EikoSim

Validation of Image-Based Modal Analysis Techniques for Dynamic Characterization Using Synthetic Images

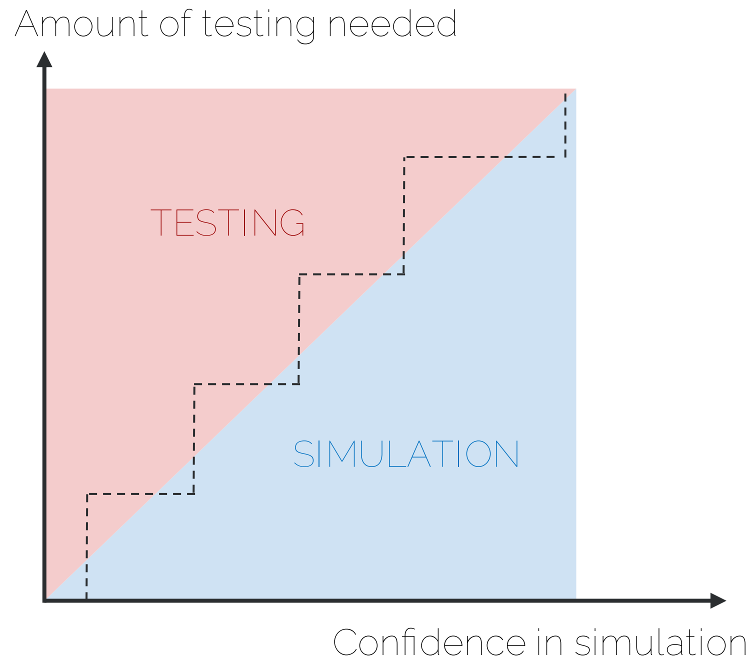
Florent Mathieu – 23/05/25, SURVISHNO Conference

A path to simulation-based engineering

New generations of products are being developed with less and less testing, but this is not a straightforward journey

- Simulation credibility has to be built brick-by-brick
- Validation criteria should be defined in advance

1. How do we know enough data has been acquired to validate a certain model?
2. What are necessary tools/scales to build model credibility?



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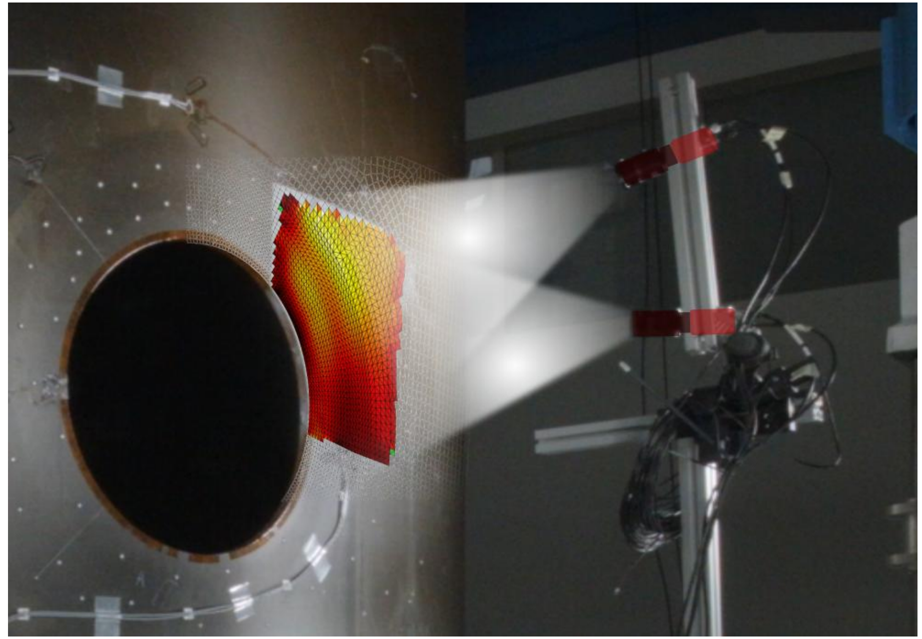
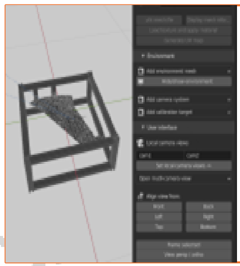
A word about EikoSim

EikoSim

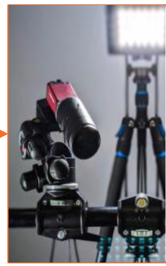
- Mission: Bridges the gap between physical testing and numerical simulation in structural mechanics.
- Technology: Utilizes Digital Image Correlation (DIC) to align simulation models with real-world experimental data.
- Value: Reduces costly physical tests and optimizes designs through accurate simulations.
- Industries: Aerospace, defense, automotive, energy, civil engineering.





