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

E.I. Mintoussov, S.V.Pancheshnyi, A.Yu.Starikovskii

Physics of Nonequilibrium Systems Laboratory,

Moscow Institute of Physics and Technology, Institutskii lane, 9

Dolgoprudny Moscow region 141700 Russia. E-mail astar@neq.mipt.ru

Keywords: flame control, pulsed streamer discharge

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 (Figure1). The data obtained allows to calculate active particles production (oxygen, hydrogen atoms, excited molecules and radicals, such a OH, CH, CN) in the discharge gap under the

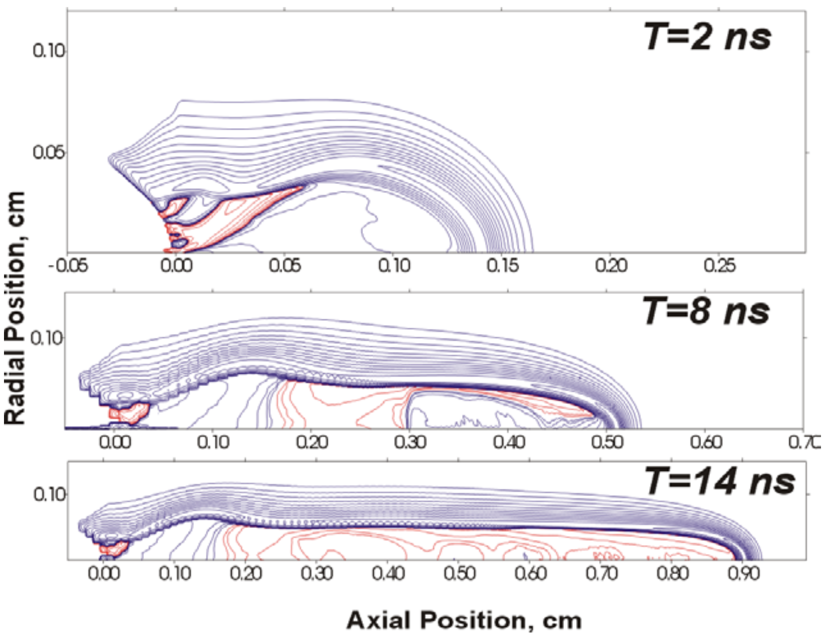

Figure 1. Streamer discharge development in H_2-air mixture. U = 13 kV. Point-to-plane geometry. Excessive charge.

pulse discharge action. The possibility of the ignition control in the H_2-Air and CH_4-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.

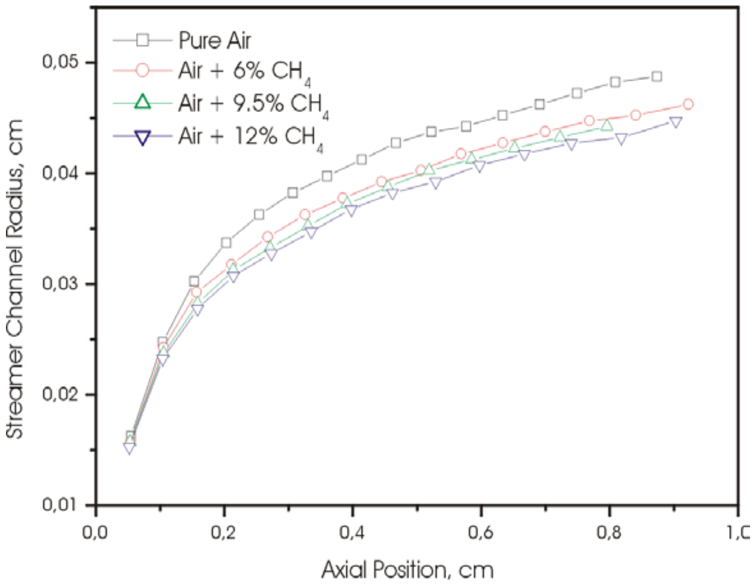

Figure 2. Streamer channel radius in dependence on the gas mixture. U = 13 kV. Point-plane geometry.

