FLUID STRUCTURE INTERACTIONS RESEARCH GROUP

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The Use of Optical Techniques to Assess the Performance of Composite Materials under High Velocity Deformations

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Background

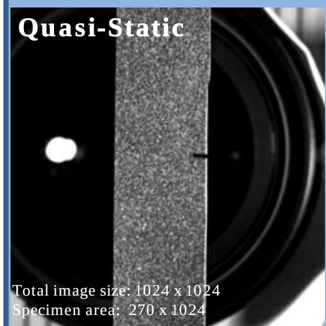
- The high strain rate characterisation of composite materials is usually limited to point or global measures.
- Non-contact, optical techniques provide full-field data over an area rather than a single point and do not interfere physically with the specimen. The techniques of Digital Image Correlation (DIC) and Thermoelastic Stress Analysis (TSA), are used in the current work.
- Modern advances in CCD technology have allowed these optical techniques the potential to be applied to study high strain rate events.
- The purpose of this work is to develop a methodology for the high strain rate testing of composite materials using optical techniques with a focus on the study of damage propagation and remnant life.

Research Aims

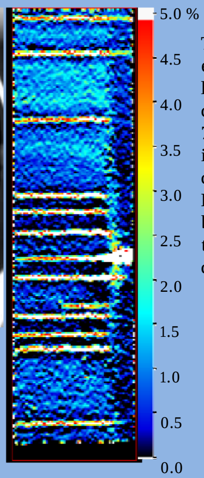
- To investigate the variables and compromises required during high speed white-light imaging and their effect on data accuracy and quality, including:
  - Speckle pattern
  - Lighting
  - Correlation settings
  - Loading methodology
- To develop a rig that is capable of applying a known level of high strain rate damage to a composite specimen without total specimen breakage
- To determine the remnant life of such damaged specimens and to use this data to develop material models over a range of strain rates
- To investigate high strain rate damage initiation mechanisms:
  - To analyse heat evolution and surface strains using IR imaging and DIC respectively
  - Combine the two optical techniques to provide a thermomechanical model of a fibrous composite during failure

Results

Initial tests were aimed at assessing the viability of using high speed imaging and DIC to analyse the surface strains up to failure during a high strain rate test and to compare the surface response to that of a quasi-static test. A side notch was cut to know the location of final failure.



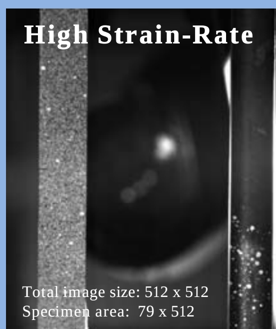
Strain Rate	2.8×10^{-4} S^{-1}
Digital Cameras	2 x Photron SA-1
Camera Frequency	60 Hz
Shutter Speed	1/200 sec



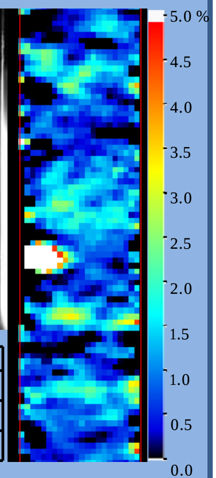
The images to the left show an example of a raw image and the longitudinal strain (%) calculated using Davis LaVision 7.4 correlation software. The image shown is the final correlated image before failure. Bands of high strain can clearly be seen on the surface, showing the formation of transverse cracks.

The correlated strain image to the right is clearly lacking in spatial resolution and is highly noisy, despite refining many correlation settings. The strain result is limited in terms of accuracy and spatial resolution by the lack of resolution in the raw image.

In future tests, ensuring adequate resolution in the raw images collected will be of paramount importance to ensure a reliable strain output from the image correlation technique.



Strain Rate	83 S^{-1}
Digital Cameras	2 x Photron SA-1
Camera Frequency	20 kHz
Shutter Speed	1/20000 sec



Future Work

Steps required in future high speed imaging work:

- Improvement of the raw image resolution over the specimen area- redesign of the protective enclosure around the high strain-rate test machine will allow closer camera positioning and greater resolution.
- A quantitative evaluation of the speckle pattern is required for future tests. The speckle pattern applied is often variable using the standard spray can method. A method of assessing the quality prior to a mechanical test is therefore vital.
- Optimisation of shutter settings and exposure time – A small aperture and a long exposure time were used to maximise the depth of field in the tests described, this could result in some blurring of the image and consequently inaccurate DIC displacement vectors

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