DEPARTMENT OF ENGINEERING SCIENCE

Overview of current status and showcase activities

Dr Clive Siviour

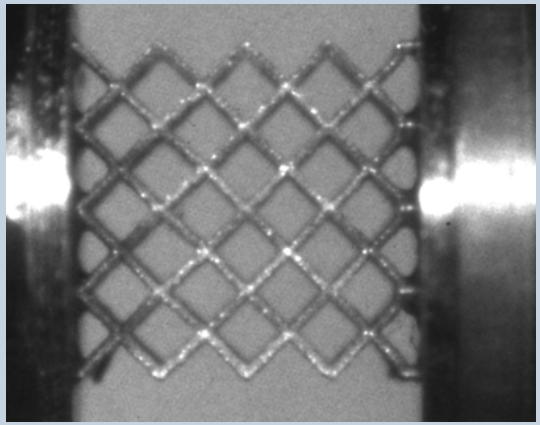
December 1, 2010

Introduction

- Overview of our uses and requirements for high speed photography.
  - Aims
    - Visualise Events
    - Reconstruct Specimens
    - Perform Measurements
- Overview of available cameras, not focussing on any specific camera, but general trends as perceived by the operator.
- Thoughts for the future.

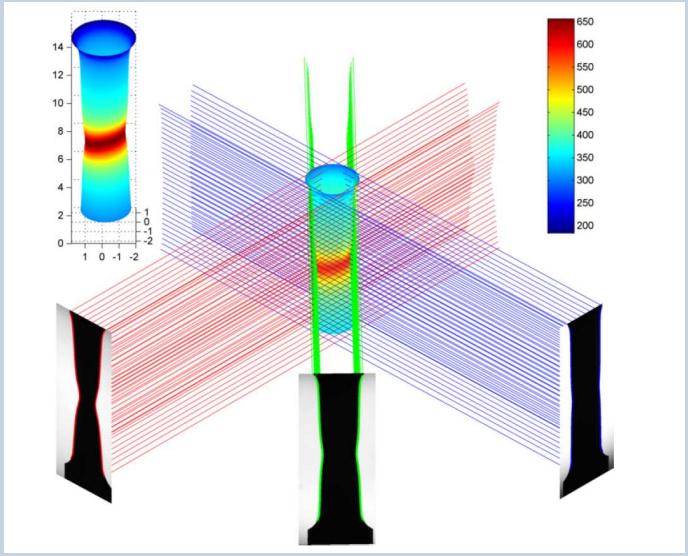
Aims

- Aims of High Speed Photography in Materials Characterisation
  - Visualise Events
  - Reconstruct Specimens
  - Perform Measurements



