ABSTRACT
of PhD thesis «Research and development of combustion chamber of GTU with low emission of toxic substances»
Specialty – 6D071700 – «Heat Power Engineering»
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Relevancy of the project. According to the Concept of development of the fuel and energy complex (FEC) of Kazakhstan until 2030, the main problems of the fuel and energy complex are followings:

- a deficit of production capacity to cover the growing demand for energy;
- low energy production efficiency;
- low ecological compatibility of technologies used in fuel and energy complex.

Gas turbines have a comparatively high efficiency of fuel combustion, maneuverability, compactness and are the most environmentally friendly among thermal engines. The wide introduction of GTU will also increase the share of natural gas in the fuel and energy complex, and also reduce the capacity deficit. However, given the ever-increasing requirements for GTU emissions, there is a need to develop new combustion chambers that have low emissions of toxic substances and high technical characteristics. For this, it is necessary to thoroughly study the combustion processes in the combustion chambers.

The issues of fuel combustion and the direction of its effective use in the energy industry are deeply troubling to the scientific circles. The Republic of Kazakhstan has huge potential reserves of natural gas and oil. The course of fuel policy for the priority development of advanced fuels - oil and natural gas will remain in our country, with the growth of coal mining. However, the use of a huge amount of organic fuel is associated with significant clogging and poisoning of the air basin with sulfur and nitrogen oxides, large ash and soot emissions [1]. According to [2] in Kazakhstan, 191 thousand tons of nitrogen oxides (in terms of NO_2), 393 thousand tons of carbon oxides, 36 thousand tons of vanadium pentoxide, 10 thousand tons of carbon, 97.2 tons of carbon disulphide, 98 thousand tons of coal ash with calcium content are thrown into the environment annually.

The quality of the organization of burning process in combustion chamber is the main factor that defines the ecological characteristics of gas turbine. Which generally determines competiveness of the unit.

Issues of fuel combustion and energy production based on heat engines are the foundation of Kazakhstan's energy sector. One of the most important issues today is the reduction of the toxic substances. In this regard, scientific society is facing problems of development of fundamentally new approaches to the combustion of gaseous fuel in the combustion chambers of gas turbines.

Therefore, modern scientific trends are concentrated on several points:

1 reduction of emissions of gas turbines;
2 increase in power and efficiency of gas turbines;
3 improved reliability (extended service life).

One of the problems of modern gas turbines is pollution of the environment by emissions of so-called «greenhouse gases», which include CO_2, SO_x, NO_x.

For the large number of engines burning natural gas, the emissions of SO_x are negligibly small, and most of the drive toward more stringent regulations for stationary gas turbines has been directed at NO_x.

Most of the nitric oxide (NO) formed in combustion subsequently oxidizes to NO_2. For this reason, it is customary to lump NO and NO_2 together and express results in terms of NO_x, rather than NO. It can be produced by three different mechanisms: thermal, prompt and fuel.

The main part of the generated nitrogen oxides is thermal NO_x. The reason for its formation is a high temperature, a long residence time of gases in the high temperature zone and the quality of mixing of fuel and oxidizer. Modern methods of solving the problems of reducing the formation of nitrogen oxides are built on reducing the influence of these factors.

One of the most promising methods for fuel combustion is microtorch burning devices. The principle of this method is in «spreading» of the flame front across entire section of the combustion chamber. This approach provides a high technical and environmental performance. It combines the most favorable characteristics of the various approaches to fuel combustion.

It is necessary to conduct research on technologies that have low emissions. Thus determines the relevance of this thesis.

The purpose of the study is the development and study of different designs and constructions of burners, combustion chambers that will reduce the toxicity of gas turbines and provide high level of technical and environmental performance.

In accordance with the above mentioned purpose the following tasks have been set:

- to develop and investigate gas burners and elements of gas burners for combustion chambers;
- to conduct numerical investigations of the combustion, mass transfer processes and toxic substances formation processes in a microtorch devices;
- to conduct an experimental investigation with microtorch devices, such as – v-gutter flameholders;
- to investigate the influence of the design of the microtorch devices on combustion characteristics.

The main idea and internal unity of work. The fundamental idea of the thesis is the development and investigation of microtorch devices with high reliability indicators and low levels of NO_x emissions that work stably in a wide range of excess air.

The obtained data on recirculation zones behind v-gutter flameholders, exhaust gas temperatures, mechanisms of stabilization and formation of nitrogen oxides can be used as a basis for the development and introduction of new types of combustion chambers.

Scientific novelty. Based on numerical simulation and experimental studies, the principles for creating efficient fuel-burning devices for gas turbine combustion chambers were developed. Wherein:

1 The optimal angle of v-gutter flameholders, which ensures the lowest emission of nitrogen oxides <10 ppm, with a high degree of fuel combustion (η_c=99%) at relatively low exhaust gas temperatures (T=520 K) has been identified.

2 A formula that establishes the relationship between «lean» blowout, shape and type of v-gutter flameholders is presented. An empirical formula for determining emissions of nitrogen oxides from combustion chamber using v-gutter flameholders was presented.

3 New design of the devices based on microtorch principle, such as burners, two zoned combustion chamber and heat generators, were presented.

The novelty of work is also confirmed by one innovative patent and three useful models and also, by one positive decision on giving patent for useful model.

Reliability of the research. The results obtained during the experiments have the necessary degree of reliability, for the following reasons:

- the fuel that was used in the studies of v-gutter flameholders and microtorch elements are the same fuel that being used in gas turbines;
- the results of experiments and numerical simulations are consistent with the results of foreign authors;
- during the experiments high precision expensive equipment was used.

The reliability of the work is also supported by a comprehensive approach to experiments.

