Recommendations for creating a noise silencer for the aerodynamic valve of the pulsating combustion chamber

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Abstract. At present, researches in the field of designing and introducing into thermal processes power plants based on pulsating combustion are actively carried out in many countries. The absence of a burner and the considerable pressure of the exhaust flue gas, which does not require a high chimney, remain operational even at excess pressure close to zero in the supply pipeline, which are additional advantages of the pulsating combustion chamber, which ensures its attractiveness in the heat and power sector of the market [1].

1. Introduction

These installations have a number of advantages over installations with flare combustion. Table 1 compares the main characteristics of pulsed and flare combustion.

Table 1. Comparison of combustion types

| Comparable characteristic                        | Flare (deflagration) combustion | Pulsating (vibrational) combustion |
|-------------------------------------------------|--------------------------------|-----------------------------------|
| The intensity of combustion, kW / m^3           | 100 - 1000                    | 100000 - 50000                    |
| Completeness of combustion, %                   | 80 - 96                        | 96 - 98                           |
| Convective heat transfer coefficient, W / m^2 K | 50 - 100                       | 100 - 500                        |
| Chemical underburning, %                        | 0 - 3                          | 0 - 1                             |
| Mechanical underburning, %                      | 0 - 15                         | 0 - 5                             |
| Concentration of CO on exhaust, ppm             | < 50                           | 0 - 10                            |
| Concentration of NOx on exhaust, ppm            | 80 - 160                       | 4 - 40                            |

Increasing the efficiency of heat sources is the main factor in the development of new heat generating devices and the modernization of existing ones. Traditional methods of increasing the power of the burner device, usage of fuel with increased heat content, rising in heat transfer surface, etc. are not always achievable and often are high-cost. Other ways of development which are more effective and environmentally less safe are needed [2]. One of such ways of development of heat power engineering should be considered the use of combustion with ordered turbulent pulsations, to which can be attributed pulsating combustion. In recent years, heat generators and hot-water boilers have been increasingly used, where the source of heat are pulsated combustion chambers. These devices have distinctive design and technological characteristics which are given in Table 2.
Table 2. Boiler comparison

| Comparable characteristic | Hot-water boilers based on the principle of flare combustion | Hot-water boilers based on the principle of pulsating combustion |
|----------------------------|-------------------------------------------------------------|------------------------------------------------------------------|
| Lack of chimney             | -                                                           | +                                                                |
| Extremely simple design     | -                                                           | +                                                                |
| Overall dimensions          | -                                                           | +                                                                |
| High efficiency             | -                                                           | +                                                                |
| Absence of fan              | -                                                           | +                                                                |
| Self-ventilation of the combustion circuit | -                   | +                                                                |
| Small surface heat exchanger| -                                                           | +                                                                |
| Full and passive safety     | -                                                           | +                                                                |
| Low heat losses for own needs| -                              | +                                                                |
| Explosion proof             | -                                                           | +                                                                |

Chambers of pulsating combustion (KPG) for the design of the air supply unit are of two main types: with mechanical and aerodynamic valves. KPG with aerodynamic valves is structurally simpler, more reliable and has no disadvantages, characteristic of KPG with mechanical valves: burnout of mechanical valves due to their location in high temperature zones; wear of petals; contamination of valves during work on unclean flammable gas. But KPG with aerodynamic valves are less studied and there are big problems of damping the valve noise. At present KPG with mechanical valves are more common.

The design of the aerodynamic valve is much simpler. The simplest design of the aerodynamic valve is a branch pipe, the length of which is approximately 5% of the length of the resonant tube of KPG. Despite the simplicity of the design, the aerodynamic valves in the KPG are practically not used because of the muffling problem.

The noise produced by the aerodynamic valve is a consequence of the working process taking place in the chamber. Therefore, its formation is inevitable. The noise in the KPG is also radiated by a resonance tube. An obvious solution to the problem is the installation of noise silencers at the output sections of the pipes: aerodynamic and resonant. There are many options for suppressing noise at the cutoff of resonator tubes, which are summarized in [1]. Much less technical solutions to reduce noise generated by the AK. This is due to the fact that in the aerodynamic valve there is a complex of gas dynamic and acoustic processes. A small intervention in these processes leads to a violation of fuel combustion. The development of a noise silencer for AK is an urgent task.