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).

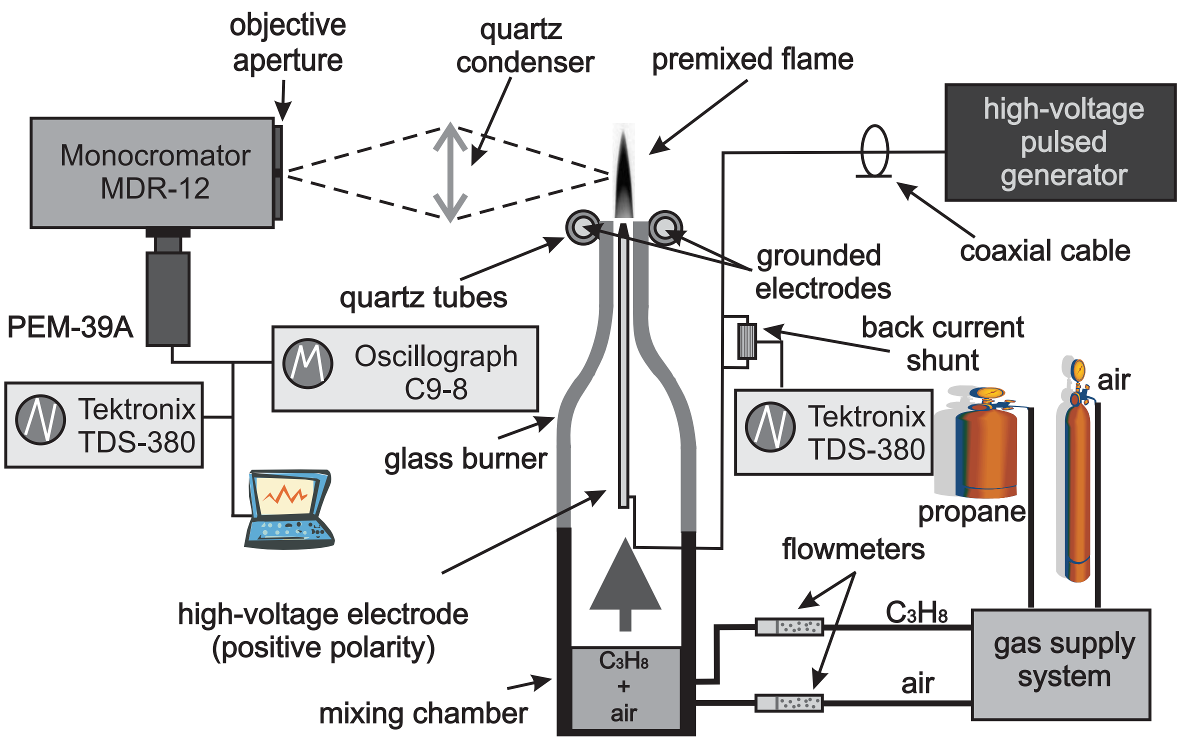

Figure 3. Flame acceleration by gas discharge. Frequency of the discharge is 1.2 kHz, voltage 25 kV, pulse duration 75 ns.

