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Materials Characterisation For Industrial Applications Using Digital Image Correlation Techniques

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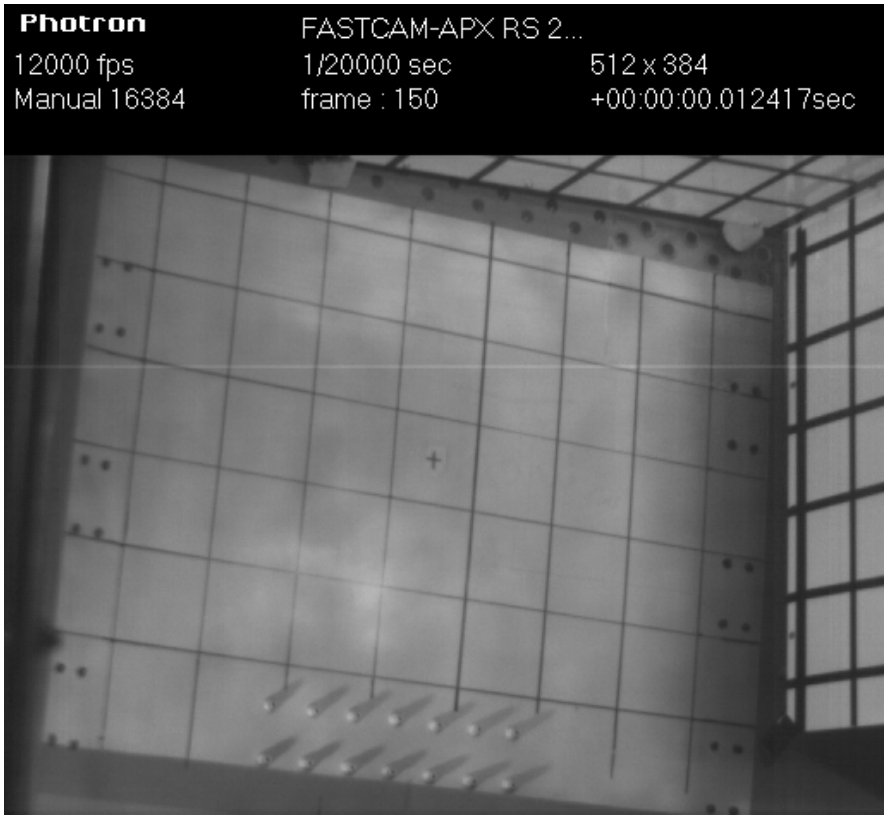
A lot of effort!



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Content

- Introduction
- Test Facilities
- Examples of Materials Characterisation with DIC
- Summary - Industrial Applications of DIC (in R&D)

The Experimental Impact Centre

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Introduction

BAE System Impact Capability

- 20 years history in impact
- Comprehensive range of capabilities for the investigation of impact phenomena and dynamic material behaviour (problem solving, consultancy, fundamental research)
- Specialist dedicated laboratories and comprehensive diagnostic suite

Experimental Impact Testing

- Impact tests m/s up to 4000m/s (with the capability of extending to 7000m/s)
- Engine and tyre debris, armour, high speed fragment,

Material Characterisation Under Dynamic Loading Conditions

- Materials data at high strain rates (>1000 /s) - metals, FRC, plastics, joints and adhesives
- EOS and shock loading studies up to 2500m/s
- Non-linear material response
- Validation tests – simple idealised geometry

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The Experimental Impact Centre

Investment has been made in buildings, hardware and high performance instrumentation to study impact events.

Indoor laboratory (completed November 2006)

Single and two stage gas guns capable of up to 4000m/s (7000m/s with H_2)