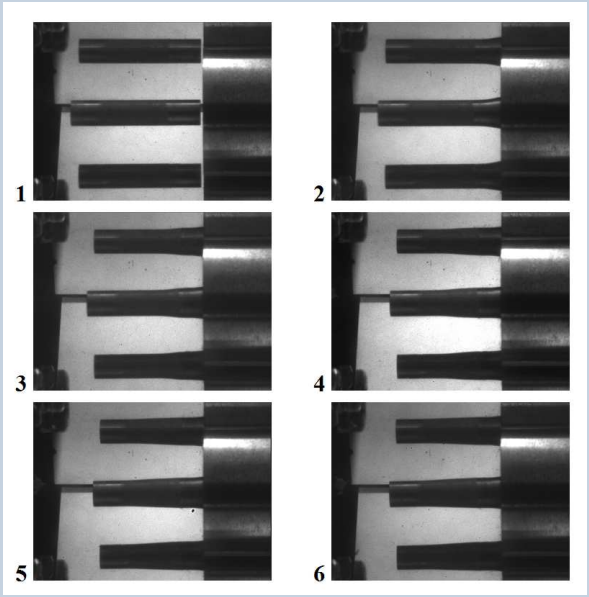
Aims

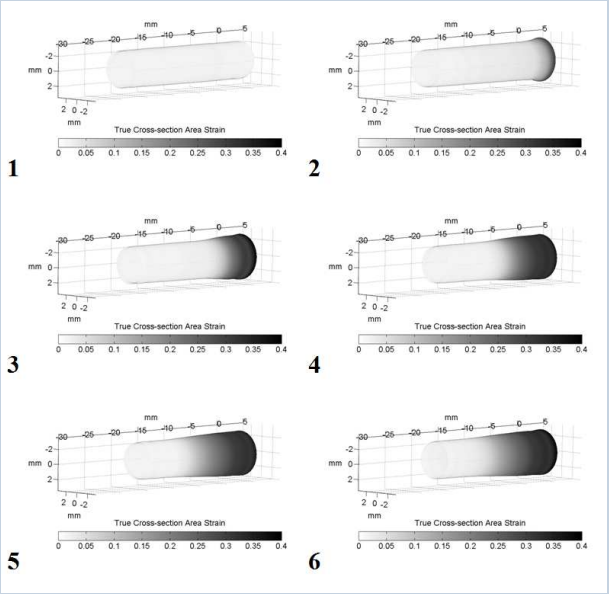
- Aims of High Speed Photography in Materials Characterisation
  - Visualise Events
  - Reconstruct Specimens
  - Perform Measurements



Aims

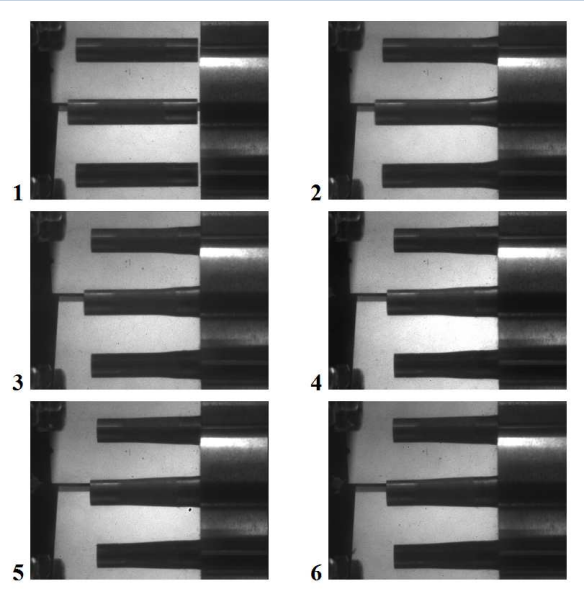
- Aims of High Speed Photography in Materials Characterisation
  - Visualise Events
  - Reconstruct Specimens
  - Perform Measurements

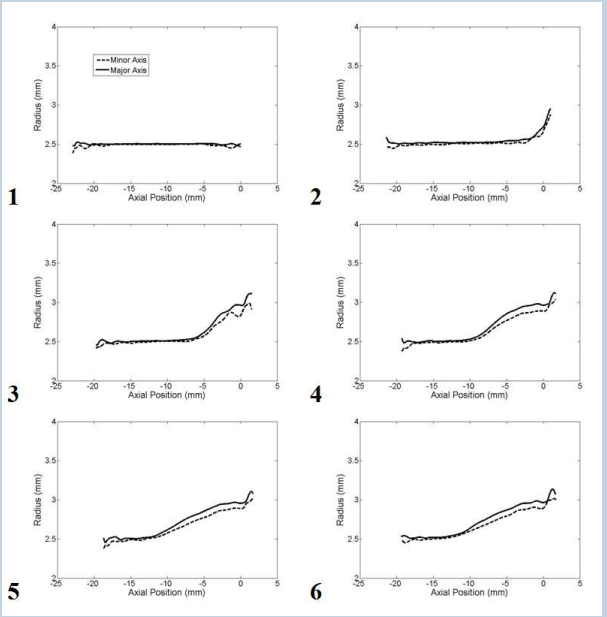




Aims

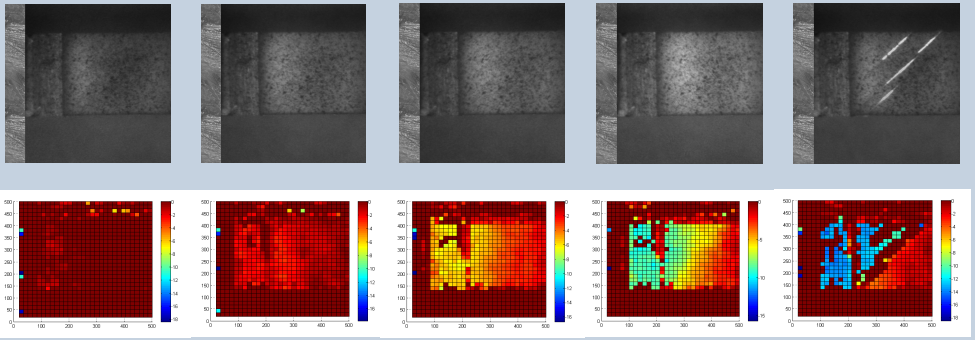
- Aims of High Speed Photography in Materials Characterisation
  - Visualise Events
  - Reconstruct Specimens
  - Perform Measurements