EIKOTWIN VIRTUAL

Synthetic image generation
- Planning
- Anticipating test difficulties

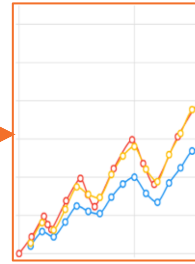


EIKOTWIN VISION

Image acquisition
- Set up cameras
- Acquire images

EIKOTWIN DIC

Image processing
- Calibration
- DIC measurement
- Test/simulation comparison



EIKOTWIN DIGITAL TWIN

Model calibration
- Boundary conditions control
- Sensitivity study
- Parameter identification

INTEGRATION PARTNERS

ALTAIR — POWERED BY ALTAIR UNITS — DASSAULT SYSTEMES — Ansys

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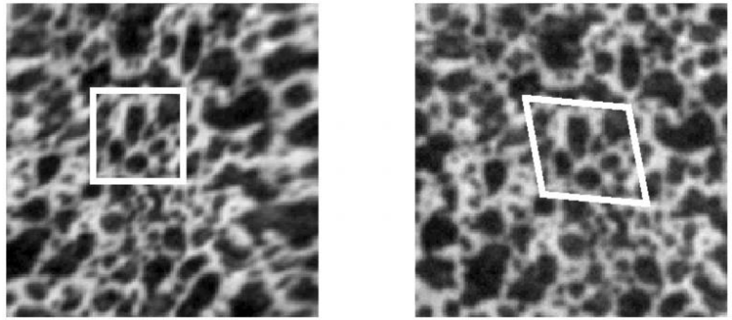
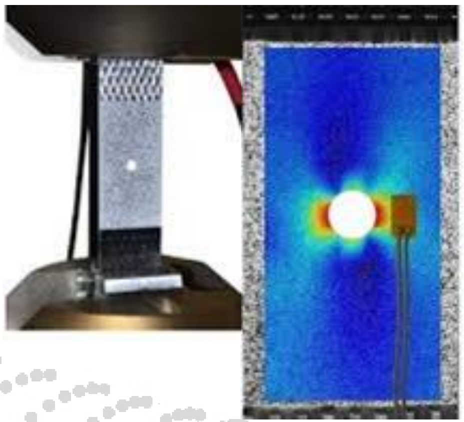
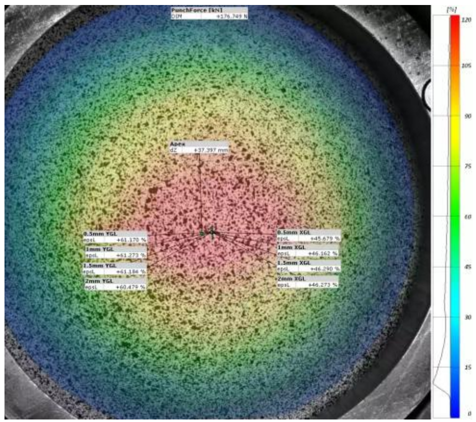
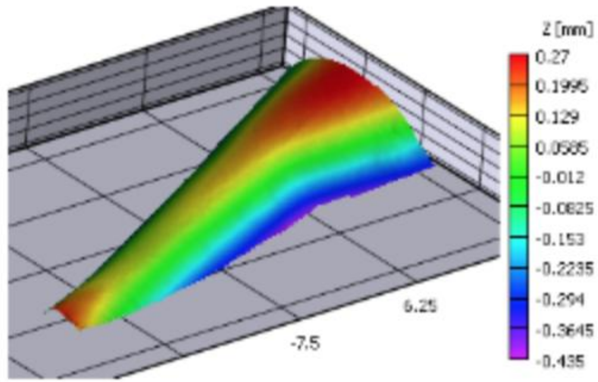
What is Digital Image Correlation?

