HIGH STRAIN RATE RELOADING COMPRESSON TESTING OF A CLOSED-CELL ALUMNUM FOAM

Alper Tasdemirci[a], Mustafa Güden[a] and Ian W. Hall[b]
[a]Department of Mechanical Engineering, Izmir Institute of Technology
[a]Gülbahçe Köyü, Urla, Izmir, Turkey 35430
[b]Department of Mechanical Engineering, University of Delaware
[b]Newark, DE 19716, USA
alpertasdemirci@iyte.edu.tr

Aluminum (Al) closed-cell foams are materials of increasing importance because they have good energy absorption capabilities combined with good thermal and acoustic properties. They can convert much of the impact energy into plastic energy and absorb more energy than bulk metals at relatively low stresses. When used as filling materials in tubes, they increase total energy absorption over the sum of the energy absorbed by foam alone and tube alone [1]. In designing with metallic foams as energy absorbing fillers, mechanical properties are needed for strain rates corresponding to those created by impact events. Quasi-static mechanical behavior of metallic foams has been fairly extensively studied, but data concerning high strain rate mechanical behavior of these materials are, however, rather sparse [2,3]. This study was initiated, therefore, to study and model the high strain rate mechanical behavior of an Al foam produced by foaming of powder compacts and to compare it with quasi-static behavior and, hence, determine any effect on energy absorbing capacity.

High strain rate tests (10^2–10^3 s^{-1}) were performed using a Split Hopkinson Pressure Bar (SHPB) apparatus equipped with aluminum bars 3.53 m long and 19mm in diameter. The samples are compressed by accelerating the striker bar from a gas chamber so that it impacts the incident bar. The resulting elastic wave travels down the incident bar to the specimen/bar interface where part of the wave is reflected and part continues through the sample and into the transmitter bar. The incident, transmitted and reflected waves are measured by strain gages on the bars. Experiments were performed in which many reflections of the waves were recorded. The raw data from such an experiment are presented in Fig. 1. The figure shows that the magnitudes of the incident and reflected waves diminish and that of the transmitted wave increases with each successive passage. In each successive passage, the foam sample reloaded and the strain rate in each loading was very similar, allowing the application reloading tests in a single SHPB testing and hence loading the foam sample to relatively large strains at a constant strain rate.

To observe how the specimen (foam) underwent deformation during SHPB testing and to compare the experimental data and numerical simulation results, a high speed camera Ultra 8, was used to record the SHPB tests. The deformation process (or fracture process) was observed by photographing the specimen sequentially in predetermined short time intervals (of the order of few microsec) using the high speed camera. With the Ultra 8 high speed camera used for the present study, a maximum of eight frames can be photographed in the speed range of 500 to 100 million frames per second. In the time domain, this implies that the interframe time can be varied between 10 nsec to 1 msec. The camera can be synchronized with the incident bar strain-gage or can be delayed to photograph the events of interest only. Fig. 2 shows the high speed camera record of the dynamic deformation process of the Aluminum foam sample during the SHPB experiment. The first image was taken before the loading pulse reached the specimen. The next four images were taken at 400 microsec intervals after the arrival of the incident pulse at the specimen. The bar on the left is the incident bar, which moves toward the right during loading. The bar on the right is the transmission bar. Finally, a three-dimensional SHPB finite element model using the commercial explicit finite element code LS-DYNA 970 was used to study stress wave propagation in aluminum foams. Numerical simulations were carried out using the MAT_HONEYCOMB material model of LS-DYNA 970 for aluminum foam.

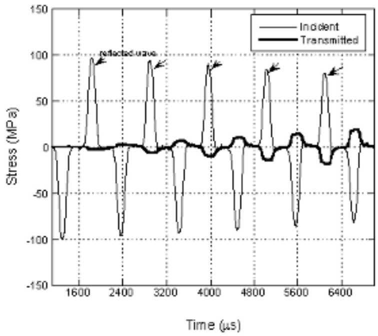

FIGURE 1. Incident, reflected and transmitted waves in a typical SHPB testing.

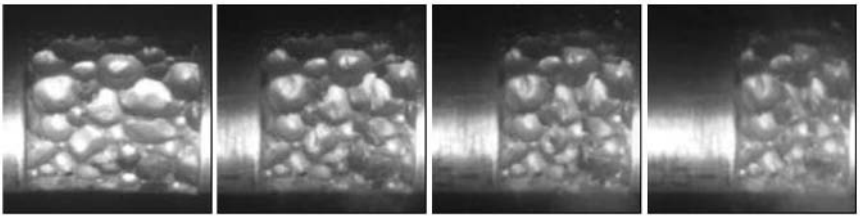

FIGURE 2. The high speed camera record of the dynamic deformation of a foam sample.

References

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