

## Interaction of electric and acoustic vibrations in combustion

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**Abstract.** The results of experimental studies of the interaction of electrical discharges in the acoustic oscillations in the combustion of isobutane are presented in the article. Electric discharges were created using a pulsed high voltage source at specified intervals. The purpose of the study was to determine the feasibility of using electrical pulse action to control combustion. The study was conducted on the specifically designed pattern of the combustion chamber with a swirl burner in the frequency range from 100 Hz to 1400 Hz. The study found that the method of periodic pulsed electrical influences can be used to control the combustion in the combustion chamber model. There is a steady increase in the amplitude of the oscillations in the combustion chamber model. Effects due to the mechanism of interaction of acoustic waves and oscillations heat release from the combustion zone. Estimated physical mechanism is a periodic change in the concentration of ions in the interaction of the combustion zone with the electric field of high potential. The proposed control method is advantageous in terms of energy costs.

### 1. Introduction

Combustion in the combustion power plants is accompanied by instability [1]. Increasing the thermal stress causes an increase in the working process of pressure fluctuations, temperature, speed, etc. These phenomena emerge and develop spontaneously. The oscillation frequency depends on the geometry of the combustion chamber. The oscillation amplitude depends on the degree of consistency ripples of heat in the combustion zone with the pressure fluctuations, gas mass flow rate, vortex shedding and other non-stationary processes [2]. Using the positive effects of the pulsating combustion can improve heat generation and ecological characteristics.

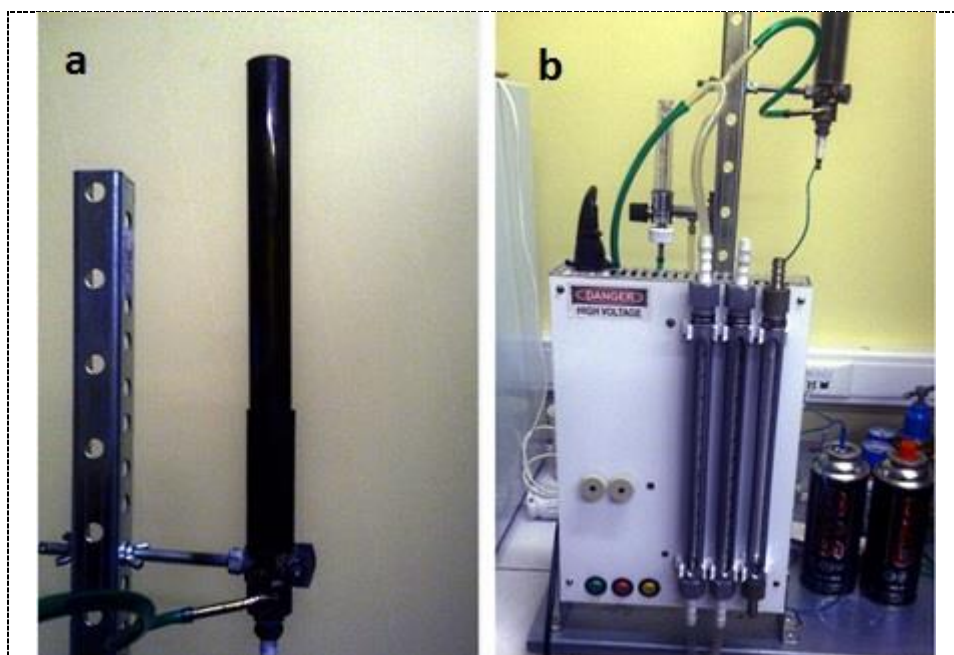
Combustion control can be carried out by different methods [3]. Among the known methods there is a group of external periodic perturbation methods is allocated. External periodic perturbations may be sound, electrical and others. These actions are aimed at changing the characteristics of heat.

The purpose of the pilot study is to determine the possibility of using the method of external electrical impulse actions to control the combustion in the combustion chamber model.

### 2. The method of investigation

General view of the experimental setup is shown in Figure 1.