DIC is an optical measurement technique that measures displacement and strain fields by following a pattern in a series of images









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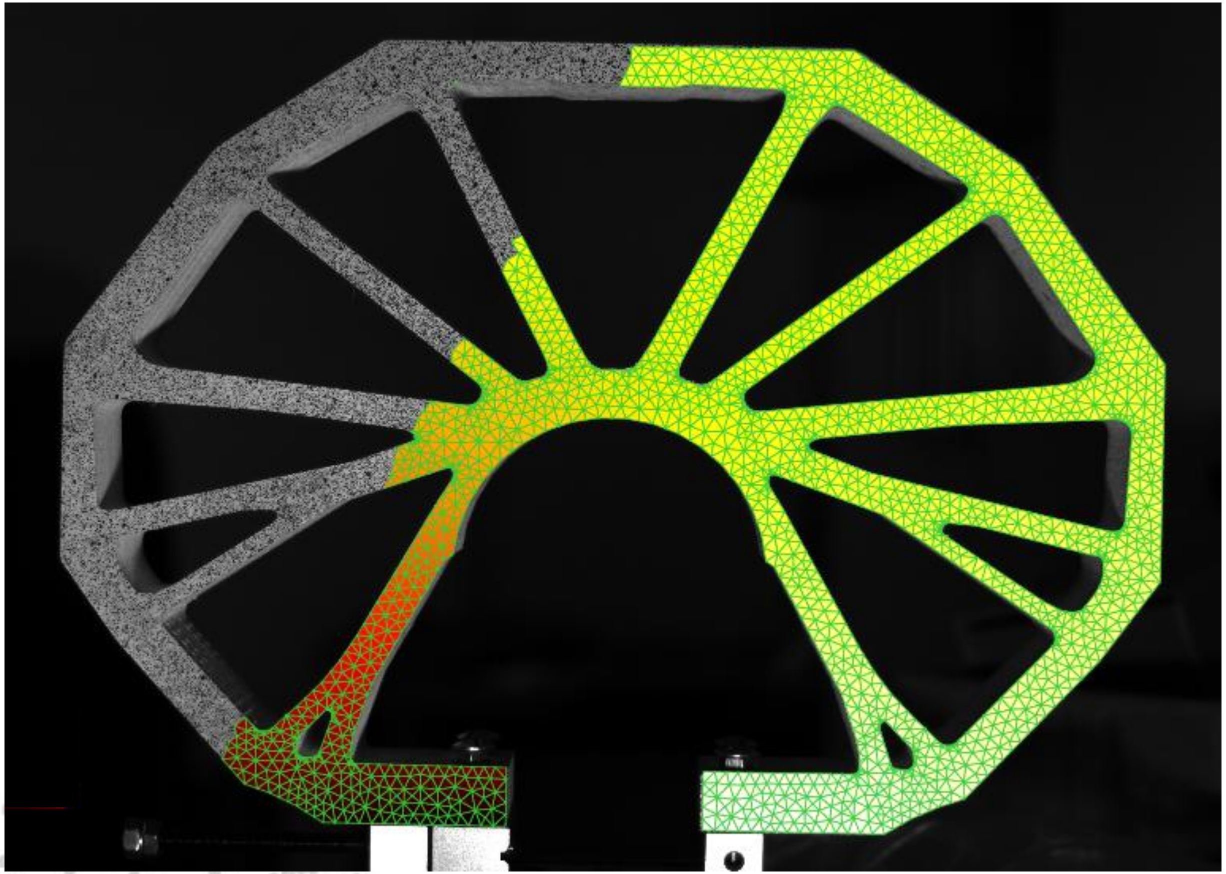
EikoTwin DIC: linking testing to simulation

