Uncertainty Quantification in Digital Image Correlation
An industrial perspective

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22 February 2017
OUTLINE
- Introduction to Structures Test, Airbus
- DIC applications
  - Workshop questions
    → What are the sources of error in DIC measurements?
    → How can we quantify the uncertainties reliably?
    → Does uncertainty quantification (UQ) really matter?
    → How do I use this uncertainty information?
    → How does it propagate into derived data?
- The FUTURE
Introduction to Structures Test, Airbus
Structures Test, Airbus

The structural integrity and safety of the airframe is typically established by analysis supported by structures tests.

Certification
Analysis and test evidence is presented to the Airworthiness Authorities so that compliance with EASA and other certifying authority’s rules, can be demonstrated, in order to achieve Type Certification. (EASA – European Aviation Safety Agency)

Development / Research
• Qualification of new materials and fastening systems
• Validation of new design and manufacturing methods
• Demonstration of durability and safety
• Concession support
• In-Service support and Repair scheme validation
• FTI Calibrations
• Research
• Analysis method and FEM model validation
• Validation of Virtual Testing models

We test metallic, composite and hybrid structures
We perform Static, Fatigue, pressure and impact tests
DIC applications
DIC applications

Applications:
- Large scale static tests
- Dynamic tests
- Pressure tests (static)
- Trouble shooting
- Wind tunnel support
- Etc.

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What are the sources of error in DIC measurements?
What are the sources of error in DIC measurements?

**Experimental Setup**
- Lens distortion
- Camera motion
- Sample motion
- Air turbulence
- Image blur
- Location in image
- Lens focal length
- Camera standoff
- Stereo angle
- System resolution

**Calibration Parameters**
- Calibration target error
- Calibration drift
- Image quality

**Image Acquisition**
- Noise
- Contrast
- Speckle size
- Aliasing

**Image Correlation**
- Interpolant
- Minimization
- Shape function
- Subset size

**Processing decisions**
- Filtering
- Strain calculations
Does uncertainty quantification (UQ) really matter?
How can we quantify the uncertainties reliably?
Does uncertainty quantification (UQ) really matter? How can we quantify the uncertainties reliably?

**What do we do in Airbus today?**
- Top-Down Evaluation – comparison with a standard e.g. strain gauges, LVDTs
- Type A simple noise floor evaluation by capturing multiple static images and analyzing displacements
- Experience based e.g. artefacts, discrepancies, sigma values, projection errors

**Examples of GOOD vs BAD experimental setup**

<table>
<thead>
<tr>
<th>GOOD</th>
<th>BAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out of plane displacement (W) at 0 kN loading</td>
<td>Out of plane displacement (W) before failure</td>
</tr>
<tr>
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</tr>
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</table>

Out of plane displacement (W) at 0 kN loading

GOOD: 0.114 - 0.088
BAD: 1.44 - 0.92

Out of plane displacement (W) before failure

GOOD: 0.94 - 1.74
BAD: 1.08 - 1.01

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Does uncertainty quantification (UQ) really matter? How can we quantify the uncertainties reliably?

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How do I use this uncertainty information?
How does it propagate into derived data?
Validation of simulations

Why to use advanced measurements?

❖ To support the Predictive Virtual Testing philosophy
❖ To allow earlier use of simulation in design, in particular as a means of compliance for certification
❖ Validation of next generation numerical capabilities
❖ To enable smarter decision makings

Benefits

❖ Robust quantitative validation with reduced lead times in the analysis.
❖ Increased confidence in simulations which will result in fewer unexpected events, reduced risks and defined uncertainties
❖ Reduced number of test specimens
❖ Reduced inspection time
❖ Reduced lead time
❖ Faster and cheaper testing
Validation of simulation using DIC

Validation parameters:
- Global displacements (behaviour) and strain distribution
- Buckling behaviour
- Onset of buckling (non-linear behaviour)
- Onset of failure
- Out of plane displacement

Full scale wing tests

Leading edge pressure test

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Validation of simulations using DIC

Ballistic impact test

Validation parameters:
- Out of plane displacement
- Strain values

QUANTITATIVE/QUALITATIVE

Ballistic impact test

FEM

Validation parameters:
- Out of plane displacement
- Strain values
The FUTURE
How can we quantify the uncertainties reliably?

Novel validation methodology for DIC

**Novel validation**

- **Features**
  - Traceable
  - Full-field
  - In-situ
  - In-plane
  - Scalable

- European patent EP3026632AP - Improvements in or Relating to Digital Image Correlation Systems

- A Traceable Technique for an In-Situ Full Field In-Plane Measurement Validation of Digital Image Correlation
  
  *Eszter Szigeti, et al. – Optical Engineering*
- Standardized and traceable DIC with defined uncertainties
- Smart data comparison (Test vs. Simulation) methodologies
- Automated decision making
Thank you