Dynamic behaviour of lightweight materials based on high speed imaging

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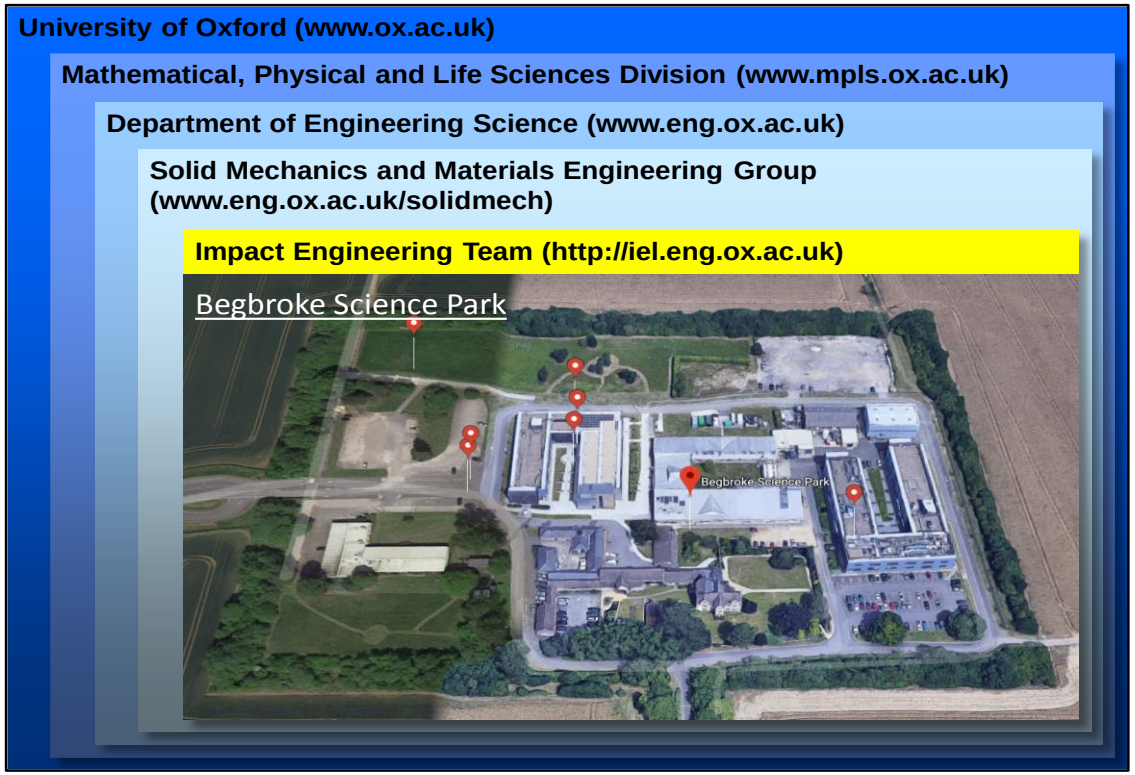
- Introduction to the Impact Engineering Team at Oxford
- Typical research activities based on high speed imaging
- Ballistic impact testing programme
- Some challenges and solutions
- Some problems to be addressed
- Summary

1. Introduction – Impact Engineering Team (IET)

- Impact Engineering Team (http://iel.eng.ox.ac.uk)
  - Leading by Prof Nik Petrinic and Dr Antonio Pellegrino
  - 9 postdoc researchers + 4 DPhils + 5 supporting members
  - Collaboration with 28 academic institutions, 30 industry partners and 9 government bodies

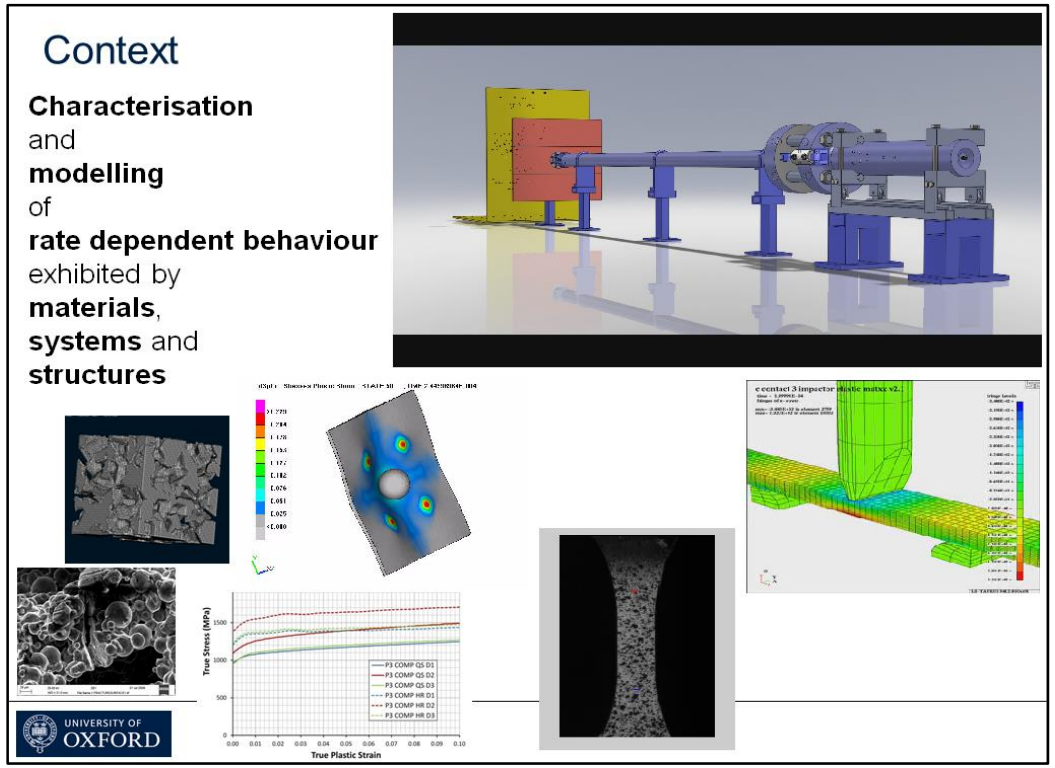


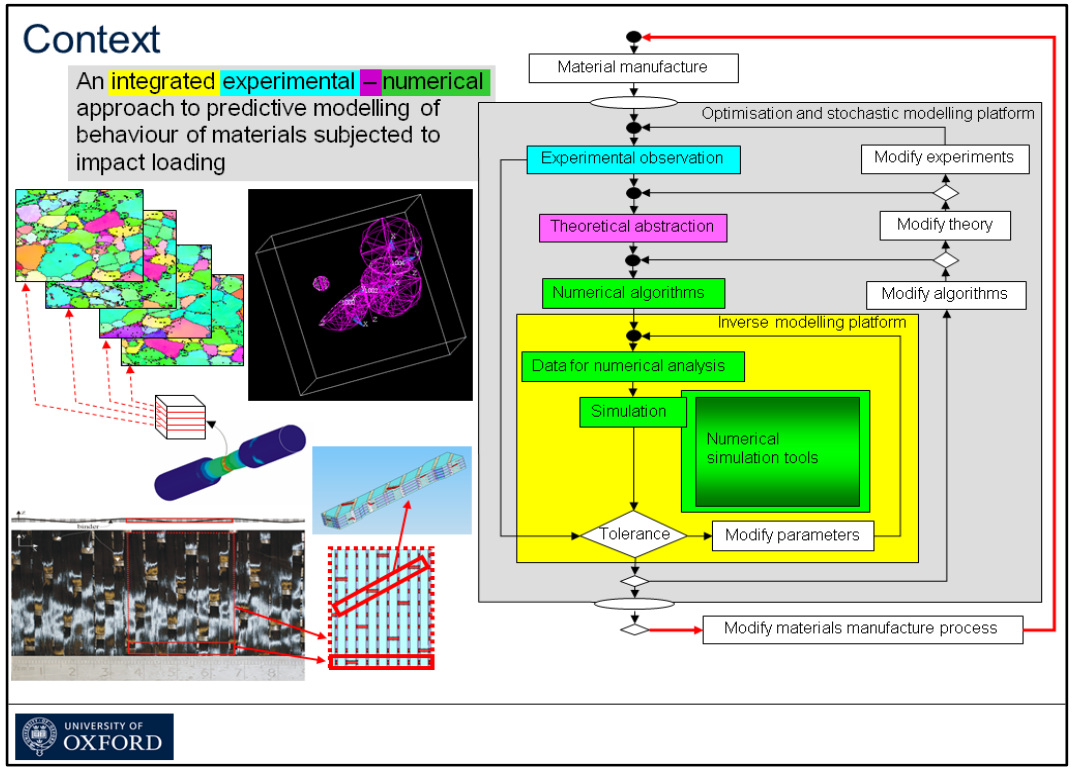
Prof Nik Petrinic

Dr Antonio Pellegrino

1. Introduction – Impact Engineering Team (IET)

- The main mission: development of methods for
  - Characterisation of materials at different strain rates
  - Numerical modelling of impact-loaded materials and structures
- The ultimate goal: development of advanced tools for impact-related problems