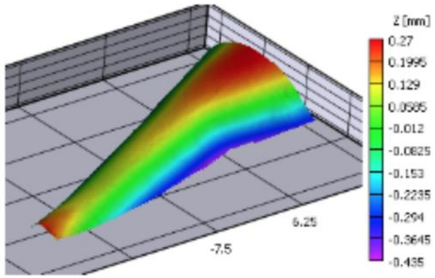


Data collection and aggregation

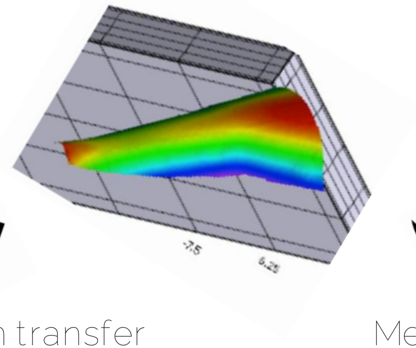
- Measure kinematic fields from images (multi-camera systems)
- Collect complementary test data (strain gauges, LVDT, force, temperature, etc) on the 3D model
- Natural simulation compatibility thanks to mesh-based image processing

Subset-base vs FE-Based DIC

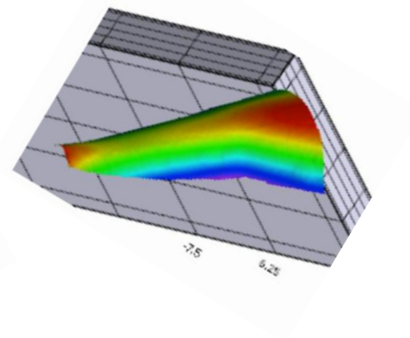
CLOUD POINT MEASUREMENT
(camera reference system)



CLOUD POINT MEASUREMENT
(part reference system)



MESH-PROJECTED
MEASUREMENT



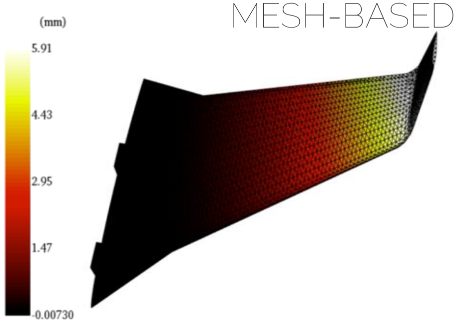
Reference system transfer
(Tools ? Errors ?)

Mesh mapping
(Tools? Errors ?)

