QUASI- STATIC INDENTATION TESTS ON CLOSED-CELL AL FOAM

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INTRODUCTION

Metal foam has the potential for use in lightweight structural components and in energy absorption and has received extensive attention[1-2].

The low impact (or indentation) behaviors of metal foam have been widely investigated in recent years. Many of these works are experimental studies on the mechanical behavior of metal foam[3-6]. Lu and co-workers[7]conducted experimental and finite element investigations on compression, tension, sharing and dynamic indentations of CYMAT aluminium foams of various densities. Sudheer et al.[8] experimentally investigated the deep indentation response of a closed-cell Al foam under different rates of penetration.

The main purpose of this paper is to characterise the indentation resistance of closed-cell Al foam for different indenter diameter、relative density and boundary condition with experiments.

EXPERIMENTAL

An available closed-cell Al foam is used in this study. The foam has an average cell size of ～2 mm and cell wall thickness of the foam ranged from 80 to 100 μm. Indentation tests were performed on three foams with different relative densities: 9, 20 and 29%. An electromechanical testing machine (INSTRAN-5569) was used with a flat-end circular cylindrical indenter (D=12.7, 16, 20, 25.4mm in diameter) in displacement control at a speed of 1mm/min and the load and the load-line displacement are recorded. The maximum indentation depth was about 8mm. The specimens are supported by a rigid foundation, so the overall bending is limited. Five samples are tested for each type of specimen. To minimize the effects of friction, the indenters were lubricated with PTFE spray. The dimensions of rectangular samples were 100×100×15mm^3.

RESULTS AND DISCUSSION

A. Indentation response characters

The total force on indenter is the sum of that to crush the foam beneath the indenter and that required to tear it at the edges of the indenter, that is

$$P = P_{crushing} + P_{tearing} = S\sigma^*_{pl} + 2\pi a\gamma \quad (1)$$

Where P is the total load, a is the radius of indenter and S is the contact area of between indenter and foam, σ^*_{pl} is the compressive plateau stress of the foam and γ is its tear energy.

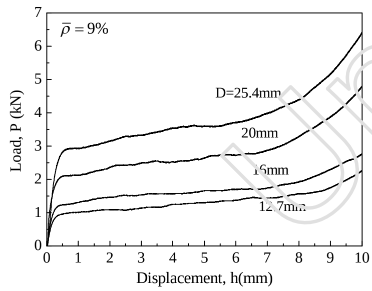

Fig. 1 $P-h$ curves of Al foam under different diameter of the indenters

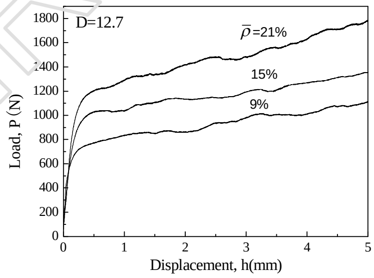

Fig. 2 $P-h$ curves of Al foam with different relative densities

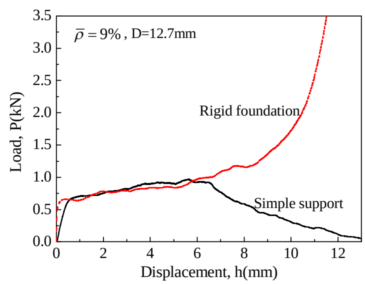

Fig. 3 $P-h$ curves of Al foam for different boundary conditions

Typical load-displacement curves for indentation of Al foam with different relative densities under different diameters indenter are shown in Fig. 1 and 2. Due to the elastic–plastic behavior of Al foam, the load–indentation curves have a generally non-linear shape. The load-displacement indentation response of Al foam is similar to that in uniaxial compression (see [9,10]). However, a couple of differences between uniaxial compression and indentation $P-h$ data are noteworthy. Overall, the contact load increases with the increasing of indenter diameters.

The above mentioned specimens of indentation test are supported by a rigid foundation. In addition, the indentation response of Al foam under simply supported boundary conditions is studied. The experiment results are shown in Fig. 3. We can see from Fig. 3, the boundary conditions have little effect on the curve segments of indentation response curves before the load drop. The role of different boundary conditions to the deformation of Al foam is if the Al foam takes place overall bending.

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B Mechanical properties and energy absorption characteristics

Mechanical properties and energy absorption characteristics of metallic foams can be investigated through indentation test. Energy absorbing capability, w, and energy absorbing efficiency, η, are two importance parameters to evaluate energy absorption characteristics of Al foam. w, the absorbed energy per unit volume in a certain strain interval $[\varepsilon_1, \varepsilon_2]$ is equal to the area below the stress-strain curve and can be expressed as

$$w = \int_{\varepsilon_1}^{\varepsilon_2} \sigma(\varepsilon) d\varepsilon \tag{2}$$

η is defined as the ratio of energy absorbed by an ideal energy absorber to that absorbed by the actual foam:

$$\eta = \frac{\int_{\varepsilon_1}^{\varepsilon_2} \sigma(\varepsilon) d\varepsilon}{\sigma_0(\varepsilon_2 - \varepsilon_1)} \tag{3}$$

w and η are calculated according to $P-h$ response curves of Al foam with different indenter sizes and relative densities at the same indentation depth, $h_c = 6mm$, as shown in Fig. 4 -5.

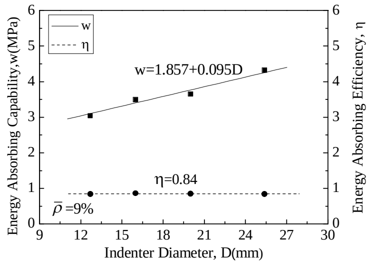

Fig. 4 w-D and η - D curves of Al foam

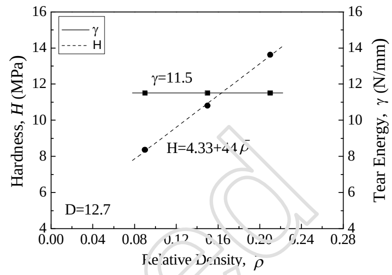

Fig. 5 w- $\bar{\rho}$ and η - $\bar{\rho}$ curves of Al foam

We can see from Fig. 4-5, Energy absorbing capability of Al foam linearly increases with the increasing of indenter sizes or relative density. The energy absorbing efficiency is independent of indenter sizes and relative density of Al foam.

CONCLUSIONS

The current study aimed at investigating the indentation behavior of Al foam by experiments under the flat-end cylindrical indenter. The key results of this investigation can be summarized as follows:

(1) The indentation response curve of Al foam under the flat-end cylindrical indenter is similar to that in uniaxial compression, but there have some different, such as deformation mechanism.

(2) Energy absorbing capability of Al foam linearly increases with the increasing of indenter sizes or relative density. The tear energy and energy absorbing efficiency are independent of indenter sizes and relative density of Al foam.

(3) At a certain indentation depth range, the difference between rigid foundation and simply supported conditions on the indentation response of Al foam can be ignored.

Acknowledgments

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