Aims

- Aims of High Speed Photography in Materials Characterisation
  - Visualise Events
  - Reconstruct Specimens
  - Perform Measurements



Visualise Events: Speeds

- Governing Speeds / Timescales

Crack Propagation	5 mm μs^{-1}	5 Mfps
Stress Wave Propagation	1-10 mm μs^{-1}	1-10 Mfps
Taylor Impact	20 µs	500 000 fps
Hopkinson bar experiment		
– Brittle Material	~20 µs	500 000 fps
– Ductile Material	~200 µs	50 000 fps
Ballistic Experiment	1 ms	10 000- 100 000 fps

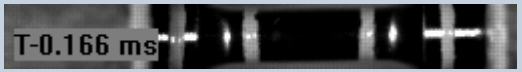
Visualise Events: Speeds

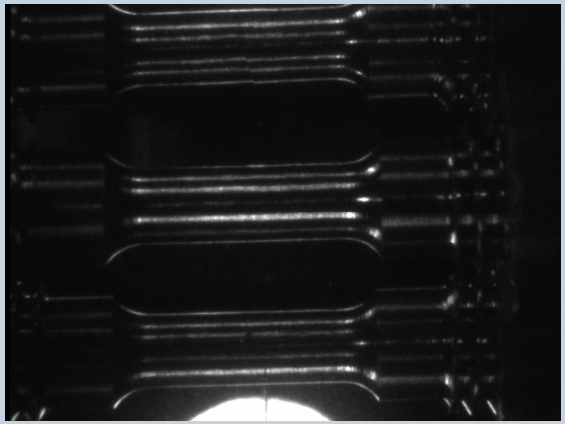
- Taylor Impact of Foam: A slow event

Visualise Events: Lengthscales

- Approximate specimen sizes
  - Taylor Impact — 25 mm long; 5 mm diameter
  - Hopkinson bar — 5-10 mm long; 5-10 mm diameter
  - Ballistic Impact — Zone of interest c.a. 20 mm diameter

- For tension tests, letterbox format is appropriate;
- For compression tests / reconstruction, letterbox less useful