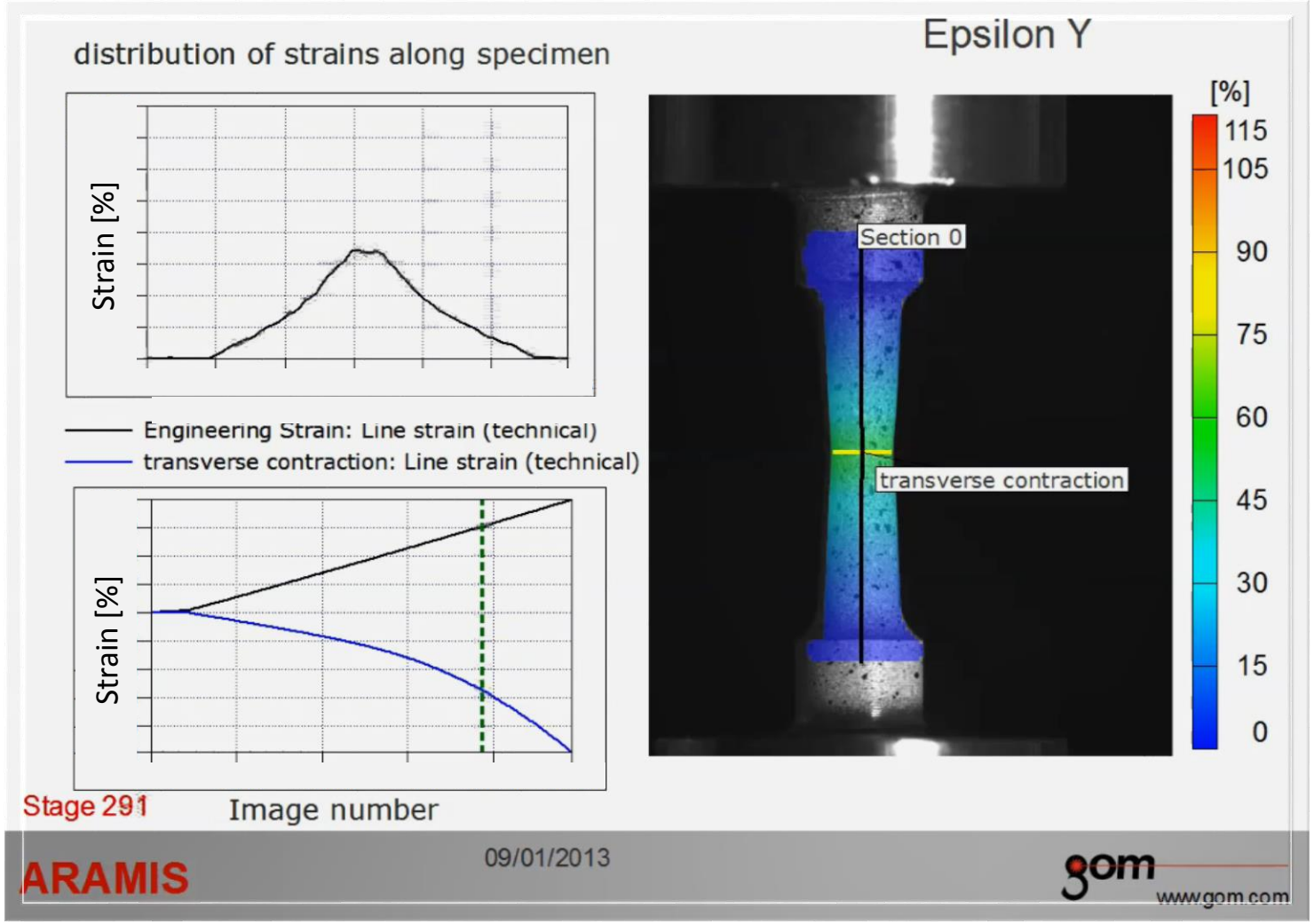


1. Introduction – Impact Engineering Team (IET)

- Experimental facilities
  - Equipment for low/medium rate testing: 2 ZWICK machines + 1 INSTRON machine
  - Equipment for high strain rate testing: 6 Hopkinson bars (5 in service, 1 in construction)
  - Equipment for low/high velocity impact testing: 1 drop weight tower + 4 gas guns
  - Equipment for environmental conditioning: low/high temperatures and humidity

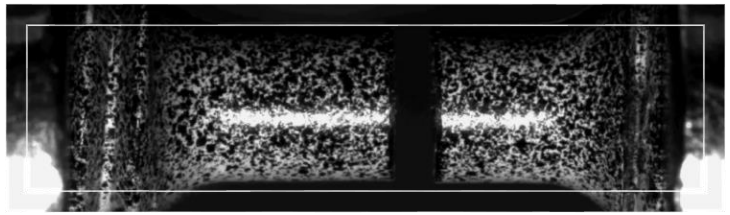
2. Typical research activities based on high speed imaging

- Characterisation of **Titanium Alloys**, Polymers and Composite Materials

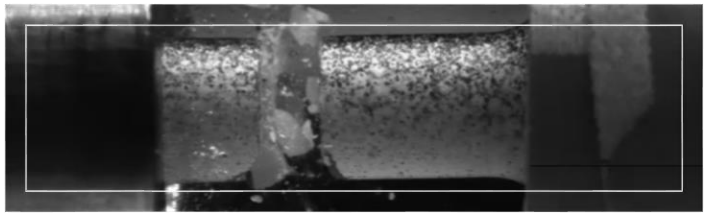


2. Typical research activities based on high speed imaging

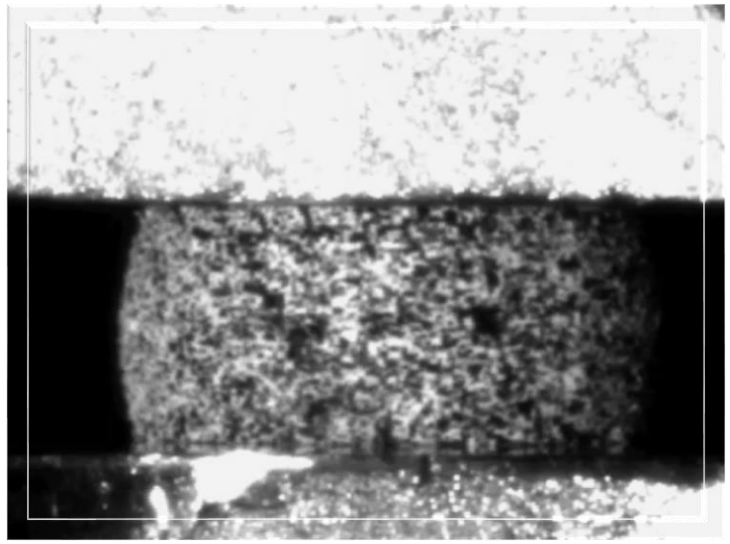
- Characterisation of Titanium Alloys, **Polymers** and Composite Materials



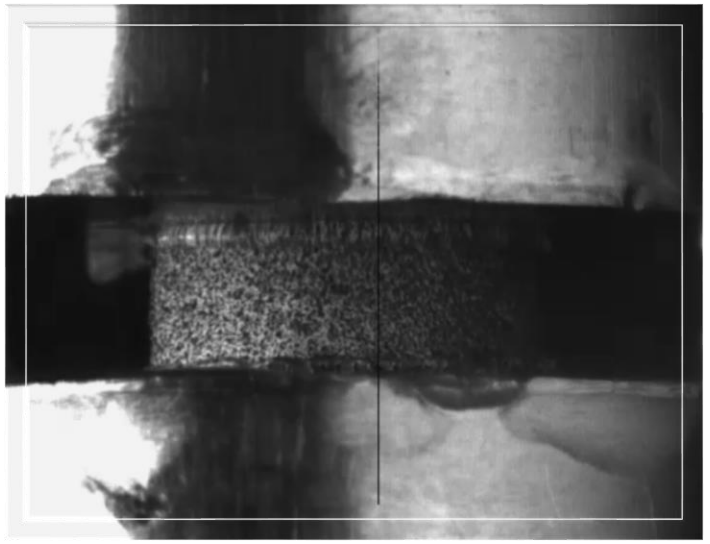
QS Tension



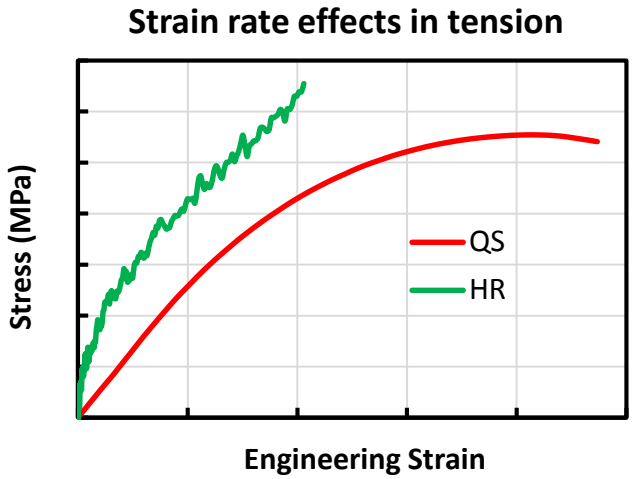
HR Tension

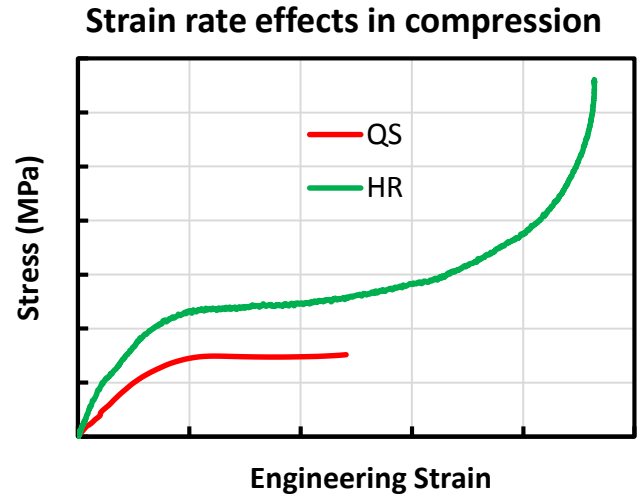


QS Compression



HR Compression





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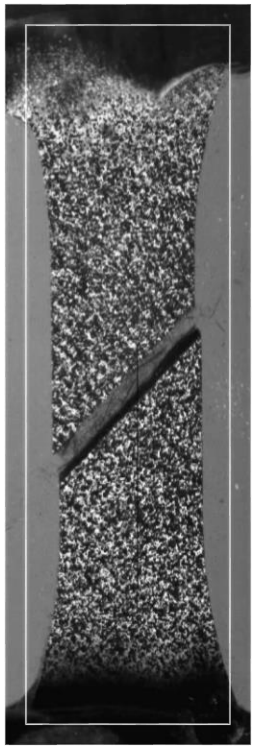
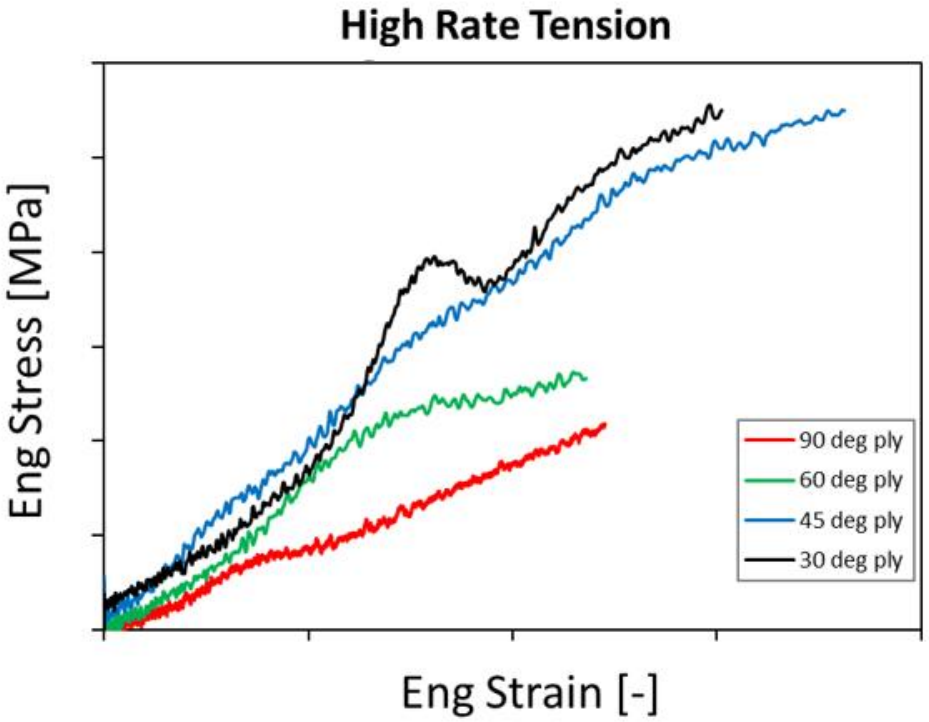
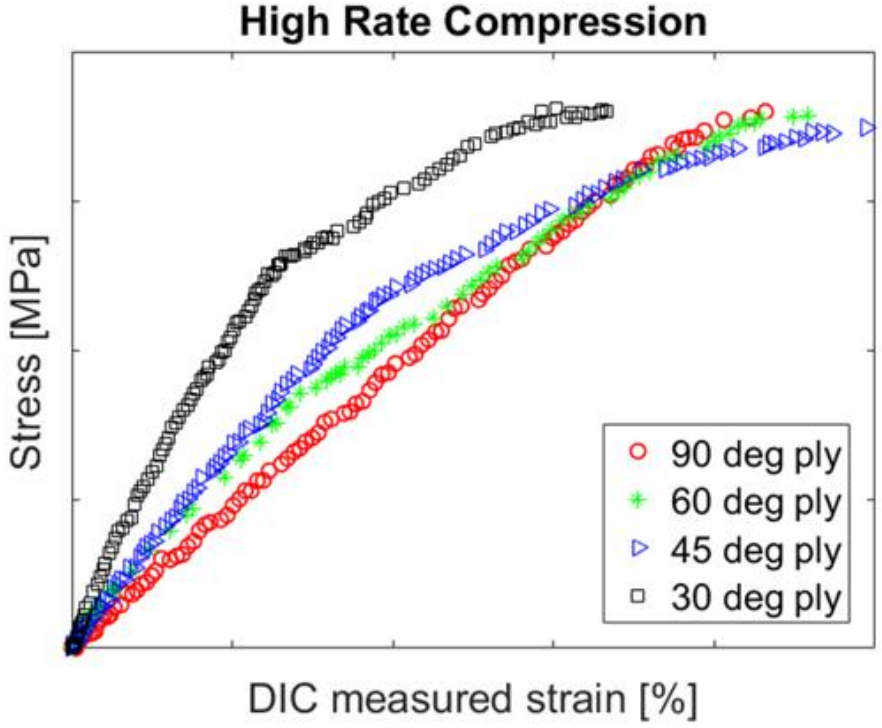
- Characterisation of Titanium Alloys, Polymers and **Composite Materials**