Subset-based DIC

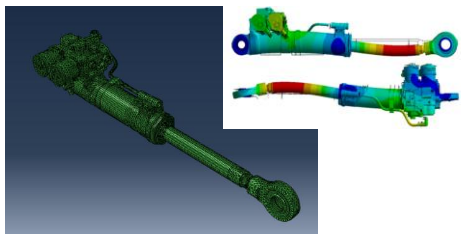
FE-based DIC

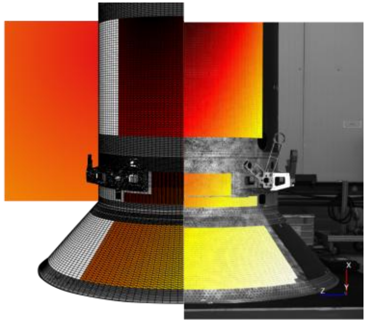
MESH-BASED MEASUREMENT

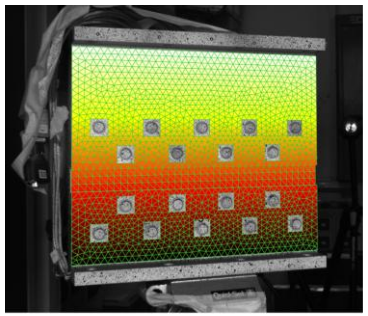


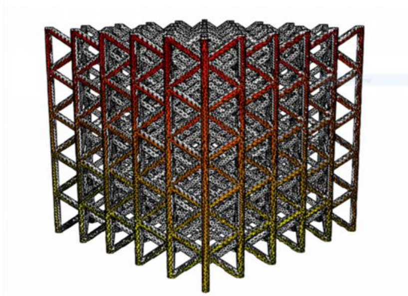
Applications

AEROSPACE





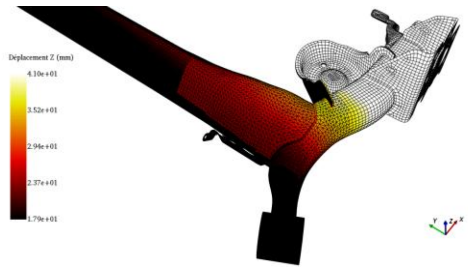


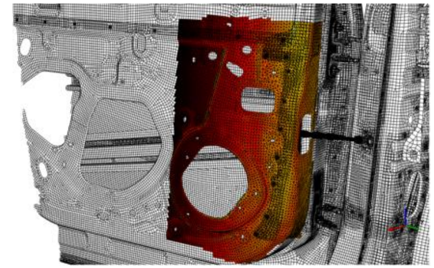


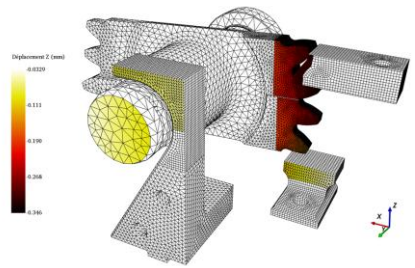
DIC covers

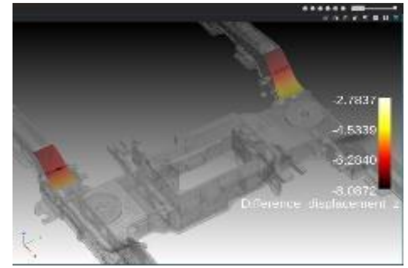
- Quasi-static testing
- Dynamic/vibration analyses
- Crack propagation
- Thermo-mechanical testing

AUTOMOTIVE, TRANSPORTATION

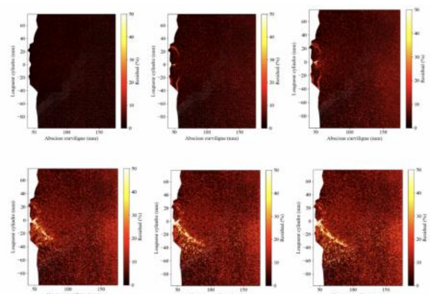








ENERGY, RAIL

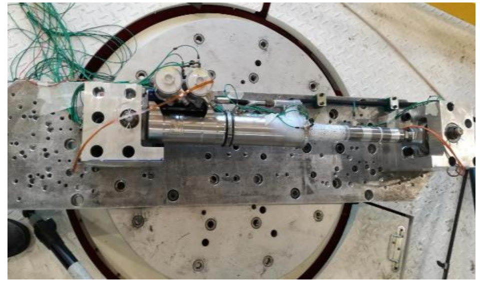


Vibration test with SAFRAN Landing Systems

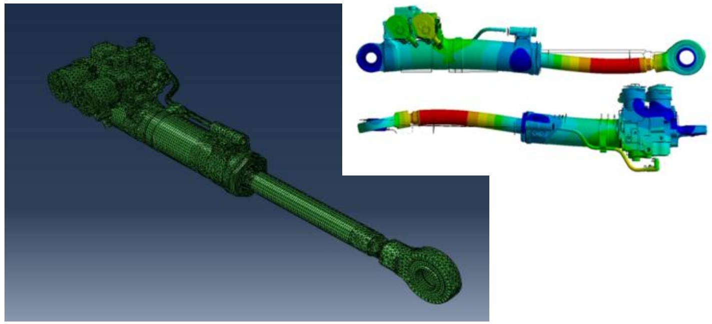
SAFRAN LANDING SYSTEMS

Context

- Structure: hydro-mecanic actuator
- Testing : certification on resonance mode
- Objective : validation of the numerical simulation

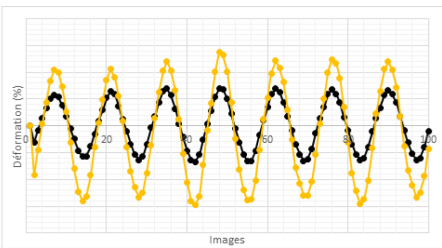


Solution

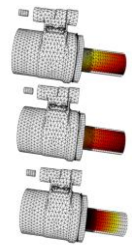


- Multi-cameras system (1000 hz)
- Measurement of the displacement and deformation
- Global comparison between test and simulation

Results



- Displacement measurement on the simulation mesh
- Manifestation of a behavior that had not been predicted by the simulation
- Simulation update directly from the test results



