DEFLAGRATION-TO-DETONATION TRANSITION IN A SEMICONFINED SLIT COMBUSTOR WITH SEPARATE SUPPLY OF ETHYLENE AND OXYGEN AT SINGLE-POINT AND TWO-POINT IGNITION

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Abstract: The paper experimentally determines the conditions for mild detonation initiation in a vertical semiconfined flat layer of stoichiometric ethylene–oxygen mixture of finite thickness. Pointwise ignition of the layer is performed by a single spark gap or two spatially separated spark gaps. Mild detonation initiation means deflagration-to-detonation transition (DDT). The flame and detonation propagation process is recorded by high-speed black-and-white and color video cameras. Mixture ignition by a single spark gap shows that the probability of DDT monotonically increases from 0 to 1 with the height of the combustible mixture layer. There is always the critical height of the layer, at which this probability has an intermediate value between 0 and 1. In the experiments, the critical height of the layer was 80–100 mm. Simultaneous ignition of the mixture by two spark gaps can lead to both deceleration and acceleration of DDT. Comparison of black-and-white and color images of the DDT process shows that the shapes of the flame front and detonation wave are similar in both cases but the color image allows obtaining additional information on the flame temperature. However, the black-and-white image with a large dynamic range better displays the structure of the flame front and detonation wave. The obtained results can be used in developing the procedures for safe and reliable starting of continuous-detonation engines, which require careful control of the time of filling the engine combustor with fuel and oxidizer as well as the ignition time of the explosive mixture.

Keywords: continuous-detonation engine; slit combustor; deflagration-to-detonation transition; ethylene–oxygen mixture; minimum height of the combustible mixture layer

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Figure Captions

Figure 1 Schematic of the distributed spark gap (only 5 of 26 discharge gaps are shown). Dimensions are in millimeters

Figure 2 Coordinates of detonation onset $(X_{\mathrm{DDT}}, Y_{\mathrm{DDT}})$ during ignition of a layer of $C_2H_4 + 3O_2$ mixture by a single spark gap located at a height of $h_{\mathrm{spark}} = 15$ (*a*), 45 (*b*), and 75 mm (*c*): *1* — $h_{\mathrm{est}} = 86$ mm; *2* — 97; *3* — 118; *4* — $h_{\mathrm{est}} = 140$ mm; and *5* — P_i, pressure sensors coordinates

Figure 3 Video frames of DDT and detonation propagation in a $C_2H_4 + 3O_2$ mixture at $h_{\mathrm{est}} = 118 \pm 2$ mm and ignition by a single spark gap with $h_{\mathrm{spark}} = 15$ mm: (*a*) experiment #1179 (color camera, $X_{\mathrm{DDT}} = 250$ mm, $Y_{\mathrm{DDT}} = 27$ mm, and $T_{\mathrm{DDT}} = 0.94$ ms); and (*b*) experiment #1187 (black-and-white camera, $X_{\mathrm{DDT}} = 260$ mm, $Y_{\mathrm{DDT}} = 28$ mm, and $T_{\mathrm{DDT}} = 0.94$ ms)

Figure 4 Video frames of DDT and detonation propagation in a $C_2H_4 + 3O_2$ mixture at $h_{\mathrm{est}} = 98 \pm 2$ mm and ignition by a single spark gap with $h_{\mathrm{spark}} = 45$ mm: (*a*) experiment #1185 (color camera, $X_{\mathrm{DDT}} = 422$ mm, $Y_{\mathrm{DDT}} = 0$ mm, and $T_{\mathrm{DDT}} = 1.65$ ms); and (*b*) experiment #1260 (black-and-white camera, $X_{\mathrm{DDT}} = 394$ mm, $Y_{\mathrm{DDT}} = 0$ mm, and $T_{\mathrm{DDT}} = 1.7$ ms)

Figure 5 Video frames of DDT and detonation propagation in a $C_2H_4 + 3O_2$ mixture at $h_{\mathrm{est}} = 98 \pm 2$ mm and ignition by two spark gaps: (*a*) experiment #1297 (black-and-white camera, $h_{\mathrm{spark,1}} = 15$ mm and $h_{\mathrm{spark,2}} = 75$ mm, $X_{\mathrm{DDT}} = 608$ mm, $Y_{\mathrm{DDT}} = 0$ mm, and $T_{\mathrm{DDT}} = 1.46$ ms); and (*b*) experiment #1291 (black-and-white camera, $h_{\mathrm{spark,1}} = 45$ mm and $h_{\mathrm{spark,2}} = 75$ mm, $X_{\mathrm{DDT}} = 305$ mm, $Y_{\mathrm{DDT}} = 18$ mm, and $T_{\mathrm{DDT}} = 1.43$ ms)

Figure 6 Video frames of DDT and detonation propagation in a mixture of $C_2H_4 + 3O_2$ at $h_{\mathrm{est}} = 140 \pm 2$ mm and ignition by a single spark gap with $h_{\mathrm{spark}} = 90$ mm; experiment # 1009 (black-and-white camera, $X_{\mathrm{DDT}} = 0$ mm, $Y_{\mathrm{DDT}} = 10$ mm, and $T_{\mathrm{DDT}} = 0.39$ ms)

Figure 7 Video frames of DDT and detonation propagation in a mixture of $C_2H_4 + 3O_2$ at $h_{\rm est} = 140 \pm 2$ mm and ignition by a single spark gap at $h_{\rm spark} = 165$ mm; experiment # 1024 (black-and-white camera, $X_{\rm DDT} = 0$ mm, $Y_{\rm DDT} = 60$ mm, and $T_{\rm DDT} = 0.62$ ms)

Table Captions

Table 1 The DDT probability, location, and time when igniting layers of a $C_2H_4 + 3O_2$ mixture with a single spark gap located at $h_{\rm spark} = 15$ mm

Table 2 The DDT probability, location, and time when igniting layers of a $C_2H_4 + 3O_2$ mixture with a single spark gap located at $h_{\rm spark} = 45$ mm

Table 3 The DDT probability, location, and time when igniting layers of a $C_2H_4 + 3O_2$ mixture with a single spark gap located at $h_{\rm spark} = 75$ mm

Table 4 The DDT probability, location, and time when igniting layers of a $C_2H_4 + 3O_2$ mixture with a single spark gap located at $h_{\rm spark} = 90$ mm

Table 5 The DDT probability, location, and time when igniting a layer of a mixture of $C_2H_4 + 3O_2$ with $h_{\rm est} = 98 \pm 2$ mm by two spark gaps $h_{\rm spark} = h_{\rm spark,1} + h_{\rm spark,2}$

Table 6 The DDT probability, location, and time when igniting a layer of a mixture of $C_2H_4 + 3O_2$ with $h_{\rm est} = 98 \pm 2$ mm by a single spark gap with 15 and 75 mm and two spark gaps with $h_{\rm spark} = h_{\rm spark,1}$ (15 mm) $+ h_{\rm spark,2}$ (75 mm)

Table 7 The DDT probability, location, and time when igniting a layer of a mixture of $C_2H_4 + 3O_2$ with $h_{\rm est} = 118 \pm 2$ mm by a single spark gap with $h_{\rm spark} = 15$ and 75 mm and two spark gaps with $h_{\rm spark} = h_{\rm spark,1}$ (15 mm) $+ h_{\rm spark,2}$ (75 mm)

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