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Composite Wall Test-Chamber Assessment for Hydrogen Blast Loads

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Abstract

Simplified energy based analytical models are used to evaluate the quasi-static and impulsive over-pressure responses of blast resistance composite wall test-chamber for different hydrogen charges, which is validated with experimental observations during hydrogen combustion tests. Further a detail three-dimensional transient finite element simulation of the test-chamber is presented to compare the test results with the finite element results. The effectiveness of evolved procedures is highlighted for the blast resistance evaluation of experimental facilities besides the other infrastructures that might be subjected to hydrogen blast loads.

Keywords: *hydrogen combustion; blast; deflagration; detonation; composite structures; impulse; transient finite element*

1. Introduction

For the prospective upcoming hydrogen economy; it will be important to carry out the safety assessment with regard to distribution and combustion of hydrogen within equipment and structural enclosures which could result into flame acceleration induced deflagration or detonation blast load under the accidental conditions for nuclear, aerospace, chemical process and transportation sectors. It is desirable to preclude hydrogen explosion with suitable design measures and mitigate or limit the consequences in case of its accidental occurrences with the assessment of the blast induced transient combustion gas impulsive pressure, acceleration time histories and peak displacements of the structural members for vented and confined hydrogen explosions in the above facilities. The evaluation of the limiting impulsive and quasi-static over-pressure capacity is useful for performing blast tests in a safe and reliable manner within suitable blast resistant experimental facilities and more importantly for the evolution of important infrastructures for hydrogen economy program.

A typical blast test-chamber facility (Fig. 1) earlier used for performing the hydrogen combustion experiments at Karlsruhe Institute of Technology (KIT), Germany consists of a composite steel wall structure with three dimensional frame and shell members [Singh et. al. (2003, 2004 & 2005)]. The test-chamber structure of 8650 mm X 5530 mm X 3640 mm size is covered with corrugated steel plate of 0.8 mm thickness bolted on the inside of the stiff frame structure and steel plate closure of 3 mm thickness bolted on its outside to form the outer structural barrier for the chamber enclosure. Rubber sheets are mounted in between the two plates and the frame structure for achieving requisite damping and acoustic characteristics of the test chamber. The composite structure thus formed

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acts as a fire wall to contain and absorb the hydrogen blast wave energies released during the explosion experiments within the test-chamber. For blast resistant structures; it is desirable to dissipate the energy over a wide range of frequencies since the deflagration and detonation induced blast waves have a very broad spectrum of frequencies

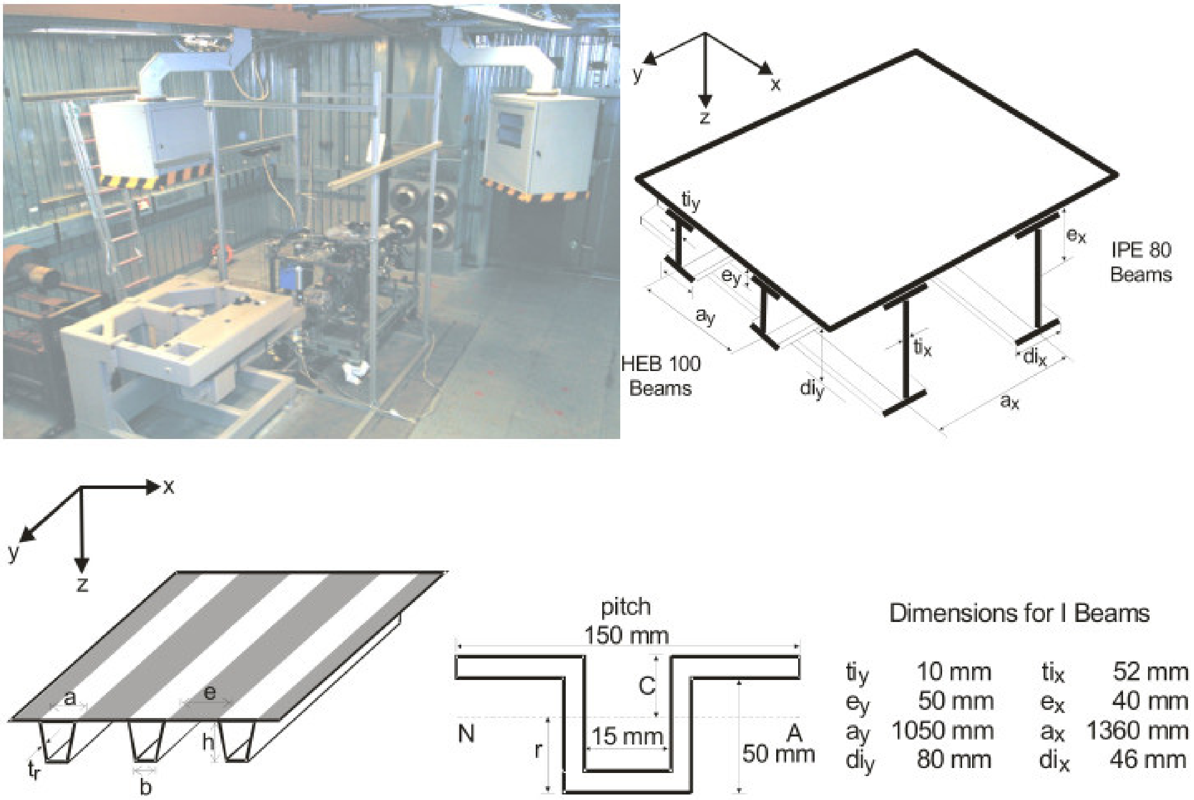

Fig.1: Hydrogen Combustion Test -Chamber and Typical Left Wall Frame Structural Details

with significant uncertainties. In case of confined explosions, the frequencies of excitation due to the released energy depend on the enclosure size, the location and size of the source kernel and the subsequent wave propagation speed depending on the flame acceleration, which decides whether the blast wave is in supersonic or sonic / subsonic regime. The composite wall structure construction helps to spread the structural frequencies over a wide range and thus accounts for the broad spectrum of blast wave frequencies. This is an important feature of the structural barrier design which helps to overcome the limitations posed by the uncertainties with regard to the wide range of hydrogen blast energies as the resultant waves may get focused at the structural wall and excite a local structural vibration mode of the barrier structure that must be analyzed systematically. The objective of this study is to validate the experimental data obtained from controlled hydrogen explosion tests for a series of experiments with 1 gm, 2 gm, 4 gm, 8 gm and 16 gm hydrogen charges ignited within the test-chamber. The feasibility to perform combustion tests for different hydrogen charges is examined with a simplified analytical structural evaluation of the test-chamber, which is followed by the detail transient dynamic characterization of the test-chamber and hydrogen blast wave with the test data collected during the initial blast tests. Finally the test data is validated with the detail transient dynamic finite element evaluation of the composite test-chamber structure to examine the limiting impulsive and quasi-static over-pressurization load that the test-chamber will be able to withstand.

2. Simplified Analytical Computation of Composite Test-Chamber for Hydrogen Blast Experiments

A computer program **COLLAPSE** was developed for estimating the dynamic collapse response of the slabs and plates that are subjected to quasi-static ultimate pressure and impulse due to blast load based on the formulations available in Baker et. al. [1988] and Jones [2003]. Baker model uses the strain energy theorem for the structural