Influence of the Chamber Volume on the Rich Explosion Limit for Hexane-Air Mixtures

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Introduction

The purpose of the research was to obtain fundamental hexane vapor-air and hexane droplets-air explosibility parameters by measuring the explosion pressure variation in closed chambers of four different volumes. The influence of hexane vapor initial temperature and droplets diameter on the explosion process was also investigated.

Evaluation of rich explosion limit for vapor-air mixtures

Research stands

The experiments were carried out by means of two research stands of 5.6 dm^3 and 40 dm^3 volume. The walls of the chambers were heated by means of two electrically powered flat bands located on the external surface of the chamber. The research was carried out for two temperatures of the mixture: 363K and 393K. The pressure course inside the explosion chamber was measured by means of Kistler piezo-electric transducer. Ignition electrodes were placed in the chamber axis in the middle of its height. The ignition source was a single electrical spark discharge of 5J energy or chemical igniter of 2kJ energy. The chemical igniter explosion caused pressure increase inside the chamber equal to 0.4 bar. The above pressure increase is not included into the value of the overpressure shown in the graphs. The ignition was performed in the established temperature conditions. The applied data acquisition system enabled continuous checking of the obtained measurement results.

It was found that chemical ignition significantly increase explosion dynamics and rich explosion limit in comparison to the electric spark ignition. It was stated, that the rich explosion limit of hexane vapor-air mixture, determine in 5.6 dm^3 chamber in the temperature of 363 K, for 5 J electric spark ignition is equal to circa 0.275 [kg_{hexane}/kg_{air}]. Using the chemical igniter of 2 kJ energy causes a considerable increase of the rich explosion limit to the value of circa 0.5 [kg_{hexane}/kg_{air}]. The exemplary obtained results are shown in Fig. 1. The increase of the mixture initial temperature up to the value 393 K does not cause any other increase of the rich explosion limit, but increases the explosion dynamics. In the conditions of the carried out research, the maximum explosion pressure did not depends from the ignition energy and was of circa 0.55 MPa in smaller chamber and of circa 0.65 MPa in the bigger one. The maximum rate of pressure rise, however, depends significantly from the ignition energy and is of circa 28.5 [MPa/s] for the electric spark ignition and equals circa 51 [MPa] for the ignition from a chemical igniter. Using the chamber of bigger volume makes it possible to decrease the influence of the pressure increase resulting from the applied ignition source. It is of a special significance in case of using a chemical igniter.

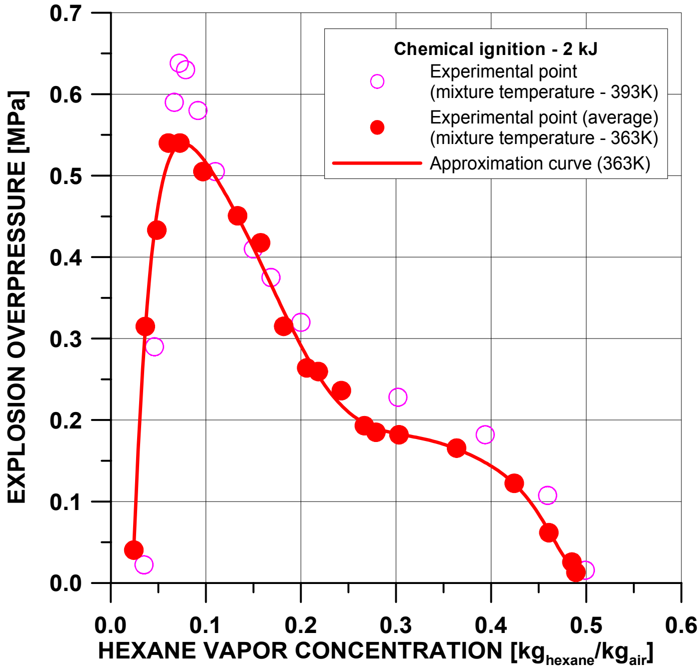

Fig. 1. The values of explosion overpressure as a function of hexane vapor concentration in air at the initial mixture temperature of 363 K and 393 K for ignition from chemical igniter of 2 kJ energy 5.6 dm^3 chamber.

