INITIAL STAGE OF THE OPERATION PROCESS IN A ROTATING DETONATION ENGINE

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Abstract: The conditions for the mild initiation of detonation of homogeneous stoichiometric ethylene–oxygen mixtures diluted with nitrogen up to $\sim 40\%$ in a planar semiconfined slot-type combustor with a slot 5.0 ± 0.4 mm wide, simulating the annular combustor of a rotating detonation engine (RDE), are determined experimentally. To ensure mild detonation initiation, the fuel mixture in the RDE combustor must be ignited upon reaching a certain limit (minimal) fill with the mixture. Thus, for mild detonation initiation in a $\mathrm{C_2H_4 + 3\,O_2}$ mixture filling the slot, the height of the mixture layer must exceed the slot width by about 10 times ($\sim$ 50 mm) and for the $\mathrm{C_2H_4 + 3\,(O_2 + 2/5\,N_2)}$ mixture, by approximately 60 times. Compared to the height of the detonation waves continuously rotating in the RDE combustor in the steady-state operation mode, for a mild start of the RDE, the fill of the combustor with the explosive mixture to a height of at least 4 times more is required.

Keywords: rotating detonation engine; engine start-up; deflagration-to-detonation transition; ethylene–oxygen mixture; minimum layer height

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Figure Captions

Figure 1 Schematic of experimental setup

Figure 2 Diagram illustrating the difference between the true height of the combustible mixture layer and its estimated value (the line corresponds to the equality of these values): *1* — $[\mathrm{N_2}] = 0\%$; *2* — 10%; *3* — 17%; *4* — 20%; *5* — 25%; *6* — 29%; *7* — 33%; *8* — 38%; and *9* — $[\mathrm{N_2}] = 40\%$

Figure 3 Pressure records: the onset of detonation in a 70-millimeter layer of the $\mathrm{C_2H_4 + 3\,O_2}$ mixture (*a*) and in a 250-millimeter layer of the $\mathrm{C_2H_4 + 3\,(O_2 + 2/5\,N_2)}$ mixture (*b*)

Figure 4 Reaction front velocity vs. distance near the bottom of the slot combustor ($Y = 10$ mm): the onset of detonation in the 70-millimeter layer of the $\mathrm{C_2H_4 + 3\,O_2}$ mixture (*1*) and in the 250-millimeter layer of the $\mathrm{C_2H_4 + 3\,(O_2 + 2/5\,N_2)}$ mixture (*2*)

Figure 5 The map of deflagration-to-detonation transition (DDT) locations in the slot combustor: *1* — $[\mathrm{N_2}] = 0\%$; *2* — 10%; *3* — 17%; *4* — 20%; *5* — 25%; *6* — 29%; *7* — 33%; and *8* — $[\mathrm{N_2}] = 38\%$

Figure 6 The onset of detonation in the layer of maximum height 50 mm, mixture $\mathrm{C_2H_4 + 3O_2}$, $X_{\mathrm{DDT}} = 640$ mm, $Y_{\mathrm{DDT}} = 7$ mm, $t_{\mathrm{DDT}} = 1.81$ ms: (*a*) $t = 0.12$ ms; (*b*) 1.80; (*c*) 1.83; (*d*) 1.85; and (*e*) $t = 1.90$ ms

Figure 7 The onset of detonation in the layer of maximum height 110 mm, mixture $\mathrm{C_2H_4 + 3(O_2 + 1/4, N_2)}$, $X_{\mathrm{DDT}} = 750$ mm, $Y_{\mathrm{DDT}} = 12$ mm, $t_{\mathrm{DDT}} = 1.52$ ms: (*a*) $t = 0.18$ ms; (*b*) 1.50; (*c*) 1.52; (*d*) 1.55; and (*e*) $t = 1.59$ ms

Figure 8 The onset of detonation in the layer of maximum height 200 mm, mixture $\mathrm{C_2H_4 + 3(O_2 + 1/3\,N_2)}$, $X_{\mathrm{DDT}} = 630$ mm, $Y_{\mathrm{DDT}} = 8$ mm, $t_{\mathrm{DDT}} = 1.21$ ms: (*a*) $t = 0.14$ ms; (*b*) 1.20; (*c*) 1.23; (*d*) 1.26; and (*e*) $t = 1.35$ ms

Figure 9 The onset of detonation in the layer of maximum height 290 mm layer, mixture $\mathrm{C_2H_4 + 3(O_2 + 2/5\,N_2)}$, $X_{\mathrm{DDT}} = 635$ mm, $Y_{\mathrm{DDT}} = 5$ mm, $t_{\mathrm{DDT}} = 1.27$ ms: (*a*) $t = 0.20$ ms; (*b*) 1.25; (*c*) 1.28; (*d*) 1.32; and (*e*) $t = 1.40$ ms

Figure 10 The onset of detonation in the layer of maximum height 390 mm layer, $\mathrm{C_2H_4 + 3(O_2 + 1/2\,N_2)}$, $X_{\mathrm{DDT}} = 665$ mm, $Y_{\mathrm{DDT}} = 162$ mm, $t_{\mathrm{DDT}} = 1.56$ ms: (*a*) $t = 0.20$ ms; (*b*) 1.55; (*c*) 1.57; (*d*) 1.60; and (*e*) $t = 1.64$ ms

Figure 11 The experimental domain of DDT in terms of the height of the layer and nitrogen content in the mixture $(\mathrm{O_2} + \beta\,\mathrm{N_2})$: empty symbols — no DDT; filled symbols — DDT; and dashed curve — approximation of the conditional boundary of the DDT domain

Figure 12 The minimum height of the layer normalized by the size of the detonation cell as a function of nitrogen content in the $\mathrm{C_2H_4 + 3\,(O_2} + \beta\,\mathrm{N_2)}$ mixture

Table Caption

Compositions of the studied combustible mixtures, their Chapman–Jouguet detonation parameters, and the minimum layer height required for DDT

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