Proceedings Paper:

Curry, R.J., Langdon, G.S., Rigby, S.E. et al. (Submitted: 2021) Improved diagnostics for structural response and impulse transfer in blast experiments. In: 15th International Conference on Advances in Experimental Mechanics. 15th International Conference on Advances in Experimental Mechanics British Society for Strain Management (BSSM).

Improved diagnostics for structural response and impulse transfer in blast experiments

R.J. Curry[1], G.S. Langdon[1,2a], S.E. Rigby[2], S.D. Clarke[2], A. Tyas[2,3]

[1] Department of Civil and Structural Engineering, University of Sheffield, Mappin Street, Sheffield, S1 3JD, UK [2] Blast Impact and Survivability Research Unit (BISRU), Department of Mechanical Engineering, University of Cape Town, Rondebosch 7700, Cape Town, South Africa, [3]Blastech Ltd., The Innovation Centre, 217 Portobello, Sheffield, S1 4DP, UK.

[a]genevieve.langdon@sheffield.ac.uk

Abstract. This paper reports on blast tests performed at BISRU where the transient responses were obtained from digital image correlation and stereo-imaging of the target plate. Specific impulse distributions were inferred from the velocity profiles and compared to directly measured values obtained from scaled tests at the University of Sheffield that employed a Hopkinson pressure bar array. The findings demonstrate the usefulness of improved diagnostics and techniques in blast experiments.

Introduction

Improved diagnostics for measuring structural response and loading characteristics resulting from explosive detonations are critically important. High fidelity experimental data is critical in supporting the efforts of blast engineers and researchers in understanding and predicting blast loading and its effects on structures and materials. There are considerable challenges in measuring and recording data, including the high pressures and temperatures, the short load duration, excessive vibrations introduced into mounts, triggering challenges, electromagnetic interference, and the bright explosive flash. In recent years, improvements in instrumentation and novel experimental approaches have provided renewed impetus to the chase for better experimental measurements from laboratory scale explosion tests [1-3]. This paper reports on parallel tests performed in a single-blind study at the Universities of Cape Town and Sheffield which aimed to measure the structural response and impulse distribution resulting from explosive detonations in air.

Brief experimental description

Experiments were performed at BISRU, by detonating 50g spherical and 3:1 cylindrical PE4 charges at SODs of 44 mm and 145 mm respectively. The blast loading was directed at deformable Domex 355MC steel plates with a circular exposed area (diameter 300 mm) that were mounted via a clamp frame to a pendulum. The global impulse transfer to the plate was estimated from the pendulum swing, while the transient response was obtained from high-speed stereo images of the rear face motion, shown in Fig. 1, following the methods developed by Curry and Langdon [2].

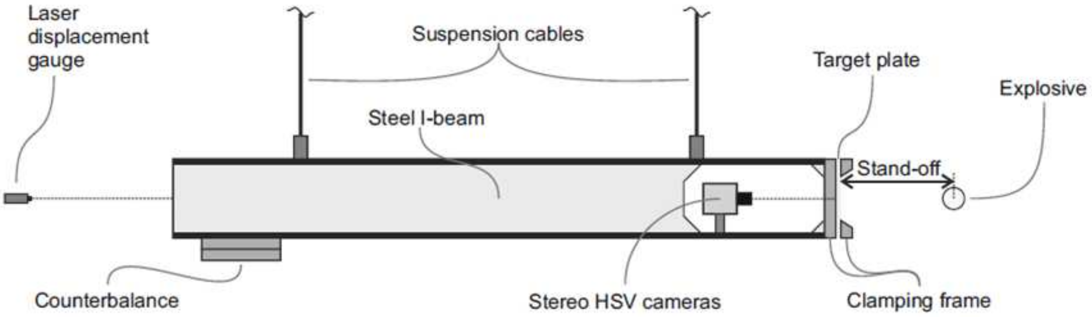

Figure 1: Schematic (side view) of the transient response blast pendulum at BISRU

Results

Digital Image Correlation (DIC) was used to post process the images obtained from the BISRU blast tests. The displacement and velocity profiles across the plates were obtained. The transient mid-point displacement-time histories for the spherical and cylindrical detonations are shown in Fig. 2. The responses all show a sharp increase in displacement up to a peak displacement, followed by an elastic recovery of the plate, as expected. It is evident that the spherical detonations produced repeatable responses in the plates, while the cylindrical detonations show more variation in both peak and permanent deformation.

The initial velocity profiles were used to infer a continuous specific impulse distribution which, after suitable scaling, were compared to the discrete specific impulses measured by the Characterisation of Blast Loading (CoBL) apparatus [1]. The COBL rig comprises a 100 mm thick steel target plate which acted as a nominally rigid boundary. Seventeen EN24 steel Hopkinson pressure bars (each 10 mm diameter, 3.25 m long) were mounted through holes drilled in the target plate and set with their loaded faces flush with the underside. The bars were arranged in the pattern to allow discrete measurements of specific impulse at each bar location. The COBL tests involved detonations of spherical (100g PE4) and 3:1 cylindrical (78g PE4) charges located at stand-off distances from the charge surface (SOD) of 55.4 mm and 168 mm respectively. The inferred (BISRU) and measured (COBL) specific impulse distributions from the spherical tests are shown in Fig.3a, where good agreement is demonstrated. The specific impulses measured using COBL showed by spread for the cylindrical tests, due to surface instabilities in the expanding detonation product cloud [4]. These were significant enough to influence the transient displacement profile of the BISRU blast loaded plates, resulting in similar differences in impulse distribution (Fig.3b).

