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Traditional methods of strain assessment may under predict cellular foam modulus values

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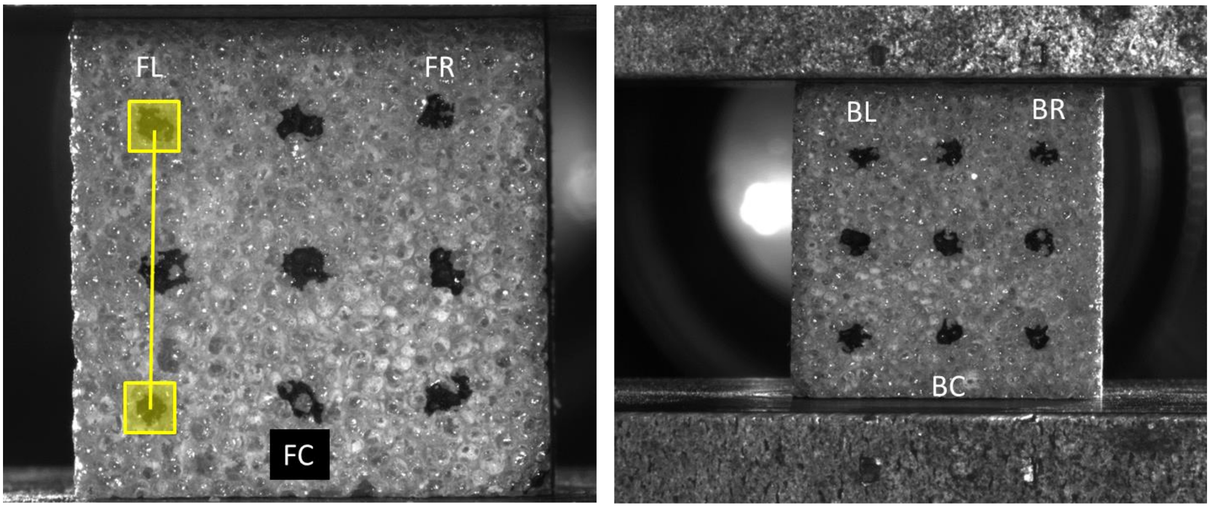
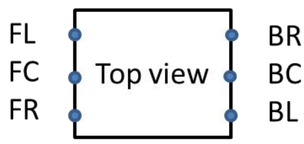
Polymer foams have been extensively used in the testing and development of orthopaedic devices and computational models. Often these foams are used in preference to cadaver and animal models due to being relatively inexpensive and their consistent material properties. Successful validation of such models requires accurate material/mechanical data. The assumed range of compressive moduli, provided in the Sawbones technical sheet, is 16 MPa to 1.15 GPa depending on the density of foam. In this investigation, we apply two non-contact measurement techniques (digital volume correlation (DVC) and optical surface extensometry/point-tracking) to assess the validity of these reported values. It is thought that such non-contact methods remove mechanical extensometer errors (slippage, misalignment) and are less sensitive to test-machine end-artifacts (friction, non-uniform loading, platen flexibility). This is because measurement is taken directly from the sample, and hence material property assessment should be more accurate. Use of DVC is advantageous as full field strain measurement is possible, however test time and cost is significantly higher than extensometry. Hence, the study also sought to assess the viability of optical extensometry for characterising porous materials.