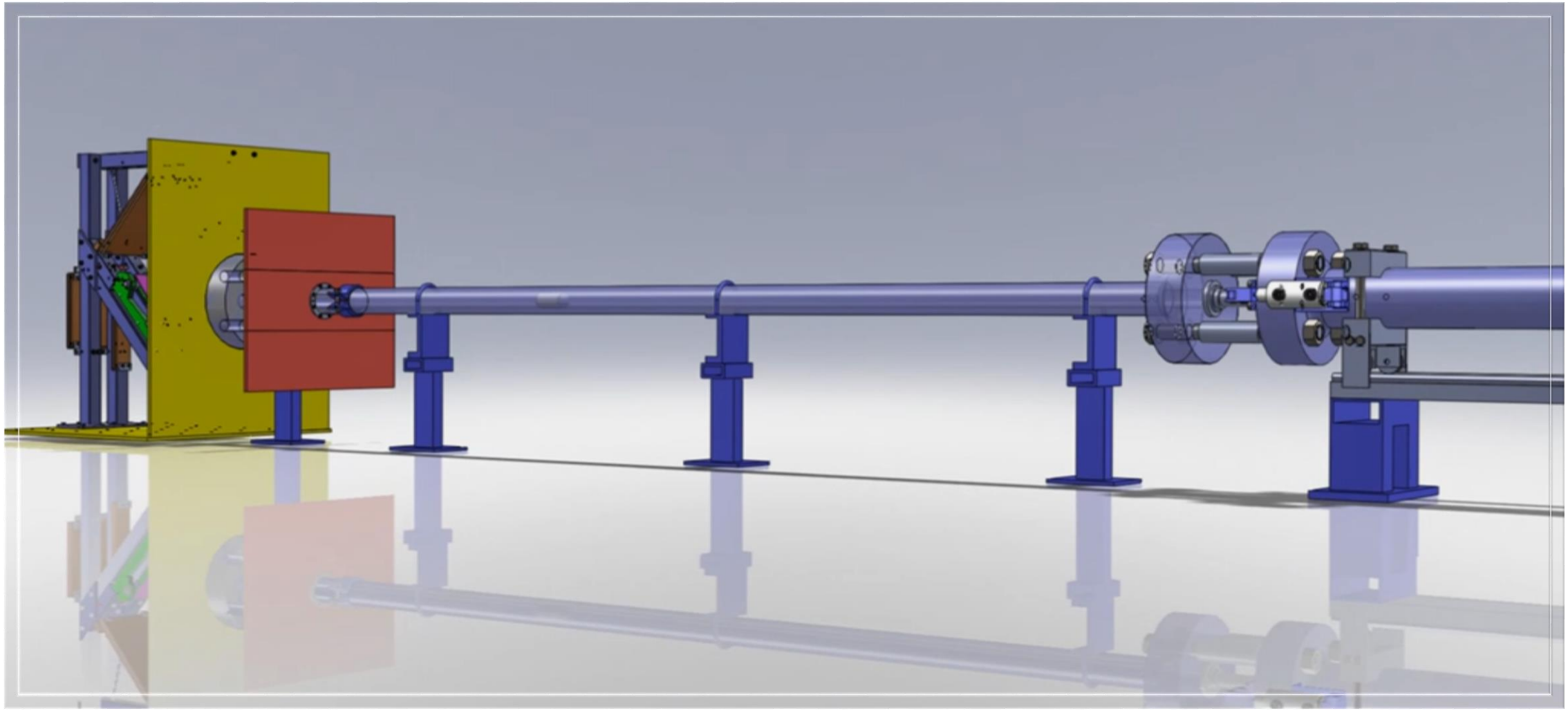






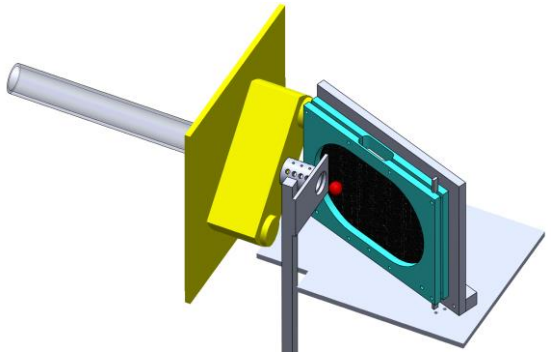
2. Typical research activities based on high speed imaging

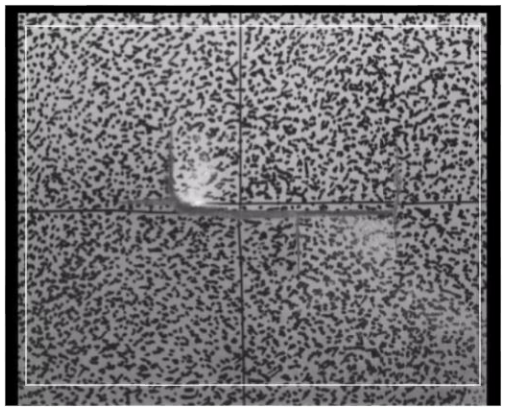
- Experimental evaluation of impact performance with gas guns

