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Modes of interaction of counterflow flames in diluted methane–oxygen mixtures in a closed reactor

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Experimental details

The experiments were performed in a reactor 140 mm in diameter and 700 mm in length with simultaneous spark initiation at opposite butt-ends of the reactor at total pressures up to 200 Torr (Figure S1).[S1,S2] At the butt-ends, the reactor was fixed in two stainless steel gateways, equipped with inlets for pumping and releasing gas and a safety shutter, which swings outward when the total pressure in the reactor exceeds 1 atm.[S2] In the first series of experiments, two compressible syringes with a diameter of 70 mm were placed coaxially opposite each other [Figure S1(*b*)] at a distance of 110 mm between their tips. In the experiments, the hot products of the propagating flames caused the compression of syringes and simultaneous emergence of counter gas jets from their nozzles; the jets then ignited in the hot gas and formed counterflow flame fronts. In other words, relatively cold jets of the initial mixture were ignited by hot gas products. The ignited jet made it possible to visualize the structure of gas flows in the process by simultaneously recording a side view and a top view using a deflecting mirror [see Figure S1(*b*), position *13*].

In the second series of experiments, another method was implemented to obtain counterflow flame fronts. Thin obstacles (140 mm in diameter) with round central openings (30 mm in diameter) were placed vertically in the center of the reactor. The obstacles were located at a distance of two ‘flame jumps’ from each other so that the flame had time to arise[S3] for both opposite flows. This distance was ~220 mm under our conditions [Figure S1(*a*)]. The obstacles were fixed in the reactor with foam rubber rings. The hot jet of the initial mixture propagated in the environment of the cold initial gas and ignited it.

The combustible mixture (15.4% CH_4 + 30.8% O_2 + 46% CO_2 + 7.8% Ar) was prepared before the experiment; CO_2 was added to decrease flame velocity and improve image quality; Ar was added to lower the discharge threshold. The reactor was filled with the gas mixture to the required pressure. Two pairs of spark ignition electrodes were located at opposite butt-ends of the reactor; the pairs were connected to the power supply in series to provide two simultaneous discharges. Each pair could be shorted out to provide a single discharge. High-speed filming of the ignition dynamics and flame front propagation was carried out from the side of the reactor using a Casio Exilim F1 Pro color high-speed digital camera (frame rate 600 s^{-1}).[S3,S4] Shooting was switched on at an arbitrary moment before initiation. The video file was saved in the computer memory and its time-lapse processing was performed. The temperature of the flame jets created by the syringes was controlled both by a Kelvin 2200 two-beam color pyrometer and by a tungsten–rhenium thermocouple 80 μm in diameter, placed on the axis at the point where the flames meet. The reagents were qualified chemically pure.

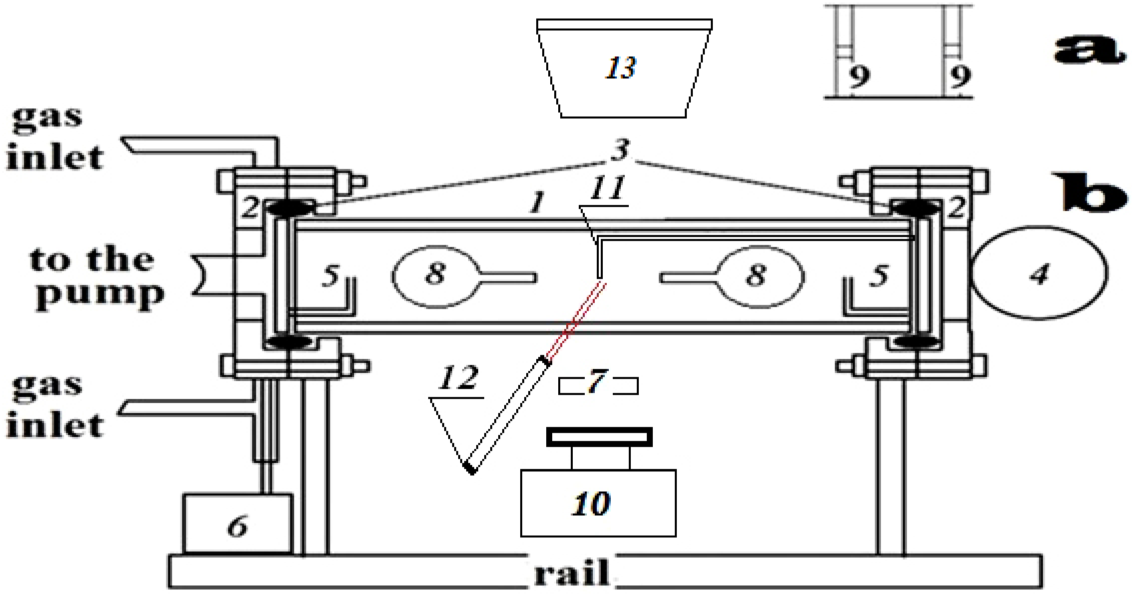

Figure S1 (*a*) Composite obstacle consisting of two planar obstacles having single central round openings 30 mm in diameter and spaced 22 cm apart. (*b*) Experimental setup: (*1*) cylindrical quartz reactor, (*2*) stainless steel gateway, (*3*) silicone gasket, (*4*) stainless steel shutter, (*5*) spark electrodes, (*6*) power supply, (*7*) Casio Exilim F1 Pro movie camera, (*8*) silicon syringe, (*9*) planar obstacle with a central round opening, (*10*) interference filter, (*11*) W–Rh thermocouple, (*12*) two-beam color pyrometer, (*13*) top view deflecting mirror.

References

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