In Application

Comparison of the Mechanical Behaviour of Standard and Auxetic Foams by X-ray Computed Tomography and Digital Volume Correlation

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Introduction

Low density polymeric foams are widely used in applications that require good low energy absorption capabilities, such as packaging. Characterisation of their mechanical properties is challenging due to their large deformation and tendency for strain localisation. Auxetic (also known as negative Poisson's ratio) foams can be manufactured from low density conventional polyurethane foams but have beneficial properties over conventional foams. Auxetic materials have increased fracture toughness and crack resistance, and excellent energy absorbing properties making them suitable for protective structures.

Until now, the mechanical behaviour of foams has been investigated at the macroscopic level and at the surface using DIC. However, standard uniaxial test and surface measurements are too limited to completely address the complex 3D large deformation behaviour of these materials. DVC allows us to investigate the bulk deformation of auxetic foams loaded in tension and compare to similar data from conventional foams in order to understand the deformation patterns of the material and relate it to the manufacturing process.

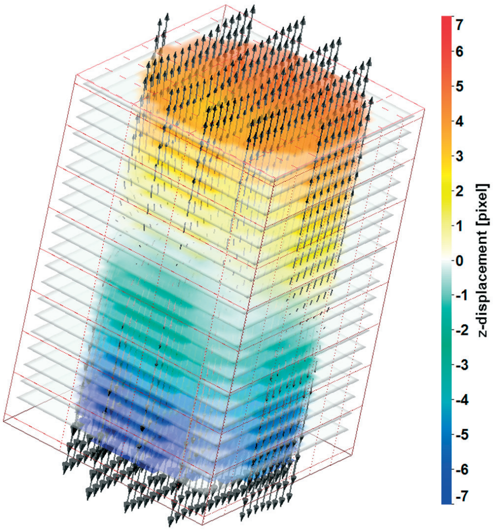

Figure 1: *3D visualisation of displacements through foam volume (vector density reduced for clarity)*

Experimental Setup

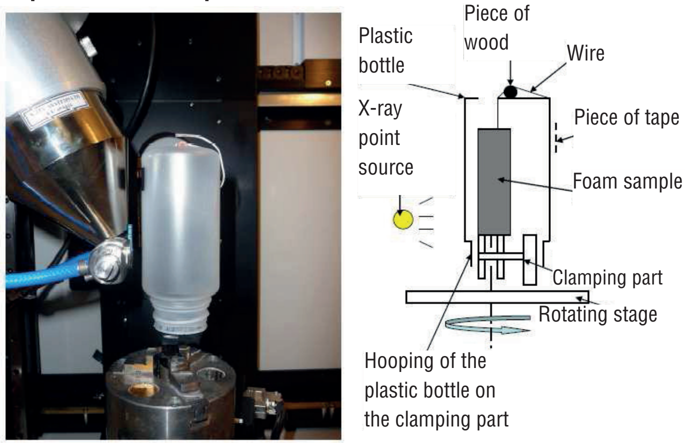

Figure 2: *Experimental setup including tensile test fixture at the Manchester X-ray Imaging facility*

The auxetic test specimen was a polyurethane foam having diameter 30 mm and length 50 mm. Both the auxetic and standard specimens were tested in tension in the chamber using a custom jig. Figure 2 shows the experimental setup. The Manchester X-ray imaging facility was utilized (225 kV Nikon Xtek XTH XCT scanner - 50 kV, current 380 µA, tungsten target, 721 projections) and an imaging resolution of 15 µm per voxel was achieved.

The DVC calculations were typically performed utilizing 48 x 48 x 48 voxels subvolumes with 50 % overlap. With these settings strain resolutions of 0.1% were achieved; this resolution having been calculated by correlating between two unloaded scans and one with a rigid body translation introduced.

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FOCUS ON IMAGING

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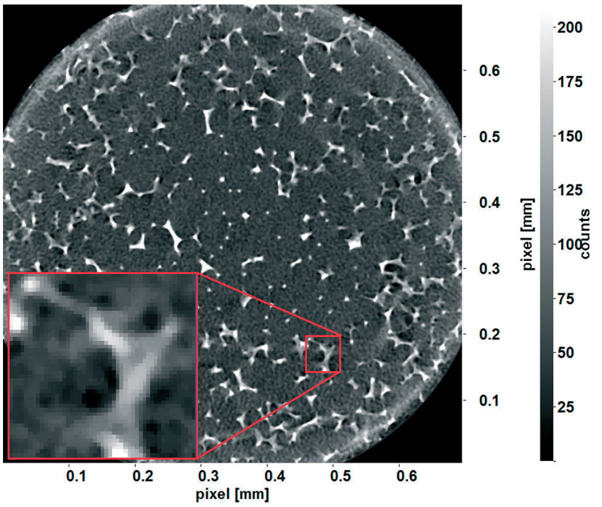