Tension and compression Hopkinson Bars, >1000/s

Conventional test machines up to 1.5 m/s

High speed Imacon/U68 cameras

Flash X-ray, 150 kV, 2 channel

Fast transient recording equipment

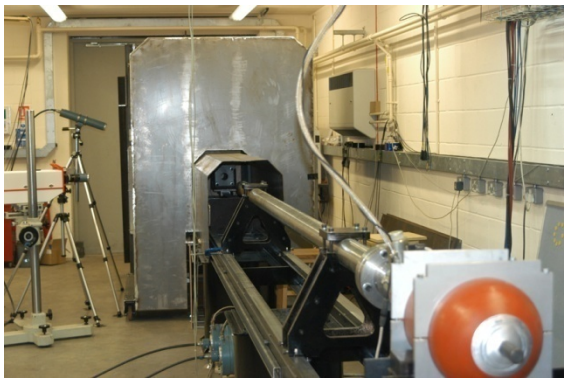
Photron APX RS

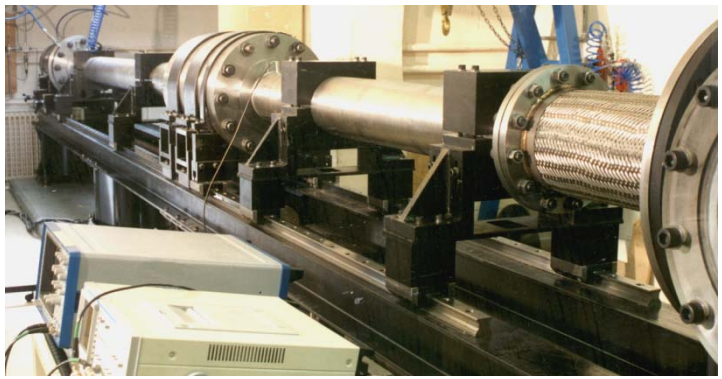
High pressure gauges, >0.5 Mbar

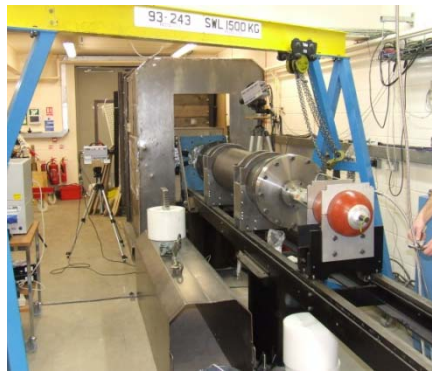
Fast response strain gauge equipment

Accurate projectile velocity measurement

Digital Image Correlation

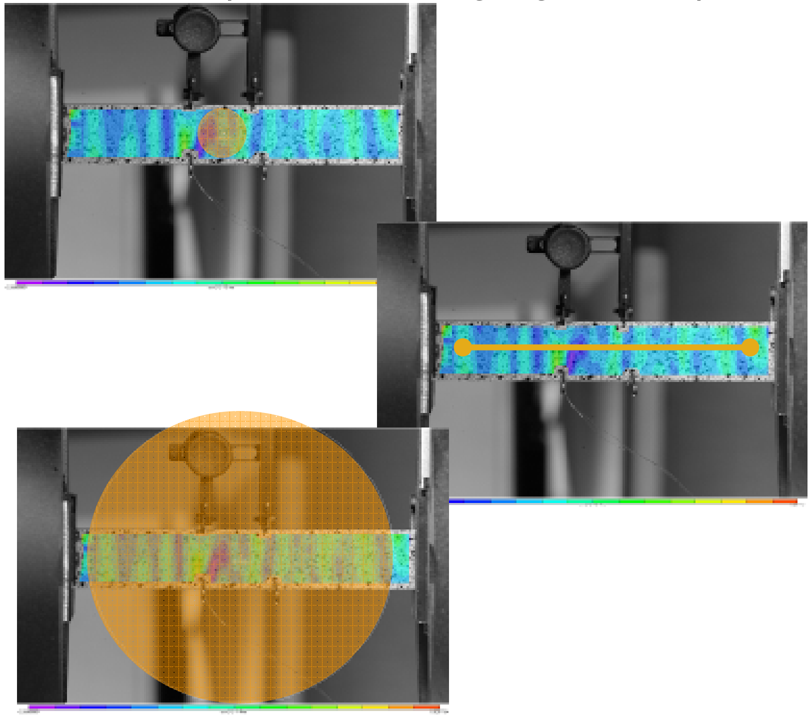


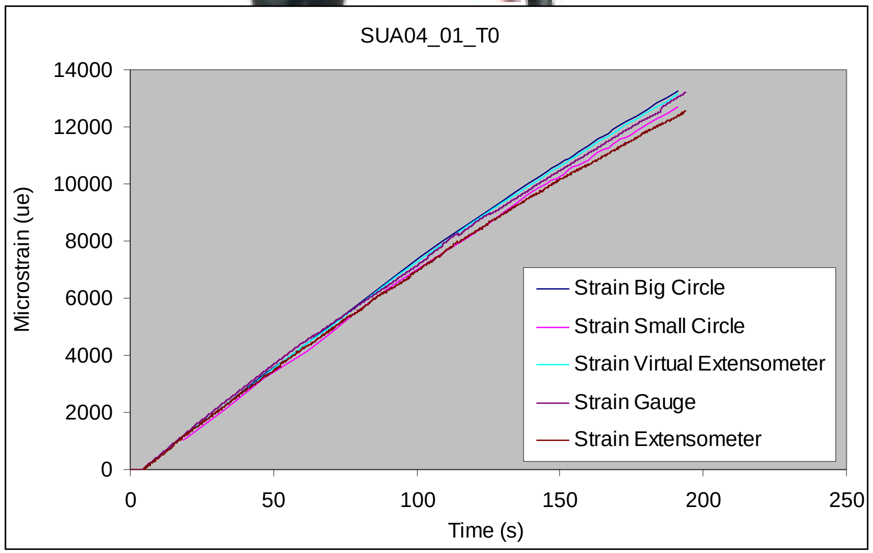




3D Image Correlation

- Correlated Solutions Vic 3D System
- AVT 2Mpixel cameras (x2)
- Photron APX (x2) – 512x512 @ 10,000 fps
- Test specimen painted with appropriate pattern
- Calibration
- Images analysed
- Used to complement strain gauge technique.





Test Sequence - Tension

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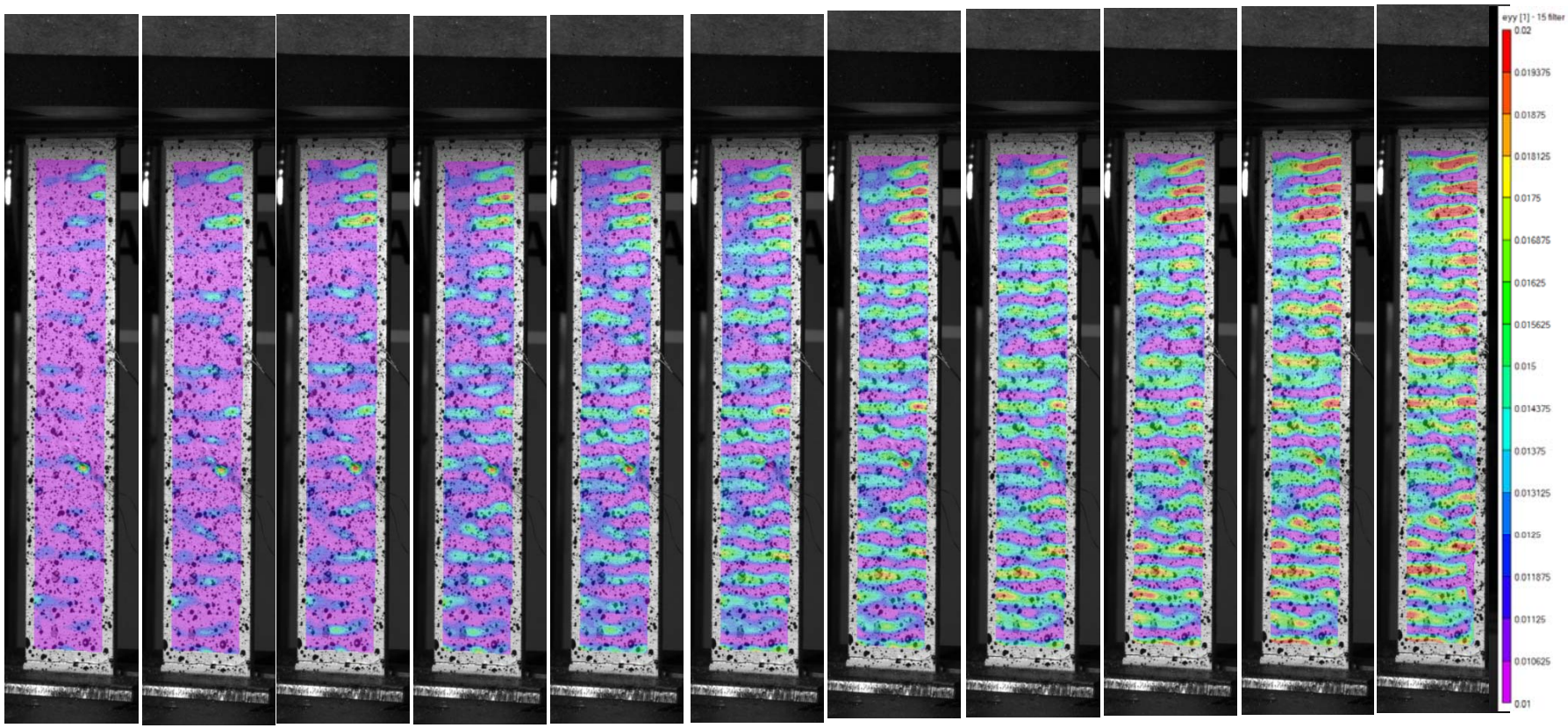
Tension Testing of a woven composite material

Images 29 – 40. 620MPa – 820MPa. 9500 – 13600 ue (strain extracted and averaged over gauge area)



Test Sequence - Compression

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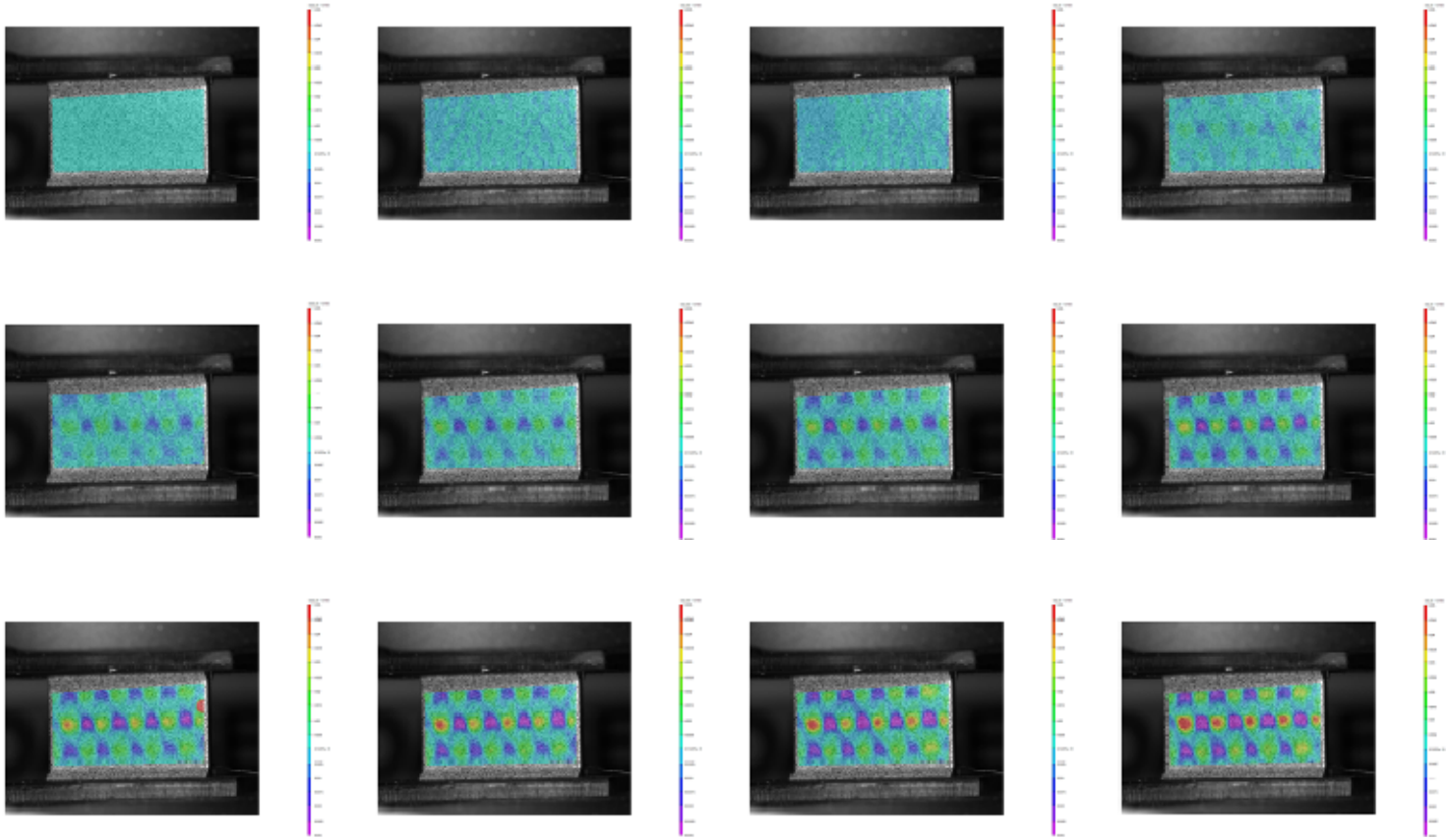
Compression Testing of a woven composite material

