Characterisation of Al Alloy Matrix Syntactic Foam by Brazilian Test

Xiaoxiao Lu and **Yuyuan Zhao**

School of Engineering, The University of Liverpool, Brownlow Hill, Liverpool L69 3GH, UK

Introduction

There has been a significant amount of research on Al matrix syntactic foams in recent years, due to their great potential for applications in lightweight structures and energy absorption. The mechanical properties of metallic matrix syntactic foams are normally studied by compression and bending (Zhao & Tao, 2008; Tao & Zhao, 2012). Their tensile behaviour is difficult to be studied by conventional tensile tests due to their brittleness.

Brazilian test, an indirect method established by ISRM in 1978 to measure the tensile strength of rocks, is proved to be suitable for any materials with similar properties as rocks (Proveti & Michot, 2006). This paper explores the feasibility of using Brazilian test to study the tensile behaviour of Al matrix syntactic foams.

Experimental

The Al alloy (6082) matrix syntactic foam samples, containing Envirosphere ceramic spheres, were produced by the infiltration casting technique (Tao & Zhao, 2009). The particle size of the ceramic spheres and the Al volume fraction of the as-produced samples are listed in Table 1. The higher Al volume fractions in Foams D, E and F were achieved by adding Al 6082 alloy particles. The samples were cut to discs (ø44×5mm) and compressed on an Instron 4505 mechanical tester, as shown schematically in Fig. 1.

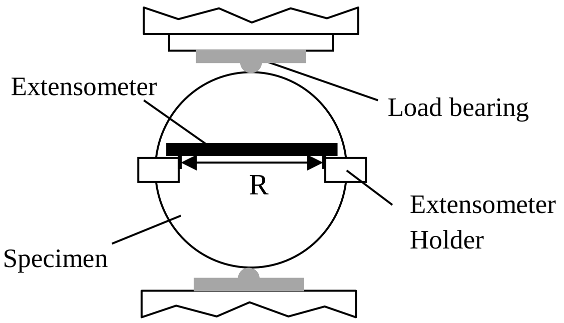

Fig. 1 Schematic of Brazilian test

The splitting tensile strength was calculated from (ASTM D3967-86):

$$\sigma_T = 2F/\pi DL \qquad (1)$$

where σ_T is tensile strength, F is the maximum load associated with fracture, and D and L are the diameter and thickness of cylindrical specimen, respectively.

Results and Discussion

Fig. 2 shows the load-displacement curves for the six samples obtained by the Brazilian test. All samples, except Foam B, show a nearly linear region in the early stage of deformation. For the syntactic foams without Al particle toughening (Foams A, B and C), the load dropped suddenly after reaching the maximum value, accompanied by a significant increase in the displacement in the transverse (tensile) direction. The samples split under diametrical tensile stress with very limited plastic deformation. Fig. 3(a) shows the micrograph of the Foam A specimen after fracture.

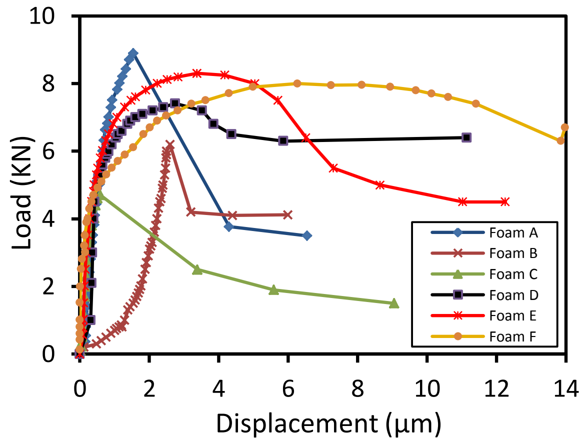

Fig. 2 Compressive load versus displacement in tensile direction

The syntactic foams toughened with Al particles (Foams D, E and F), however, showed significant plastic deformation. The load increased gradually before reaching the maximum value and then decreased more steadily with increasing transverse displacement. Increasing Al volume fraction resulted in considerable increases in ductility. Different from Foams A, B and C, the discs did not split completely; a diametrical crack propagated until final failure (Fig. 3(b)). There was also considerable yielding in the regions in direct contact with the load bearings.

