DEFORMATION OBSERVATION OF CLOSED-CELL ALUMINUM FOAMS IN THE SPLIT HOPKINSON PRESSURE BAR TEST

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Summary The SHPB technique is often used to investigate the dynamic behaviours of metal foam under the assumption of the axial stress and strain uniformity within specimen. Considering the special porous structure of metal foam, the assumption needs further evaluation and verification based on the analysis of deformation at meso-scale. The present work aims to evaluate the feasibility of SHPB test to characterize the mechanical performance of metal foam through experimental observation and measurement. The deformation at meso-scale of aluminum foam under a SHPB impact was captured by a high-speed camera system and it was shown that the strain distribution of the specimen was nonuniform. This implies that the assumption of the axial strain uniformity within specimen cannot be satisfied and this makes the classical SHPB technique fail to characterize mechanical properties of metal foams. In order to characterize material foam reliably, improvement to the traditional SHPB method is necessary.

INTRODUCTION

Metal foam has many excellent properties, among of which the most important is the energy absorption under impact. The split Hopkinson pressure bar (SHPB) was first introduced by Kolsky in 1949 and widely used in the later dynamic experiments [1-4]. With the ever-increasing researches on metal foams, the dynamic compression behaviors of closed-cell metal foams were extensively studied and reported [5,6]. Validity of SHPB test is based on assumption of the axial stress and strain uniformity within specimen. However, metal foam is an inhomogeneous low wave resistant material with porous mesostructure and the deformation may not reach uniform during each impact in SHPB tests. As a consequence, the assumption needs further evaluation and verification.
This paper aims to evaluate the feasibility of SHPB test to characterize the mechanical performance of metal foam through experimental observation. An experimental approach has been designed to monitor the morphology change during the impact process in the SHPB test with a high-speed camera system mounted. The experimental results show that the aluminum foam fails to meet the assumption of uniform deformation in the SHPB tests.

EXPERIMENTAL OBSERVATION

SHPB with a high-speed camera system

A SHPB system with high-speed camera has been designed to capture the deformation of specimens during the procedure of impact. The schematic diagram of SHPB - High-speed camera system is shown in Figure.1. There are three strain gauges on the SHPB bars, Gauge 1 and gauge 2 are semiconductor strain gauges and used for traditional purpose in SHPB test. Gauge 3 and the solid-state relay are used to trigger high-speed cameras.

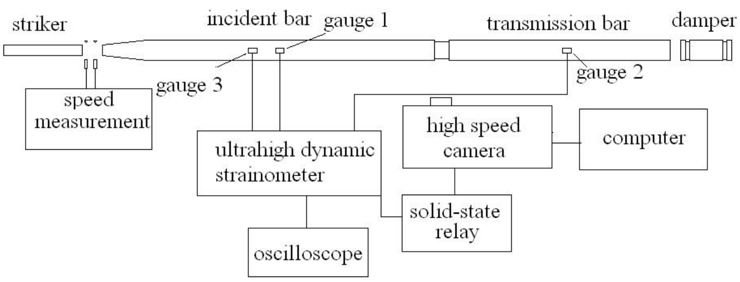

Fig .1 Schematic diagram of the experimental setup

Materials and preparation of specimens

The diameter of closed-cell aluminum foam specimens is 74mm and the thickness of specimens is 37mm, with an average cell size of 4mm and the relative density of 0.2. The surfaces of specimens were preprocessed for capturing the high-speed images clearly as shown in Fig.2.

Deformation observation

The impact process of a specimen in the first impact was captured successfully by the SHPB-High speed camera system (see Fig.3). Except for the marked areas, there is no noticeable deformation observed in other positions.

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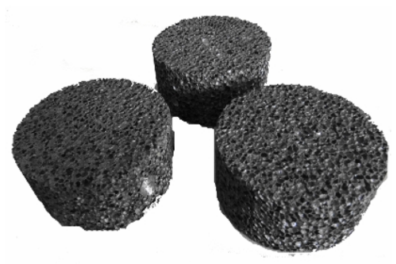
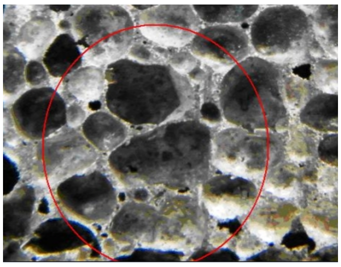