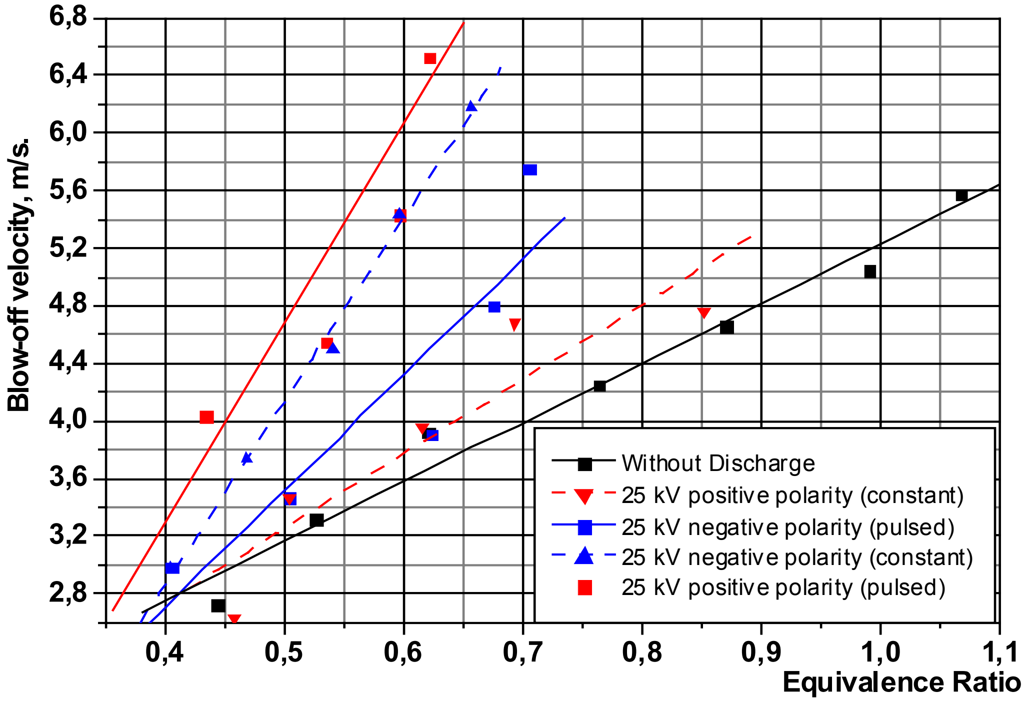

Figure 4. Flame acceleration by gas discharge. Discharge power is <1% of the burner power.

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.)

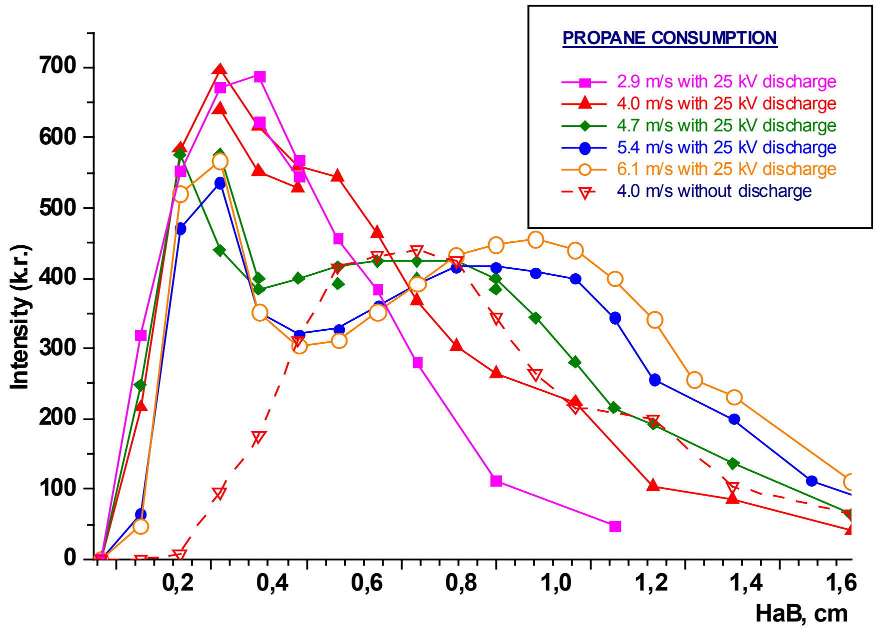

Figure 5. OH Emission Profile Along Flame Height. $\phi = 0.6$

Conclusions.

Numerical model of pulsed discharge development in chemically active mixtures was elaborated. Simulations of the properties of a positive streamer in H_2 and CH_4-air mixtures in a non-uniform electric field in 2D-geamotry 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.

The work was supported in part by RFBR (grants 02-02-06523, 02-03-33376), ISTC 1474 and CRDF MO-011-0.