Work-in-Progress-Poster Abstract ICDERS 2019

Ignition by electrical discharges – Interaction of the hot gas kernel with self-generated vortices

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Electrical discharges in combustible atmospheres represent a safety relevant risk in several industries. The determination of minimum energies using capacitive sparks is a classical method to examine ignition hazards of combustibles. The minimum ignition energy (MIE) depends on the characteristics of the ignition source i.e. electrode types, spark gap and the characteristics of the electrical source. The MIE of a given combustible is not characterized by a single threshold value but is rather of a statistical nature. After the end of the energy coupling by the electric spark with a duration of 50 ns, the transition into a self-sustained combustion is hindered by various factors as the ignition process is a combination of physical and chemical effects comprising flow effects. In this work, numerical results are assessed to identify and quantify the processes influencing the ignition and early flame propagation, especially two-dimensional flow effects of hydrogen/air and methane/air mixtures at energy levels close to the MIE. An in-house tool for two-dimensional unsteady flames was employed which includes detailed transport and chemical kinetics models. The results are compared to Schlieren images from experiments.

Our investigations reveal that the hot gas kernel produced by the electrical discharge interacts with vortices produced by the expansion of the gas kernel and the shedding shock wave. Therefore, the temperature and hence the ignition process are significantly influenced by enhanced mixing and cooling. The results of this work help understanding of processes relevant to the ignition by electrical discharges near the MIE.