Determination of transient behaviour and spatial impulse distributions of Armox 440T plates subjected to explosions in air

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Abstract. This paper discusses the experimental technique used to extract spatial impulse distributions across Armox 440T plates that were subjected to loading generated from detonating high explosives in close proximity to the plate surface. In this experimental work, Armox 440T plates were subjected to air-blast loads that resulted in plastic deformation of the plates. The transient deformation was measured utilising ultra high-speed stereo imaging and Digital Image Correlation (DIC) to determine the spatial deformation. The impulses were inferred from initial velocity measurements across the mid-line of the plates obtained using DIC.

Introduction

Determination and measurement of experimental data during blast experiments is an extremely challenging undertaking. The shock, thermal energy and light emitted during detonation of explosive are chiefly responsible for these challenges. The most robust and reliable data from tests is the post failure analysis and measurement which will give users the final deformed shape of the plates but adds no information about the path the plates and structures take to get to that deformed shape. Potential information in the transient response of blast loaded plates which can be used to uncover important differences in the structural response of these plates as seen in literature [1,2]. Non-contact measurements such as DIC have become more widely used in recent years leading to an increase in the potential information that can be extracted from a single test [2]. These techniques are particularly suitable for Armox plates; their high yield strength makes elastic effects more significant in their transient behaviour.

We recently showed that it is possible to infer an initial impulse distribution from experimental data obtained using stereo high speed video and DIC [3]. The test data in the tests was correlated to experimental data obtained on the CoBL facility at the University of Sheffield and indicated definitively that the two separate methods gave the same result, however that worked was limited by the speed at which the cameras were able to operate in the blast environment (about 35 000 fps). Newly acquired Shimadzu cameras at the University of Sheffield are now capable of filming at rates up to 5 million fps which allows for the techniques to be extended into new time domains showing in much finer detail the spatial impulse distribution across these plates. This abstract reports on preliminary experimental work using this new system to measure transient deformation response and spatial impulse distribution from the ultra-high speed stereo images.

Experimental design

The experimental arrangement is shown in Figure 1, where 600x600mm Armox 440T plates were fastened in a square clamp frame resulting in an exposed area of 500x500mm. A 38mm diameter, 50g, cylindrical charge of PE4 was placed at a stand-off distance of 100mm. The charge was detonated from the rear at the radial centre using a Euronel 2 detonator. The rear side of each plate was painted with a speckle pattern to enable DIC processing.

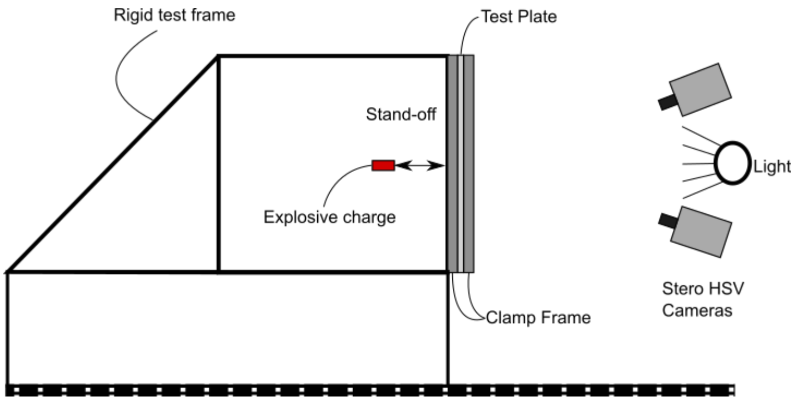

Figure 1: Experimental schematic showing the test plate, frame and camera setup.

Two Shimadzu HPV-X2 cameras were used to film the movement of the panels, with sufficient lighting provided using a Luminys 30k High speed lab light. A key difference in these tests is the use of a stationary clamp frame which is mounted to the ground (c.f. ref [2-3] which used a swinging pendulum system for mounting), but still facilitate determination of the transient response and spatial impulse distribution of the plates. Two different filming speeds were attempted to capture the deformation of the plates (50 kfps and 100 kfps)., significantly extending the experimental capability beyond [2-3]. The images captured were post processed using Dantec Dynamics Istra 4D DIC software.

Results

The test results (an example is shown in Figure 2) show both the initial velocity field and inferred spatial impulse distribution obtained from these tests. As the frame rate of the cameras increased, the resolution improved on the initial impulse distribution. The heat maps show that it is possible to extract both spatial information and point or line information using this technique. The limiting factor of the technique is the view of the camera systems and available light. The transient response of the Armox 440T plates showed an initially linear response; once the material yields, the plate reaches its peak displacement and then oscillates about its permanent displacement. The post-peak oscillation amplitudes are large due to the elastic energy in the plates.

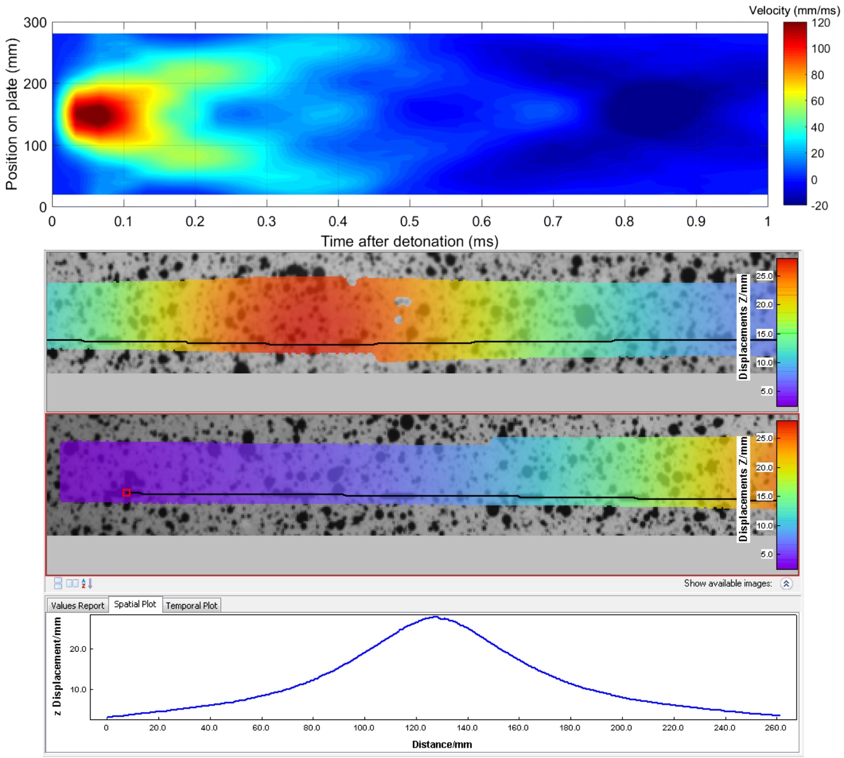

Figure 2: Results of the spatial impulse distribution shown for a strip of the plate.

These results align well with previous work, demonstrating the reliability of the new testing capability for determining the spatial initial velocity, the inferred impulse distribution and transient displacement of flexible plates subjected to air-blast loading when using ultra-high speed stereo imaging techniques.

Conclusion

The newly commissioned ultra high-speed stereo imaging facility at Sheffield was used to reliably determine the spatial initial velocity, the inferred impulse distribution and transient displacement of Armox 440T plates subjected to air-blast loading. As the frame rate of the camera system increase, the resolution of the initial impulse calculation improves. Lighting remains a challenge and further improvements to the lighting and speckle pattern application will increase the versatility of the measurement technique.

References

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