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GEOMETRIC RECONSTRUCTION AND NUMERICAL SIMULATION OF 3D DEFORMATION OF UNMARKED MACROSCOPICALLY ANISOTROPIC, HOMOGENEOUS MATERIALS SUBJECTED TO UNIAXIAL TENSION AT DIFFERENT RATES OF STRAIN

***M. Arthington, N. Petrinic, C. Siviour and B. Elliott**

Impact Engineering Team Solid Mechanics and Materials Group
Department of Engineering Science
University of Oxford, Parks Road, Oxford
matthew.arthington@eng.ox.ac.uk,
http://www.eng.ox.ac.uk/NP/iet.html

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ABSTRACT

Material characterisation is often performed by uniaxial loaded cylindrical specimens. When the material in question is anisotropic in nature, the transverse behaviour of these specimens is recorded and analysed with respect to the material orientation to determine the relevant material properties for development of constitutive models. During low strain rate testing, measurements of the transverse lengths of a specimen may be taken using contacting techniques, however at high strain rates and in situations where remote observations are required, such as in environmentally controlled experiments, these techniques may no longer be convenient and alternative approaches must be taken. Also, at low strain rates, the true stress rate control of loading has been achieved using visual techniques for isotropic materials [1]. The methodology given in this paper extends this control to anisotropic material behaviour.

Here, a technique is presented that utilises images from a minimum of three calibrated views of a single, initially cylindrical, specimen under loading. Subpixel edge detection of the specimen silhouette is used to detect 6 surface tangents at every distinguishable position along the specimen's length. Under the assumption of elliptical cross-sectional shape for homogeneous, anisotropic materials, a least squares solution based on the algebraic distance [2] is used to find the non-interpolating ellipse without any prior knowledge of its size or orientation. The least squares solution is extendible and allows the incorporation of more views to improve the accuracy of the reconstruction. Along with the recording of specimen shapes during testing, other applications for this methodology include the quality control of any elliptical cross section in manufacture or construction.

The need to observe all silhouette edges without obscurement to obtain accurate measurement, and also the desire to measure extension, has led to the development of machining mark tracking to obtain extension fields. The machining marks that are visible in the specimens tested during these experiments do not have an adverse effect on its behaviour during fracture, while at the same time they provide

points on the material surface that are permanently fixed and trackable. One problem with this kind of feature tracking is that of a “picket fence” nature and an algorithm has been developed to overcome it. The edge points that are detected for the cross section determination are sufficiently accurately detected to use their autocorrelation function as a measure of displacement from one frame to the next.

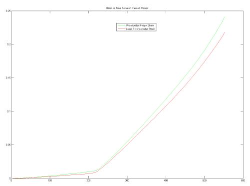
Evaluation of these techniques has been carried out using wire-eroded elliptical prisms for cross section shape determination (1(c). Tensile dumbbell specimens have been loaded in tension at quasi static rates of strain and a laser extensometer has been employed (figure 1(a) to evaluate the effectiveness of the edge feature tracking. A high speed video camera has been employed with two mirrors to provide three views at strain rates up to $\approx 10^3 s^{-1}$ to evaluate the method’s application to high strain rate deformation (figure 1(c)).

A hypoelastic-viscoplastic-damage model has been improved to simulate the observed behaviour. Results of simulations at two distinct rates of strain have been compared against experimental results and show good agreement in 3D deformation behaviour.

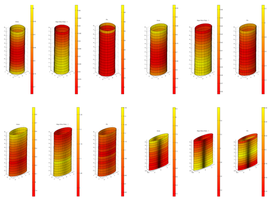
REFERENCES

[1] G’Sell, C. “Video-controlled tensile testing of polymers and metals beyond the necking point”. *Journal of materials science, Vol.* **27**, *5031–, 1992*

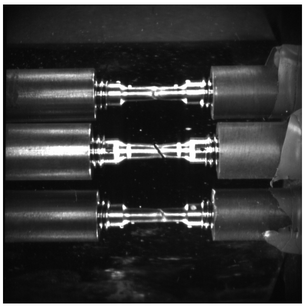
[2] Paul L. Rosin. “A note on the least squares fitting of ellipses”. *Pattern Recogn. Lett., Vol.* **14**, *799–808, 1993*



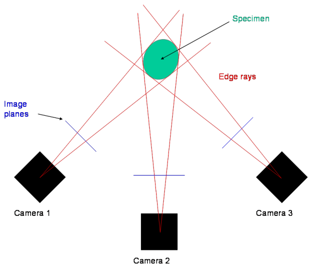
(a) Early preliminary results comparing laser extensometer recorded strain measurement to edge tracked measurement. The discrepancy arises from the lack of calibration in the camera, which is readily performed



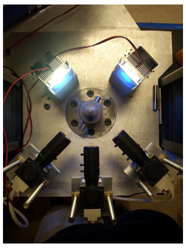
(b) Comparison of 4 different elliptical prisms with contours describing area, orientation and elipticity values



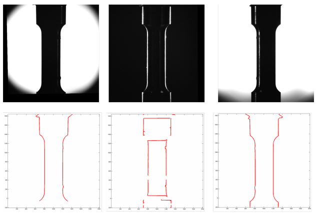
(c) Three views using two mirrors at $> 10^5$ frames/s



(d) The idealised apparatus



(e) The actual apparatus used during the quasi-static experiments



(f) The three views and the detected edges