IGNITION OF METHANE IN ELECTRIC FIELD

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Abstract: The criteria of autoignition of air mixtures of combustible gases are among their most important characteristics that determine the optimal conditions and safety of their practical use. An important task is to control the processes of ignition and combustion of gas mixtures. However, various types of low-power gas discharges widely used for their ignition do not expand the concentration limits of flame propagation. One of the interesting ways to influence the ignition of gases is to use an electric field. The effect of relatively weak electric fields on the ignition of stoichiometric methane–air mixtures, which do not lead to a breakdown in the gas, is experimentally investigated. For the first time, the possibility of a significant decrease in the ignition temperature of gas in an electrostatic field in the absence of its breakdown and plasma formation is shown. The kinetic interpretation of this phenomenon is presented. Such an effect ensures a minimal external energy for ignition, which is insignificant compared to the chemical energy released during combustion, and opens up the practical possibility of rational control of gas combustion and oxidative conversion processes.

Keywords: ignition; autoignition temperature; electric field; methane–air mixtures

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Figure Captions

Figure 1 Reactor diagram: *1* — stainless steel bomb; *2* — electric heater; *3* — thermal insulation; *4* — bypass valve; *5* — high pressure mixer; *6* — video camera; *7* — quartz window; *8* — spherical electrode; *9* — pressure sensor; *10* — registration system; *11* — millivoltmeter for thermocouple; and *12* — high voltage unit

Figure 2 Time history of pressure during mixture ignition (*1*) and a reference signal modulated by a 50-hertz frequency indicating a moment of high voltage supply to the electrode (*2*)

Figure 3 Temperature dependence of the autoignition delay of stoichiometric methane–air mixtures at a pressure of 1 atm and an electrode voltage of $U = 12$ kV: *1* — results of [10]; and *2* — results of the present work

Figure 4 High-speed video recording of the ignition of a stoichiometric methane–air mixture at $T = 540$ °C and $U = 12$ kV. The shooting frequency is 5000 fps

Figure 5 Time history of the radius of the combustion zone (*1*) and the apparent flame propagation velocity (*2*) based on the results of high-speed video shooting at a frequency of 5000 frames/s, $T = 540$ °C, and $U = 12$ kV

Figure 6 Dependence of the apparent flame velocity on the distance along the reactor radius based on the results of high-speed video recording with a frequency of 5000 frames/s at $T = 540$ °C and $U = 12$ kV

Figure 7 Calculated time histories of temperature (*1*) and concentrations of $H^\bullet$ (*2*), $CH_3^\bullet$ (*3*), and CH_3OOH (*4*) (X_i) during autoignition of a stoichiometric methane–air mixture at $T_0 = 685$ K and $\Psi_0 = 5 \cdot 10^{14}$ molec./(cm^{3}s)

Figure 8 Dependence of the autoignition temperature at an autoignition delay of $\tau \approx 20$ s (*a*) and the autoignition delay time (*b*) on the rate of generation of active centers Ψ_0 for a stoichiometric methane–air mixture

Figure 9 Dependence of the maximum concentration of methylhydroperoxide CH_3OOH on the initial temperature of the methane–air mixture at $\tau \approx 20$ s

Table Caption

The required for autoignition of a stoichiometric methane–air mixture at ignition delay time of ~ 20 s maximal concentration of CH_3OOH ($[CH_3OOH]_{max}$) and its concentration at the moment of ignition at various temperatures as well as required for this the rate of radical generation Ψ_0

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