Investigation of a Non-steady State Discharge in a Pilot for Ignition and Flame Control

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Subject of the paper is investigations of non-steady state behavior for high-pressure gas discharge in the air-hydrocarbon mixtures as applied to the problem of ignition and flame stabilization. The device, used in the experiments (Fig. 1), is based on design of classical arc plasmatron [1, 2]. However, the distinctive feature of the plasmatron operation in our experimental conditions is that an average current is limited by the ballast resistor R_b at a level of about 0.1 A. Average power dissipated in plasmatron does not exceed 100 W. In spite of extremely low average power, plasmatron demonstrates reliable ignition and flame stabilization for air-propane mixtures in a wide range of equivalence ratios.

A key point in understanding physical mechanism of flame ignition and control is elucidation of non-steady state discharge behavior. An important role in the non-steady state discharge processes belongs to capacitance C of connecting cable. If the current from the power supply were high enough, then the discharge would be able to burn as a steady state thermal arc with distinctively expressed cathode spot. However, in the conditions of low current, the cathode spot is extinguished, and during some time, the discharge is sustained in a low-current glow mode. The characteristic feature of a high-pressure glow discharge is so-called glow-to-spark transitions that occur randomly. When such a transition occurs, the capacitor C is discharged via the gap and a high-current pulse with duration of about 100 ns forms on background of glow discharge. The short duration spark channel is able to give origin to the ignition process. The temporal development of the ignition goes efficiently because of the surrounding medium does not represent a “cold gas”, but a low-density non-equilibrium glow discharge plasma where the chemically active particles are already available. In such conditions, even small energy dissipation in the spark channel seems to be sufficient to start the burning process [1, 2].

Investigations of the discharge had been carried out with a use of oscilloscope measurements with nanosecond time resolution and by means of recording the discharge image with CCD camera. An example of voltage and current waveforms is shown in Fig. 2. Here we can see the bright channel (*1*) that originated at the instant of glow-to-spark transition. The breakdown occurred from central part of the cathode end to inner surface of the anode nozzle over a short distance. The spark discharge transforms in a glow mode with distinctively expressed anode current attachment (anode spot). At the glow stage, the gas flow essentially affects to the discharge behavior. It results in displacement of the anode spot over the anode surface in direction of plasmatron exit and increasing the plasma column length. The anode spot does not migrate smoothly, but its migration resembles a consequence of jumps (see dotted structure of the anode trace in Fig. 2).

At the end of exposition time, the plasma channel is already attached to the edge of plasmatron exit aperture (position *2* in Fig. 2). After that, new glow-to-spark transition occurs and the described cycle is repeated.

As a whole, the discharge burning regime can be referred to as a kind of glow discharge with random transitions from glow to spark. Two types of transitions have been observed: completed

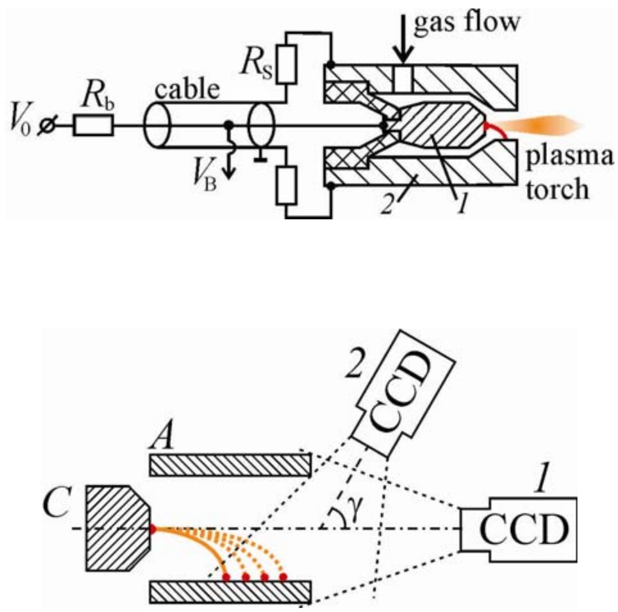

Fig. 1. Experimental arrangement of plasmatron and schematic of the optical observation by means of CCD camera. R_b – ballast charging resistor; R_S –shunt for current recording; V_B – discharge voltage

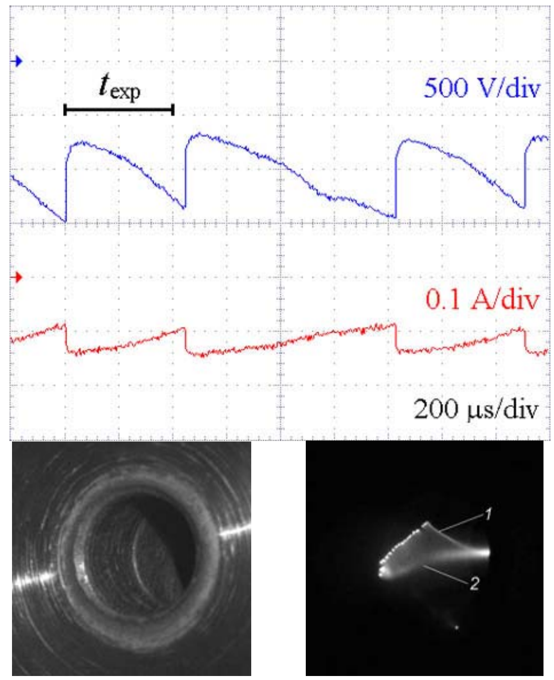

Fig. 2. Voltage and current waveforms and CCD photographs of the discharge image. (γ = 45°). R_b = 13.6 kΩ, C = 300 pF, V_0 = 3.0 kV. Gas flow G(air) = 0.1 g/s (v_{gas} = 4 m/s)

and non-completed transitions. For the case of completed transition a high-conductivity spark channel appears in the gap, and for non-completed transitions the diffuse channels with a moderate conductivity arise. Both types of the channels serve as efficient starting mechanism for initiation of the burning process.

References

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