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Experimental and Numerical Study of Ethylene-air Flame Propagation in Closed Cylindrical Vessels

Codina Movileanu, Venera Giurcan, Vasile Gosa¸ Domnina Razus
Ilie Murgulescu Institute of Physical Chemistry, 202 Spl. Independentei, Bucharest, Romania
cmovileanu@icf.ro; venerab@icf.ro; vgosa@icf.ro; drazus@icf.ro

Extended Abstract

Explosions of gaseous mixtures in closed vessels are characterized by important damaging effects. The knowledge of characteristic parameters of confined explosions affords the assessment of explosion risks for flammable mixtures in various conditions and the design of equipment and industrial plants where flammable mixtures might be formed. Among important flammability parameters, the burning velocity is relevant for understanding the chemical reactivity of fuel-air mixtures and for modelling the flame propagation in various conditions, especially in vented explosions.

In the present work, explosions of gaseous ethylene-air mixtures with various concentrations between 4.0 – 12.0 vol.% and initial pressures between 20 – 150 kPa have been experimentally investigated at ambient initial temperature, using several elongated cylindrical vessels with L/D = 1 – 2.4. The ignition, made by inductive-capacitive electric sparks, took place in the geometrical centre of the vessel. Two fast response pressure transducers and 2 ionization probes, mounted near vessel's top and bottom have been used to monitor the flame propagation.

A common feature of *p(t)* records from explosions in cylindrical vessels is the appearance of a short period of rapid pressure increase, at the beginning of flame propagation. As Xiao et al. showed, optical measurements reveal that the flame propagates undisturbed in this stage, keeping its spherical symmetry both in central and side ignitions. After this period, the flame front is stretched in axial direction and it is slowed down, as a consequence of decrease in its surface, at the contact between flame and vessel's walls and of flow direction inversion.

Examination of *p(t)* only in the first stage of undisturbed flame propagation affords the evaluation of the laminar burning velocities characteristic for the initial moment of combustion, $\boldsymbol{S_u}$ (p_0, C_0), using a recent correlation developed by Razus et al., based on the cubic law of pressure rise during the early stage of explosions in closed vessels ($\Delta p = k \cdot t^3$). For all examined cases, the cubic law constants have been evaluated by a non-linear regression analysis on *p(t)* data restricted to $\Delta p \leq p_0$. However, at the increase of L/D ratio the pressure rises at a faster rate so that ***m***, the exponent of the power law $\Delta p = k \cdot t^m$ has higher values ($3.2 < m < 4.5$). A fair agreement between our results and laminar burning velocities from literature was obtained from measurements in low L/D vessels.

The burning velocities of ethylene–air mixtures derived from experimental data have been examined against computed values, obtained by a detailed numerical modelling of flame propagation. The modelling of free laminar premixed flames has been made with the package INSFLA using an extended reaction mechanism with 592 elementary reactions and 53 species. Both experimental and computed burning velocities have been examined as functions on the initial pressure and the initial concentration of flammable mixtures.

References

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