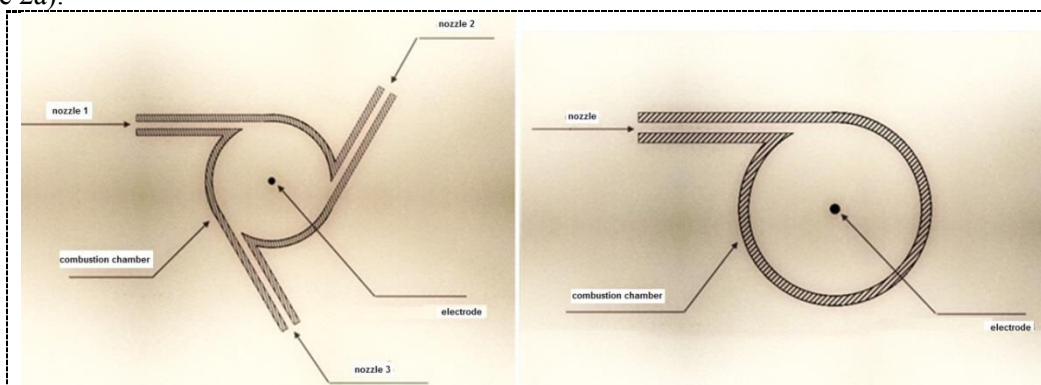




**Figure 1.** Appearance of the experimental setup: a- the combustion chamber, and b - measuring equipment

The combustion chamber of the experimental setup (figure 1 a) is a cylindrical tube. Its inner diameter is 25 mm, the total length of the resonance part 249 mm. Burner device was manufactured from heat-resistant stainless steel.

At a distance of 55 mm from the lower end of the burner have three tangentially disposed nozzles (Figure 2a).



**Figure 2.** Ways tangential feed gas mixture into the combustion chamber

In addition, for measuring the average temperature in the combustion zone mica used. The temperature of the heating plate mica flame recorded imager.

At the lower end of the burner has a ceramic sleeve for attaching the internal high voltage electrode. The inner electrode is designed as a rod made of refractory steel. The diameter of the electrode was - 1.0 mm. Stem length varied from 50 to 250 mm. The optimal length is 75 - 90 mm.

The combustion zone is formed around the center electrode. The positive potential was applied to the tube body. The negative potential was applied to the rod axis. The fuel gas mixed with air fed into the combustion chamber tangentially at the bottom of a core electrode. Gas mixture swirled counterclockwise. The ignition of the fuel mixture occurs when submitting the first electric pulse

In experimental studies, the supply of gas-air mixture is made on the circuit with a tangential channel (Figure 2, b). The internal diameters of the gas nozzles were 3 mm.

Scheme fuel gas through three nozzles has been more successful. Working gas-air mixture is evenly distributed within the combustion chamber.

The fuel gas is pre-prepared mixture of isobutane and air in stoichiometric ratio. Premixing was carried out immediately prior to feeding the fuel gas to the nozzles.

Costs gases (isobutane and air) were measured by flow meters brand RMF-063G and REF-554000, respectively. Flow Air RMF-063G has full scale of 0.63 m<sup>3</sup> / h (10,51 / min). During the experiments, the air flow rate ranged from 7.35 to 8.4 l / min. Flowmeter for isobutane REF-554000 had a full scale of 5 liters / min. During experiments isobutane flow rate ranged from 0.83 to 1.38 l / min.

The sound pressure level pressure oscillations in the combustion chamber are measured by means of an integral sound pressure analyzer IBP-1. Weighted sound pressure level inside the combustion chamber was equal to 140 dBell. Natural frequency of the combustion chamber at the stoichiometric flow rate was equal to 400 Hz.

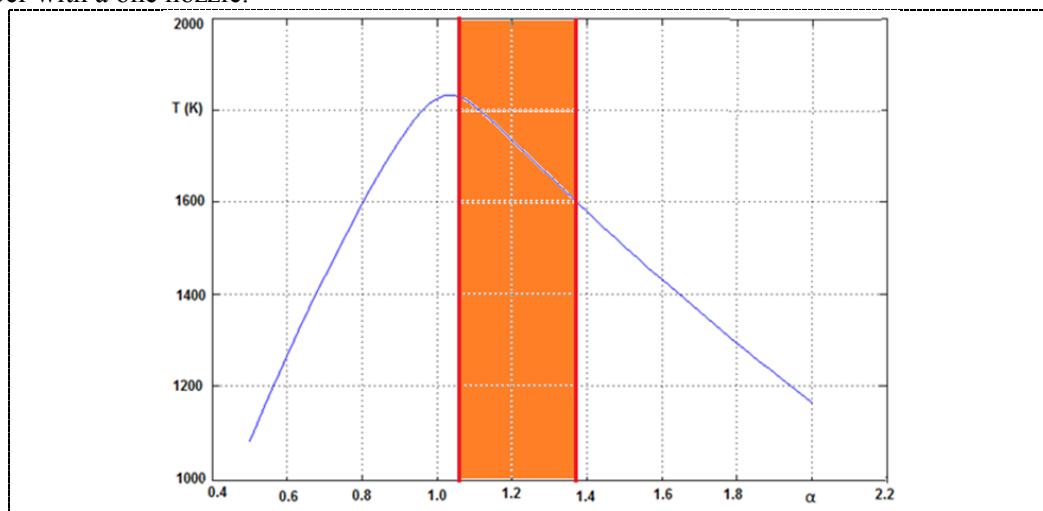
### 3. The results of the study and discussion

