September, 21st - 24th 2014
FLAME STRUCTURE 2014
8th International Seminar on Flame Structure

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Berlin Institute of Technology (TU Berlin)

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EFFECT OF ROTATING ELECTRIC FIELD ON THE DIFFUSION FLAME

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Abstract.

An experimental study of the effect on the shape of the diffusion flame of the electric field (EF), intensity vector of which rotates around the axis of the torch, was carried out. Application of multispectral registration gave information about the intensity distribution of the radiation at the wavelengths of intermediate reaction products (OH, CH and C_2). Change in the intensity of natural light along the length of the torch at different wavelengths shows the influence of the rotating EF on the intensity of mixing.

Introduction.

The possibility of controlling the combustion by means of EF connected with the presence of free charges in the flame. Ion concentration in the hydrocarbon-air flames significantly exceeds the level of thermal ionization and is determined by chemi-ionization reactions. In [1], some of the mechanisms of ion formation are presented and it is shown that the main negative charge carriers are electrons, among the positive ions the H3O+ should be distinguished, its concentration in the flame front is comparable to the electron concentration.

Application of an external EF leads to an imbalance of existing hydrodynamic forces [2]. The effect depends on the spatial configuration of the EF. In [3], different forms of fire in EF of various configurations have been analyzed. The authors concluded: «Results from many of the experiments in the literature cannot be compared as the field they have used is very different». In [4], it is noted that in the pulse-periodic mode the position of the flame front can be deformed more than under the action of a constant EF. Application of non-stationary EF allows for more efficient influence on the hydrocarbon fuel combustion process.

In this paper, we examined the effect of the EF, intensity vector of which varies over time (rotates around the axis of the flame).

Approach.

In the experiments, commercial propane gas (propane-butane mixture) was used as fuel. The mode of combustion was laminar one with the flame stabilization on the edge of the burner. Fig. 1 is a schematic diagram of the experiment. The test installation included: diffusion type burner hav-

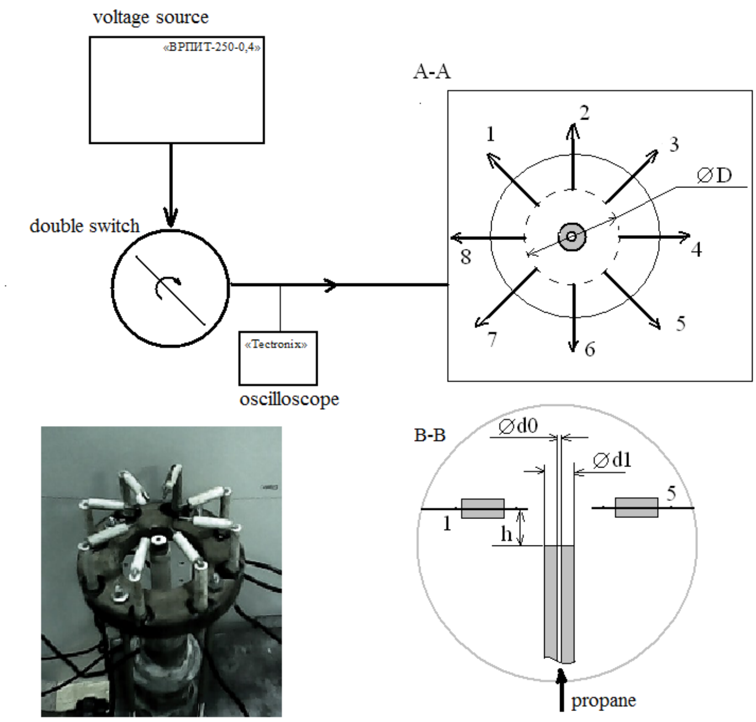
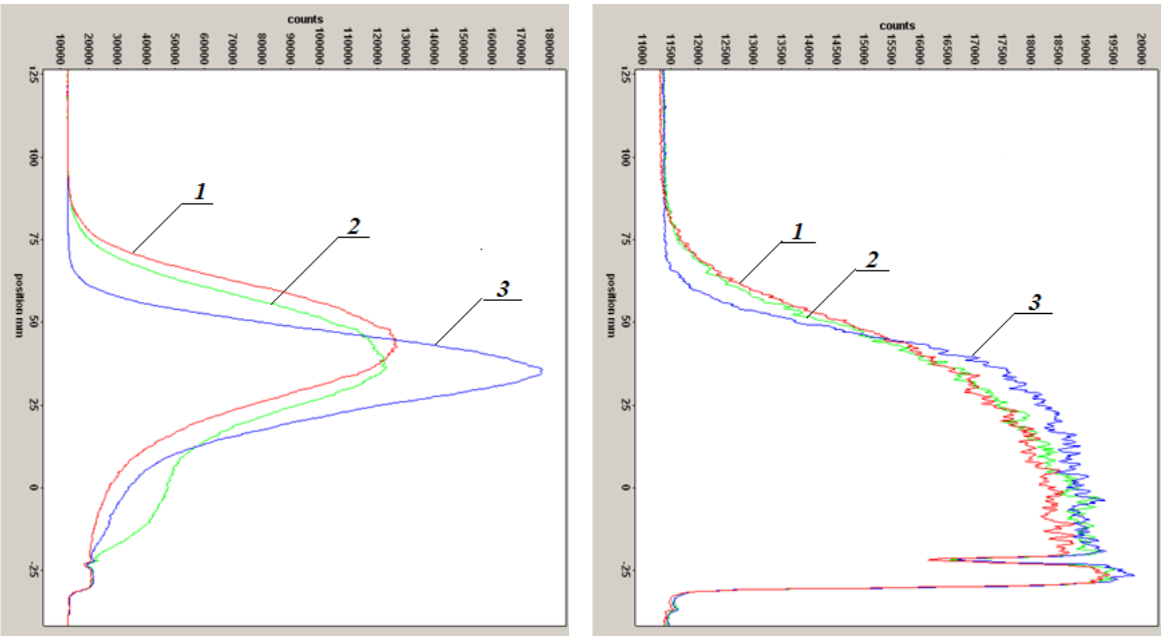