Images 0 to 11. 0 to 242 MPa, 0 – 4500 ue (strain extracted and averaged over gauge area)



Strain Field Maps in Compression Specimens

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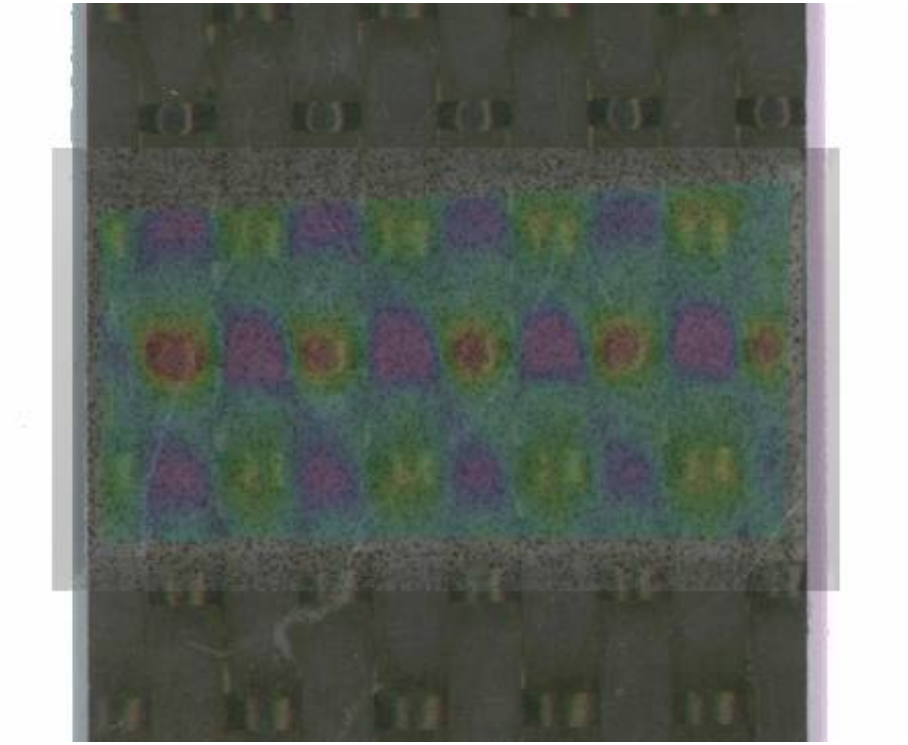
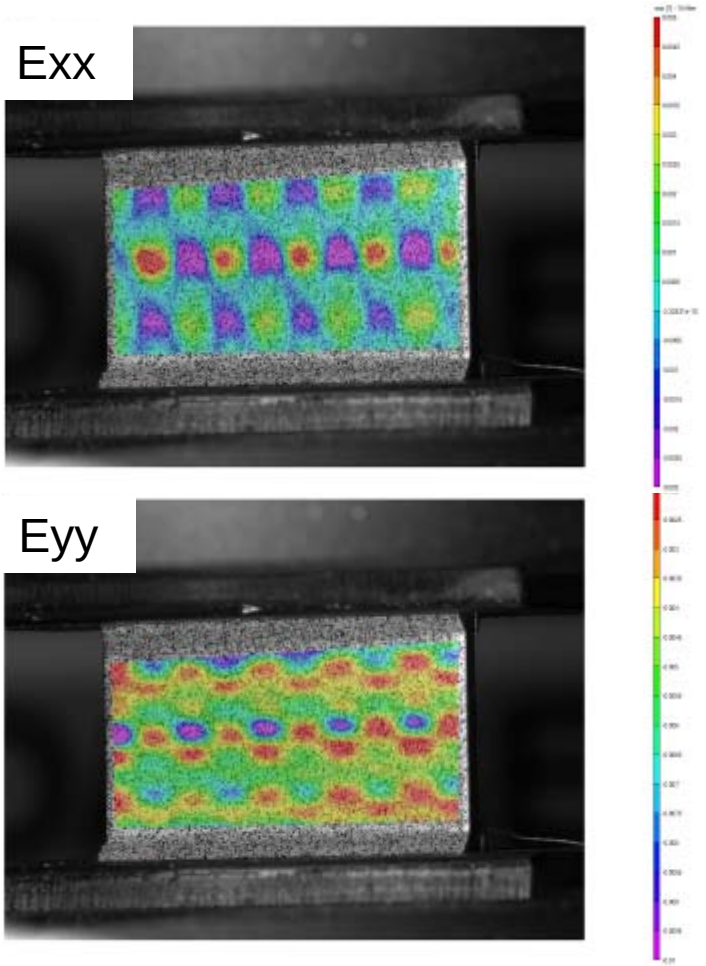
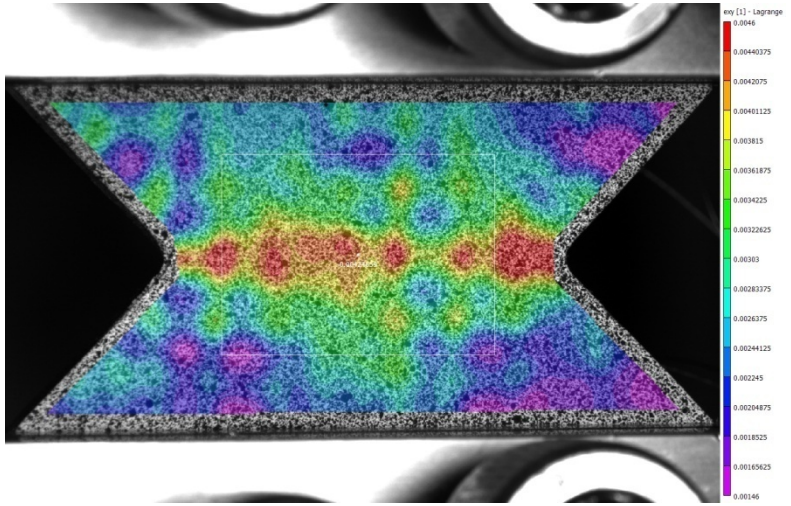
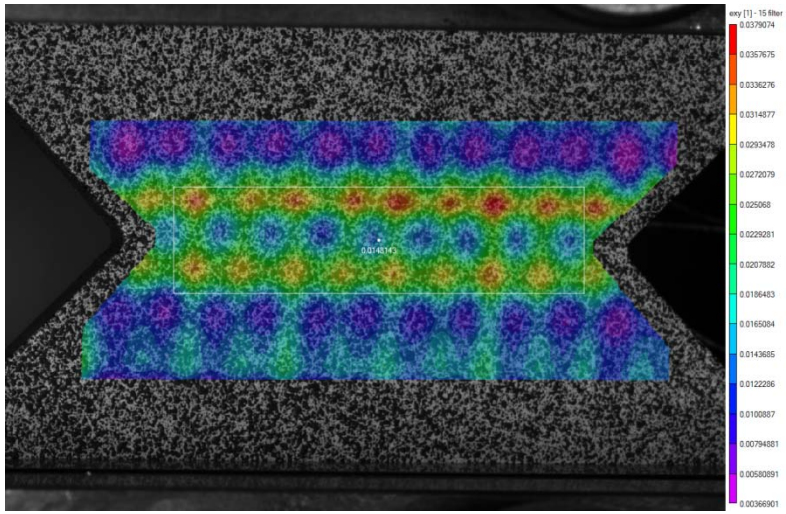