2. Research

The authors of the article proposed for the first time the noise silencer AK based on the fluidized bed (PS). The results of investigations of this silencer are given in work [3,4,5]. In this article, a description of the KPG with a low-noise aerodynamic valve is presented, on the basis of which it is planned to develop a hot-water boiler. The characteristics of the proposed KPG were determined experimentally at the experimental stand. The layout of the stand is shown in Figure 1. A detailed description of the stand is given in [6].
There are complex gas-dynamic flows in AK. In [7], the results of experiments on the visualization of the motion of air flow by the method of adding water through capillaries are presented. Based on the results obtained, a flow diagram of the gas flow at the valve cutoff has been developed.

It is noted that the structure of the air flow in the valve consists of two oppositely directed currents: in the wall layer, the gas flow is directed into the combustion chamber (CS) (2), in the flow core - to the opposite direction (1) (at the time of compression).

The authors of the article attempted to "smooth" the pulsating component of the gas velocity in the valve with various dampers: a grid, springs, balls, a sudden expansion of the outlet section of the pipe. However, the taken technical decisions always led to a breakdown in combustion. Based on the analysis of the results of a huge number of experiments, an important conclusion was drawn, according to which the developed muffler should not influence gas dynamics. The design of such a silencer was proposed by the authors, in which the fluidized bed is the main absorber of the pulsation energy. The muffler is a pipe, one end of which is closed tightly, the other is slightly open. There are two discs with annular gaps for air access at the slightly open end of the pipe. A truncated cone is attached to the first disc. PS is located in the zone of maximum ripple speed (in the middle of the noise silencer). In order to create a PS, medium-strength ceramic granules were used in the experiments, which are subject to wear. PS had a uniform flow structure, which contributed to the slowest wear. The studies described in the book reflected it [7].

In [6], the spectra of acoustic signals are shown, from which it can be seen that the "energy-carrying" frequencies of the CNG are low frequencies. It is known from the literature that low-frequency noise is effectively reduced by reactive and resonance type silencers. To test this, the existing experimental stand was modernized and the optimum length of the muffler chamber (tube) was obtained by the experimental method. It was noted that by changing the length of the pipe it is easy to influence the energy-carrying frequencies. The general view of the upgraded stand and the pipe diagram are shown in Figure 2. The working area was a cylindrical tube with a length of 2000 mm and a diameter of 150 mm. At one end of the tube coaxial to the cylindrical chamber was located AK. The cut of the valve pipe was removed from the end wall of the chamber by 5 to 8 mm. At the other end of the pipe was inserted a piston, the position of which could vary. Moving the piston in the cavity of the pipe can affect the energy-carrying frequency. The results of these studies were published in [5].
It has been experimentally established that for the CNG with the chosen geometric parameters the length of the noise silencer should be 650 mm. Further studies were carried out in a silencer-pipe of the specified length. In this case, the second noise source KPG - the open end of the resonant tube was placed in another muffler. The degree of its influence on the results of research was minimized. A detailed description of this silencer is given in [3]. Calculation of the thermal power of the KPG was carried out. The fuel consumption was determined by the weight method. Figure 3 shows the comparative spectrum of the acoustic signal at the maximum thermal power of the KPG.

Experimental data indicate that as the KPG is forced, the pulsation amplitudes of the pressure at higher frequencies increase. From these data it is also evident that the proposed noise silencer reduces the sound pressure level in the entire frequency range. Frequency values also do not change. This indicates the independence of the operation of the aerodynamic valve from KPG. Detailed studies were carried out on the effect of AK on the amplitudes of pulsations of gases in KPG. The essence of the studies consisted in obtaining experimental data of pulsations of gas pressure in a chamber without AK and with AK. From the comparative analysis of the obtained data, it is easy to determine the influence on the values of the pulsation amplitude of the aerodynamic valve. The parameters of the pulsations of gases in the KPG were recorded by a piezoelectric transducer, which was connected to the KPG through a tubular probe. The signal from the output of the piezoelectric transducer was fed to an electronic oscilloscope, which after the conversion was displayed on the oscilloscope's screen in the form of a graph. Such graphs were obtained during the operation of KPG at different costs. Noise
A silencer does not influence the amplitude of the pulsations of the gas pressure in the combustion chamber.

3. Conclusion

The positive results outlined in this article can serve as a good prerequisite for the widespread introduction of KPG into heat power engineering. In particular, on the basis of KPG with an aerodynamic valve, it is possible to create a highly efficient water heater. The proposed water heater will have all the advantages of a water heater with KPG based on mechanical valves. The performance characteristics of such water heater will be significantly higher.

References

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