DETONABILITY OF AIR MIXTURES OF POLYETHYLENE PYROLYSIS PRODUCTS

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Abstract: Based on the measured values of deflagration-to-detonation transition run-up distance and time, the detonability of air mixtures of polyethylene (PE) pyrolysis products (pyrogas) of different composition is determined in the standard pulsed detonation tube. The pyrogas was obtained in a reactor at decomposition temperatures of 650–850 °C. Chromatographic analysis of the pyrogas showed that at high decomposition temperature (850 °C), it mainly consists of hydrogen, methane, ethylene, and ethane and has a molecular weight of 5–10 kg/kmol and at low decomposition temperature (650 °C), it mainly consists of methane, hydrogen, ethylene, ethane, propane, and higher hydrocarbons and has a molecular weight of 24–27 kg/kmol. It has been shown that in the fuel–air mixtures with the equivalence ratio ranging from 0.6 to 1.6 at normal pressure, the pyrogas of PE possesses the detonability close to that of homogeneous air mixtures of ethylene and propylene. On the one hand, this indicates a high explosion hazard of PE pyrogas which can be formed, for example, in industrial and domestic fires. On the other hand, PE pyrogas can be considered as a promising fuel for solid-fuel detonation ramjets.

Keywords: detonability; standard pulsed detonation tube; granulated polyethylene; thermal pyrolysis of polyethylene; pyrogas, fuel–air mixture; deflagration-to-detonation transition; detonation ramjet

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Figure Captions

Figure 1 Schematic of the standard pulsed detonation tube with measuring segments: 0 — cross section of distance count; * — ignition site; and 1–18 — positions of ionization probes and/or pressure transducers. Dimensions are in millimeters

Figure 2 Schematic of the gas generator with pyrogas sampler (*a*), with simultaneous pyrogas and liquid fraction sampling (*b*), and photograph of samplers (*c*)

Figure 3 Examples of records of pyrogas temperature (*a*) and pressure (*b*) (the mass of granular polyethylene is 1 g) in a closed reactor at the decomposition temperature 850 °C (upper row); also, the rates of change of temperature and pressure are shown (lower row)

Figure 4 Examples of records of pyrogas temperature (mass of granulated polyethylene 15 g) in an open reactor at decomposition temperatures 650 (*a*) and 750 °C (*b*): *1* — oven temperature; and *2* — temperature at reactor bottom. Vertical lines correspond to the time interval of pyrogas sampling for chromatography

Figure 5 Examples of records of pyrogas temperature (*a*) and pressure (*b*) and the calculated time history of the shot-mean mass flow rate of pyrogas (*c*) in the experiment on the standard pulsed detonation tube with $T_p = 765$ °C and $m_0 = 10$ g

Figure 6 Measured velocities of shock waves (closed circles) and flame fronts (open circles) in each shot of the standard pulsed detonation tube in the experiment of Fig. 5 ($T_p = 765$ °C and $m_0 = 10$ g). The horizontal dashed line corresponds to the typical value of the Chapman–Jouguet detonation velocity $\overline{D}_{\mathrm{CJ}}$ in stoichiometric mixtures of hydrocarbon fuels with air

Figure 7 Measured dependences of the shock wave (closed symbols) and flame front (open symbols) velocities on the distance from the ignition source in each shot of the standard pulsed detonation tube in the experiment of Fig. 5 ($T_p = 765$ °C and $m_0 = 10$ g); the horizontal dashed line corresponds to the typical value of the Chapman–Jouguet detonation velocity $\overline{D}_{\mathrm{CJ}}$ in stoichiometric mixtures of hydrocarbon fuels with air: *1* — shot 2; *2* — 3; *3* — 4; *4* — 5; *5* — 7; *6* — 8; *7* — 9; *8* — 10; *9* — 11; and *10* — shot 13

Figure 8 Measured values of DDT run-up time in detonation shots of the standard pulsed detonation tube in the experiment of Fig. 5 (($T_p = 765$ °C and $m_0 = 10$ g)

Figure 9 Measured dependences of the mean velocities of shock waves (closed circles) and flame fronts (open circles) in the measuring section of the standard pulsed detonation tube on the fuel-to-air equivalence ratio of the pyrogas–air mixture. The solid curve corresponds to the thermodynamic detonation velocity D_{CJ} in a homogeneous ethylene–air mixture

Figure 10 The dependence of the DDT run-up time on the fuel-to-air equivalence ratio for the gaseous mixtures of the polyethylene pyrolysis products with air: solid and dashed curves correspond to DDT run-up time in the homogeneous ethylene–air and propylene–air mixtures, respectively [7]

Table Captions

Table 1 Measurement errors of gas generator characteristics

Table 2 Characteristics of gas generator at pyrolysis of granular polyethylene (1 g) in a closed reactor

Table 3 Composition of pyrogas (%(vol.)) at polyethylene pyrolysis in a closed reactor with $T_p = 650$ and 850 °C and $m_0 = 1$ g

Table 4 Characteristics of gas generator at pyrolysis of polyethylene sample with $m_0 = 15$ g in an open reactor

Table 5 Composition of pyrogas (%(vol.)) at pyrolysis of polyethylene in an open reactor ($m_0 = 15$ g)

Table 6 Operation cyclogram of the standard pulsed detonation tube

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