

# Influence of sound absorbing surfaces on acoustic oscillations and flame acceleration in hydrogen–air mixture

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**Abstract.** The frequency spectrum of acoustic disturbances that are emitted by accelerating flame front in an air–hydrogen mixture within an axially symmetric channel with a uniform cross section is experimentally determined. The effect of acoustic disturbances that are reflected from the closed end of the combustion chamber on the flame front acceleration is studied. It is revealed that the frequency spectrum of generated acoustic disturbances under experiment conditions has maximums at frequencies close to 250, 800, and 1500 Hz.

## 1. Introduction

The flame front acceleration in the process of deflagration in hydrogen–air mixtures strongly depends on the instability of the flame front. The behavior of the flame front in gases is determined by the geometrical characteristics, thermodynamic parameters, and disturbances of various types that act in the zone of chemical reaction. The feedback cycle between combustor acoustics and heat release rate oscillations typically involves three steps:

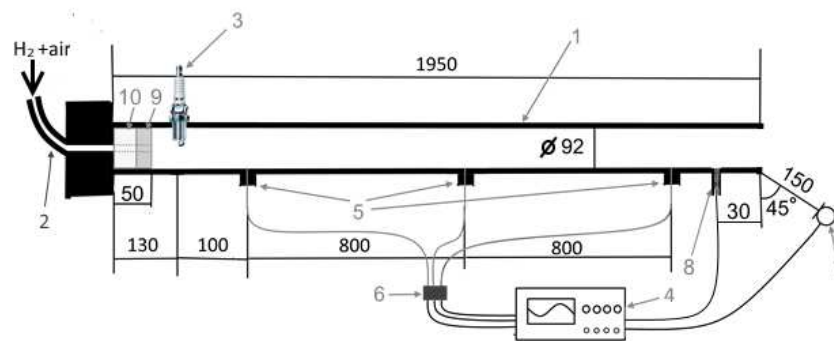
- heat release rate oscillations;
- acoustic oscillations;
- flow oscillations.

So, the interaction of flame with acoustic oscillations is natural self-sustaining process, which leads to flame acceleration.

In spite of the fact that the external acoustic oscillations may promote the acceleration of the flame front, an analogous acoustic oscillations may also result in the destruction of acceleration when the field intensity exceeds the intensity of generated instabilities and the frequency or the phase are out of resonance. A similar method may be effective for prevention of the development of dangerous combustion modes.

The generation of compression waves by flames propagating in a closed volume and the interaction between them were studied as much as the burning itself [1]. The instability effect on flame front dynamics is presented in [2–4]. The acoustic field effect on the energy release phase and thermodynamic parameters of burning gas is given in [5] for deflagration to detonation transition and in [6] for combustion. Influence of the acoustic absorption surface on a detonation wave can be found in [7]. In [8, 9], the action of acoustic oscillations on the fuel jet and further





**Figure 1.** Schematic of the experimental setup (dimensions are given in millimeters): 1—detonation tube, 2—mixture-supplying pipe, 3—ignition plug, 4—oscilloscope, 5—optical fibers, 6—photo gauges unit, 7—microphone, 8—piezoelectric pressure sensor, 9—sound absorber coating, and 10—plate set (additional collection).

combustion of the mixture is described. It can be seen that the known works have been devoted to the sound generation by combustion or combustion response to an external acoustic impact.

The aim of present research was to determine the acoustic oscillations that are emitted by the accelerating flame front. Absorbing surfaces impact on the oscillations of the flame acceleration and the pressure wave impulse were determined.

## 2. Equipment

The acoustic disturbance spectrum was determined using a steel detonation tube, which was closed at one end by a sound-absorbing element with a rigid aluminum wall. The schematic experimental setup is represented in figure 1. The geometrical parameters of the detonation tube and arrangement locations of sensor are given in the figure.

