EXPERIMENTALLY DETERMINED FLAME PROPERTIES NEAR FLAMMABILITY LIMITS UNDER GRAVITY AND MICROGRAVITY CONDITIONS

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Flammability limits identified in a vertical tube depend on direction of flame propagation. Usually such limits are determined during flame propagation from the open to the closed end of the tube. Differences between flammability limits for upward-and downward-propagating flames depend on the Lewis number of considered mixtures. For the Lewis number, defined as the thermal diffusivity of the mixture to the mass diffusivity of the deficient reactant, which is less than 1 (Le=a/D<1), flammability limits, in a gravity field, are always different for flames propagating up or down the tube. Ethylene propane and other higher hydrocarbons are characterized by Le < 1 for rich mixtures. Thus flammability limits for flame propagating in rich propane/air mixture is 6.3% C_3H_8 for downward propagation and 9.2% C_3H_8 for upward propagation [1]. The concentration gap between two limits is extremely large. The flammability limits under microgtravity conditions were found to be between the upward and downward limits obtained in a standard flammability tube under normal gravity conditions [1-4]. It was also found that there are two limits under microgravity conditions: at concentration 8.75% C_3H_8 when indicated by visible flame propagation and 9.0% C_3H_8 when indicated be an increase of pressure without observed flame propagation [1]. These limits were found to be far behind the limit for downward-propagating flame at 1g (6.3% C_3H_8) and close to the limit for upward-propagating flame at 1g (9.2% C_3H_8).

It was decided in the present work to study in detail flame behavior near flammability limit under gravity and microgravity conditions. To do this effectively a special schlieren system was designed for a drop tower and instant temperature measuring system was installed to observe temperature history during propagation of the flame front.

The falling assembly in a form of steel framework of size 800mm × 800mm × 1000mm was used for microgravity experiments. It contained a compact schlieren system, high speed video camera, instant temperature and pressure measuring systems and spark ignition system with large spark gap. A shortened standard flammability open tube and small (about 0.5 liter) cubic closed vessel with schlieren quality glass windows were used to study limit flames under gravity and microgravity conditions.

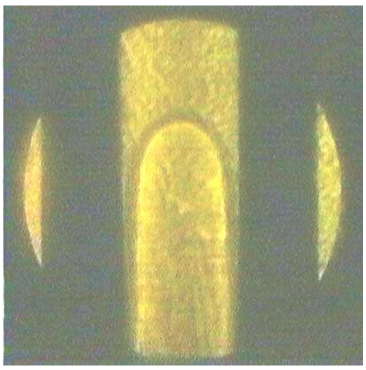

Fig. 1. Schlieren image of flame propagating upward in a vertical tube of 9.1% propane/air mixture

The schlieren system applied to flammability study and microgravity experiments appeared to be extremely useful in flame diagnostics. Such flames are very differentiated in their inner structure especially during their development in time. Some parts of them are not visible for strait photography and other emit very bright light with following to it production of soot. An example of schlieren picture of very thick flame propagating upward in a vertical tube in rich propane/air mixture is shown in Fig. 1. A schlieren picture of similar flame propagating in a closed vessel is shown in Fig. 2 while pressure and local temperature development history related to this experiment is shown in Fig. 3.

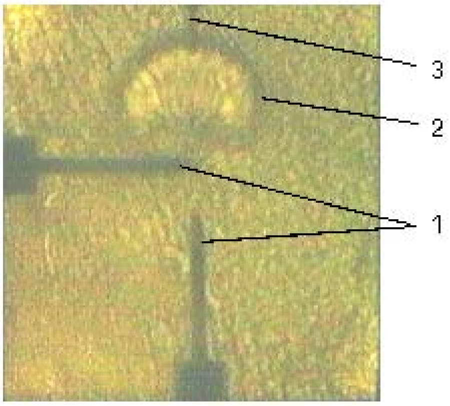

Fig. 2. Schlieren image of flame propagating in a closed cubic vessel of 9.1% propane/air mixture. (1-Electrodes, 2-Flame front, 3-Temperature probe). Frame made at time 120ms after ignition, indicated in Fig. 3

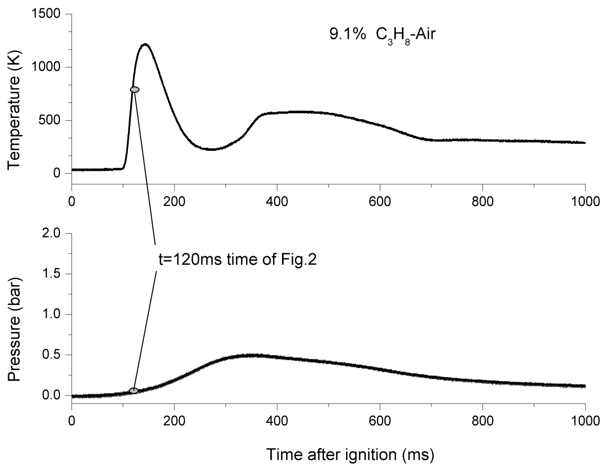

Fig. 3. Pressure and local temperature development history related to experiment indicated in Fig. 2.

Flame development in rich limit mixtures under microgravity conditions, before not visible for strait photography, was identified with the use of schlieren method. In the paper the mechanism of flame propagation under gravity and microgravity conditions is systematically studied and compared.

Acknowledgements

The work reported here was sponsored by the Marie Curie ToK project from the 6th FP contract No MTKD-CT-2004-509847 and by the State Committee for Scientific Research (KBN).

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