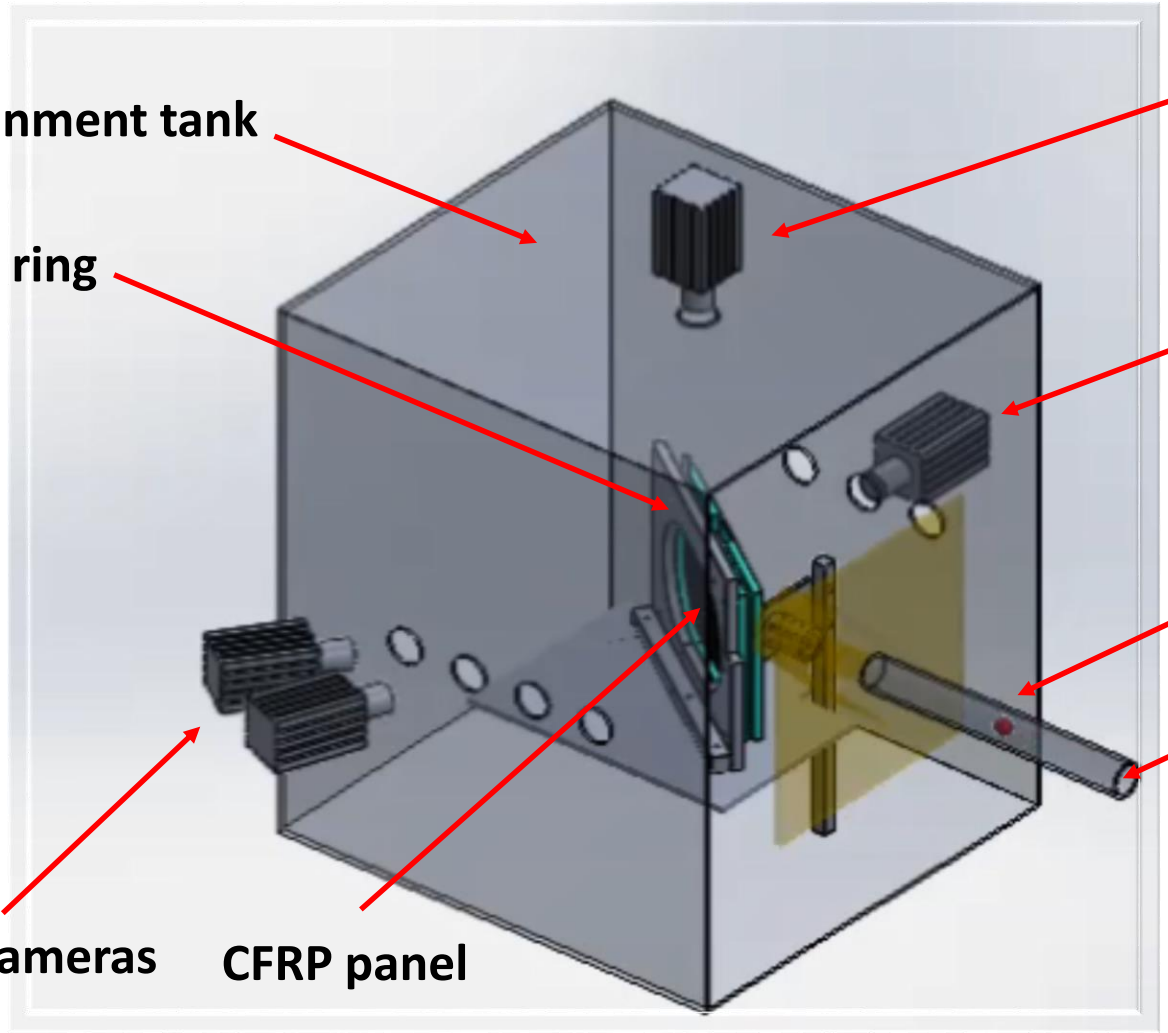


3. Ballistic impact testing programme

- Aim: the impact performance of composites with different architectures

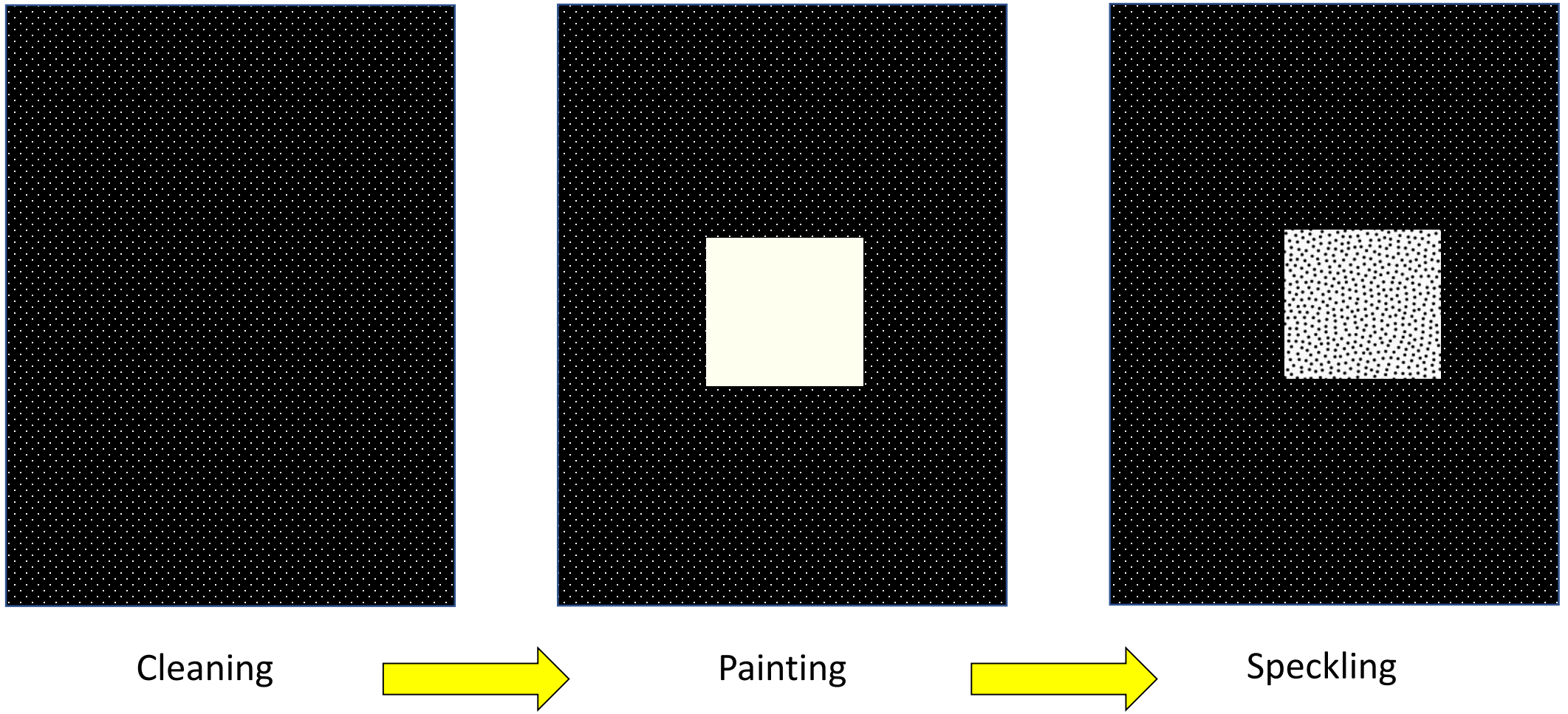






3. Ballistic impact testing programme

- Procedure: **Panel preparation** | Installation | DIC calibration | Testing | Data analysis



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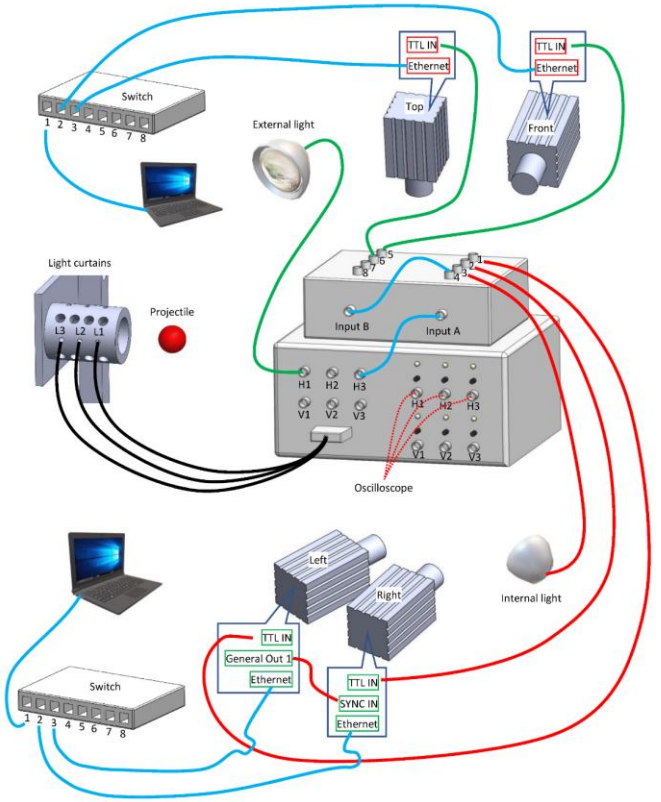

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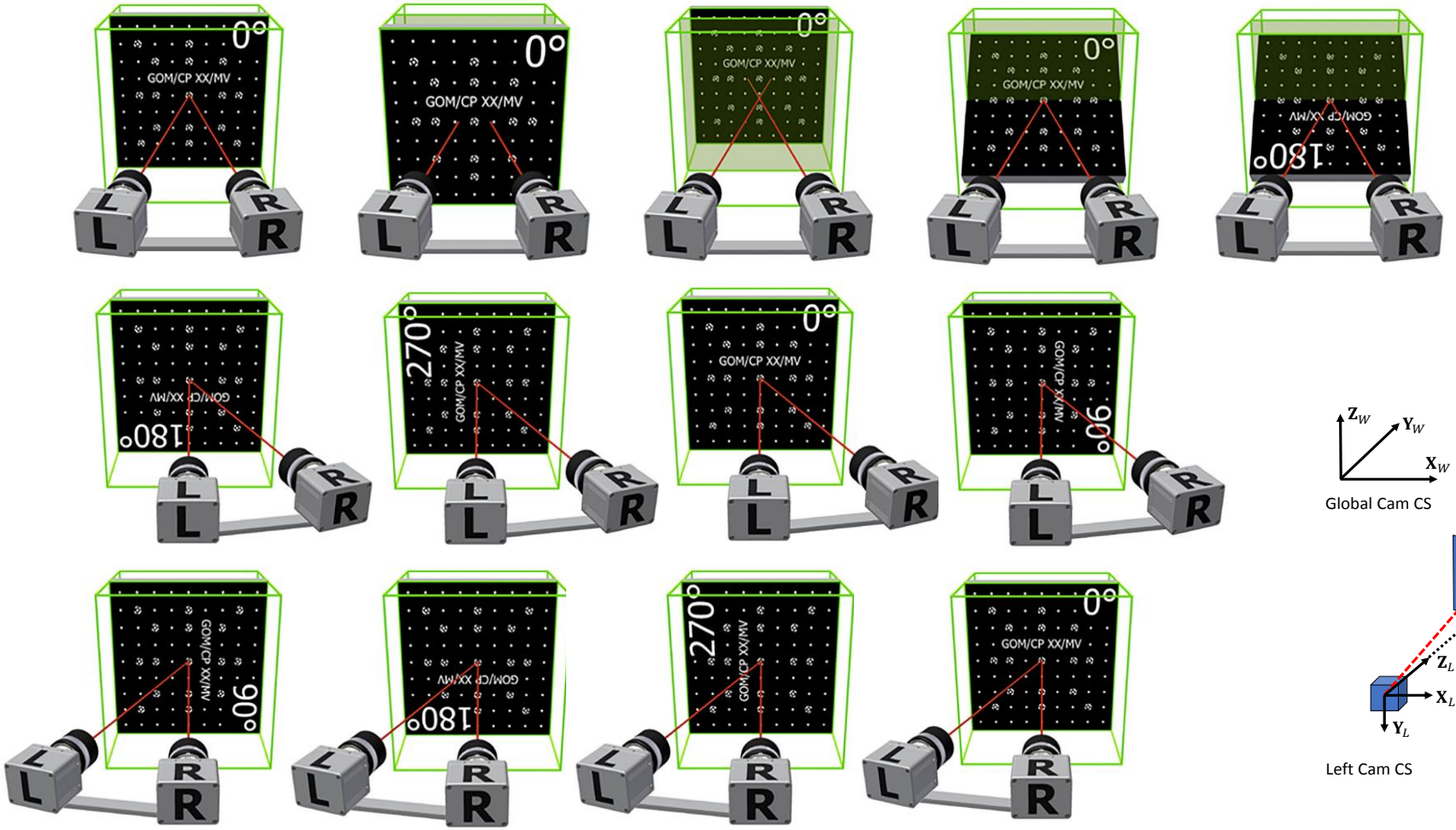

