Dynamic Stress Measurement Behind Shock-Loaded Collapsible Materials

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Collapsible materials like closed-cell aluminum foams, being lightweight and effective energy-absorbers, are desirable options in the manufacture of blast shields. In order to minimize the damage, the collapsibility of such materials is utilized to arrest shrapnel, solid debris and fragments flying out of a blast. But these materials are not effective mitigators of a blast wave emerging out of a detonation, for the reason of stress amplification at the distal end [1], damaging the objects covered by the collapsible shields. Due to the impulsive collapse involved in the phenomenon, the direct sensors used for measuring the distal-end stress are often worn-out and damaged during the process requiring multiple replacements affecting the accuracy, repeatability and reliability of the measurement [2]. Hence an accurate, robust and a high-fidelity stress measurement technique is required for the analysis of shock mediation by the collapsible materials used in blast shields.

In this backdrop, we developed a transducing-type measurement technique to capture the dynamic stress-time history at the distal-end of collapsible materials exposed to shock waves. The technique involves a T-beam transducer instrumented with high-frequency strain gauges, in which the head of the T-beam is exposed to the collapse of the functional material, while the sensing junction is located near the bottom of the beam, away from the spot of impact, thus preventing the sensor impairment. The strain gauges are rigged in a modified, full Wheatstone bridge configuration, embedded in a strain meter. Calibration of the sensor was carried out using known inputs from an impulse hammer of PCB Piezotronics make, yielding a sensitivity of $0.556\mu\varepsilon/N$. Post calibration, the sensor was tested in a shock tube for a dynamic response under shock loading, without and with two collapsible materials, viz. closed cell of aluminum foam ($\rho = 0.374g/cc$) and balsa wood ($\rho = 0.142g/cc$), which have a potential utility as blast shield materials. The output of the sensor was collected on a PC-based data acquisition system, through a signal conditioner. The sensor output indicated an amplification of 4.8 times the applied shock load at the proximal end of the aluminum foam, which is consistent with the information reported in literature [1, 2]. At the distal end of balsa wood, the amplification factor was 2.95 times the applied load/pressure at the proximal end. Finite element analysis was performed on the transducer, using ANSYS, to validate its dynamic response numerically, the results of which show a good agreement with the experimental data. The sensor developed is compact, durable, cost-effective and moreover, can be designed to suit the harsh test environments of blast loading.

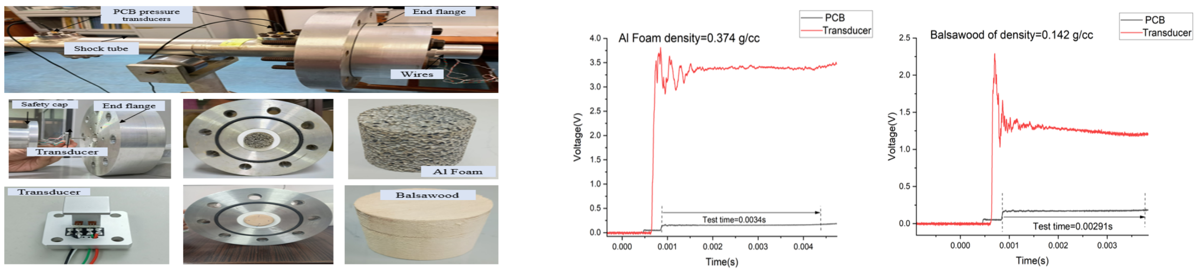

Figure 1. Experimental setup and signal output of the stress transducer.

[1] O.E. Petel, S. Ouellet, A.J. Higgins, D.L. Frost, *Shock Waves.* **23(1)**, 55-67, 2013. https://doi.org/10.1007/s00193-012-0414-7

[2] M. Thorat, V. Menezes, A. Gokhale, C. Dey, *Journal of Performance of Constructed Facilities.* **35(6)**, 06021005, 2021. https://doi.org/10.1061/(ASCE)CF.1943-5509.0001673