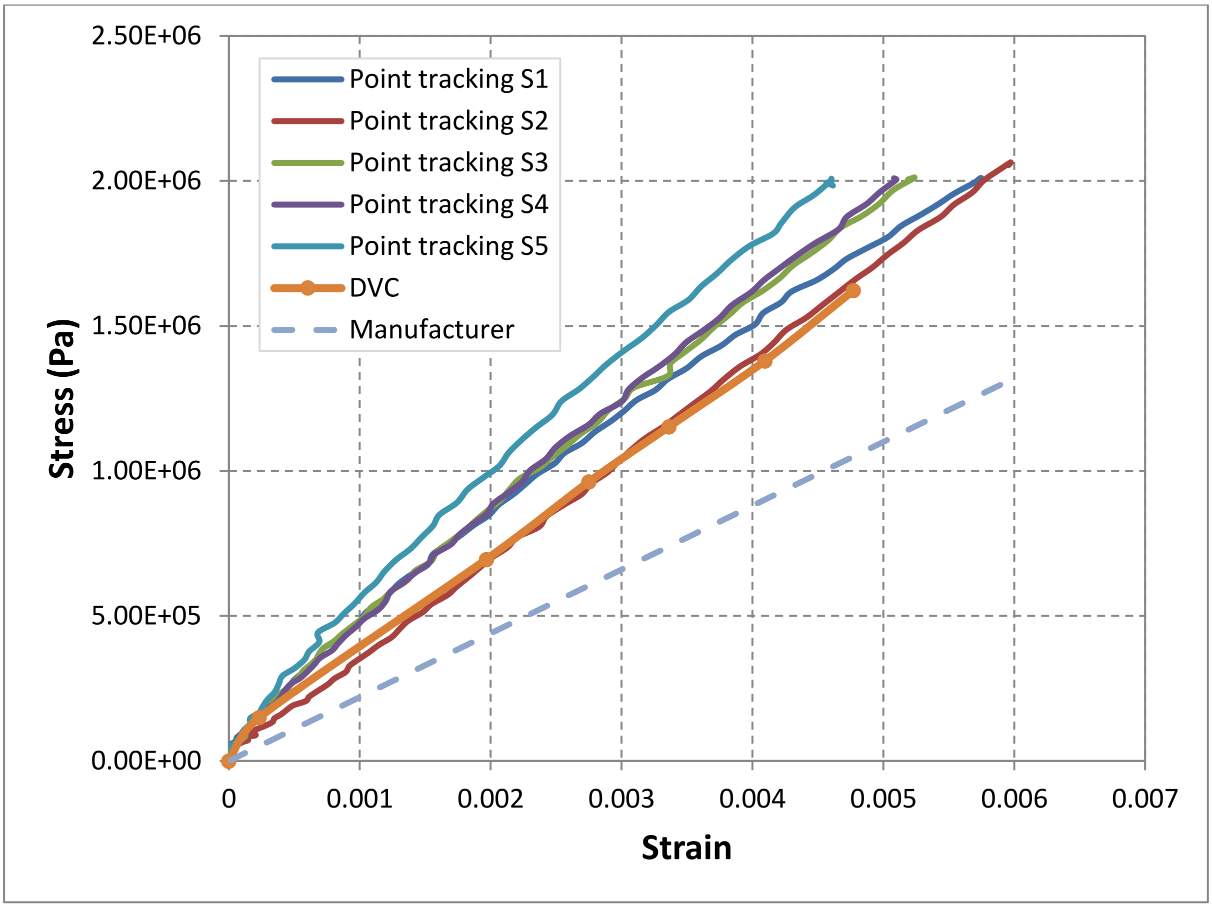
Testing was conducted on five 20 mm cubic samples of 0.32g/cc (20 pcf) solid rigid polyurethane foam (SAWBONES^{TM}). The strain behaviour was characterised by incremental loading via an in situ loading rig. Loading was performed in 0.1 mm increments for 8 load steps with scans between loading steps. Full field strain measurement was performed on one sample by micro focus tomography (muVIS Centre, Southampton) and subsequent DVC (DaVis, Lavision). Average strains in each direction were then calculated to enable modulus and Poisson's ratio calculation. These results were subsequently corroborated by use of optical point-tracking (MatchID). To account for heterogeneities, axial strain measurements were averaged from six points on the front and rear surfaces (fig.1). In each test compressive displacement was applied to 900N (~2MPa) to remain within the linear elastic region.





Significant variability of individual strain measurements was observed from point couples on the same sample, indicating non-uniform loading did occur in all samples. However by averaging across multiple points, linear loading profiles were ascertained (fig.2). For all non-contact methods the calculated elastic moduli were found to range between 331-428 MPa whilst the approximated modulus based on cross head displacement was ~210 MPa, similar to the manufacturer's quoted value (220 MPa). The point-tracking gave a significantly higher modulus ($p = 0.047$) than the DVC results as only surface measurements were made. It is thought that a correction factor may be ascertained from the finite element method to correct this. Both the DVC and point-tracking results ($p = 0.001$) indicated substantially higher compressive modulus than the manufacturer provided properties.

This study demonstrates that methods of measuring displacement data on of cellular foams must be carefully considered, as artefacts can lead to significant errors of up to 70% compared to optical and x-ray based techniques.



Sample/method		Modulus (MPa)
Point-tracking	Sample 1	345
	Sample 2	341
	Sample 3	378
	Sample 4	388
	Sample 5	428
	Average	**376**
DVC		331
Data sheet value		220