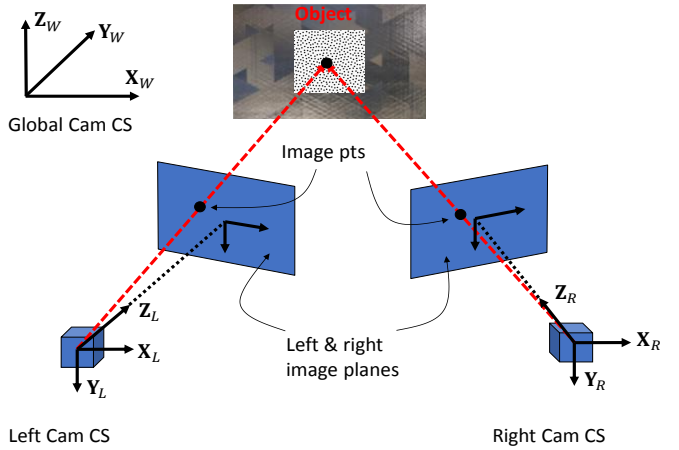

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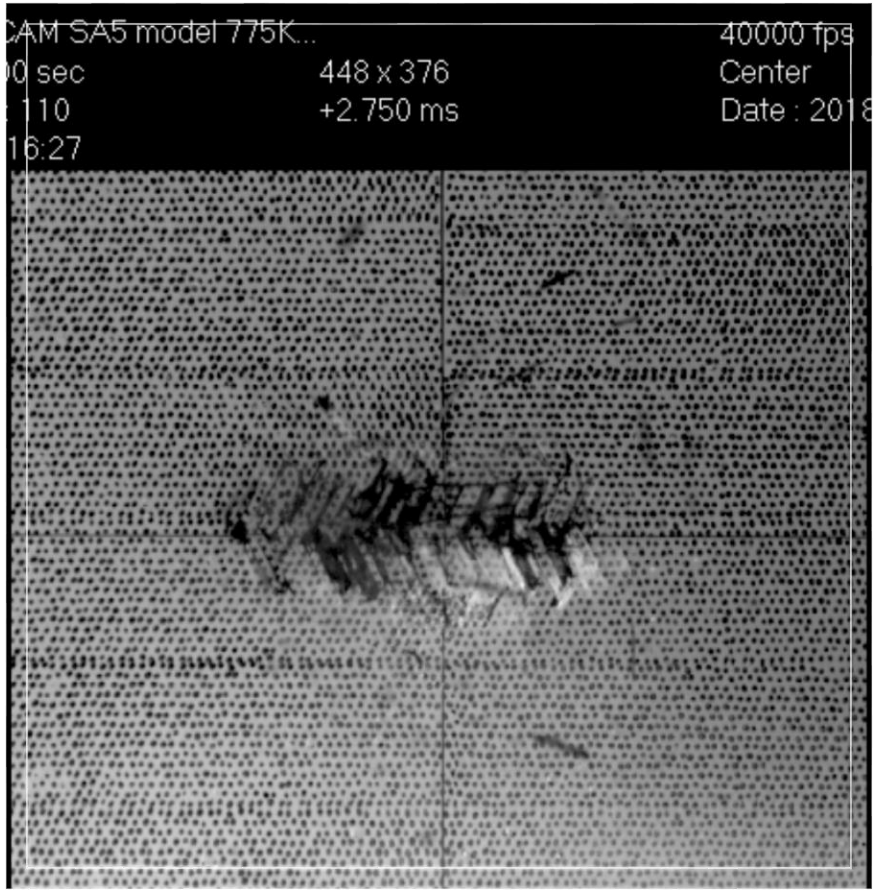

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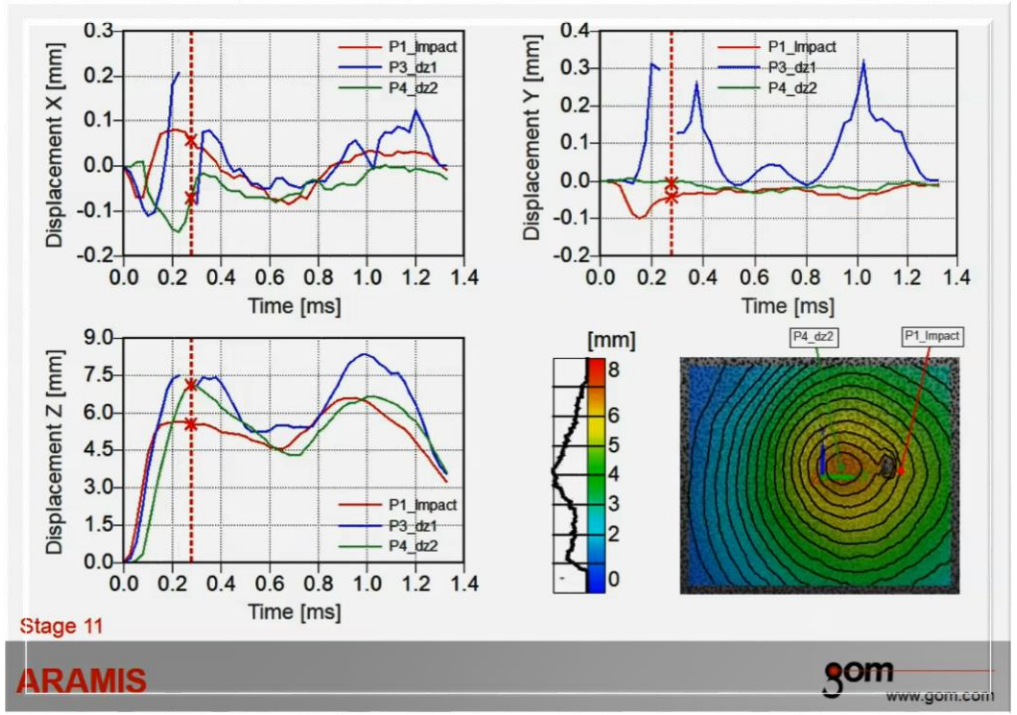
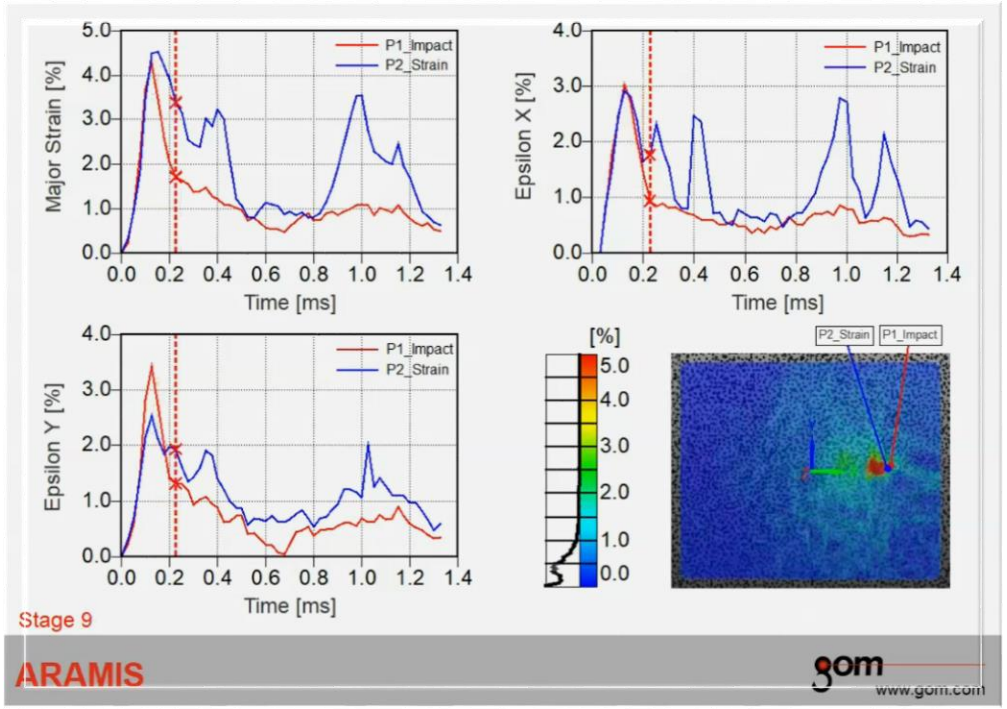




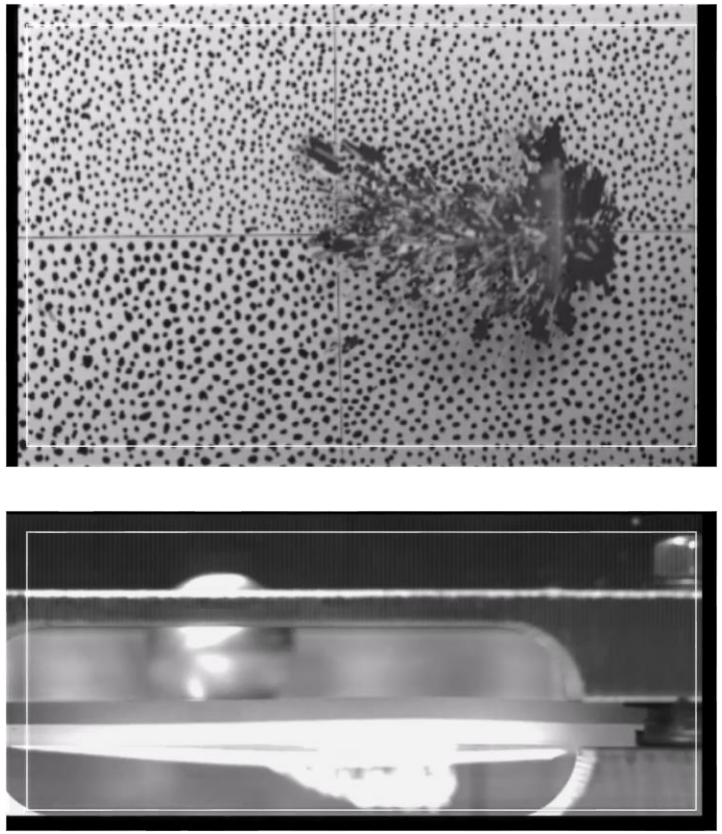
Deformation analysis
- Displacement X
- Displacement Y
- Displacement Z
- Deformation contour

Points of interest
- Initial impact point
- Primary deformation point
- Secondary deformation point
- Peak strain before failure point

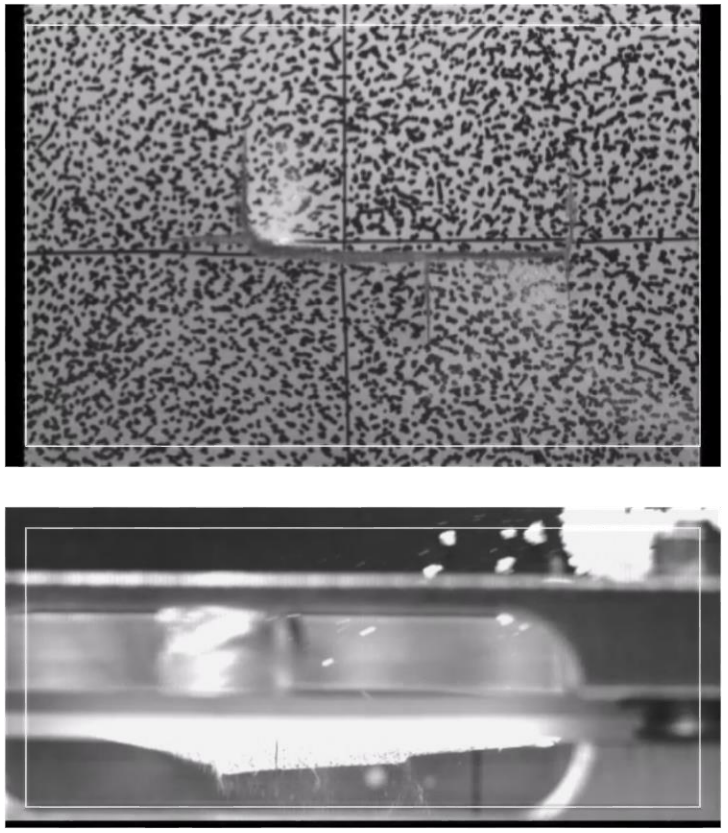
Strain analysis
- Major strain
- Strain X
- Strain Y
- Strain contour