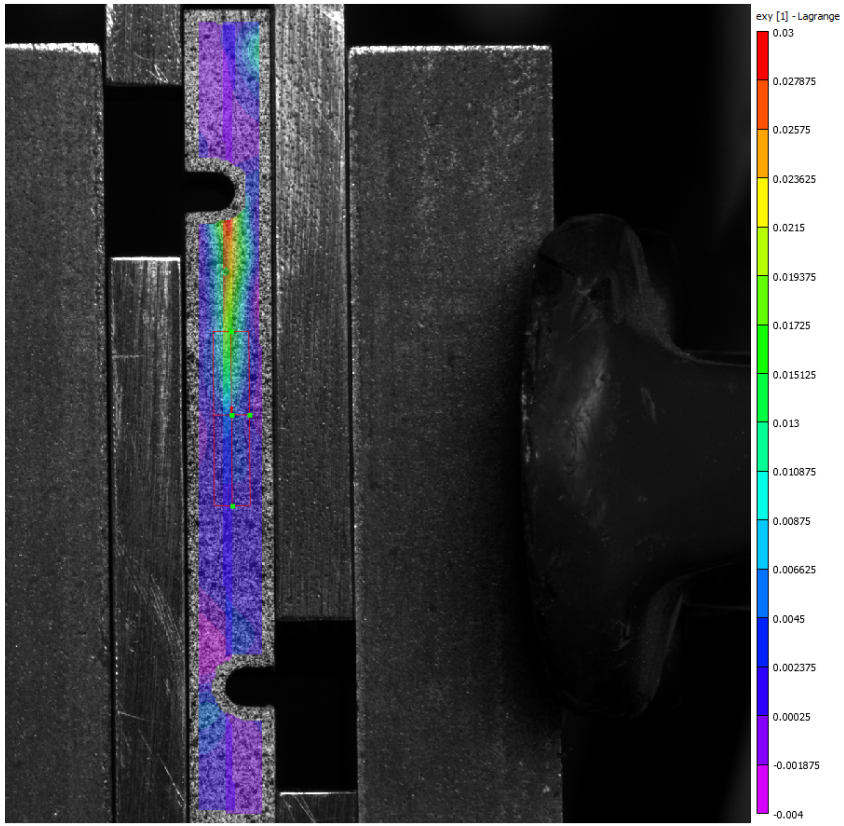
Image showing Exx strain map and specimen surface weave overlaid