(a) Specimens


（b）Surface before preprocessing

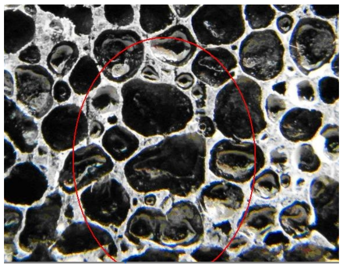
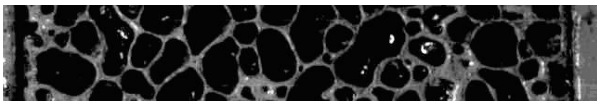
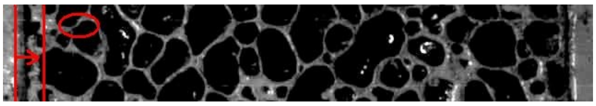
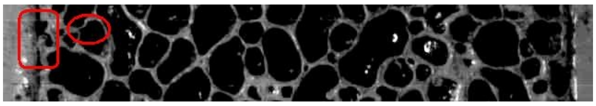

(c) Surface after processing

Fig .2 Photography of aluminum foam specimen


(a) t = 0ms


(b) t = 0.1ms


(c) t = 0.2ms

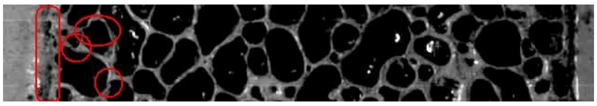

(d) t = 0.3ms

Fig.3 Dynamic impact process captured by high-speed camera with 20,000 fps

Strain distribution

Seven typical positions as marked in Fig.4 are selected to calculate the engineering strain on the surface. As shown in Fig.5, the strain distribution on the surface is not uniform along the specimen and larger strain occurs at the ends of specimen that is three times higher than the average (horizontal lines in Fig.5). As a consequence, the assumption of homogeneous deformation in SHPB test is not satisfied and this poses a question on the feasibility of SHPB technique on characterizing foam materials.

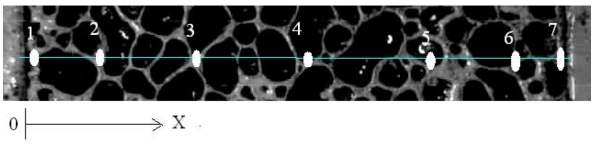


Fig.4 Seven typical positions on the surface of specimen

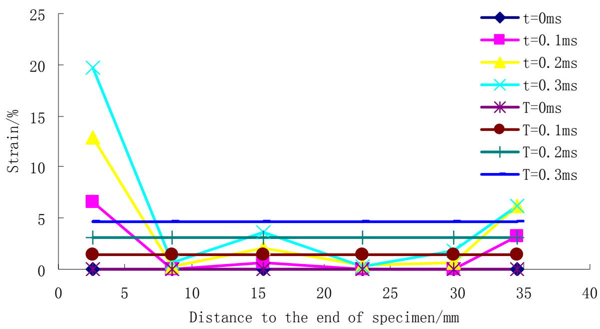


Fig.5 Strain of different positions on the specimen's surface

CONCLUSIONS

The experimental observations show that deformation of closed-cell aluminum foam in the SHPB impact process is non-uniform. Most of the deformation occurs at the end of specimen and is much greater than the average strain of the total specimen. This finding suggests that aluminum foam cannot be assumed to be homogeneous during a SHPB test in that it fails to meet the assumption of uniform deformation. Therefore, in order to characterize material foam reliably, improvement to the traditional SHPB method is necessary.

References

[1] Kolsky H.: An Investigation of the Mechanical Properties of Materials at Very High Rates of Loading. *Proceedings of the physical society London* **B62**: 676-700, 1949.

[2] Johnson T.P.M., Sarva S.S., Socrate S.: Comparison of Low Impedance Split-Hopkinson Pressure Bar Techniques in the Characterization of Polyurea. *Exp Mech* **50**:931-940, 2010.

[3] Song B., Forrestal M. J., Chen W.: Dynamic and Quasi-static Propagation of Compaction Waves in a Low-density Epoxy Foam. *Exp Mech* **46**:127-136, 2006

[4] Sunny G., Yuan F., Prakash V.: Design of Inserts for Split-Hopkinson Pressure Bar Testing of Low Strain-to-Failure Materials. *Exp Mech* **49**:479-490, 2009.

[5] Edwin R.R., Paramesmaran V., Daniel B. S. S.: Comparison of Quasi-static and Dynamic Compression Behavior of Closed-cell Aluminum Foam. *Mat Sci Eng* A **526**:11-15, 2009.

[6] Dannemann K. A., Lankford J.: High strain rate compression of closed-cell aluminum foam. *Mat Sci Eng* A **293**:157-164, 2000.