4. Some challenges and solutions

- **Painting** and speckling of large specimens
  - Challenge: Primer paints do not stick well on impacted specimens
  - Solution: Utilisation of a layer of epoxy resin before applying the primer



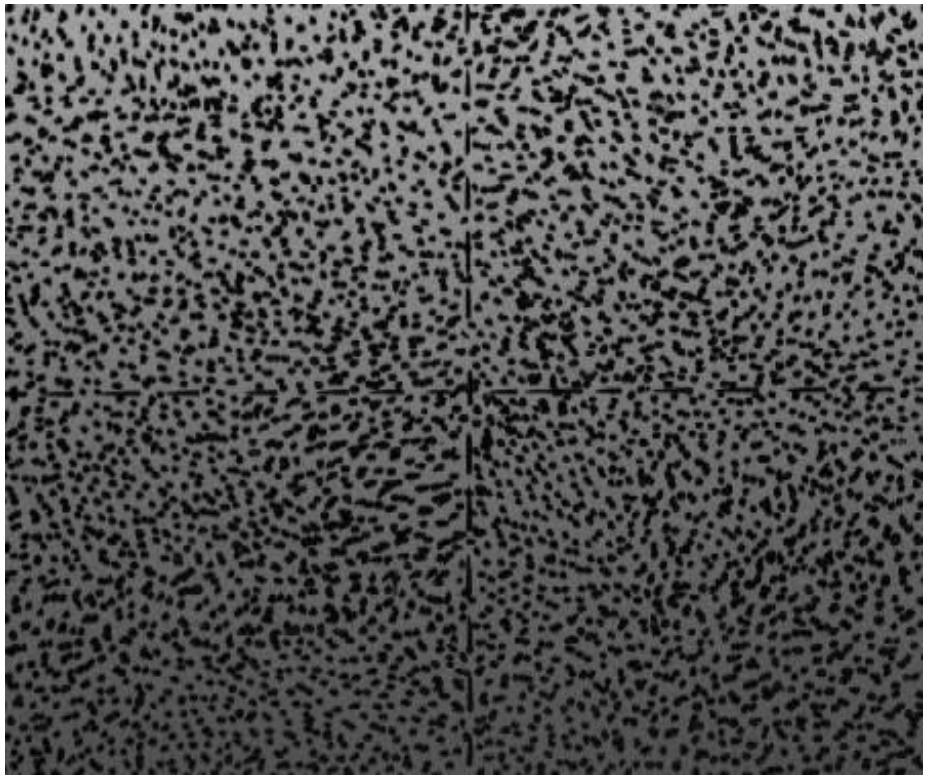
Primer only



Epoxy resin + primer

4. Some challenges and solutions

- Painting and **speckling** of large specimens
  - Challenge: Manual speckling (150 mm * 150 mm) → 10,000 dots → 2 hours for speckling
  - Solution: Stamp speckling → completed in minutes (a reduced randomness)



Manual speckling

Stamp speckling

4. Some challenges and solutions

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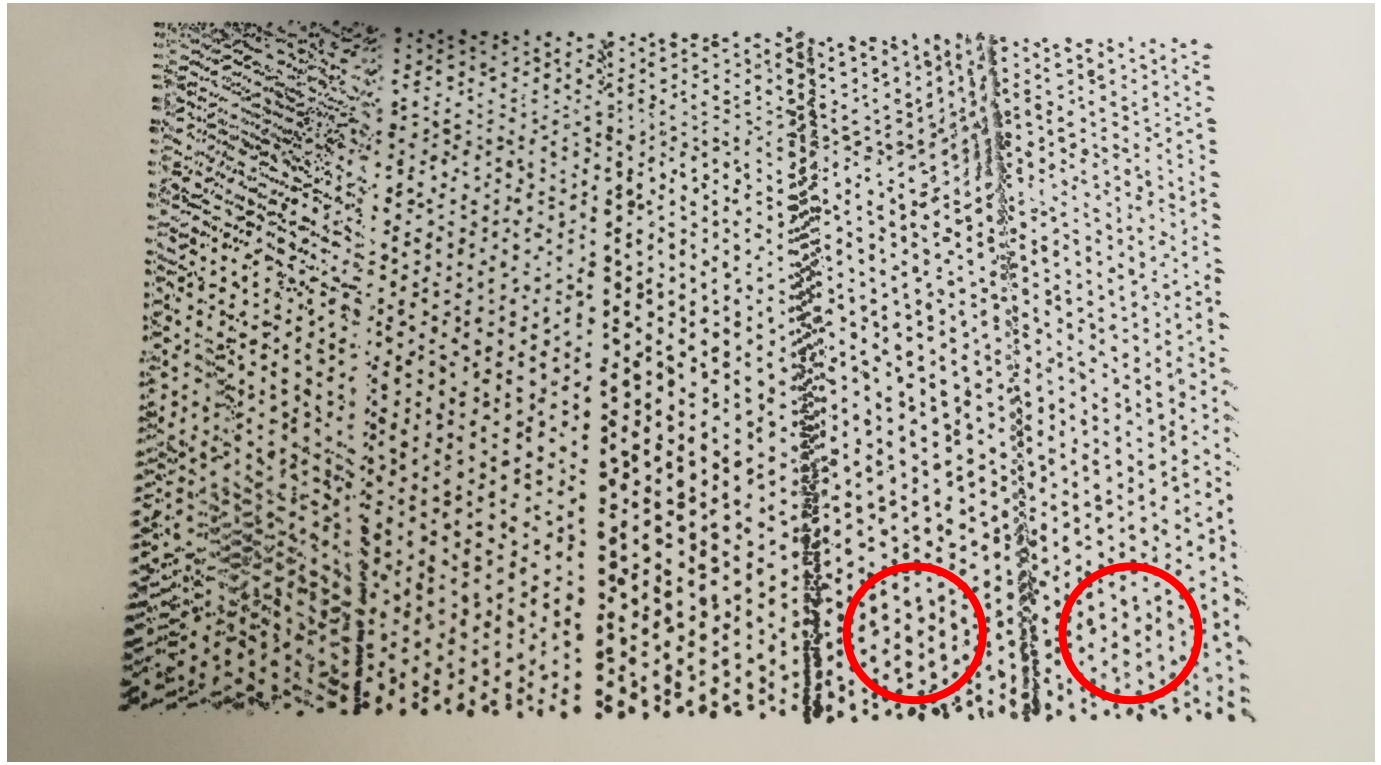
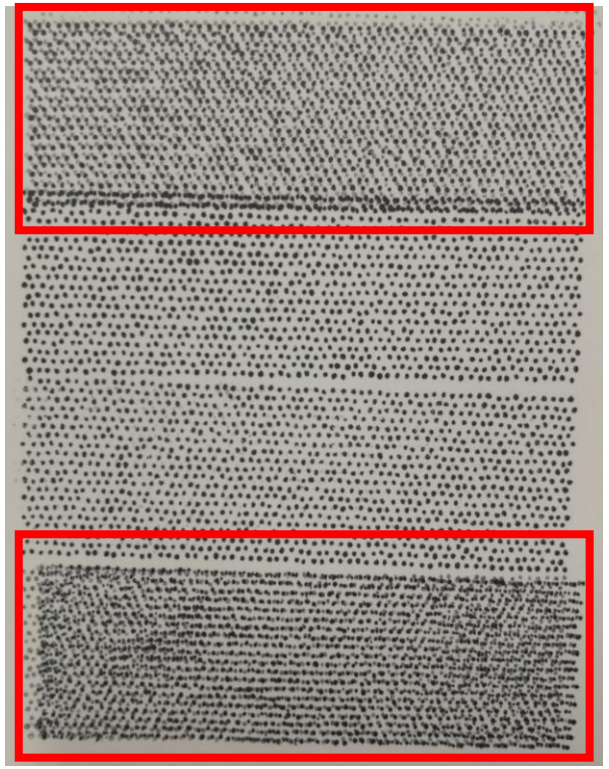


