Topic number: 3

ULTRA–LEAN FLAMES STABILIZATION BY HIGH–VOLTAGE NANOSECOND PULSED DISCHARGE

Andrei Nikipelov(1,2), Ilia Popov(2), Giuseppe Correale(2), Aleksandr Rakitin(1,2,*), Andrei Starikovskii(1,3)

(1) Moscow institute of physics and technology, Dolgoprudny, 141700, Russia
(2) NEQLab Research BV, The Hague, 2521 AL, The Netherlands
(3) Drexel Plasma Institute, Drexel University, Philadelphia, PA
(*) **arakitin@neqlab.com**

One of the approaches for lean flames stabilization is the application of plasma–assisted burners, also referred to as plasmatrons. Mainly plasmatrons are based on arc, spark, or microwave discharges, since they have been thoroughly studied and present relatively simple designs at low cost. The general problems of these approaches are significant energy consumption and short life cycles due to overheating and erosion of electrodes. The best examples provide 100 operating hours while the necessary life cycle is approximately 1000 hr for industrial applications.

One of the main features of nanosecond gas discharge is its efficiency in production of nonequilibrium low–temperature plasma with high concentration of active radicals combined with rapid heating of the gas. This is due to the high values of reduced electric fields (50—500 Td) which are present in the discharge channels at typical pulse voltages of 10—20 kV. Under such high fields, the energy input into the gas is branched between rapid heating and radical production, which is mostly atomic oxygen in 1D excited state, as was shown in [1]. Also shown was that atomic oxygen is extremely efficient in starting chain reactions and, thus, in promoting ignition. High pulse amplitude up to 15—20 kV and short pulse duration of 10—20 ns enable discharge development in a wide range of pressures, temperatures, and gas compositions with relatively low pulse energy. The paper presents the intermediary results of the development of a series of plasmatrons driven by repetitive high–voltage pulsed nanosecond discharge. The tests have been carried out in methane and automotive diesel fuel vapors in a wide range of equivalence ratii.

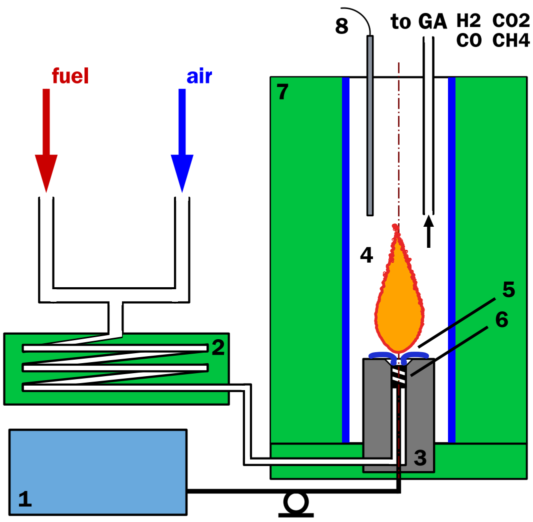

Fig. 1: Scheme of experimental setup for plasma–assisted flame stabilization.

The experimental setup consisted of the following systems (Fig. 1): high–voltage pulse generator (1), fuel— air supply, premixing and preheating system (2), plasmatron (3), reaction chamber (4), ground electrode (5), high–voltage electrode/swirler (6), heat insulation (7), ungrounded thermocouple (8), multi–channel gas analyzer, and a 500 MHz oscilloscope not shown in the scheme.

The mixed flow to be ignited was directed through the plasmatron into the thermally insulated chamber (4). The chamber was made of a SiC tube, wrapped in 50 mm Fiberfrax thermoinsulating blankets and enclosed in a stainless steel cylinder. The discharge developed inside the nozzle of the plasmatron, starting from the high–voltage electrode which also acted as a swirler. The discharge is produced by 15 kV pulses generated at a frequency of 10 kHz in a 60 slpm air flow. During the experiments, temperature and composition (CO, CO2, CH4) of the flow at the outlet of the plasmatron were measured. The gas for analysis was sampled 5 cm above the plasmatron. The thermocouple measurement of the products temperature were carried out in the same spot.

The main results with methane are presented in figure 2 in terms of products of oxidation of premixed methane–air flow at inlet temperatures of 400 C and 580 C. The gas flow rate was 30 and 60 slpm, the equivalence ratii ranged from 0.06 to 0.4.

The nanosecond spark created radicals during the streamer phase and increased temperature during the arc phase faster than radicals recombined. Non–thermally created radicals initiated chain reactions within times shorter than those of gas mixing, thus efficiently igniting the flow in the afterglow of the nanosecond spark.

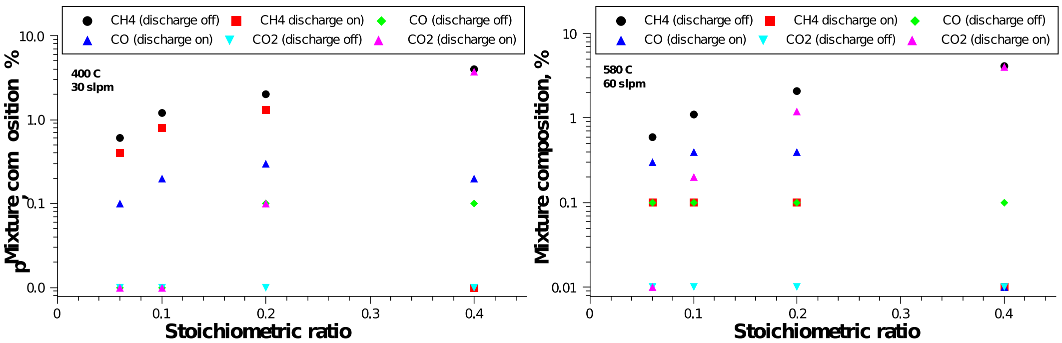

Fig. 2: Plasma–assisted stabilization of premixed methane–air flame. Left: inlet temperature 400 C, flow rate 30 slpm. Right: inlet temperature 580 C, flow rate 60 slpm.

Reference

[1] A. Y. Starikovskii, Plasma supported combustion, in: Proceedings of the Combustion Institute, 30th Interantional Symposium on Combustion, Chicago, USA, 2004, p. 326.