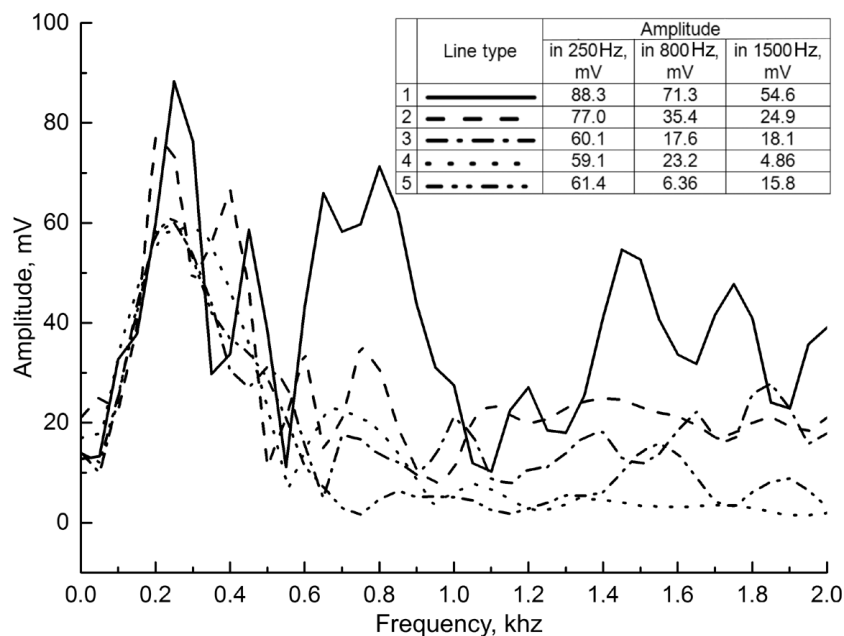
The preliminary mixed stoichiometric hydrogen–air mixture was supplied through copper pipe 2 with a diameter of 4 mm into detonation tube 1. The mixture excess flows out through the opened tube end into the atmosphere. At 2–5 s, the mixture was ignited by spark discharge 3 with energy of about 20 mJ. Thus, the initial mixture pressure was equal to the atmospheric pressure, while the temperature was 300 K.

To determine the amplitude–frequency characteristics of the flame, we used an MDM-7 microphone 7, which was mounted at a distance of 150 mm from the opened end. The signal from the microphone was supplied to a Tektronix DRO 7054 digital oscilloscope 4. The obtained data underwent the Fourier discrete transformation (since flame initialization to the flame exit from open end of tube). Thus, the spectrum was produced for acoustic disturbances generated by the flame. The types of sound-absorbing surfaces 9 used are listed in the table 1. Plexiglas plate 10 is set between the metallic tube end and the sound-absorbing surface was applied to provide the constant equal distance between the surface of the sound-absorbing element and the spark gap; i.e., the distance from the spark gap to the rigid or sound-absorbing wall was equal in overall experiments.

The flame velocity was determined using FD-256 photo gauges 6. The photo gauges were connected with the detonation tube via optical fibers 5, which were mounted at the wall of the detonation tube in the radial direction relative to the axis. The pressure profile at the outlet of the tube was measured using PCB-111A24 piezoelectric pressure sensor 8. Signals of sensors of light and pressure were supplied to Tektronix TDS 3014B digital oscilloscope.

**Table 1.** Types of sound absorber surfaces and their parameters.

No.	Material	Thickness, mm	Density, kg/m <sup>3</sup>	Porosity, %	Size of pores/fibers, $\mu\text{m}$
1	Without coating	—	—	—	—
2	Polyurethane foam	9	14.15	98.87	285
3	Basalt wool	50	45.00	98.50	22
4	Polyurethane foam	38	56.52	95.48	218
5	Metallic wool	50	157.19	98.00	56

**Figure 2.** Spectrum of acoustic oscillations for different sound absorber material (the tube diameter is 92 mm): 1—without sound absorber coatings, 2—9-mm polyurethane foam, 3—basalt wool, 4—38-mm polyurethane foam, and 5—metallic wool.

