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Hydrogen explosions in 20′ ISO container

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ABSTRACT

This paper describes a series of explosion experiments in inhomogeneous hydrogen air clouds in a standard 20′ ISO container. Test parameter variations included nozzle configuration, jet direction, reservoir back pressure, time of ignition after release and degree of obstacles. The paper presents the experimental setup, resulting pressure records and high speed videos. The explosion pressures from the experiments without obstacles were in the range of 0.4–7 kPa. In the experiments with obstacles the gas exploded more violently producing pressures in order of 100 kPa.

Introduction

With increasing interest in hydrogen safety the recent years, a strong effort has been made to learn more about hydrogen dispersion and explosions. Some examples of this work are reported by Shirvill et al. [1], Alcock et al. [2] and Takeno et al. [3]. Computational Fluid Dynamics (CFD) codes calculating dispersion and flame propagation are necessary tools for performing safety studies. Validation and benchmarking of these codes have been reported in Papanikolaou et al. [4], Giannissi et al. [5] and Middha and Hansen [6], among many others.

This article describes the experiments that were performed at the NDEA[1] test facility at Raufoss, Norway, June 2005, as part of an IEA-HIA[2] task 19 project on hydrogen safety. The test series consisted of calibration experiments with C-4 high explosives and 39 gas explosions experiments with inhomogeneous hydrogen air clouds in an ISO container. The results consisted of pressure records and high-speed videos. The first 37 experiments were performed with an empty container, and with both the doors open. In experiments 38 and 39 the container were filled with obstacles, respectively 2 and 8 ordinary euro pallets. The explosion pressures from the experiments without obstacles were relatively low, in the range of 0.4–7 kPa. In the two experiments with obstacles the gas exploded more violently. The objective of this paper is to present a set of experimental data of a meso-scale experimental campaign with inhomogeneous hydrogen-air clouds.

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[1] Norwegian Defence Estates Agency.

[2] International Energy Agency – Hydrogen Implementing Agreement.

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Fig. 1 – Image of the container used in the experiments.

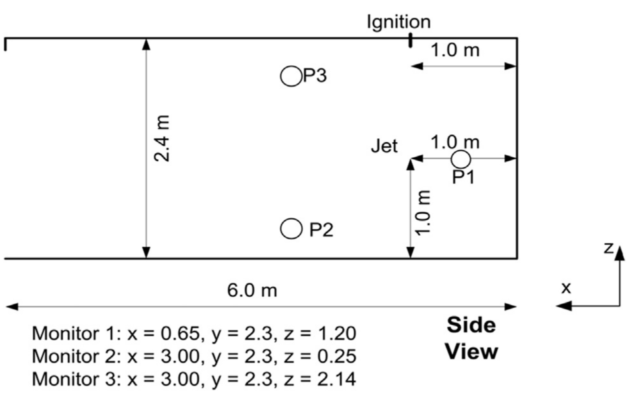

Fig. 2 – Side view of the container with measurements.

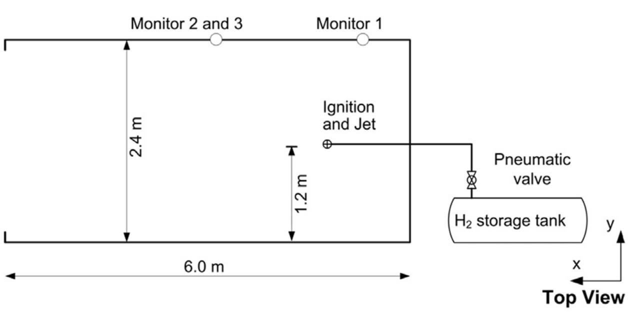

Fig. 3 – Top view of the container and filling system.

Experimental setup

Module geometries

The hydrogen experiments were performed in a standard 20″ ISO container, shown in Fig. 1. The container had inner dimensions L = 6 m, W = 2.4 m and H = 2.4 m, and the steel walls and roof were corrugated. The doors shown on the container left hand side could be fully opened, whereas the end wall was solid (right side).

The container was placed approximately 30 m from a shooting range bunker, where the instruments and high speed

Fig. 4 – Gas storage tank and fuel supply system.

Fig. 5 – Nozzle position in container (left) and 9 mm nozzle close-up (right).

Fig. 6 – Ignition source mounted in the roof of the container.

video cameras were set up. Figs. 2 and 3 show a schematic overview of the container with lengths and pressure monitor placements. Two large web bands were used to tie the container to the ground. The gas filling system was placed behind the closed end wall.

Fuel supply system

The fuel supply system consisted of a 0.3 m^3 storage tank and a steel tube connecting the tank and the container, shown in Fig. 4. The tank was placed behind the closed end wall. A nozzle was mounted at the tube outlet, experiments ranging from nozzle diameter 5, 7 and 9 mm respectively. The nozzle was placed in two different locations, 1.0 m and 3.0 m from the solid back wall at a height of 1.0 m above the container door. Different experiments were performed with the nozzle directed upwards and downwards. The storage tank was filled with hydrogen at different pressures, ranging from 0.6 to 2.4 MPa(g), and the steel container was then filled with hydrogen through the steel tube. The fuel supply was