The fuel burning intensification in the swirl burner using air ionization on the power-generating heat-and-power plant

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Abstract. According to experts, the power-generating complex in the entire chain from fuel production to the thermal energy application efficiency of the use of energy resources is only 44%. That necessitates the researching of ways to enhance efficiency of organic fuel burning. One of the way to solve the problem is the burning fuel in the swirl burner with using of ionized air. Domestic and international researches have shown that atomic oxygen increases the completeness combustion and reduces the number emitted into the atmosphere of pollutant emissions. At present, the reduction of air pollution of toxic substances allocated by industrial enterprises, is one of the most important problems facing humanity. Air pollution has a unhealthy exposure for humans and the environment. In this paper estimated effectiveness of existing chemical kinetic mechanisms of natural gas burning for the swirl burner and mechanisms unhealthy emissions produced based on the results of the evaluation. The purpose of work is to increase the effectiveness of fuel combustion and technical and economic, as well as environmental indicators in the swirl burner on the heat-and-power plant.

1. Introduction

Existing kinetic mechanisms of natural gas combustion in the swirl burner in terms of atomic oxygen ionization are not validated because the lack of validation experimental data. Development of heat and power engineering in current days is connected with the necessity of the most important task of the combustion chamber (CC) and firebox furnaces (FF) toxicity reducing, used in gas, steam turbines and in combined-cycle plants [1 — 8]. Various methods are used for the toxic emissions from CC and FF suppression [1, 4, 5, 9 — 13], the most promising of which to the method of air ionization, supplied to the fuel combustion zone [14 — 22]. So, this work dedicated to experimental investigation of fuel burning intensification in swirl burner using air ionization on the heat-and-power engineering plant, which the most important. By the object of research was chosen swirl burner because it proved its high characteristics of ignition, durability, technological effectiveness reliability and as well the possibility of considering the swirl burner as physical model of fuel combustion in CC and FF. The purpose of paper is to increase of fuel combustion efficiency as well, as environmental indicators in the swirl burner on the heat-and-power object. For achieve this target we developed testing stand, consisting of: swirl burner, ionizing device releasing atomic oxygen and the measuring equipment for carrying out experiments and obtain results [18]. Simultaneously following research works were solved: have been carried out experimental studies, information processing and analysis of experimental studies [29-34].
2. Methods
For carrying out scientific experimental researches the physical simulation method was used as the most optimal. In accordance with compatible schematic diagram of testing stand in published works [18, 20], special testing stand was developed, where new experimental data were obtained. The photograph of this stand is shown on Fig. 1.

Figure 1. Purpose-designed polyfunctional testing stand:
1 — exhaust pipe;
2 — flue gas analyzer;
3 — aneroid barometer;
4 — pressure gauges (flammable gas);
5 — pressure gauges (air);
6 — thermometer;
7 — swirl burner;
8 — ionizing device;
9 — laptop pc;
10 — soothing pipe for flammable gas;
11 — soothing pipe for air.

The main requirements for modern gas turbine, steam turbine and combined-cycle plants are low production costs and compliance with permissible emission levels NOₓ and CO. Oxidation of fuel is a finite rate process and a minimum residence time is required for high combustion efficiency and low emissions [2, 11, 15]. As a flammable gas, a propane-butane mixture of the following composition was used: propane (C₃H₈) — 80%; butane (C₄H₁₀) — 13%; ethane (C₂H₆) — 3.5%; ethylene (C₂H₄) — 3.5%. Preliminarily flammable gas and air were fed into the swirl burner (7) from sources. At the same time, the following indicators were measured: air temperature — \( T_{\text{air}} = 300.15 \, ^\circ\text{K} \); gas temperature — \( T_{\text{gas}} = 300.15 \, ^\circ\text{K} \); static air pressure — \( P_{\text{static\ air}} = 3236 \, \text{Pa} \); static gas pressure — \( P_{\text{static\ gas}} = 4423 \, \text{Pa} \); total air pressure — \( P_{\text{air}}^* = 3481 \, \text{Pa} \); total gas pressure — \( P_{\text{gas}}^* = 4444 \, \text{Pa} \). Further, according to the received data, the following were calculated: air speed — \( c_{\text{air}} = 20.2 \, \text{m/s} \); gas speed — \( c_{\text{gas}} = 4.7 \, \text{m/s} \); air flow rate — \( G_{\text{air}} = 0.005 \, \text{kg/s} \); gas flow rate — \( G_{\text{gas}} = 0.0003 \, \text{kg/s} \). In accordance with the results of the calculations, the reaction mass were fed into the swirl burner (7) through soothing pipes (10) and (11). Before the air was supplied to the combustion, it was passed through the ionizing device (8). That is air passed through an inhomogeneous stationary electric field. This produces the formation of atomic oxygen, which is the most powerful oxidant. More detailed description of the work ionizing device is contained in a published work [19]. In the swirl burner (7) simulated the processes occurring in CC. Combustion products were discharged through the exhaust pipe (1) and certain chemical compounds were determined by means of a flue gas analyzer (2).

3. Results and discussion
Based on the results of the experimental data processing, the dependence of the concentration of carbon monoxide in the combustion products of gaseous fuel when it is burned in a swirl burner from the temperature of the exhaust gases. This dependence is shown on Fig. 2. In this case, the experimental values of the concentration CO, obtained without of ionization air, are indicated — by points 1 and with of ionization air — by points 2. The set of points 1 was approximated — by line 3, and points 2 — by line 4.
Figure 2. Dependence of the concentration of carbon monoxide in the combustion products of gaseous fuel when it is burned in a swirl burner from the temperature of the exhaust gases:
1 — experimental points corresponding to carbon monoxide concentrations without ionization air before the combustion process;
2 — experimental points corresponding to the concentrations of carbon monoxide with ionization air before the combustion process;
3, 4 — approximating lines.

From the analysis of the graphs shown on Fig. 2, it follows that with an increase in the temperature of the combustion zone, corresponding to an increase in the temperature of the exhaust gases from 470 to 600°C, emission of carbon monoxide increases both in the ionization of air and without it. However, with increasing temperature in combustion zone, in lack of ionization air, the CO emission increases from 0 ppm to 0,23·10⁴ ppm and in availability of air ionization from 0 ppm to 0,14·10⁴ ppm. Thus, in availability of ionization air at exhaust gases temperature of t = 600°C, emission CO is reduced by 0,09·10⁴ ppm, id est by 39,1 %. For the rational use of air ionization at the entrance to the swirl burner, it is necessary to create scientifically grounded methods for their design and operation. For the development of such methods requires a large amount of experimental research. However, the number of published results of such studies is still small. Of particular interest are the papers [11, 17, 23 — 28]. At the same time, it should be noted that the published reports do not contain sufficient information on the effect of air ionization before the entrance to the swirl burner on fuel combustion in CC [29-35].

4. Conclusion
The performed analysis of experimental studies allows us to draw the following conclusions:
1. The air ionization air before entering the swirl burner in the research range of temperature changes in the combustion zone leads to a reduction in emissions CO by 39,1 %;
2. Scientific novelty lies in the fact that we are acting not on fuel, with the air agent in the combustion zone, we activate atomic oxygen in a way that the activation energy without temperature increase will be sufficient for efficient combustion, and this economical effectiveness;
3. The performed experimental studies have shown the efficiency of purpose-designed polyfunctional testing stand and the expediency of its further use for expanding the range of experimental studies.

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