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Experimental Studies of Methane-Air Flame Acceleration in Tubes with Obstacles

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Investigation of methane – air flame acceleration in semi-closed volumes is of practical importance, in particular for safety reasons in coal mines, natural gas transportation systems, process plants, etc. According to numerous experimental observations in laboratory-scale tubes and channels with regular obstacles, flames in the stoichiometric methane – air mixture can spontaneously accelerate to the visible propagation velocity on the order of 900-1000 m/s. Depending on the experimental conditions, further flame propagation can be either quasistationary or decelerating. However, at certain conditions (elevated pressures, properly arranged obstacles, etc.) deflagration-to-detonation transition (DDT) can occur. At present, despite wide application of methane and natural gas in process industries, the level of knowledge on their explosion hazards and, in particular, on the conditions of DDT is still insufficient.

The objective of the work briefly outlined in this paper was the experimental study of methane – air flame acceleration in tubes of different diameter (70 and 94 mm) with obstructed sections. The statement of this work differs from those existing in the literature mainly by the use of a relatively large volume for flame ignition and initial propaga tion equipped with a perforated plate (Fig. 1). Mixture ignition in the large volume with the perforated plate results in fast turbulent flame development and displacement of a considerable amount of unburned mixture first to the attached smooth-walled tube of smaller cross section and then to the tube with regular obstacles in the form of orifice plates. As a result, the arising flame propagates in the high-speed turbulent flow and exhibits fast acceleration. The obstacles in the obstructed tube are used for generating additional preflame turbulence at a relatively large distance from the ignition source and sustaining it at a high level until flame arrival.

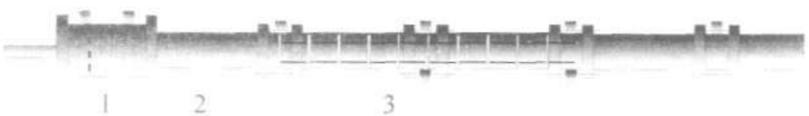

Fig. 1. Experimental setup: 1- large volume; 2 – smooth tube; 3 – obstructed tube

The accelerating flame generates compression waves which cumulate with each other giving birth to a series of shock waves (Fig. 2). Under certain conditions in terms of the configuration and position of the perforated plate, length of the smooth-walled tube and the blockage ratio of obstacles, the intensity of the shock wave can drastically increase to a level of 1000–1100 m/s at very short distances (1.0–1.5 m) which is clearly seen in Fig. 3. Clearly, the setup configurations corresponding to curves 2 and 3 in Fig. 3 are

characterized by progressive shock acceleration with a higher potential of DDT than the configuration corresponding to curve 1.

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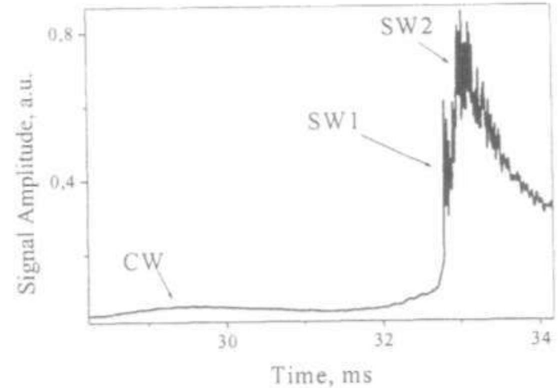

Fig.2 Example of pressure history: CW = compression wave, SW = shock wave

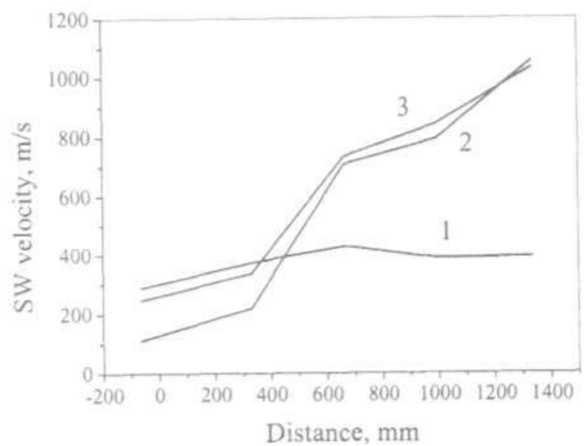

Fig.3 Measured velocities of lead shock waves along the tube in three different configuration of perforated plates and obstacles in the experimental setup