Shear Tests – V Notch and Double Notch



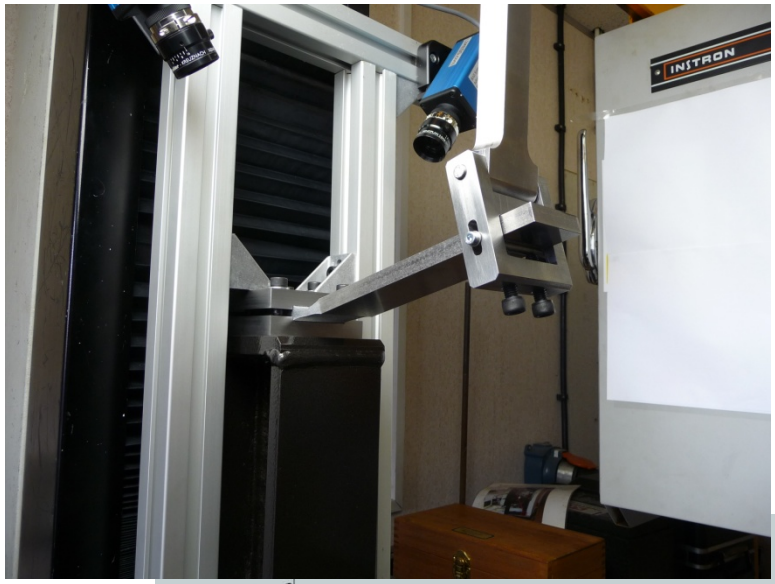


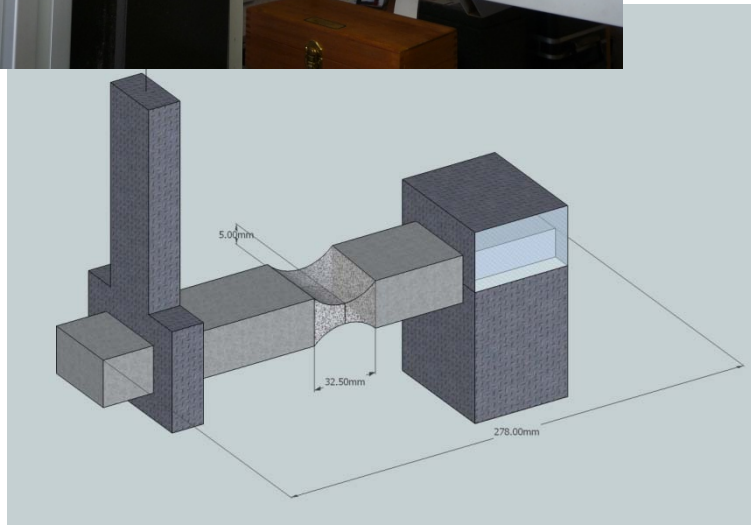


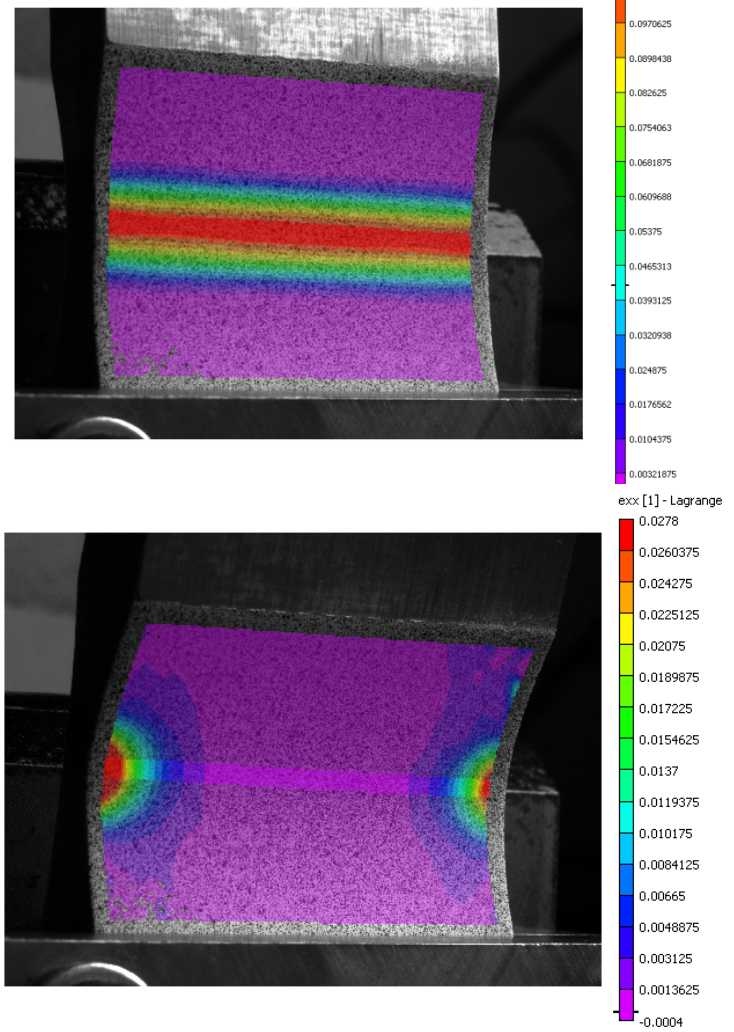
Ability to measure local strains

Data for validation of materials models

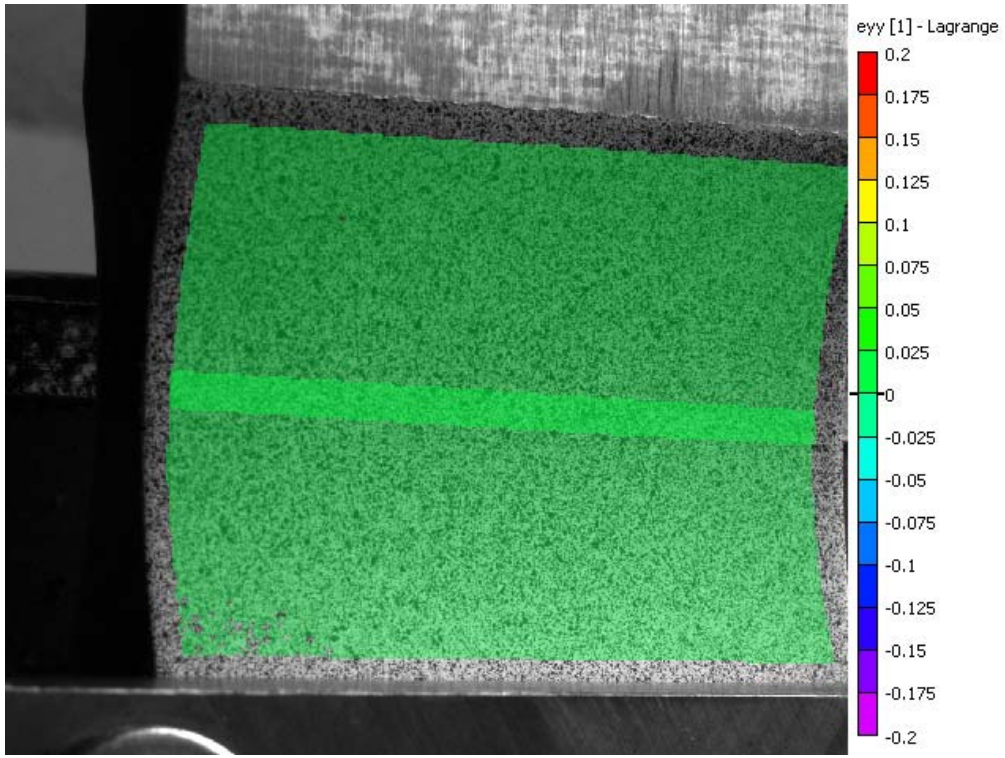
Fatigue – Very Low Cycle







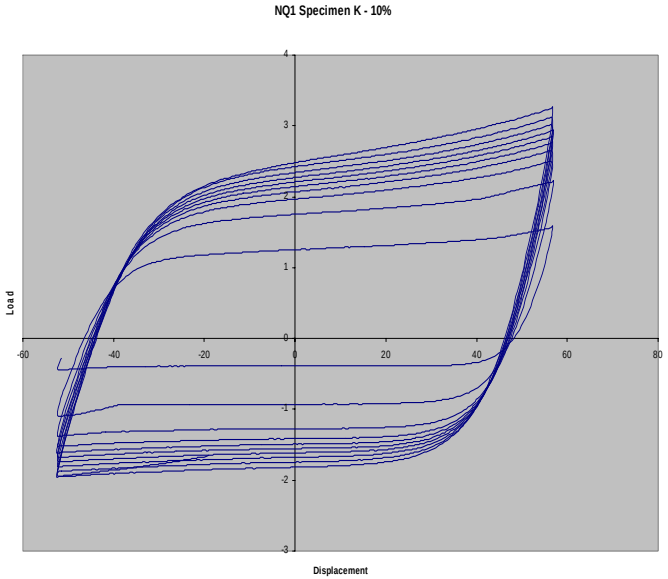
Fatigue – Very Low Cycle

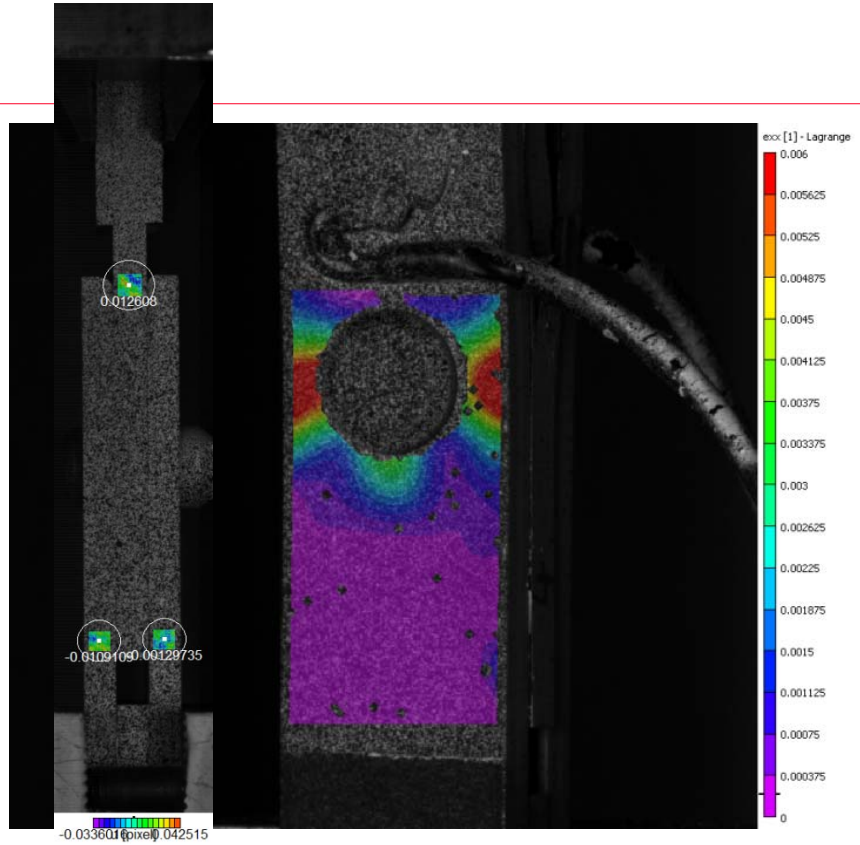


Low cycle fatigue of steel

-High Strain + /- 10%

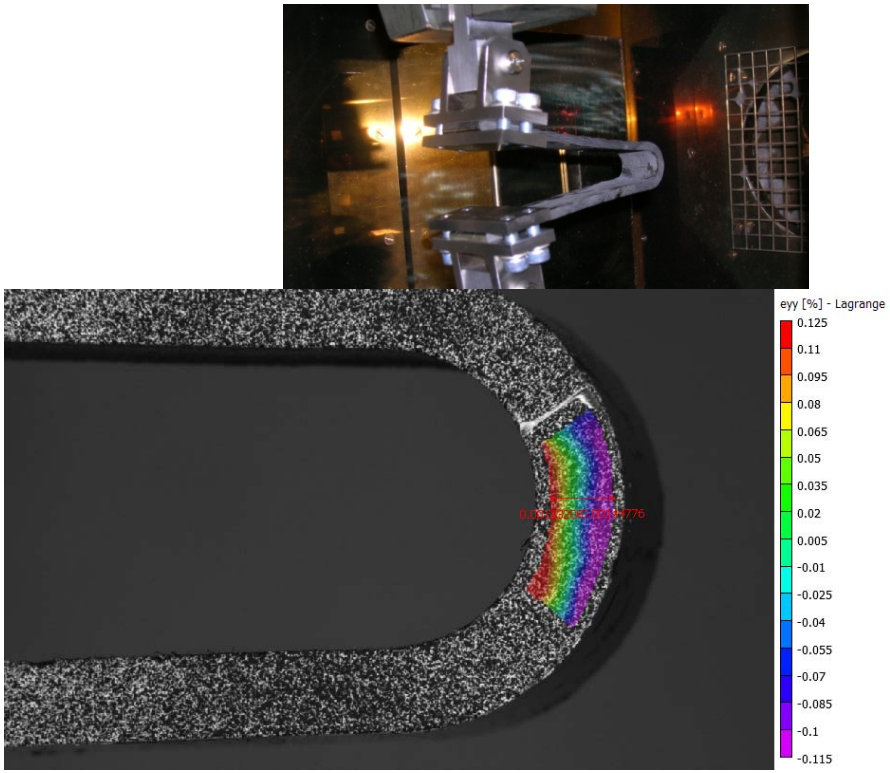
- Several cycles





High Rate Loading of Joints

- Loading rate up to 5m/s
-Displacement
- Strain Field
-Tested at Southampton University



Validation of Material FE Models

-Simple geometry
- Strain field
- Load and Displacement

Testing of Components

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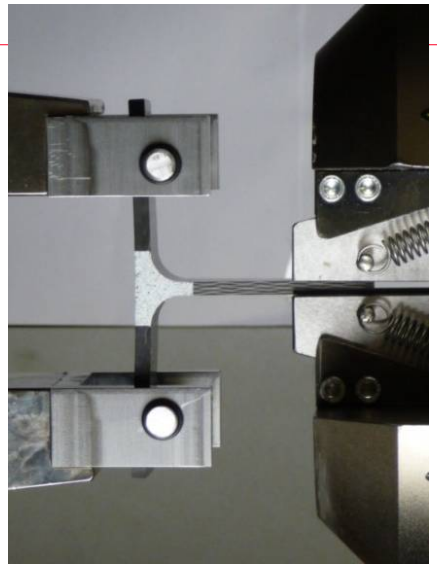
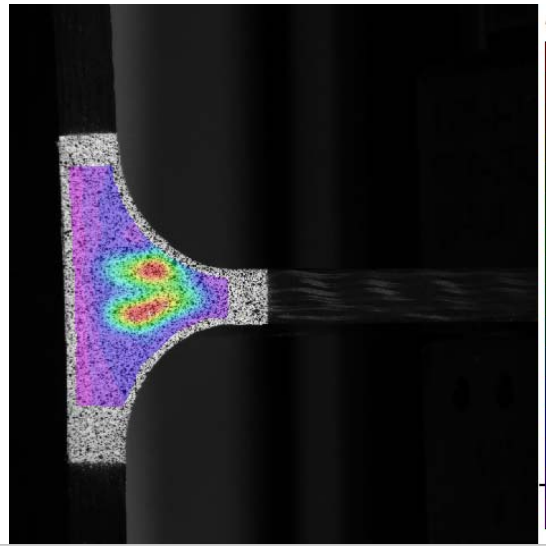
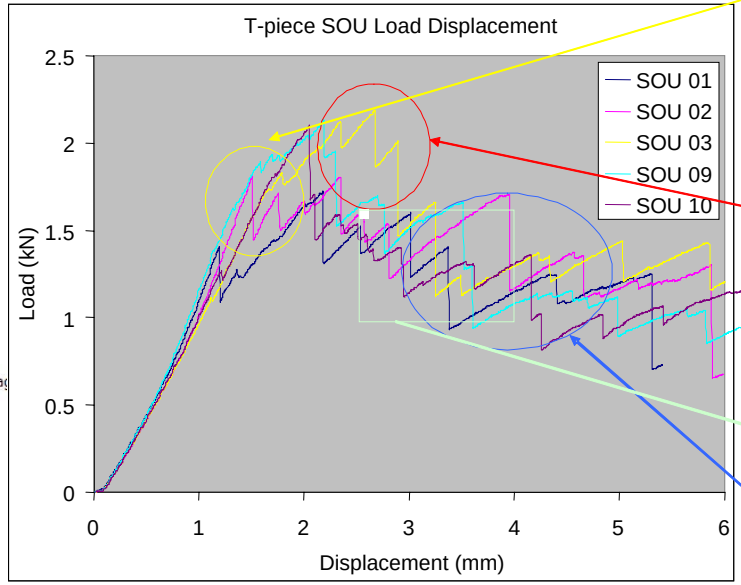




SOU Experimental Observations: Failure Order