The experiments were performed in the following sequence.

Initially, we conducted research on the impact of the proposed method of the combustion chamber with a single nozzle. After ignition of the fuel gas to the central axis of the combustion chamber electrode pulse voltage was applied. The amplitude of the sound vibrations in combustion without pulse exposure was equal to 60 dB. Then it was applied pulse voltage. The pulse rate changed. When the pulse frequency was closed to 400 Hz and the excess air ratio exceeding the stoichiometry were increased acoustic oscillations in the combustion chamber. This was appreciable by change of sound pressure level and change of the character of combustion. Thus estimation excess air ratio is in the range from 1.05 to 1.35. Sound pressure level at the measurement point is 120 dB.

The actual amount of air required for complete combustion of 1 kg of fuel in fact different from design. In the practice of burning fuel not all the amount used. Therefore it does not play a part in the combustion reaction resulting in poor mixing of air and fuel. Part of the air does not have time to enter into contact with the carbon in the fuel and leaves flues in the free state. Therefore, the ratio of the amount of air really and theoretical values of the excess air in the combustion chamber differ. The calculation of the excess air ratio by the formula:  $\alpha_T = V_r / V_t$ , where  $V_r$  - the actual volume of air supplied to the furnace at 1 kg fuel;  $V_t$  - theoretical volume of air.

Figure 3 is a graph of the theoretical combustion temperature of the air excess factor. Colour allocates the working range of the excess air in an experimental investigation of for the combustion chamber with a one nozzle.



**Figure 3.** Dependence of the theoretical combustion temperature of the excess air ratio

Then, experiments were conducted to the combustion chamber with three gas inlet nozzles.

In this case, after the ignition of the fuel mixture arose to acoustic oscillations at a resonant frequency of the combustion chamber. This was caused by a known mechanism of excitation of oscillations in the vortex burners [1]

The original sound pressure level is 140 dB. The electrical effects at frequencies close to the resonant frequency of the first half-wave resonator modes of oscillation were increased. Amplification was not significant. As the frequency of external influence to the resonance frequency of the first effect was observed capture frequency. This phenomenon is observed in the range of 2-3 Hz of frequency resonance. Interesting to note that when you change the frequency of the external electric effects of the resonance in the range of 3 Hz frequency change occurred recorded acoustic oscillations. These changes were visible instruments and listening.

The observed phenomenon may explain the mechanism of asynchronous interaction of external periodic perturbations and the natural frequencies of the combustion chamber [3].

The physical nature of this phenomenon is in the interaction of the electric field with the charged particles  $\text{CHO}^+$  [5]. These particles are formed by chemical ionization of fuel gas by oxidation by atmospheric oxygen. It is known that the concentration of ions in the flame can be 4-6 orders of magnitude higher than the concentration that would be observed in a purely thermal mechanism of ionization, and flame can actually behave like weakly ionized plasma. However, the temperature of the flame is not sufficient to ensure that the components of the mixture can be ionized by collisions between the molecules is [4]. The concentration of ions and their charge is dependent on the excess.

#### 4. Conclusion

Method of external electrical disturbances can be used to control the combustion in the combustion chambers of power plants. Depending on the frequency of the external electrical influences has been increasing oscillations in the combustion chamber and at the resonant frequencies close to it. This is due to the mechanisms of synchronous and asynchronous interaction. Estimated physical mechanism is a periodic change in the concentration of ions in the interaction of the combustion zone with the electric field of high potential.

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