NUMERICAL TOOLS FOR MODELLING EXPLOSIONS OF FUEL VAPORS IN MILITARY AIRCRAFT TANKS

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The present work describes three approaches developed at the PRISME laboratory to study the explosion phenomenon in the ullage of aircraft fuel tanks impacted by ammunition. In this respect, three numerical tools are employed, depending on which phenomena the modelling efforts are focused.

The MIRAGE code employs a detailed kinetic scheme for the oxidation of a kerosene surrogate. It is particularly well suited for the modelling of the ignition phenomenon. It provides relevant values for the Minimum Ignition Energies (MIE), but also successfully predicts the pressure evolution in a single volume. A good agreement is found with experimental data for the maximum pressure and the severity of explosion. Correlations are provided for these parameters over a wide range of conditions.

The second model is developed for Comsol, a multi-physics finite element solver. It employs a single step chemical reaction, but represents both the ignition and the flame propagation steps in a two dimensional geometry made of several compartments. The results are in good agreement with the MIE data obtained with the MIRAGE code for stoichiometric mixtures. The results also highlight the dynamics of combustion is strongly influenced by the ignition location, the flight conditions - temperature and pressure-, and the tank geometry. The approach neglects the flame-turbulence interactions, but it is worth noticing it successfully describes the phenomenology of the different stages of explosion and the effects of several parameters.

The third approach does not describe the chemistry nor the ignition step. The modelling effort is rather focused on the dynamics of pressure rise once the combustion has started. In this respect, the Fluent CFD code is employed to compute the two dimensional propagation of a turbulent premixed flame through tanks made of several compartments. Quantitative predictions are expected and the explosion severities agree well with experimental data in simple geometries. Parametric studies quantify the influence of the tank geometry on the mechanical effects of explosion.

In conclusion, three models were developed to study several aspects of explosions in military aircraft tanks, providing valuable data for safety or vulnerability issues.