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Observations: Crack initiation on the lateral bond-line between the 3D weave and deltoid region. Several small cracks appear prior to maximal loading surrounding main void.

Observations: At breaking load voids appear on the horizontal bond-line between weave and deltoid region. Failure of this combined with void growth represents absolute failure. Photos 17 and 18 are taken either side of absolute failure respectively.

Observations: The cracks start to propagate with each step representing staggered growth.
The change in gradient post-failure is the onset of other cracks appearing on the opposite side of the deltoid respective of the initial crack, this is seen as longer steps in load profile, please refer to pictures 23 and 24 for clarification of this. The Horizontal void grows along the length of the horizontal arms until sample de-layering.

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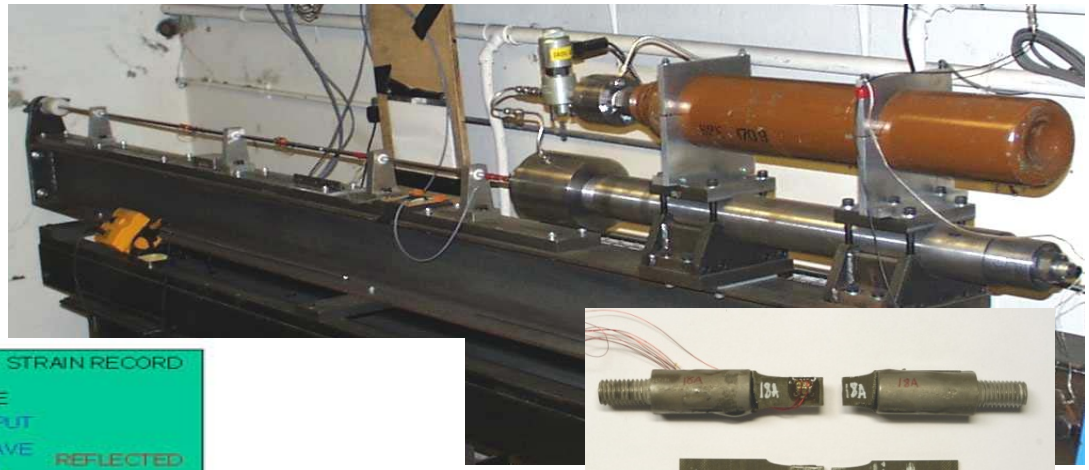
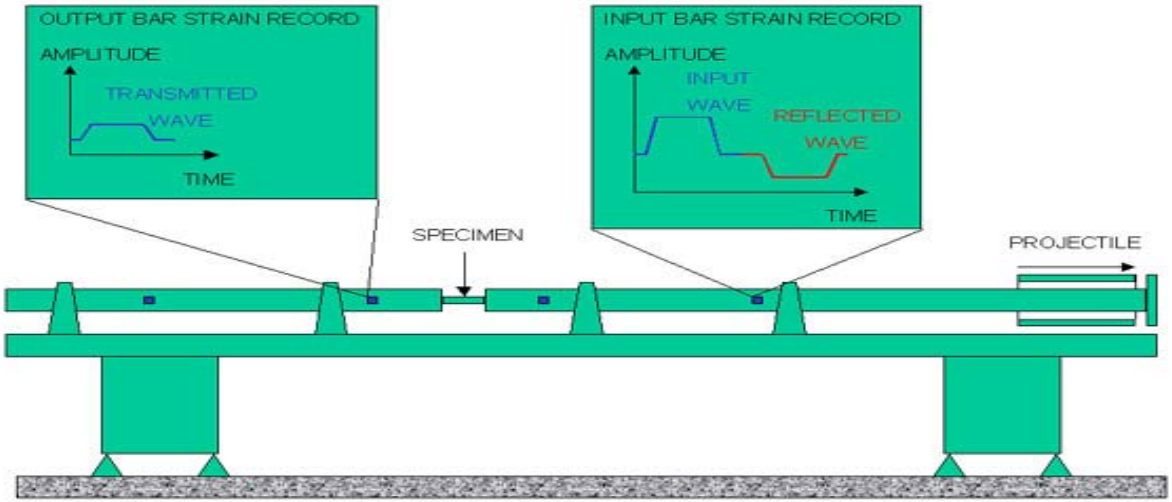
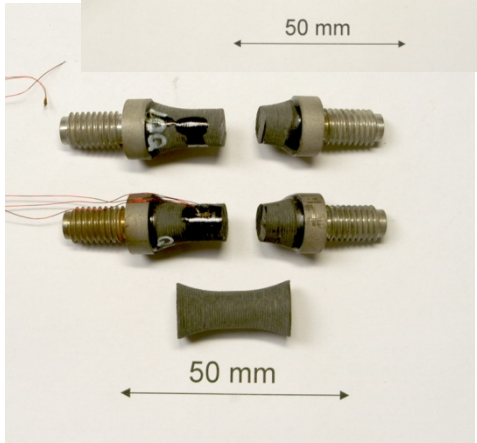
High Strain Rate Tests – Hopkinson Bar







