# DETONATIONS OF HEXANE VAPOR/DROPLETS-AIR MIXTURES

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Summary Detonation characteristics of hexane droplets/vapor-air mixtures were determined on the basis of experiments in a vertical 13-m long detonation tube. Hexane droplets were injected at the top of the test section with generators containing different numbers of needles of 0.5-, 0.8- and 1.2-mm in internal diameter. The droplets moved down and – when first of them reached the bottom of the test section – a initiating shock wave (generated by detonation of oxygen-hydrogen-helium mixture) entered the tube.

## INTRODUCTION

For a better understanding of the nature of fuel-air explosions and detonations it is important to evaluate basic explosive and detonation parameters of such mixtures. There are a lot of data available on gaseous detonations but spray detonations have not been explored so thoroughly, especially when it comes to sprays with big droplets (> 1 mm).
The purpose of the present research is to obtain fundamental hexane droplets/vapor–air detonation characteristics in a vertical 13-m long detonation tube (0.13 m in internal diameter). The main objectives of the initial part of the experiments included design of the droplet generator and determination of time-space characteristics of droplet motion in air. At the beginning we carried out a theoretical analysis of breakup of a liquid jet and free motion of a droplet in air. Results of the analysis were applied to design the first model of the droplet generator. Next the theoretical predictions were verified experimentally and the average hexane droplet and suspension parameters (diameters, concentrations) were determined. During the second stage of the detonation tube experiments we performed following tasks:

- characterization of the droplets produced by droplet generator with needles of 0.5, 0.8, and 1.2 mm in internal diameter,
- determination of the of the shock velocity and pressure of the initiating pulse in air (i.e. without hexane injection) and in suspension of water droplets,
- determination of shock wave and flame velocities for different droplet diameters and hexane concentrations,
- determination of pressure histories for different droplet diameters and hexane concentrations and at different distance from the initiation section,
- determination of the detonation characteristics of the hexane droplets/vapor – air mixtures produced with generators containing 0.5-, 0.8-, and 1.2-mm needles,
- estimation of the detonation limits of hexane droplets/vapor – air mixtures at three average droplet sizes and one intensity of the initiating shock wave.

## EXPERIMENTAL

A scheme of the test stand is shown in Fig. 1. The detonation tube was equipped with twelve membrane pressure switches (M0÷M11) for shock wave velocity measurement, six photodiodes (D1÷D6) for monitoring flame propagation and three piezoquartz transducers (P1÷P3) for pressure measurement.
Pressure profiles in the detonation tube at three different distances from the booster were recorded by means of a 4-channel oscilloscope. The oscilloscope was connected with quartz pressure transducers through a 4-channel signal conditioner with selectable gain. To record signals generated by six photodiodes and twelve pressure switches (Fig. 1), a 24-channel tape recorder was applied.
To generate the initiating pulse, the 1.3- m long initiation section (booster was filled with a mixture containing 2 moles of oxygen, 4 moles of hydrogen and 9 moles of helium. Thin plastic foil separated the booster from the test section. The detonation of the mixture was ignited with electric spark. The detonation parameters were changed by changing the initial pressure in the booster within a range of 0.1÷0.5 MPa, with a step of 0.1 MPa.

## RESULTS

Pressure profiles and shock velocities obtained when hexane was injected through 12, 25 and 70 needles of 0.8 mm in internal diameter showed that the shock wave parameters are nearly the same and they decrease along the test section. This means that in each case hexane concentration was too low to affect the shock front propagation and below the lower explosibility limit. Therefore in consecutive experiments we used generators with 85, 100 and 110 needles. Results of the pressure and velocity measurements are given in Fig 2.