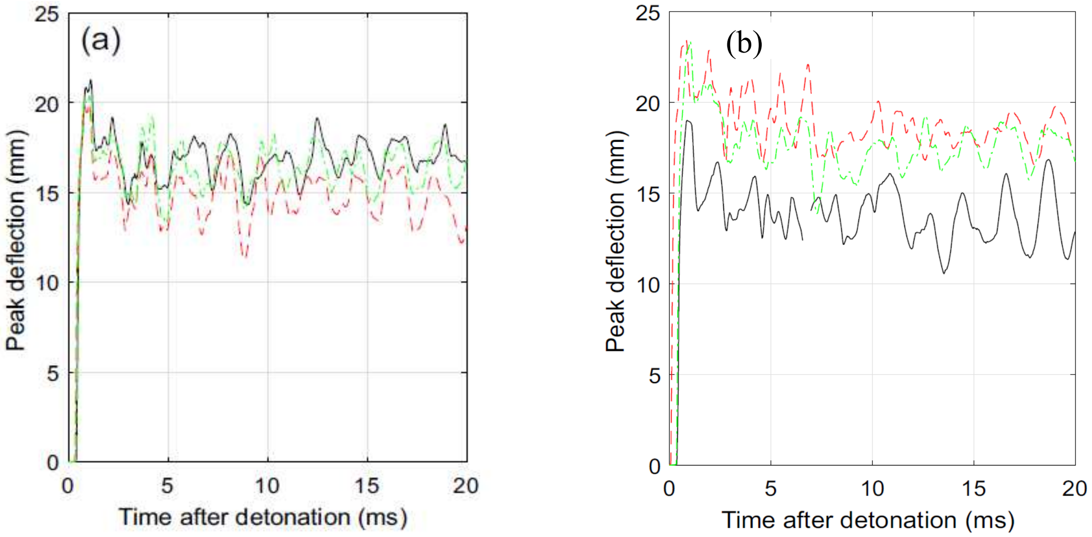

Figure 2: Measured transient mid-point displacement-time histories for (a) spherical detonations and (b) cylindrical detonations (c) residual plate profiles from the cylindrical tests

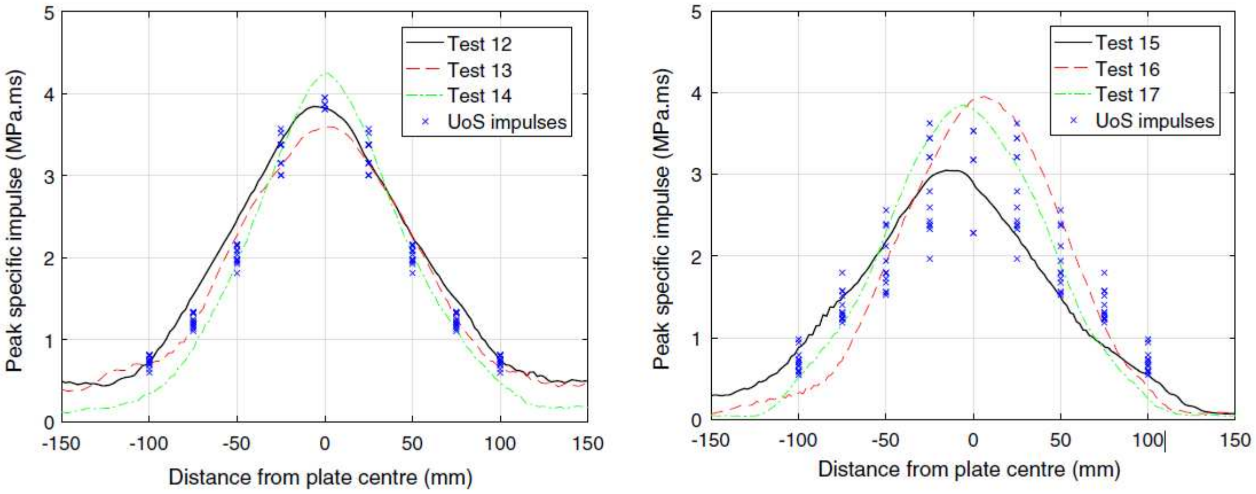

Figure 3: Measured (COBL) and inferred (BISRU) specific impulse distributions for (a) spherical detonations

Conclusions

The findings show significant progress in the chase for better experimental measurements that characterize the loading and transient response of structures subjected to near-field explosions, with initial velocity profiles obtained using stereo-imaging and DIC techniques at BISRU producing inferred specific impulses that matched well with the discrete specific impulse measurements obtained using COBL at the University of Sheffield. The inferred impulse method seems to be sensitive enough to detect spatial variations in loading caused by surface instabilities in the expanding detonation product cloud from cylindrical charge detonations.

References

[1] S.D. Clarke, S.D. Fay, J.A. Warren, A. Tyas, S.E. Rigby, I. Elgy. *A large scale experimental approach to the measurement of spatially and temporally localised loading from the detonation of shallow-buried explosives*. Meas Sci Technol 26:015001 (2015).

[2] R.J. Curry, G.S. Langdon. *Transient response of steel plates subjected to close proximity explosive detonations in air*, Int J Impact Eng, 102:102-116 (2017).

[3] S.D. Clarke, S.E. Rigby, S. Fay, A. Barr, A. Tyas, M. Gant, I. Elgy. *Characterisation of buried blast loading* (under review)

[4] S.E. Rigby, A. Tyas, R.J. Curry, G.S. Langdon. *Experimental measurement of specific impulse distribution and transient deformation of plates subjected to near-field explosive blasts*, Expt Mechanics, 59:163–178 (2019).