- **Hopkinson pressure bar.**
- **High strain rate Tension and Compression to rates of >1000/s for Metals and Composites**
- **Materials Deformation and failure Models for FE Analysis**

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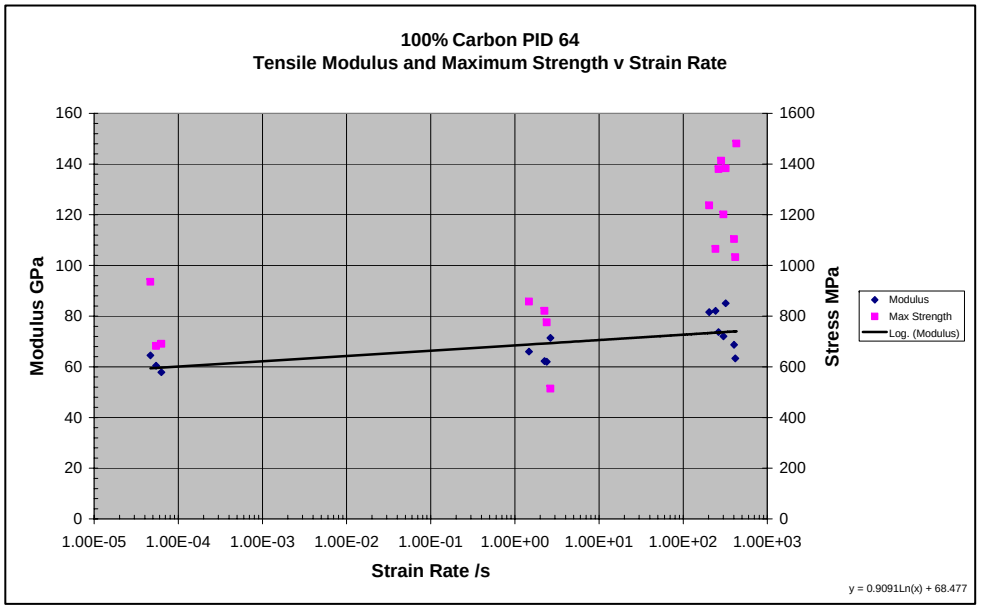
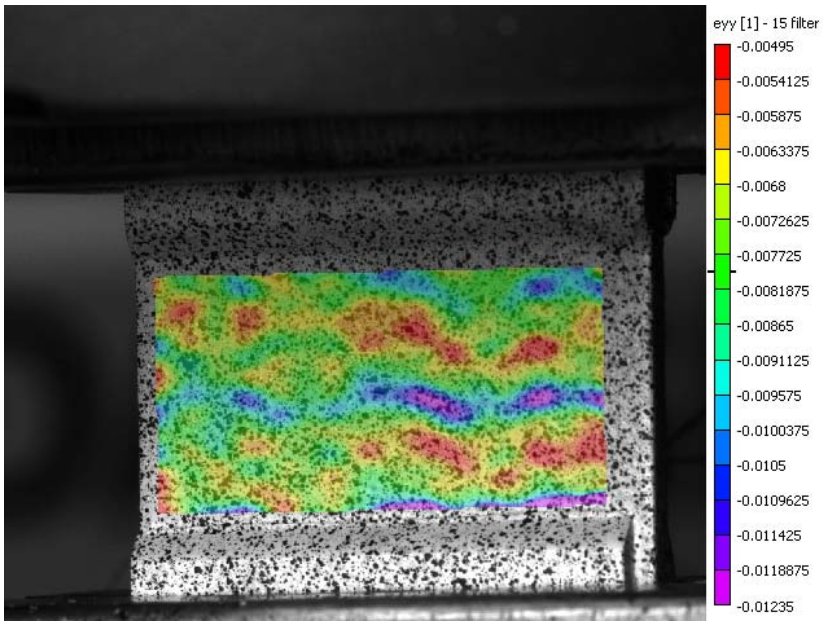
High Strain Rate Tests – 100% Carbon Fibre Composite

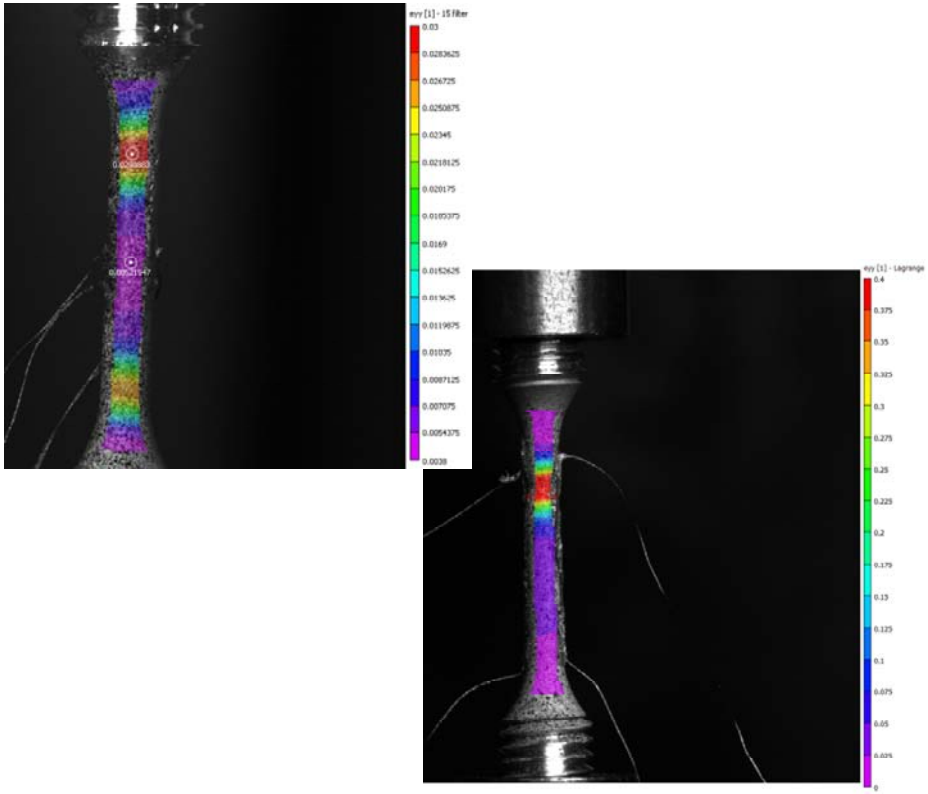
100% Carbon - Tension 0° Longitudinal Results			
Strain Rate	Tensile Modulus (E)	Fracture Strength (σ_f)	Failure Strain (ε_f)
Low Strain Rate (4.6 – 6.3 x10^{-5} /s)	60.9 ± 2.7 GPa	770 ± 117 MPa	0.0128 ± 0.0012
Intermediate Strain Rate (1.47 – 2.64/s)	65.4 ± 3.8 GPa	818 ± 34 MPa	0.0125 ± 0.0010
High Strain Rate (200 – 450/s)	63.3 GPa to 85 GPa	1032 to 1481 MPa	0.0128 ± 0.0015.