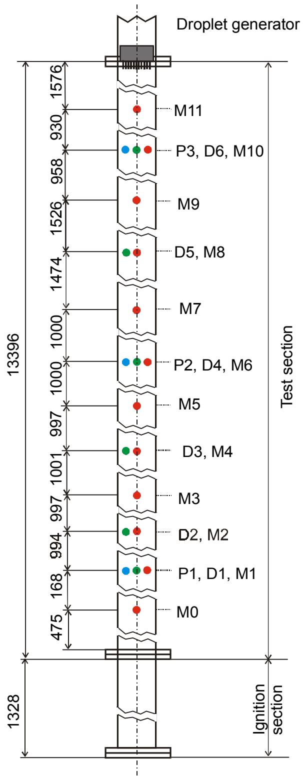


Fig. 1. Experimental setup

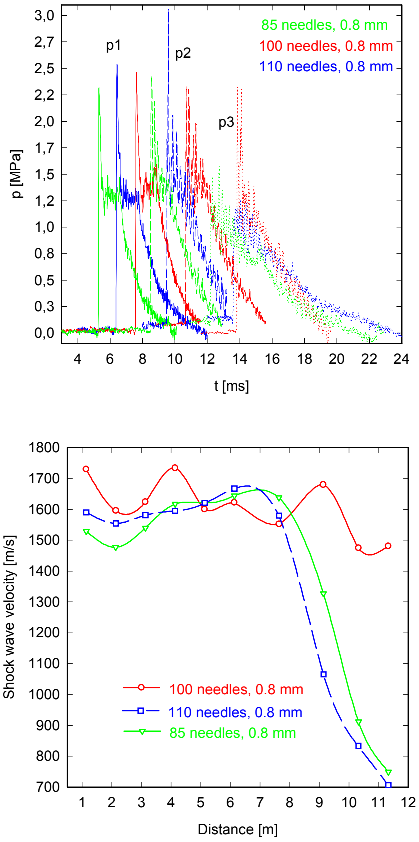


Fig. 2. Pressure profiles and shock wave velocities in hexane spray – air mixtures produced with 85-, 100- and 110-needle generators, pressure in the booster – 0.4 MPa

Identical tests were carried out with generators containing different number of 0.5- and 1.2-mm needles. Their results can be summarized as follows:

1. The droplet generators equipped with 1.2- 0.8- and 0.5-mm needles and working at an inside overpressure of 0.02 MPa produce hexane droplets of ca. 3.2, 1.9 and 1.3 mm in an average diameter, respectively. By changing the number of needles, it is possible to obtain hexane droplets/vapor – air mixtures in the detonation tube within the needed concentration range – up to 1.6 g of hexane per 1 g of air.
2. An initiation of hexane droplets/vapor – air mixtures by a strong shock wave generated by the hydrogen-oxygen-helium mixture at an initial pressure of 0.4 MPa can result in detonation. For the tested droplets the detonation velocity equals to 1600±100 m/s with corresponding peak pressure rise of 2.5÷2.7 MPa. The maximum parameters do not depend on the droplet diameter.
3. The detonative regime is achieved for hexane suspensions produced with the generators containing 28 needles of 1.2 mm in internal diameter for which the estimated concentration of hexane in the detonation tube equals to ca. 0.7 g of hexane per 1 g of air. The optimal hexane concentration equals to ca. 0.9 $g_{hexane}/g_{air}$ (35 needles in the generator). The detonation does not occur when the generator contains 70 needles. Under this conditions the estimated concentration of hexane 3.2-mm droplets/vapor in the tube is ca. 1.6 g of hexane per 1 g of air.
4. For generators containing 0.8-mm needles, the detonative regime was observed for hexane suspension produced with the 85-needle generator. Then the estimated concentration of hexane in the detonation tube equals to ca. 0.9 g of hexane per 1 g of air. The detonation decays when the number of needles in a generator is higher than 120. Under this conditions the estimated concentration of hexane droplet/vapor in the tube is ca. 1.2 g of hexane per 1 g of air. The best conditions for initiation and propagation of detonation were observed when hexane was injected with the 100-needle generator providing hexane droplets/vapor – air mixtures with concentration of ca. 1 g of hexane per 1 g of air
5. In the case of generators with 0.5-mm needles, detonation processes occur when hexane was injected with 150-needle generator. Then the hexane concentration is ca. 0.6 g of hexane per 1 g of air. The hexane droplet/vapor – air mixtures produced with 170-needle generator is not able to detonate under the test conditions. This means that the rich detonation limit for the droplets of 1.3 mm in diameter equals to ca. 0.7 g of hexane per 1 g of air.
6. The upper detonation limit increases with increasing hexane droplet diameters – it equals to: 0.7 $g_{hexane}/1g_{air}$ for 1.3-mm droplets (0.5 mm needles), 1.2 $g_{hexane}/1g_{air}$ for 1.9-mm droplets (0.8 mm needles) and 1.6 $g_{hexane}/1g_{air}$ for 3.2-mm droplets (1.2 mm needles).