Evaluation of rich explosion limit for vapor-air mixtures

The research was aimed at determination of the rich explosion limit of hexane droplets-air mixtures for selected droplets diameters. For this purpose special injectors were constructed enabling formation of sprays of three different droplet diameters: 0.25 mm, 0.5 mm and 0.7 mm. Besides, there was possibility to change droplets density in the stream. It was especially difficult to work out the hexane dispersing system for the chamber of 1.25 m^3 volume (Fig. 2). The experiments were carried out by means the three explosion chambers of different volume i.e. 40 dm^3, 150 dm^3 and 1.25 m^3. In every case at the top of explosion chamber a fuel dispersing head was located. The ignition was performed using a chemical igniter of 2 kJ energy, located at a distance of 15-20 cm from the output of dispersing head.
The research was carried out at ambient temperature. The pressure course inside the explosion chamber was measured by means of piezo-electric transducer. The applied data acquisition system enabled continuous checking of the obtained measurement results. The exemplary obtained results are shown in Fig. 3. The investigation showed, that in small chamber (5.6 dm^3), the ignition energy value and the kind of ignition source considerably influenced the obtained results. Acting of hexane droplets on the chemical igniter can strongly disturb conditions of the investigated process and, consequently, influence the values of the measured parameters. But in large chambers, a prolonged time of dispersion of very volatile hexane and accumulation of significant amount of liquid hexane at the bottom of the explosion chamber increases the amount of evaporated hexane at the moment of ignition, which intensifies the explosion dynamics and disturbs dependences resulted from the cubic low. An attention should be also paid so that the volume not filled in with the spray should constitute possibly the least fraction of the total explosion chamber volume, because the droplets free space in the chamber also influences significantly the obtained results. It was found, that independently of the chamber volume, the rich explosion limit increases along with the increase of the hexane droplets diameter. While comparing results obtained in chambers of different volumes, an

Fig.2. The view of the dispersing heads configuration inside the explosion chamber of 1,25m^3 volume.

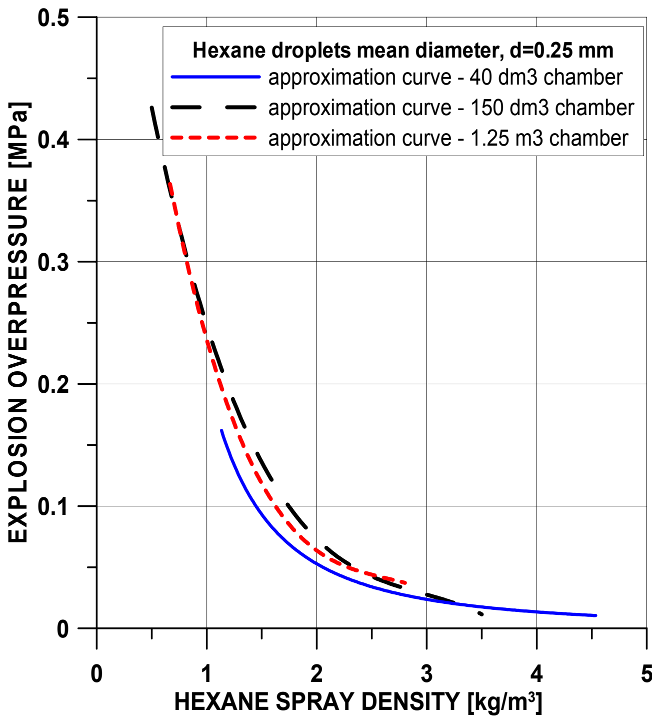

Fig.3. Comparison of the explosion overpressure versus hexane spray density ($d_{droplets}$ =0.25 mm) for three different chambers volume.

effort should be made so that the chambers should have a similar geometry. It specially concerns the ratio of chamber heights to its diameter. The best solution is, if the ratio is close to one.

Summary

The carried out investigations enabled determination of explosibility limits of hexane vapor and hexane droplets-air mixtures for the assumed research conditions.
Evaluation of rich explosion limit for hexane-air sprays of different mean droplets diameters was conducted in a 40 dm^3, 150 dm^3 and finally in the 1250 dm^3 vessels. It was found that the rich explosion limit for hexane droplets – air mixture is in the range of 1.8÷5.5 kg/m^3, however, most of the data obtained in the larger chambers are in the range of 2÷2.7 kg/m^3. The highest influence on the rich explosion limit obviously depends on droplet size and it is rising with increasing diameter of droplets. Generally, rich explosion limit for hexane droplets – air mixture is about 30 to 40 times higher than the stoichiometric concentration and 3 to 9 times higher than the one for hexane vapors – air mixtures. This is evidently because only a part of droplets takes part in combustion at reach limit. It should be also stated, that some difficult to estimate part of droplets evaporates during dispersion of fuel, so at the moment of ignition flame is propagating in the vapors – droplets – air mixture.
Since the evaluations were curried out in three chambers of sizes ranging from 40 dm^3 to 1250 dm^3, the effect on vessel size was estimated. For hexane vapor – air mixture most significant effect on rich explosion limit is from igniting energy, however, influence of vessel size on this limit (for the chamber volume ranging from 5.6 dm^3 to 40 dm^3) is not distinguishable. For hexane spray – air mixture very clear effect is visible of droplets diameter as well as chamber size on rich explosion limit. It was found that rich explosion limit is increasing along with increase of the droplets mean diameter as well as the chamber size.

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