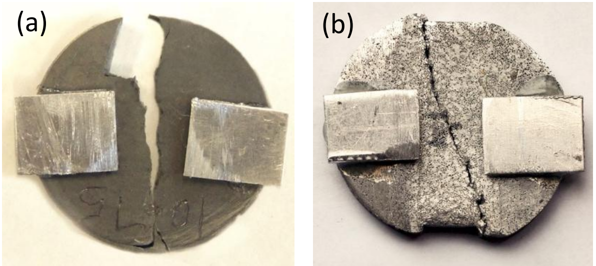

Fig. 3 Diametrical crack formed during Brazilian test: (a) Foam A and (b) Foam D

The tensile strength values of the six samples, calculated from Eq. (1), are shown in Table 1. The tensile strength values obtained by the conventional tensile test for Foams A, B and C are also included. For comparison purposes, Table 1 also listed the theoretical values obtained from an empirical equation developed by Johnson (1989).

Tab.1 Tensile strength values obtained from Brazilian test, tensile test (Tao & Zhao, 2012) and theoretical estimation (Johnson, 1989)

Foam	Particle size (μm)	Al (vol.%)	σ_T (Bra.) (MPa)	σ_T (ten.) (MPa)	σ_T (est.) (MPa)
A	75-150	35.0	25.8	15.8	29
B	150-250	44.5	16.8	19.0	29
C	250-500	49.5	11.4	18.2	29
D	250-500	57.5	21.5	-	83
E	250-500	70.5	24.0	-	119
F	250-500	76.0	23.8	-	157

Assuming no coupling, i.e. negligible interfacial bonding, between the matrix and ceramic spheres, the ceramic spheres can be considered as pores and the tensile stress is only borne by the matrix. If the defects in the matrix and the stress concentration can be ignored, the tensile strength can therefore be estimated by (Johnson, 1989):

$$\sigma_T = \sigma_m \left(1 - 1.2V_p^{\frac{2}{3}}\right)$$

where σ_m is the tensile strength of the matrix material (340MPa for Al 6082 alloy) and V_p is the volume fraction of the ceramic spheres.

For a low Al volume fraction (Foams A, B and C), the tensile strength values measured by Brazilian test were sensitive to the particle size of the ceramic spheres, while those measured by tensile test were insensitive to the particle size. Both sets of measured values were lower than the theoretical values, indicating that stress concentration and matrix defects in the Al alloy matrix syntactic foam have significant influence on the tensile behaviour.

For the syntactic foams toughened with Al particles (Foams D, E and F), the tensile strength was largely independent of the Al volume fraction and was much lower than the theoretical predictions. This indicates that Brazilian test is not suitable for metal matrix syntactic foams showing ductile behaviour.

Conclusion

Al alloy matrix syntactic foams with Al volume fraction from 35% to 76% were manufactured by infiltration casting and Brazilian test was conducted. The compressive load versus transverse displacement curves were good indicators of brittle to ductile transition. The measured tensile strength was largely independent of the Al volume fraction, but was sensitive to the particle size of the ceramic spheres, indicating that Brazilian test is a useful technique for brittle metal matrix syntactic foams but is unsuitable for those with considerable ductility.

References

1. Johnson, W. S. (ed.), 1989, Metal matrix composites testing, analysis and failure mode, ASTM International, USA.
2. Proveti, J. and Michot, G., 2006, The Brazilian test: a tool for measuring the toughness of a material and its brittle to ductile transition. *Int. J. Fracture*, **139** 455-460.
3. Tao, X. F. and Zhao, Y.Y., 2009, Compressive behavior of Al matrix syntactic foams toughened with Al particles, *Scripta Materialia*, **61** 461-464.
4. Tao, X. F. and Zhao, Y.Y., 2012, Compressive failure of Al matrix syntactic foams manufactured by melt infiltration, *Mat. Sci. Eng.*, **549** 228-232.
5. Zhao, Y. Y. and Tao, X. F., 2009, Behaviour of metal matrix syntactic foams in compression, Proc. Mat. Sci. Tech. (MS&T) 2009, The Printing House, Inc., Stoughton, WI. 1785-1794.