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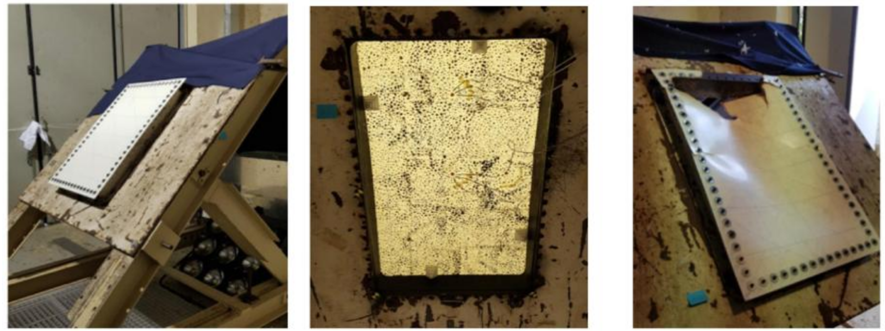
Bird impact test with Saint-Gobain

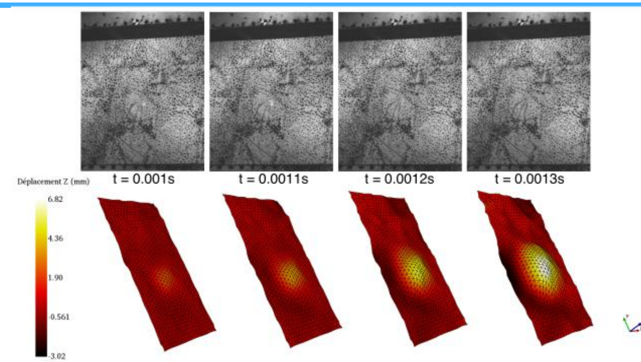
Context

- Composite panel impact test
- "Radome" composite material

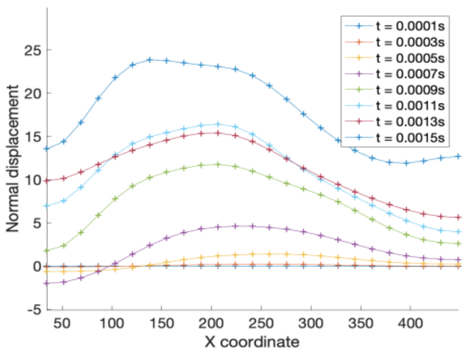


Solution

- Dynamic testing: stereovision at 1000Hz
- Displacement field measurement on the FE mesh