The practical value of the research is in developing and obtaining:

- the principle of creating combustion chambers and gas burners, providing high environmental and technical performance;
- gas burners working on the principle of microtorch burning, protected by author's certificates;
- heat generators, protected by author's certificate, working on the principle of microtorch burning, in which v-gutter flameholders are used;
- two zoned combustion chamber protected by author's certificate.

The following provisions are made on the defense

- results of numerical investigations and experimental studies of combustion processes, formation of toxic substances using v-gutter flameholders;
- formulas of dependence of «lean» blowout and emissions of NOx from combustion chambers with v-gutter flameholders, on the basis of which new types of heat generators were developed;
- gas burners with high ecological and technological indicators, working on the principle of microtorch burning were developed;
- the design of a two-zone combustion chamber has been developed, in which v-gutter flameholders are used which provides high technological and ecological parameters.

The personal contribution of the author is:

- in the analysis and consolidation of literary data;

- in numerical simulation;
- planning, organizing and conducting experimental research, processing and generalization of results;
- in development of new technological solutions.

Approbation of the results. The main results were presented and discussed at the scientific-practical conferences and forums:

- Scientific forum with international participation «SPbPU's science week» (Russia, Saint-Petersburg, 2015);
- VII International scientific-practical conference «Fundamental and applied sciences today» (USA, North Charleston, 2015);
- I International scientific-practical conference «Techno-technological development of industries and enterprises» (Russia, Nizhny Novgorod, 2017);
- VII International scientific-practical conference «Eurasiascience» (Russia, Moscow, 2017);
- VIII International scientific-practical conference «Advances in Science and Technology» (Russia, Moscow, 2017).

Publications. Main results of the study were published in 20 articles and publications, 6 of them in scientific journals, recommended by the Committee for the Verification of Education and Science of the Republic of Kazakhstan, 5 in the international scientific - practical conferences, 4 in patents, one in a positive decision to grant a patent, one article is in the «Thermal science» journal included in Thomson Reuters journal database and two in the journals «International Journal of Mechanics and Mechanotronics», «Espacios» included in Scopus journal database. The last article is in the «International Journal of Pharmacy and Technology» which was excluded from Scopus database in 2017.

Structure. The work consists of an introduction, five sections, conclusion, list of references and appendixes. The total volume of the dissertation is 139 pages of typewritten text and includes 5 tables, 89 figures and the list of references which consists 167 names.

In the introduction, the relevancy of scientific work is revealed, the problem under investigation is specified. The main idea, scientific novelty, reliability of the research, the practical value, provisions on the defence, personal contribution of the author, as well as approbation of results and publications are given.

The first section of the thesis provides a review and analysis of the state of the development of gas turbines. The mechanisms of combustion processes and the way of formation of nitrogen oxides are considered. Equations that determine the kinetics of formation of nitrogen oxides are presented. The main types of toxic nitrogen - thermal, prompt, fuel were analyzed. The main technological types of suppression of the formation of nitrogen oxides, which include the injection of water or steam, recirculation of exhaust gases, the optimal distribution of air, intensification of the mixture formation, staged combustion, and catalytic combustion were analyzed. And also, the analysis of constructive methods of suppression is given, which include - staged combustion chambers, combustion chambers with variable

geometry and catalytic combustion chambers. According to the goal, research tasks were formulated.

The second section deals with technical solutions based on microtorch devices. An analysis of gas burners developed at the Kiev Polytechnic Institute using the principles of microtorch combustion are given, as well as an analysis of the development of Kazakhstani authors. The air nozzles-stabilizers developed in Kazakhstan have high technical and ecological characteristics. Proceeding from the analysis, the developments in the field of microtorch devices are presented in the form of the scheme. The most optimal approaches to providing microtorch combustion are determined. Additional tasks were determined.

The third section presents the results of numerical modeling of combustion, mixing and formation of nitrogen oxides. To study the advantages of microtorch burners, schemes and separate main parts of gas burners were used, for which the author obtained the author's certificates (RK 92515 innovative Patent and useful model RK 93801 Patent).

V-gutter flameholders of various shapes, types, and angles on the top were investigated, which formed the basis for technical solutions for which the author obtained certificates (RK 1703 Patent and RK 1734 Patent). Conducted numerical simulations allowed a deeper analysis of experimental results.

The fourth section presents the results of experimental studies of the combustion processes behind v-gutter flameholders. The results of the study of the effect of the angle of v-gutter flameholder, type of fuel supply, the presence of perforations, as well as the location of perforations on the formation of toxic substances, flame stabilization and «lean» blowout were presented. Based on the results of the experiments, the formula of «lean» blowout for combustion chamber using v-gutter flameholders, and also, the formula determining the emissions of nitrogen oxides of combustion chamber with v-gutter flameholder were presented.

The fifth section contains developed technical solutions for which the author obtained author's certificates, as well as a positive opinion on the grant of a patent. A comparison of the technical solutions obtained by the applicant with their prototypes was conducted. A gas burner has been developed which has more sophisticated design than the prototype, which ensures high combustion efficiency, low nitrogen oxides emission and high flame stabilization. The second technical solution is a gas burner, which has high stabilization characteristics, due to the use of the fuel supply chamber. The design of the heat generator is developed which, in comparison with the prototype, has such advantages as high combustion efficiency, low emissions of toxic substances, small dimensions and metal content. The developed, two-zone combustion chamber is presented which, in comparison with the prototype, has a high combustion efficiency, a wide range of stable combustion and low emissions of toxic substances due to the installation of new types of v-gutter flameholders. A heat generator has been developed that has high technical characteristics, which makes it possible to use it building heating and in agriculture.

In conclusion, the main results and conclusions on the thesis work are reflected.