***Figure 3:** Image slice of auxetic foam illustrating subvolume*

Results

For the standard foam, good uniformity of strain was observed at low strains giving a tangent Poisson's ratio of 0.5. Some heterogeneity of strain was observed at higher strains, which may be related to the fixtures. The behaviour of the auxetic foam (Figure 4) was totally different, with strain being spatially heterogeneous with transverse strains both positive and negative but giving a negative Poisson's ratio on average. This suggests that the unfolding tendency of some groups of cells was higher than others because of the complex frozen starting microstructure.

The study demonstrated the capabilities of Digital Volume Correlation, showing that it is possible to perform volume strain measurements on low density polymeric foams by coupling X-ray CT and DVC. Volume strain maps were obtained on conventional and standard foam specimens tested in tension over several load steps. The standard foam specimen exhibited reasonably homogeneous strain distributions with positive Poisson's ratios. However, the increase of Poisson's ratio with longitudinal strain as well as unequal v_{zx} and v_{zy} values are still unexplained. Values above 0.5 at the last load step suggest some load-induced stiffness anisotropy. The auxetic specimen showed very heterogeneous strain distributions, probably because of its complex shrivelled microstructure.

Zones of positive and negative transverse strains clearly demonstrated that the auxetic behaviour is not uniform throughout the foam. DVC is the only experimental method able to identify these phenomena and is further being utilized to validate and optimize Finite Element (FE) simulations.

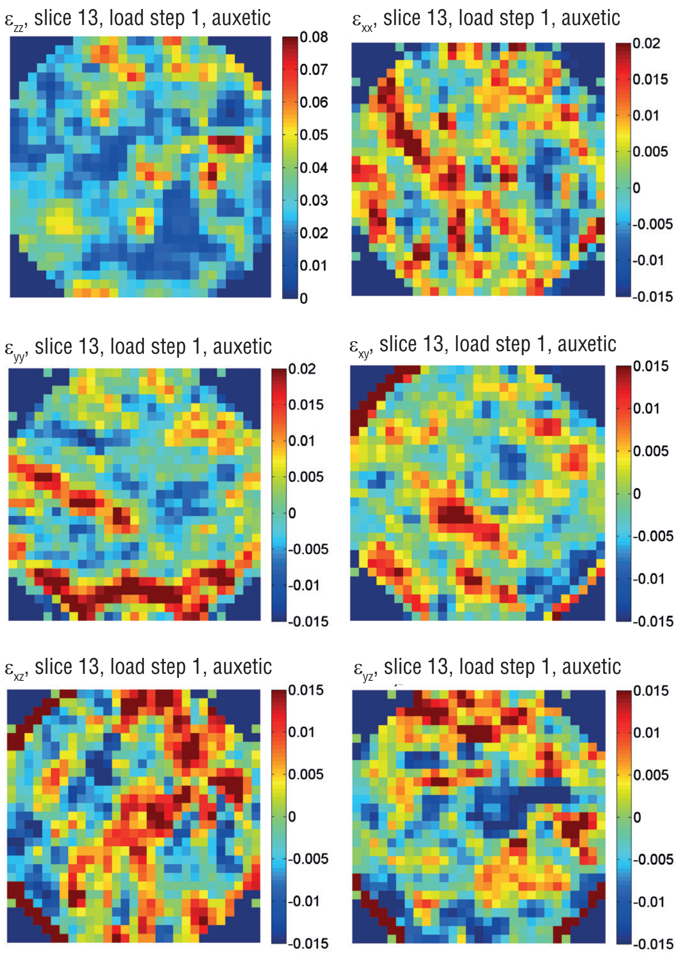

***Figure 4:** Strain maps for auxetic foam type*

For more information the reader is referred to Pierron F., Mc Donald S., Hollis D., Fu J., Withers P. J., Alderson A., Comparative investigation of the mechanical behaviour of standard and auxetic low density polyurethane foams by X-ray tomography and Digital Volume Correlation, Strain, vol. 49, n° 6, pp. 467-482, 2013. http://dx.doi.org/10.1111/str.12053.

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