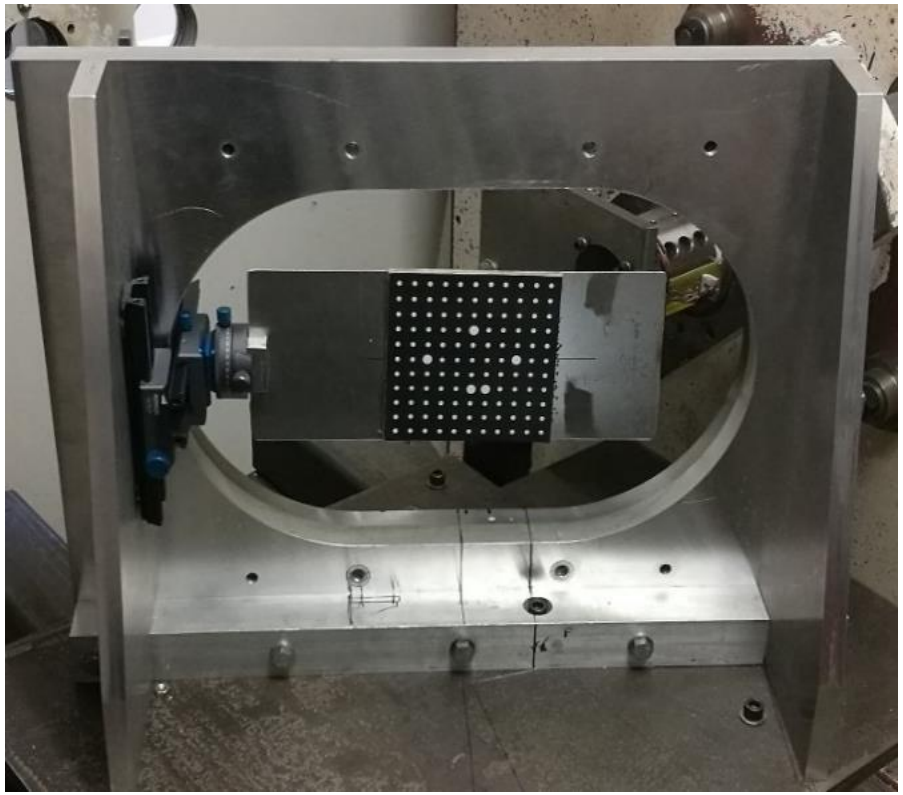
Reduced randomness on large specimens



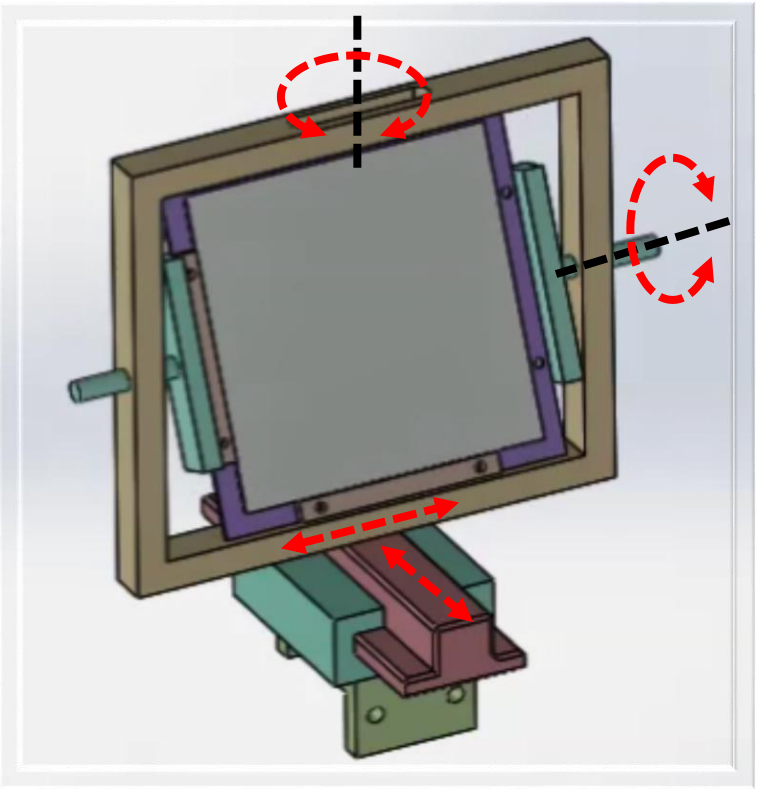
Repeated stamping

4. Some challenges and solutions

- Digital image correlation (DIC) calibration
  - Challenge: Manual positioning of the panel: time consuming, less accurate and less stable
  - Solution: Calibration with a mechanism: more efficient, more accurate results and very stable



Manual positioning



CAD model

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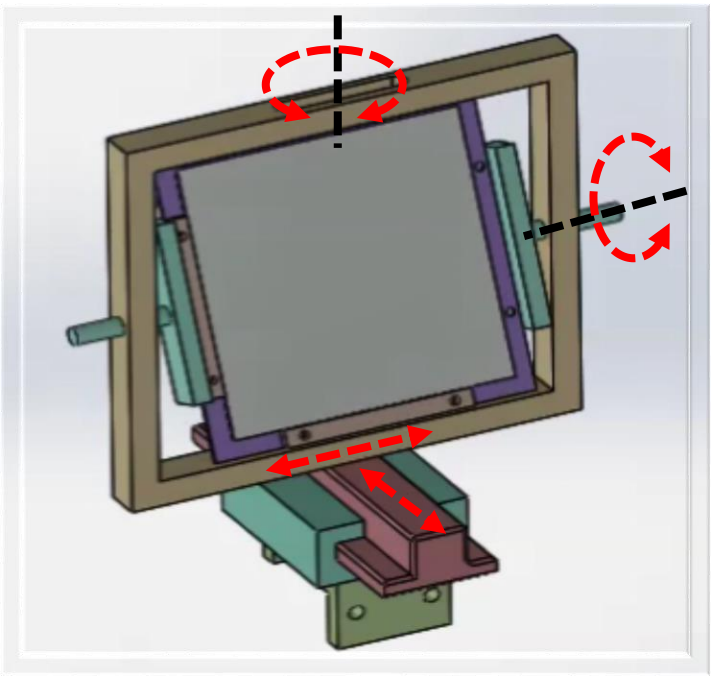
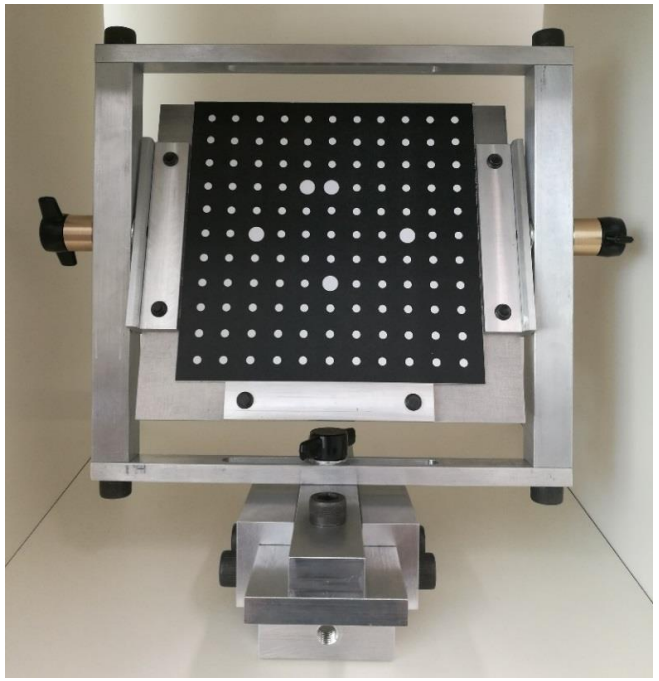
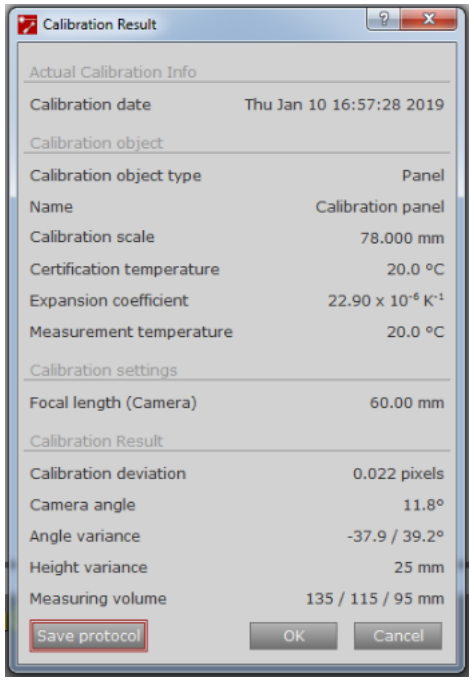


