carried out.

In the third section, a description of the experimental setup, a technique for carrying out experiments and measurements of the main parameters is presented, and an estimate of the measurement errors is given.

The fourth section presents the results of an experimental study of triangular prisms, as well as a microflame burner for heating metal products. The results of measurements of temperatures, concentrations of nitrogen oxides at the outlet from experimental installations are presented. The results of the analysis are given. Based on the results of experimental studies, new burners are presented, for which patents for inventions and utility models have been obtained.

The fifth section presents technical solutions developed within the framework of the dissertation research. Flare burners, a multi-module device for heating metals, as well as devices for flame hardening of metal products are presented.

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