DIC – High Strain Rate Testing of Materials



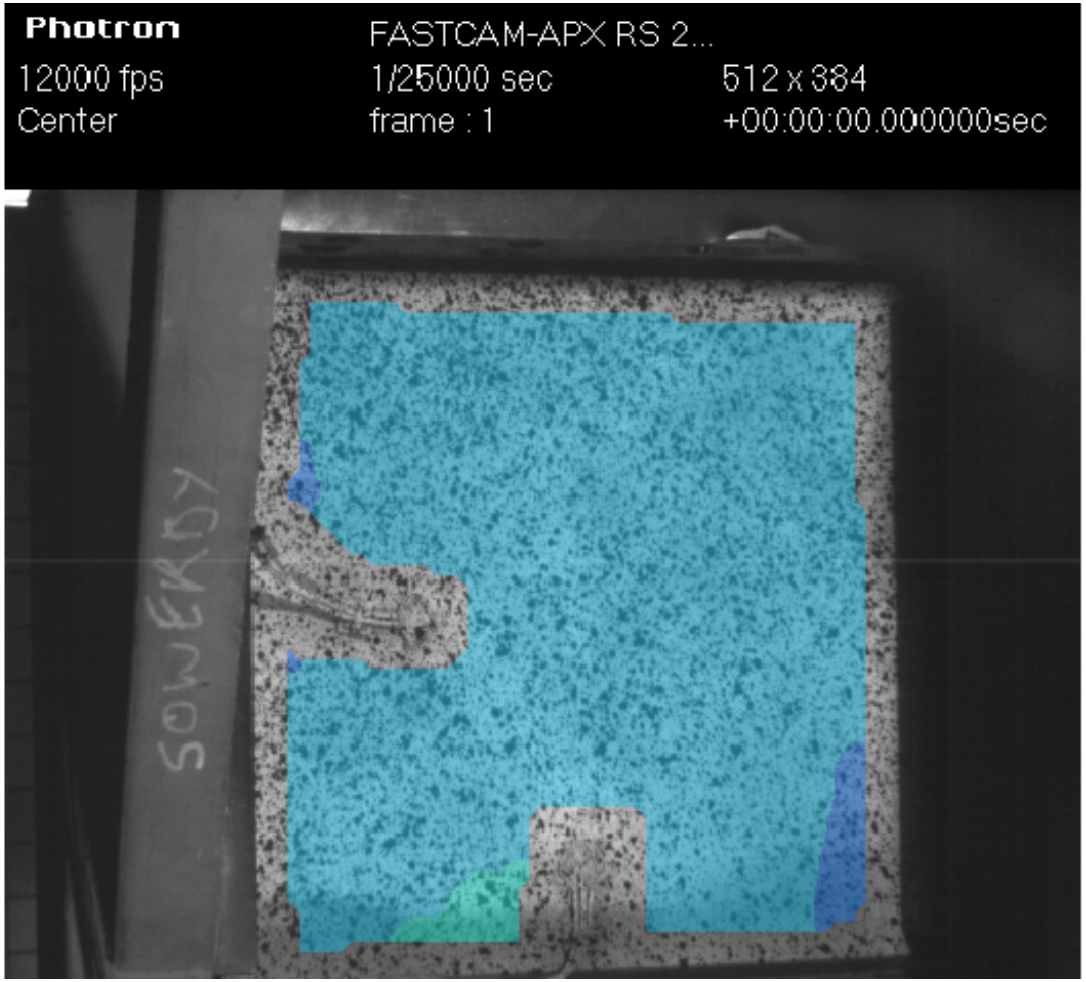
High rate compression of CFC

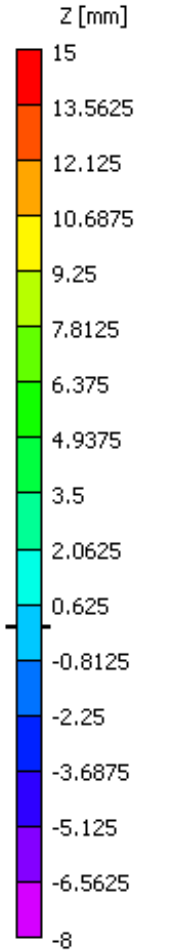


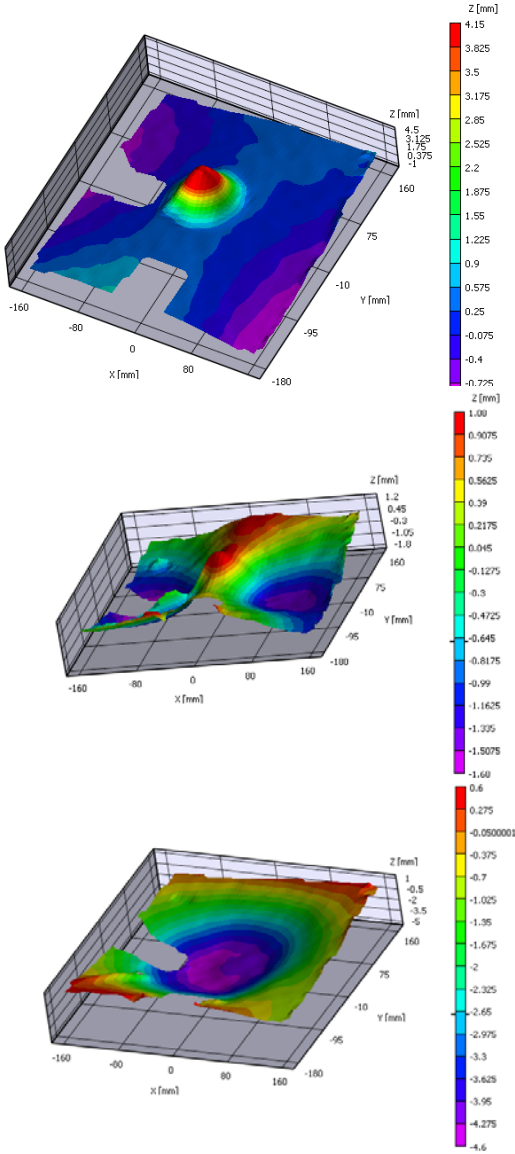
High rate tension of welded aluminium

- Necking and failure may not occur at the centre of the gauge length

High Speed Impact







Rear view of composite panel hit by steel projectile at 120m/s

Summary – Industrial Applications of DIC

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- Digital Image Correlation technique is a useful and valuable tool
- Complement strain gauge techniques
- Applied to static and dynamic events
- 2D and 3D
- Strain measurement
- Displacement measurement
- Reanalyse images
- Support validation of FE techniques

Limitations

- Resolution spatial and temporal
- Speckle pattern
- Calibration
- Analysis – can be expensive