Researching of the reduction of shock waves intensivity in the “pseudo boiling” layer

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Abstract. This article applies to the field of acoustics and deals with noise reduction of pulsating combustion chambers, in particular the reduction of the shock waves’ intensity with the help of pseudo boiling layer. In the course of work on a test stand that included a pulsator, a compressor with the receiver and a high pressure fan was simulated gas jet flowing from the chamber pulsating combustion and studied the effect of different types of fluidization on effect of reducing the sound pressure levels. Were obtained the experimental dependence of the sound pressure levels from parameters such as: height of the layer of granules; diameter of the used granules; amplitude of the pressure pulsations in the gas stream at the entrance to the camera; frequency of pressure pulsations. Based on the results of the study, it was concluded that the using of a pseudo boiling layer is promising for reducing shock wave noise.

1. Introduction

Pulsed combustion chamber (PCC) has been used in heat power engineering for a long time. They are also used as engines on unmanned aerial vehicles [1]. This is due to the simplicity of the design, the completeness of combustion and high efficiency. On performance characteristics, (PCC) with an aerodynamic valve (AV) is preferable. Such chambers are cheaper to manufacture and have a great service resource. However, their widespread introduction is limited to an increased level of noise. The complexity of solving the noise problem of PCC is related to certain features characteristic of combustion chambers - in (PCC) fuel combustion occurs in a resonant pulsating mode. Moreover, oscillatory processes in (PCC) are low-frequency, than the adoption of this or that design decision aimed at noise reduction is limited. Lots of researches are engaged in noise reduction (PCC). A number of interesting ideas and constructive schemes have been published in the scientific and technical literature [2,3]. Despite this, effective silencers for (PCC) are not manufactured by industry. (PCC) with an aerodynamic valve has two sources of noise: a gas jet flowing out of the aerodynamic valve; High-temperature combustion products emitted from the (PCC) through the resonant tube. The most problematic in terms of noise cancellation is noise (AV), since (AV) at one moment of time should ensure reliable locking of the cavity of the combustion chamber, at another moment of time - to ensure the full flow of the air oxidizer into the combustion zone. (PCC) with an aerodynamic valve, as a device, has been known for a long time. However, there is no work with detailed studies of the
mechanism of noise generation (AV) in open printing. Without a clear representation of the physical picture flowing in the aerodynamic valve, it is not possible to solve the problem of noise reduction.

2. Researches

It has been established by experiments that the main noise source (AV) is low-intensity shock waves. The shape of the acoustic signal recorded at the valve cutoff is not sinusoidal, has an impulse character (Figure 1). At the same time, pressure pulsations recorded directly in the combustion chamber vary according to the harmonic law (Figure 2).

![Figure 1. The shape of the electrical signal recorded at the output of the microphone, located near the AV.](image)

![Figure 2. The shape of the electrical signal recorded at the output of the piezoelectric transducer.](image)

(The piezoelectric transducer is connected to the PCC)

The revealed fact narrows down the field of research and concretizes the direction of further research. The mechanism of formation of shock waves in the aerodynamic tube is the following. After the combustion products are released from the combustion chamber, the process of filling the chamber with a fresh combustible-air mixture begins. The ignition of this mixture is carried out by high-heated gases, which remain in the wall layer of the resonance tube when the combustion products flow out of it. In the zone of formation of a fresh combustible mixture, heated gases are "thrown in" when the pressure wave moves in the opposite direction (from the open end of the resonance tube towards the combustion chamber) and become fire ignition of the fresh mixture. The fire ignitions represent a set of small vortexes. From these sources, the gas mixture is ignited by micro volumes that form a string of compression waves. These waves rush towards the aerodynamic valve and, overlapping each other,
form a compression wave of shock type. This idea of the noise generation mechanism in the aerodynamic valve allows you to choose more specific technical solutions aimed at reducing noise intensity. The authors of the work proposed for the first time the noise suppression effect of gas jets by dispersed particles in a suspended state. An attempt to use the above-stated effect to reduce the intensity of shock waves generated by the (AV) pulsed combustion chamber was the main goal of this work’s authors. However, without detailed studies of the influence of the fluidized bed on the intensity of shock waves, it was not possible to achieve these goals. A gas jet flowing from the (AV) pulsed combustion chamber was simulated on the stand. Cold air was used as a working fluid. Schematic diagram of the test bench is shown at Figure 3.