Fig.1. Experimental set-up.

ing an inner diameter d0 = 1 mm, an outer diameter d1 = 6 mm (non-conductive), voltage was applied in pairs ("+", "-") on 8 thin electrodes arranged uniformly in a circle (diameter D = 14 mm) at a height h = 12 mm from the burner. Switching between the electrodes was performed by rotating a dual-switch closing / opening the contacts connected to the power supply. The frequency of the applied voltage and the pulse shape were registered on a Tektronix Oscilloscope.

The voltage magnitude was set by the "VRPIT-250-0.4" high-voltage power supply. Propane flow rate was controlled by an EL-FLOW series Mass Flow Meter with an accuracy of 0.1%. The geometry of the diffusion flame (Re ≈ 200-400) was registered by its own glow at wavelengths of CH, OH, and C_2 radicals. For this purpose, Imager Intense CCD camera with a spatial resolution of 1376 x 1040 pixels, shooting frequency of 9.4 Hz and an exposure time of 1 ms with an Intensified Relay Optics (IRO, LaVision) image intensifier was used.

Radiation of OH (λ = 307 nm), CH (λ = 430 nm), C_2 (540 nm and 560 nm) radicals was distinguished using the corresponding interference filters. When voltage is applied, the flame is deflected to the negative electrode. Sequential switching of electrodes in a circle caused rotation of the flame around the jet axis. In the experiments, the switching frequency was 10 Hz. Processing of the multispectral registration results was carried out using a



a) b)

Fig.2. The intensity own flame radiation for different wavelengths (a – CH, b – OH):
1 – without EF; 2 – with DC EF; 3 – with rotating EF

DaVis Software package.

Results and discussion.

The distributions of the radiation intensity of OH, CH and C_2 radicals along the torch were obtained. Fig. 2 shows an example of the distribution of the radiation intensity of CH and OH radicals along the torch: vertical - coordinate along the torch, horizontal - the intensity in relative units. Switching-on an EF leads to a shift of the intensity maximum in the radiation distribution at wavelength of the CH radical to the mouth of the burner. Rotation of the EF intensifies this effect and reduces the range of the band emitting at this wavelength. A similar behavior of the intensity distribution of self-illumination of the flame is observed at a wavelength of C_2 radical.

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Reducing the emission zone is also noted in the radiation distribution at wavelength of the OH radical, which maximum is located on the burner edge and does not move.

It should be noted that during combustion of hydrocarbons the distribution of the CH radical radiation is proportional to the heat release function, the integral of which gives the change in combustion efficiency along the length of the torch. In the experiments, the total integral of CH radiation remained constant during rotation of EF and also for the case without EF.

Conclusions.

Rotation of intensity vector of an external EF leads to a shift of the intensity maximum in the radiation distributions at wavelengths of the CH and C_2 radicals to the mouth of the burner, representing a decrease of furnace zone (flame length). The findings suggest the intensification of the mixing process.

Acknowledgements

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