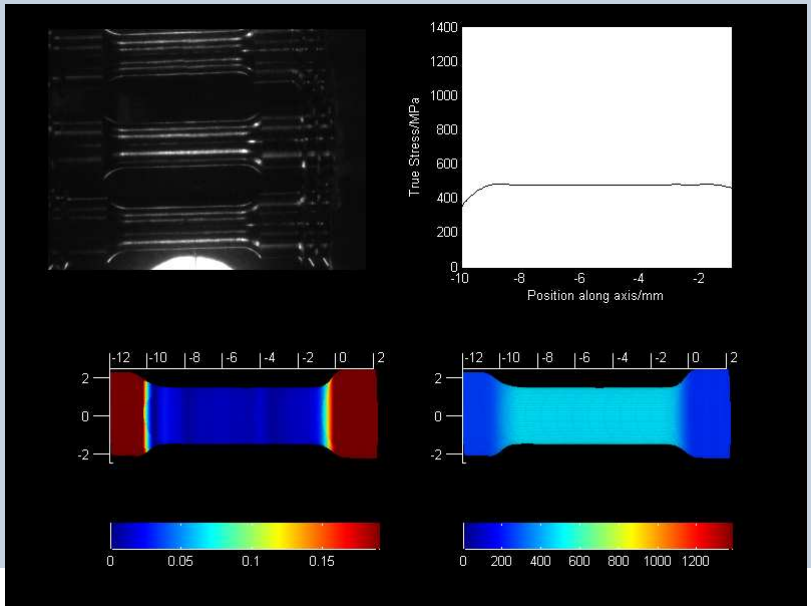


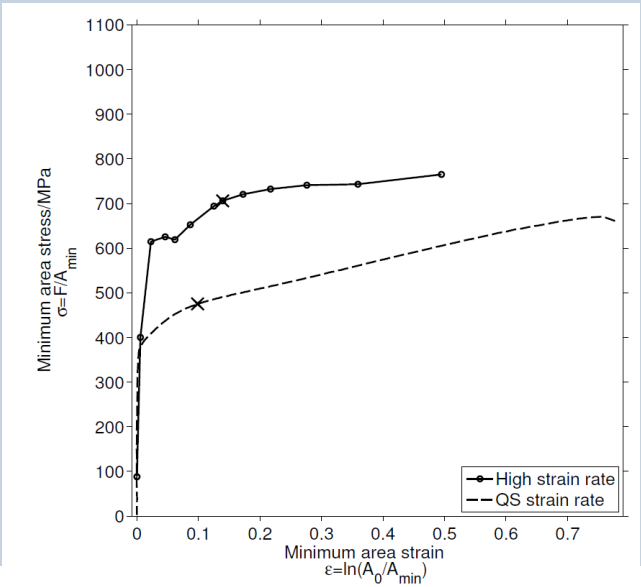
Visualise Events: Lengthscales

- Approximate specimen sizes
  - Taylor Impact — 25 mm long; 5 mm diameter
  - Hopkinson bar — 5-10 mm long; 5-10 mm diameter
  - Ballistic Impact — Zone of interest c.a. 20 mm diameter
- For tension tests, letterbox format is appropriate;
- For compression tests / reconstruction, letterbox less useful
- However
  - Increasing interest in microstructural effects: shorter lengthscales
    - Larger magnifications
    - Shorter timescales
    - Need lots of light!
  - E.g. ability to resolve features of order 10 μm desirable.

Reconstruct Geometry

- For example, in tensile tests or Taylor Impact.
  - Geometry Reconstruction allows true stress-strain response
- For our applications, especially tensile test, current limit is number of photos, more than speed or resolution.





Performing Measurements

- DIC can be used to obtain displacements with sub-pixel displacement resolution.
  - Commercially available codes claim 1/100 to 1/1000 pixels.
  - Achievable with current high speed imaging?
  - E.g. Fabrice talk this morning: 0.2 pixel, improved by smoothing
- Resolution limited by noise, both between sensors and in a single sensor between images:
  - image intensifier, vibration from moving parts, pixel intensity variation, etc.
- Also distortion (e.g. from lens), but this can be corrected by appropriate calibration.
- Other limits: e.g. difficulty of producing appropriate high quality speckle patterns on many specimens; lighting issues.

Performing Measurements

- Good data important, because we want to differentiate data:
  - With respect to position for strain.
  - With respect to time (twice!) for velocity and acceleration.
  - Again, often limited by *number of images*.

Imaging systems and capabilities (very approximate!)

- High speed video
  - High quality images (both resolution and number of pixels).
  - Generally easy to use and transport.
  - Large number of frames (measured in seconds, not frames!)
  - Resolution and Speed trade off, e.g.
    - 10 000 fps at 640 x 480
    - 100 000 fps at 128 x 128
    - 500 000 fps at 32 x 32
  - Post-triggering possible.
  - Low Cost!

Imaging systems and capabilities (very approximate!)

- ‘Intermediate’
  - Up to 100 frames at full resolution up to 1 M fps
  - Post trigger possible

- Ultra high speed
  - Speeds of 200 M fps
  - Typically use image intensifiers: 1 M pixel sensor but lower resolution
  - Range from 8-32 frames.
  - No post triggering: although you can’t post-trigger your flash either!
  - More costly.

Imaging systems and capabilities (very approximate!)

- Streak
  - Streak offers many advantages for uniaxial characterisation.
  - Traditionally streak systems are very fast, e.g ps / mm, and expensive.
  - Digital system producing up to 520 000 lps is available at reasonable cost.
- Infra Red
  - Speeds of 32000 fps in commercial systems.
  - Higher speeds are less sensitive (no infra-red flash).
  - In house ultra high speed system has also been built (8x8 pixels at 1 M fps).
- X-ray
  - Flash X-ray systems available, but single shot and lower resolution.

Limitations as *I* see them

- Speed vs resolution vs # frames vs noise
  - My ideal camera:
    - 10 Mfps
    - Single detector, non-intensified, no fibre optics
    - 1000 * 2000 pixels minimum
    - a range of triggering options
  - My ideal flash
    - Bright!
    - Long duration!
- Cost, especially as we move to more stereoscopic work.

Useful Info

- Buying a camera is something that we can only do rarely.
- It’s worth getting it right!
- Use the EPSRC Engineering Instrument Pool!

http://www.eip.rl.ac.uk/