External high-frequency control of combustion instability

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Abstract. The article presents the results of experimental studies of combustion instability in the pulse combustor. Propane-air mixture is burned in the chamber with the flame holder. It was experimentally found that feeding high-frequency sound vibrations into the combustion chamber causes the suppression of pulsating combustion. The oscillation frequency ranges in 870 to 1400 Hz. This corresponds to 9-12 resonance frequencies of oscillations in the combustor. The physical mechanism of the observed phenomenon consists in changing the conditions of formation and destruction of fuel jets in the vortex zone behind the flame holder.

1. Introduction

It was noted earlier that the instability of combustion in power plants with combustion is accompanied by fluctuations of pressure, temperature, speed, etc. [1, 2]. The oscillation frequency depends on a number of factors, but the geometrical characteristics of the combustion chamber is of central importance. The use of pulsating combustion in practice can substantially increase the efficiency of combustion processes.

In theoretical and practical studies of the pulsation of the burning tasks of suppression and creation of pressure pulsations remain relevant [3, 4].

To suppress vibrations applied in a variety of ways. For example, an external periodic perturbation [5], steam injection [6] and others. The possibility of using any way to suppress the oscillations depends on the cost of its practical implementation. For the method of control pulsating combustion of an external periodic perturbation is required to create perturbations of the electrical power.

The study of the physical mechanisms of oscillations in combustion chambers has led to the conclusion that the excitation of oscillations and their suppression may be carried out using the same methods [7]. Thus, the control of combustion instability is a more general term that combines both tasks.

The purpose of the study was to determine the possibility of practical use of external acoustic perturbations of the high-frequency range to control the instability of combustion.

2. The method of investigation

Experimental investigation of control of combustion instability by the method of external periodic perturbations were carried out in the chamber pulsating combustion. Scheme of the experimental chamber is presented in Figure 1.

Propane-butane mixture 3 enters the combustion chamber through the tube 8 into the flame stabilizer 9. Air enters through the tube 4 in an air receiver 6. Then the flow passes through the
confuser and the diffuser 7 into the combustion chamber. The mixing of the fuel gas with air takes place at the working edge of the flame stabilizer and vortex formations behind him. The axial displacement of the flame stabilizer 9 in the diffuser 8 enables the preparation of sustained resonant combustion in the combustion chamber. The pulsation frequency of burning depends on the length of the pipe resonator 12. The sound vibrations created by the sound generator 1 electrodynamics 2. They entered the combustion chamber through the gas inlet tube 5. The pressure fluctuations in the combustion chamber were recorded with a microphone 10 and a spectral frequency analyzer 11.

Figure 1. The main elements of the experimental stand.

The result of the influence of external periodic perturbations was assessed by changes in the domains of existence of pulsating combustion in the combustion chamber [7], as well as the change of the sound pressure level of the pulsation of the combustion in the combustion chamber. The boundary of the region of existence of pulsating combustion was built in the coordinate system of the thermal intensity of combustion chamber q (MW/m²) and the flow rate of air at the working edges of the flame stabilizer v (m/s).

The presence of pulsating combustion in the combustion chamber was determined visually and the spectrum analyzer. The sound pressure level of the pressure oscillations in the combustion chamber depends on the fuel and reaches values of 130 to 150 dB. The research was carried out in the frequency range from 100 to 1400 Hz.

3. The results of the study and discussion
In Figure 2,a is marked with: Lao – source sound pressure level, fa IX, fa X, fa XI and fa XII – calculation of the resonance mode of self-oscillations in the combustion chamber, L is the sound pressure level in the combustion chamber after exposure. The estimated first resonant mode of the vibrations in the camera for the length of the resonator was equal to 105 Hz. Figure 2,b presents the sound pressure levels of the external sound disturbance for the relevant frequencies Lei measured in the combustion chamber. In Figure 2,c is a graph showing changes of electric power at electrical dynamics spent to generate acoustic oscillations external disturbances.

The graphs are observed intervals reduce the level of sound pressure oscillations in the combustion chamber in the frequency range from 880 up to 980 Hz, from 1030 to 1050 Hz and from 1150 to 1300 Hz. In this case, the resulting sound pressure level reaches levels from 123 to 127 dB.

The sound pressure level of external disturbances in the combustion chamber is changed from 83 to 105 dB. It depends on the frequency of disturbance.

Diagram of electric power on the electrodynamics spent on the excitation of disturbances depends on the disturbance frequency. The minimum value of the electrical capacity range from 3 to 5 W in the first and from 5 to 12 W in the third frequency intervals of exposure. In the second the frequency value of electrical power is much higher and ranges from 50 to 75 W.

It should be noted that the study of the reaction of the combustion chamber to external stimuli were carried out in a wide enough range of frequency increments of 10 Hz. The first effects of the damping of the pulsation in the combustion chamber was observed in the frequency range from 30 to 280 Hz. This corresponded to the frequency range from the first to third resonance modes of vibrations of the
camera. The frequency variation from 290 to 870 Hz did not provide the effect of reducing the sound pressure level in the combustion chamber.

The effect of suppressing self-oscillation is observed only in the frequency range of the external perturbations from 880 to 1300 Hz. Thus, we can assume that in the high-frequency impacts the physical mechanism of suppression of self-oscillations differs from the physical mechanism of suppression of low-frequency oscillations under the influence.

A graph of the areas of existence of pulsating combustion is presented in Figure 3.

![Figure 3](image)

**Figure 2.** Graphs of sound pressure level in the combustion chamber after exposure (a); the sound pressure level of the external acoustic perturbation, as measured in the combustion chamber (b); diagram of electric power on the electrical dynamics (c).
Unlike the changes of the areas of existence of pulsating combustion with low frequency external influences [7] the graph is compressed in the left margin. Noted feature proves suggested another mechanism of damping of self-oscillations in the combustion chamber during high-frequency effects.

Figure 3. Modify areas of existence of pulsating combustion in high-frequency sound effects.

4. Conclusion
The physical mechanism of the observed phenomenon consists in changing the conditions of formation and destruction of fuel jets in the vortex zone behind the flame holder.

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