Measurement of volume change in sheet elastomer testing using back-to-back stereo DIC

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Abstract

Elastomers are generally considered incompressible meaning that their density remains constant during loading. However, depending on the material system, this assumption can be incorrect and there is a necessity to measure such volume change. In the past, this has mainly been done on dog-bone rubber-like material specimens by measuring the strain field over two or more of their faces to calculate the volume change (1-2). A similar methodology was applied to plasticity in (3). The main limitation of such approaches is that it can only be applied to uniaxial stress states while volume changes are likely to be dependent on stress multi-axiality.
An alternative is to use more complex test geometries in the spirit of Material Testing 2.0 (4-5) so that volume change could be measured as a function of stress multiaxiality. For this, it has been shown that two back-to-back stereo Digital Image Correlation (DIC) systems could lead to an average through-thickness deformation (6). This is obtained as the difference of the out-of-plane displacements measured on the front and back faces. However, because of the large mismatch between the deformation in the longitudinal direction and that in the transverse ones, it is essential to have a very accurate registration of the two stereo-systems otherwise, some 'leakage' occurs from the vertical displacement to the out of plane one leading to spurious volume changes (7). This also casts some doubts about the values obtained in (6) as this registration had not been performed accurately there.

The present study revisits this methodology by carefully looking at the registration procedure. The novelty lies in the availability of a tool that allows to simulate camera images from a stereo DIC calibration file and a finite element model (8-9) to verify the data processing procedure. A finite element model of a rectangular tensile specimen was developed in Abaqus using a Neo-Hookean incompressible material model with shell elements. Image deformation from (8-9) was performed using the FEDEF module of MatchID (10). These images were then processed as if they were experimental which allowed to verify the complete data processing chain and to illustrate the sensitivity of the data processing to the local orientation of the material coordinate system.

Experimental data was acquired on a 50 x 50 x 3 mm natural rubber sheet specimen, loaded in tension at a crosshead speed of 0.1 mm/s. Speckle patterns were obtained by paint spraying both faces. Two back-to-back stereo DIC systems were used, employing four 5 Mpx cameras. The specimen was tested up to 60% of longitudinal strain and 80 loads steps were recorded at 0.28 Hz, generating 160 pairs of stereo images. Slippage in the grips occurred

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which led to specimen warping. This challenges the extraction of the through-thickness deformation. To understand this, experimentally measured boundary conditions were extracted and applied to an FE model. This was used to revise the procedure and ensure that this 'leakage' could be minimized. In the future, the procedure will be applied to a range of different elastomers tested on a biaxial machine to understand the compressibility of these materials as a function of stress multiaxiality and strain levels. The procedure will also be applied to the material system tested in (6) to verify their results. It would also be very interesting to study polymeric materials and also investigate the influence of strain rate on the compressibility of such materials.

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