The test stand included a high-pressure fan, a compressor with a receiver, a pulser, a control panel, a system for measuring the pulsations of pressure in the flow before and after the fluidized bed, and also in the near acoustic field, a manometer. The pulser was driven by a fan. Necessary amplitude of pulsations was established in front of the pulser by changing the pressure of the compressed air. The pressure pulsations in the flow were measured by a piezoelectric sensor and in a near acoustic field by a condenser microphone. The object of the research and the microphone were located in a separate soundproof room. The six-channel "Ecophysics" measuring system with the "Signal +" software was used as the recording equipment.

The hydraulic resistance of the gas-dynamic tract was determined by the manometer. The object of the research was a model of a sound attenuator with a fluidized bed. The general view of the model is shown in Figure 4.
3. Experimental activities

The model consisted of the following main parts: a vertically located cylindrical chamber partially filled with granules, an input and an output device. For visualization the interaction of the granules with a pulsating gas jet the window was provided on the side surface of the chamber (Figure 5).

Prior analysis of the experimental data indicates that in other conditions being equal the effect of reducing the sound pressure level does not depend significantly on the type of fluidization. Further studies were carried out on a model with a homogeneous fluidized bed. The research tasks were to obtain experimental dependences of the sound pressure level on parameters such as: the height of the layer of granules; diameter of used granules; amplitude of pressure pulsations in the gas flow at the entrance to the chamber; frequency of pressure pulsations. The hydraulic resistance of the fluidized bed was also determined.

An effectiveness evaluation of the smoothing efficiency of the pulsating gas flow was carried out by comparing the amplitude of the pressure pulsations obtained at the input and output of the noise-damping device. Plastic balls were used as the dispersed particles. The size of the balls conformed to the following diameters in mm: 4, 6, 8, 10. The experiments were carried out at frequencies equal to 50, 80, 200, 500, and 650 Hz. They corresponded to the values of the frequencies that are energy-carrying for the acoustic signal spectrum (AV) of the PCC. Table 1 shows the sound pressure levels in the near acoustic field of the sound attenuating device. The height of the fluidized bed was 40 mm.
Table 1

| Granule diameter, mm | Frequency, Hz | 4  | 6  | 8  | 10 | Without granules |
|----------------------|---------------|----|----|----|----|--------------------|
|                      | 50            | 77 dBa | 72 dBa | 74 dBa | 74 dBa | 84 dBa |
|                      | 80            | 79 dBa | 76 dBa | 78 dBa | 77 dBa | 89 dBa |
|                      | 200           | 89 dBa | 83 dBa | 88 dBa | 83 dBa | 97 dBa |
|                      | 500           | 96 dBa | 91 dBa | 94 dBa | 93 dBa | 104 dBa |
|                      | 650           | 99 dBa | 95 dBa | 97 dBa | 97 dBa | 109 dBa |

From the experimental data given in table 1, shows that the height of fluidized bed height of 40 mm significantly affects the reduction of sound pressure level in the gas stream. In this case, granules with a diameter of 6 mm are most suitable. Increasing the height of the fluidized bed affects the hydraulic losses. In all studied cases (with granules of different diameters) backpressure gas path increased in 2 ... 2.5 times compared with the fluidized bed 40 mm in height.

Based on the results of the studies a technical scheme of a noise silencer for (AV) is proposed. Ceramic granules were used as dispersed particles. The general view of the granules is shown in Figure 6.

![Figure 6. Ceramic granules (diameter 6 mm)](image)

The working fuel for (PCC) was propane. The experimental model of PCC with noise silencers is shown in Figure 7.

![Figure 7. Experimental model of the AV silencer on the test stand](image)
A detailed description of the experimental model is given in research [9]. The efficiency of the silencer and its effect on the work of the PCC were evaluated in the course of the experiments. It was noted that in the range of the thermal power of the PCC equal to 40 kW to 120 kW the sound pressure level in the near acoustic field did not exceed 82 dB. The concentration of harmful substances at the exit from the resonator tube remained at the same level as without a noise-damping device. This indicates that the proposed noise silencer does not interfere with the operation of the aerodynamic valve.

4. Conclusion
On the basis of the done work it is possible to draw an important conclusion about the prospects of using a fluidized bed to reduce shock-wave noise. The resulting effect can be explained by the strong fragmentation and reflection of shock waves in the layer of granules and also by the friction of gases on the surface of dispersed particles. By "tossing" the granules with a pulsating jet the transparency of the layer increases and the hydraulic resistance decreases as a consequence.

5. References
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