Propane-Butane-Air Premixed Flame Control by Nanosecond Pulsed Streamer Discharge

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An experimental investigation of the laminar premixed propane-air flame control by high-voltage streamer discharge was performed. Streamer discharge development in chemically active mixtures at long distances was investigated by direct numerical simulation in 2D geometry using hydrodynamic approximation. Calculations of streamer propagation in hydrogen-air and methane-air mixtures were performed (Figure 1). The data obtained allows to calculate active particles production (oxygen, hydrogen atoms, excited molecules and radicals, such as OH, CH, CN) in the discharge gap under the...

Figure 1. Streamer discharge development in H₂-air mixture. U = 13 kV. Point-to-plane geometry. Excessive charge.
pulse discharge action. The possibility of the ignition control in the H₂-Air and CH₄-Air mixtures at high pressures by high-voltage nanosecond discharge has been demonstrated. The ignition threshold dependence on the main parameters of the system has been determined.

Burned was made from glass with the outlet dimension 2x28 mm. This allows to generate the non-equilibrium plasma ahead of the flame front in the wide range of flow parameters (Figure 3).

Figure 2. Streamer channel radius in dependence on the gas mixture. U = 13 kV. Point-plane geometry.

Figure 3. Flame acceleration by gas discharge. Frequency of the discharge is 1.2 kHz, voltage 25 kV, pulse duration 75 ns.
The results obtained are shown in the Figure 4. It is clearly seen the flame acceleration by the discharge. The total discharge power was less than 1 percent from the burner power. This result demonstrates the possibility of wide control of premixed flames by non-equilibrium plasma of gas discharge. The mechanism of discharge influence on the flame propagation was investigated. Figure 5 demonstrates the OH emission distribution in dependence on the height above the burner. It is clearly seen that pulsed discharge adds the radicals into the flow and creates the secondary reaction zone in front of the main flame. This region is characterized by strongly non-equilibrium concentration of active particles produced by electron impact in the discharge zone. Additional heat release in this region and radicals production lead to the blow-off velocity increase (Figure 4.)
Conclusions.

Numerical model of pulsed discharge development in chemically active mixtures was elaborated. Simulations of the properties of a positive streamer in H₂ and CH₄-air mixtures in a non-uniform electric field in 2D-geometry were performed. The production of active particles including atoms, radicals and electronically excited molecules by a long positive streamer versus gas composition, pressure, and temperature has been calculated. The results have been used to estimate the efficiency of the streamer-corona ignition of the combustion in the considered gaseous mixtures.

The possibility of flame control by a streamer discharge has been demonstrated. Physical mechanism of the discharge influence on the flame propagation based on the non-equilibrium active particles production in the discharge zone was proposed.

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