東京大学グローバルCOEプログラム　機械システム・イノベーション国際拠点

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# Multiaxial Yield and Fracture of Microcellular Aluminium


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## 要旨


We address the behaviour of highly porous metals under multiaxial stress and in the presence of a crack. We do so by means of experiments conducted on replicated microcellular aluminium, a material produced in our laboratory by infiltrating a packed bed of salt with molten aluminium, which is later solidified; leaching the salt in water then creates a highly porous metal “foam”.

The first part of the presentation reports a study of multiaxial yield in replicated aluminium foam. For this purpose a new triaxial loading frame was built to test cubical specimens; these data are supplemented with tests on uniaxial and pipe specimens. Data show that the yield surface shape is essentially independent of the relative density, and a function of all three stress tensor invariants, a dependence that has recently emerged from theory and finite element simulation but has hitherto not been demonstrated in porous metal. More specifically, data demonstrate a dependence of the yield surface on the third stress tensor invariant such that the yield surface becomes trilobal at elevated hydrostatic stress (tensile or compressive), while remaining circular at zero hydrostatic stress, a feature that is captured by a few expressions proposed in the literature, and also by an empirical yield criterion that emerges from the present experiments. The second part of this presentation addresses foam fracture toughness, using data produced in disc-shaped compact tension testing of replicated 400 μm pore microcellular aluminium. The material shows marked *R*-curve behaviour, and the presence of bridging ligaments in the crack wake. Fractography reveals that the crack propagates via the rupture of struts normal to the crack plane, this being accompanied by a degree of plastic deformation of neighbouring struts near the crack plane. Measured crack initiation and steady state propagation *J* values vary roughly as $V_m^3$; this is a stronger dependence than has been observed in commercial (closed-cell) metal foams. A simple model is proposed to describe the initiation toughness of ductile open-cell foams, based on an estimate of the crack tip opening displacement at the moment when a strut aligned in the loading direction fails by ductile rupture just ahead of the crack tip. The model agrees well with the data up to a relative density of 20%, accounting in particular for the observed scaling of the toughness of replicated foams on the third power of the relative density.



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