CAD model



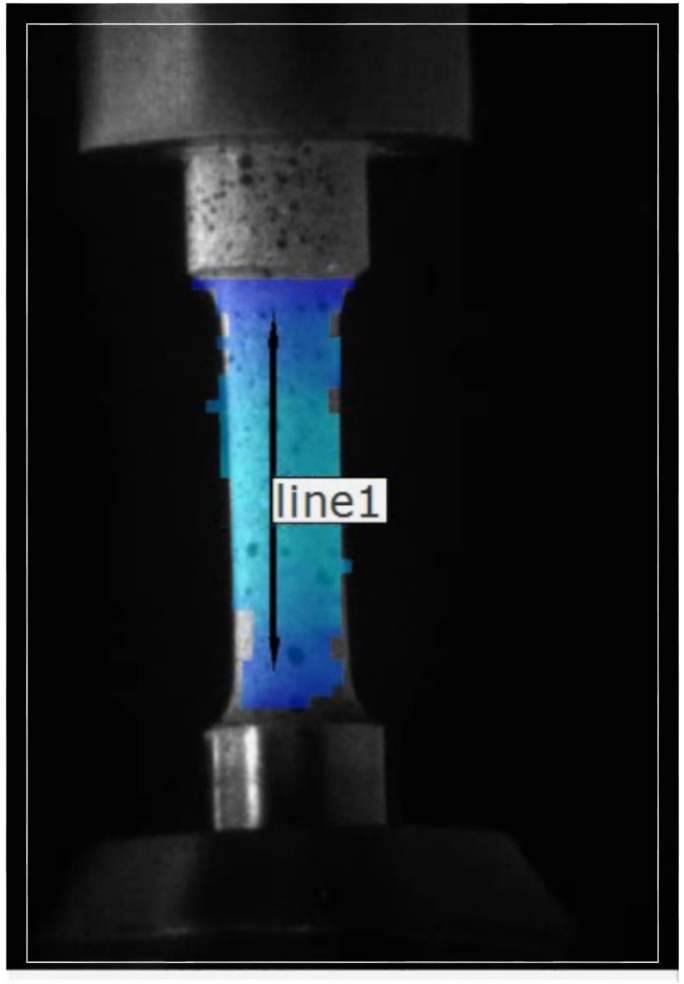
The mechanism



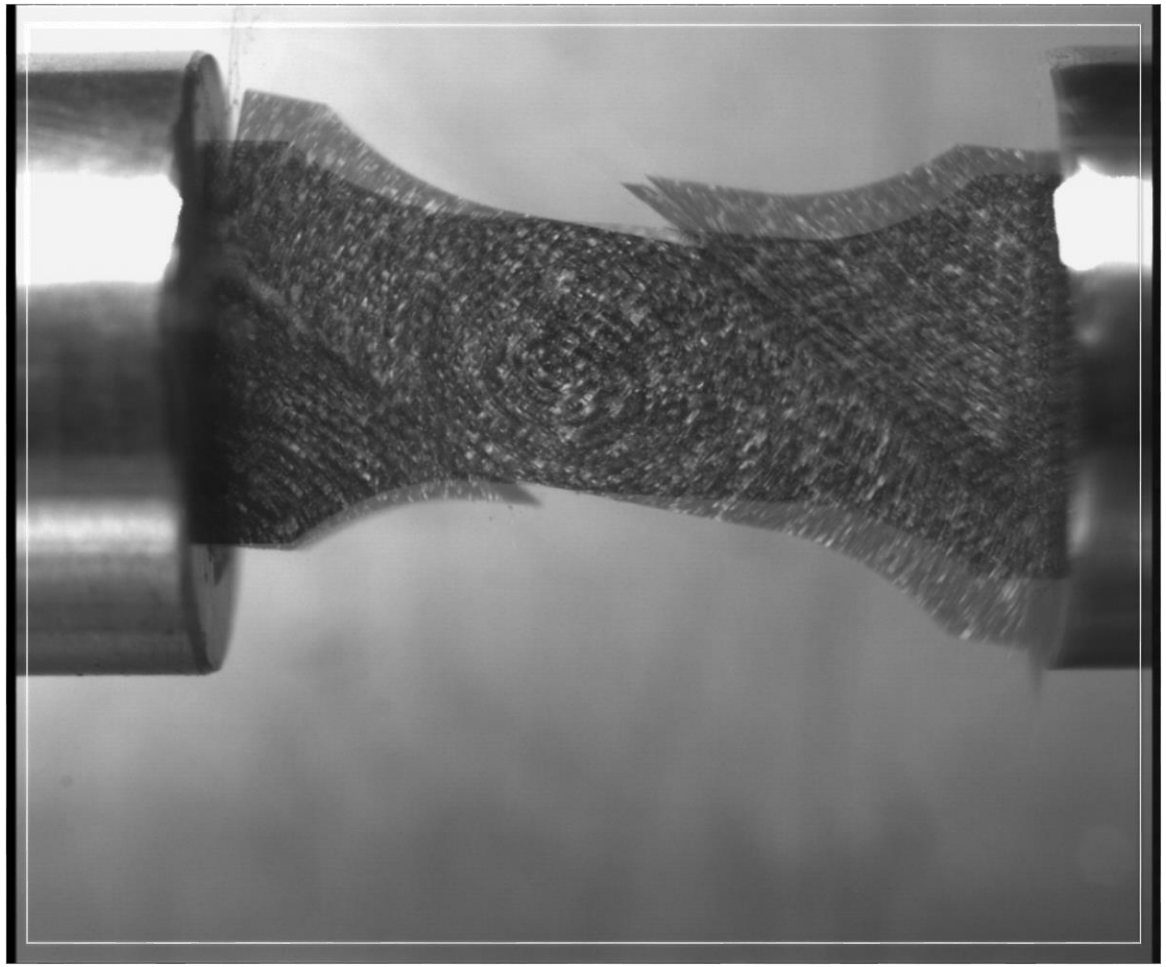
Deviation: 0.02 pixels

5. Problems to be addressed

- Wired effects in the recorded videos



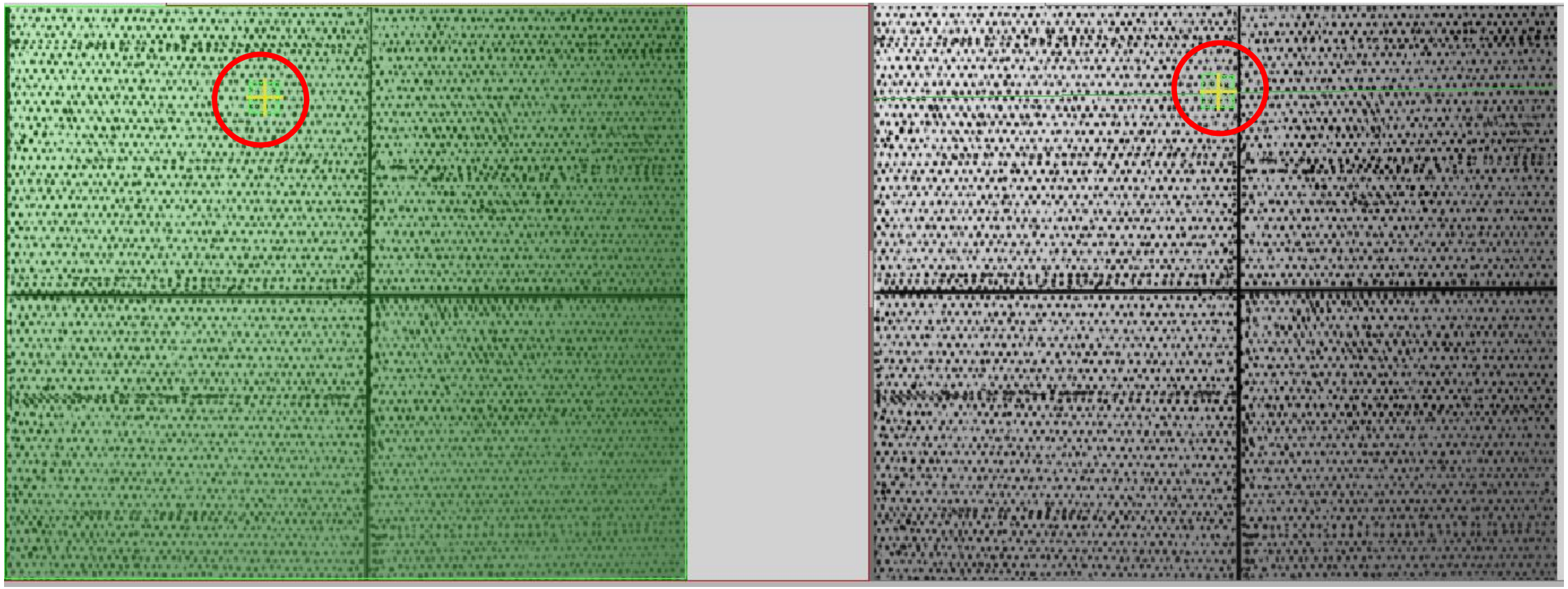
Jumping effect



Ghosting if the specimen start deforming

5. Some problems to be addressed

- DIC analysis: Incorrect correlation of the start point

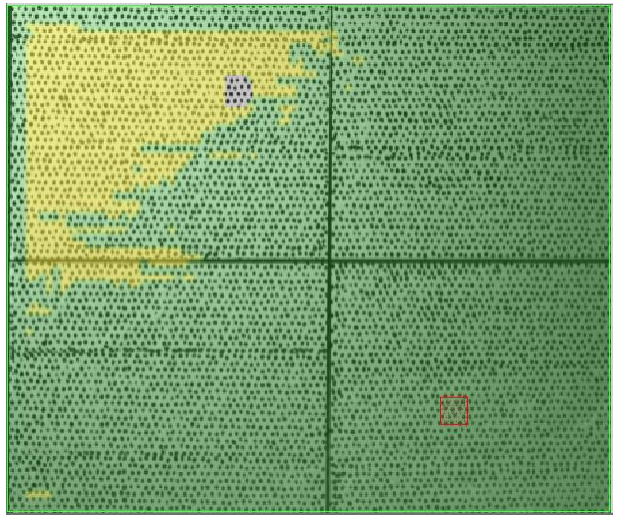


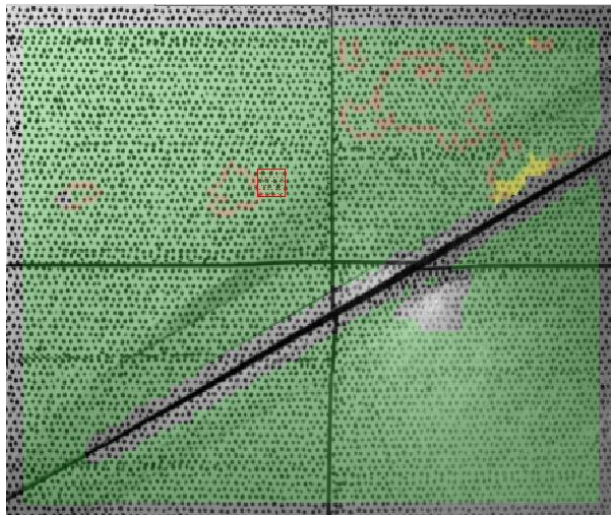
Left image

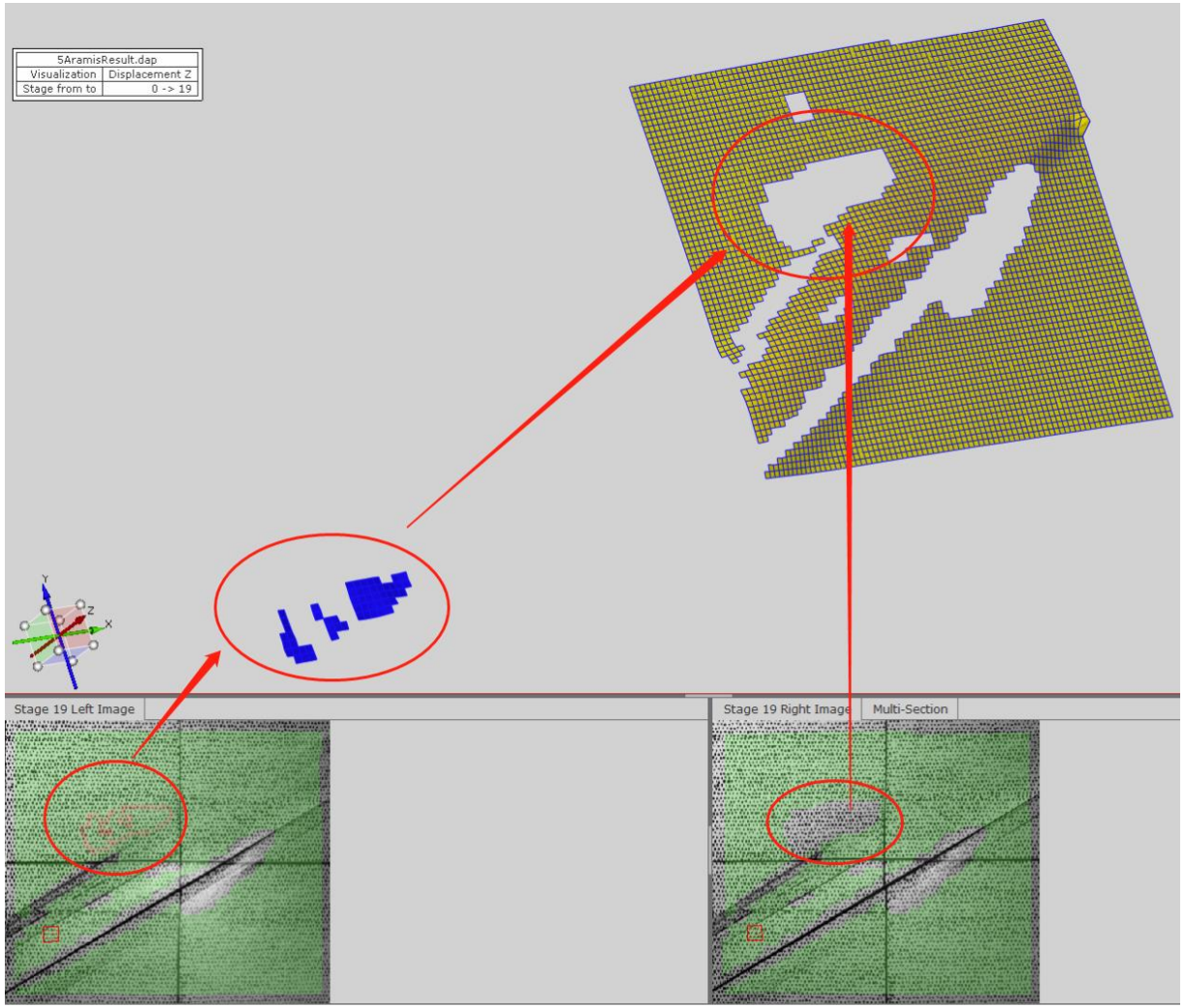
Right image

5. Some problems to be addressed

- DIC analysis: Yellow overlays and red regions led to unrealistic results







6. Summary

- Typical research activities involving the use of high speed imaging
  - Characterisation of lightweight materials at different strain rates
  - Evaluation of impact performance of structures on gas guns
- Ballistic impact testing programme
  - Procedure of a complete impact test
  - Evaluation of impact performance based on DIC results
- Challenges in high speed imaging and solutions
  - Painting and speckling of large specimens
  - Positioning of the calibration panel for 3D DIC calibration
- Some problems regarding high speed imaging
  - Jumping and ghosting effects in recorded videos
  - Problems in DIC analysis