Shock tube study of plasma-assisted dimethyl ether ignition at temperatures near self-ignition threshold

Kosarev I.N., Kindysheva S.V., Grigorenko V.D., Belov S.O., Starikovskiy A.Yu.*, Aleksandrov N.L.

Moscow Institute of Physics and Technology, Dolgoprudny, Russia
*Princeton University, Princeton, USA

With growing concerns on environmental pollution and oil supplies, the global community is seeking non-petroleum based alternative fuels. Dimethyl ether (CH_3OCH_3 or DME) has remarkable self-ignition characteristics and is considered a promising alternative fuel. The purpose of this work is, using a shock tube with a discharge cell, to study DME ignition intensified by non-equilibrium discharge plasma for a wide range of gas temperatures including the values near self-ignition threshold.

Ignition delay time was measured behind a reflected shock wave after a high-voltage nanosecond discharge and in its absence. We studied stoichiometric DME:O_2 mixtures diluted with inert gases (Ar and He) for gas temperatures in the range 1000 – 1800 K and gas pressures in the range 0.3 – 1 atm. The experimental setup and methods used in this study are essentially the same as the ones used in our previous work [1]. Ignition delay time was measured using CH emission at 431 nm. Initiation of the discharge led to an order of magnitude decrease in the ignition time and to a decrease in the gas temperatures at which the same values of ignition time were observed. A numerical simulation of the processes in the discharge phase and the ignition phase were made to reveal the mechanisms of the plasma effect on DME ignition under the conditions studied. The densities of atoms, radicals, excited particles and charged particles produced in the discharge plasma were calculated and used as input parameters for ignition modeling.

Agreement was obtained between the calculated and measured self-ignition delay times in the mixtures under consideration. We reached reasonable agreement between measurements and calculations for plasma-assisted ignition only when considering plasma non-uniformity and the uncertainty in the cross section of electron-impact ionization of DME molecules, the process that is important during the discharge phase. These effects are more profound for gas temperatures near the self-ignition threshold. It was experimentally shown that the ignition delay time depends strongly on gas temperature for high temperatures and is independent of temperature near 1000 K. This seems to be associated with the so-called negative temperature coefficient behavior when an increase in temperature results in a decrease in reactivity. This behavior was previously observed for DME self-ignition at gas temperatures lower than 1000 K.

This work was supported by the Russian Science Foundation (project No 17-12-01051).

[1] I.N. Kosarev, S.V. Kidysheva, R.M. Momot, E.A. Plastinin, N.L. Aleksandrov, A.Yu. Starikovskiy. Combustion and Flame. **165** (2016) 259.