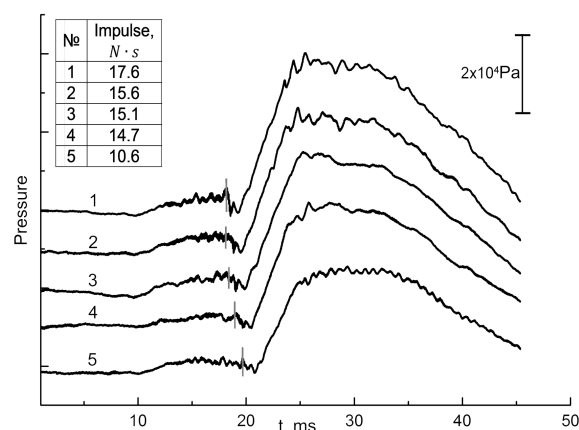
### 3. Results

Figure 2 represents the spectrum of acoustic oscillations, which were recorded by a microphone at the tube opened end. The spectrum was obtained using Fast Fourier Transform for the microphone signal before the flame front exit from tube.

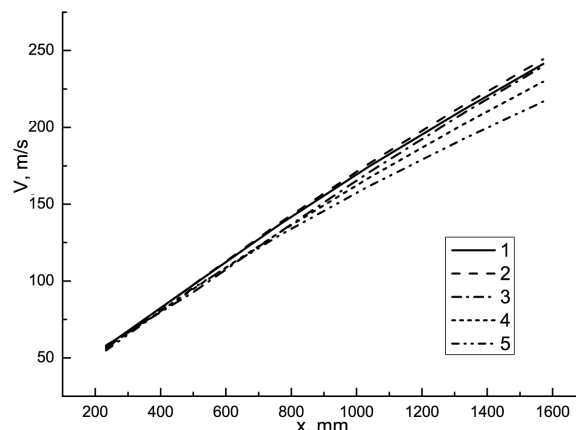
There are three local maximum: about 250, 800, and 1500 Hz. As follows from the figure 2, the greatest efficiency at this frequency was observed for metallic wool.

It is revealed that, overall, the used sound absorber materials weakly affect low-frequency sound oscillations. This is explained by that the wavelength at a frequency of 250 Hz in the stoichiometric air–hydrogen mixture significantly exceeds the thickness of sound absorber materials. With an increase in the frequency, the efficiency of the used sound absorber materials increases.

Figure 3 shows pressure profiles near the opened tube end. Overall, the considered materials show a decrease in the maximum pressure and the pressure impulse (time integral). A better



**Figure 3.** Pressure at the opened tube end. The vertical gray line marks the moment of the flame exit: 1—without sound absorber coatings, 2—9-mm polyurethane foam, 3—basalt wool, 4—38-mm polyurethane foam, 5—metallic wool.



**Figure 4.** Flame front velocity along the tube: 1—without sound absorber coatings, 2—9-mm polyurethane foam, 3—basalt wool, 4—38-mm polyurethane foam, 5—metallic wool.

result was obtained when metallic wool is used as the sound absorber material. This corresponds to the greatest efficiency at frequency of 800 Hz. The pressure impulse was attained to decrease by 40%.

Figure 4 shows flame front velocity along the tube. Maximum decrease in the flame velocity also was observed in using the metallic wool. The decrease in mean flame velocity was about 10%.

#### 4. Conclusions

Influence of sound absorbing surfaces on the spectrum of acoustic oscillations generated by the flame, on the flame front velocity and on the pressure impulse has been investigated. Maximum damping by 91% of disturbances amplitude was observed in the case of metal wool used. It is shown that the metallic wool application allows the flame velocity to be reduced by 10% and the pressure impulse of the compression wave to be decreased by 40%.

#### Acknowledgments

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