Results



- Deformation pattern as a function of time
- Comparison with the FE model

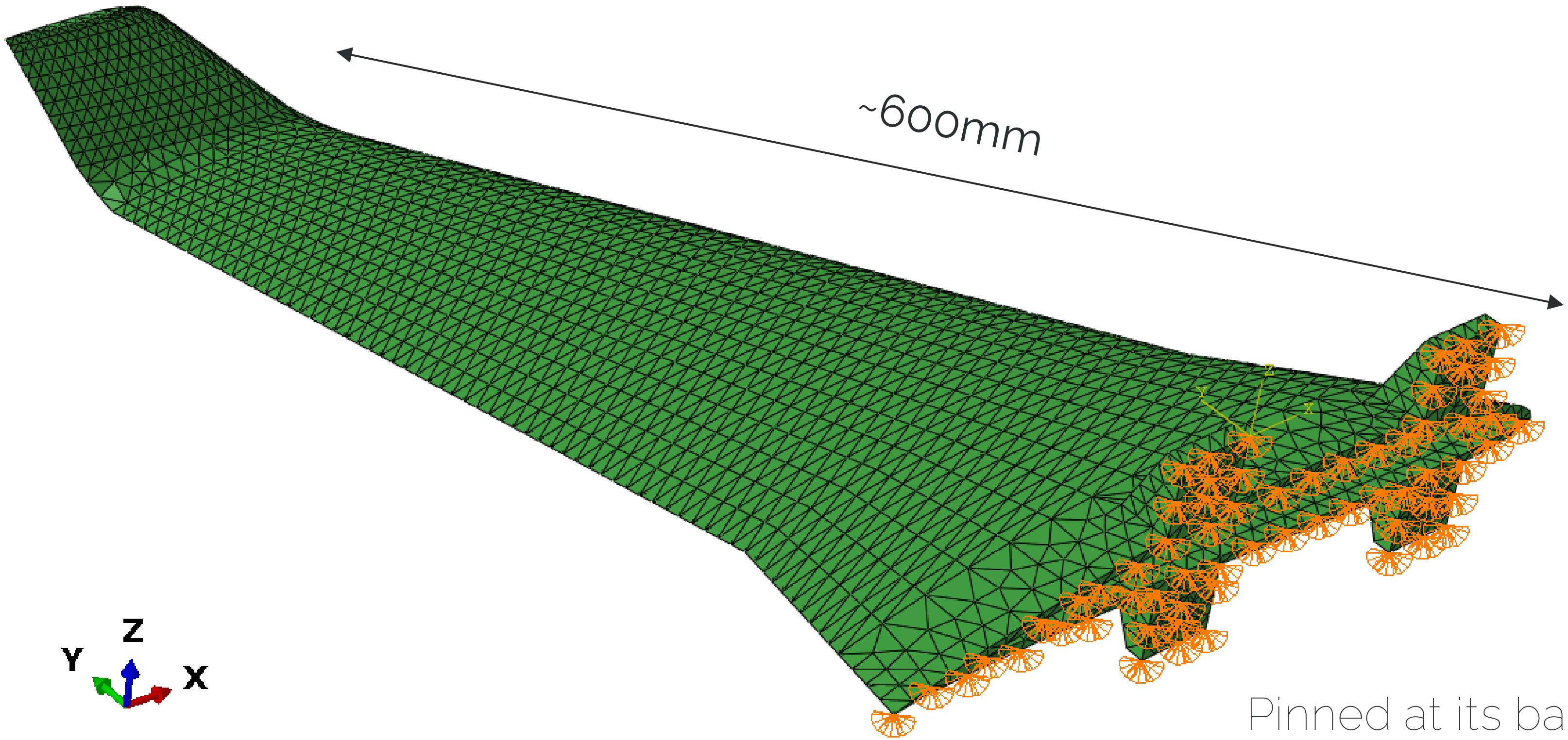
Study

- OBJECTIVE: Assess the possibility to determine mode shapes and frequencies using DIC

- Use of synthetic test data:

1. Choice of a use case
2. Computation of mode frequencies and shapes using FEM simulation
3. Creation of a displacement field mixing the modes through time
4. Creation of virtual images using the displacement field
5. DIC measurement using EikoTwin DIC
6. Application of a code under development to determine mode shapes and frequencies
7. Comparison with the FEM simulation

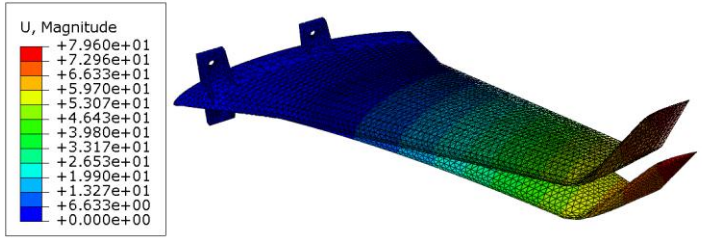
Use case: Model Wing



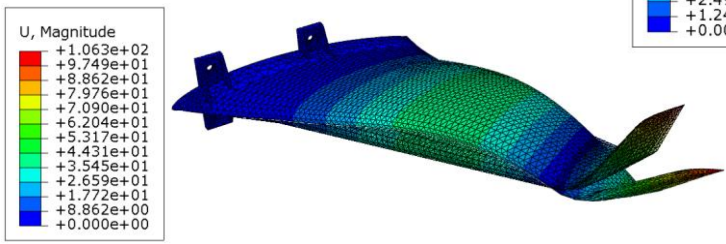
Pinned at its base

EikoTwin DIC

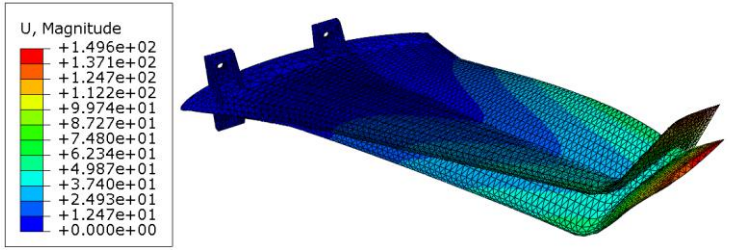
Computation of the 5 first modes using Abaqus



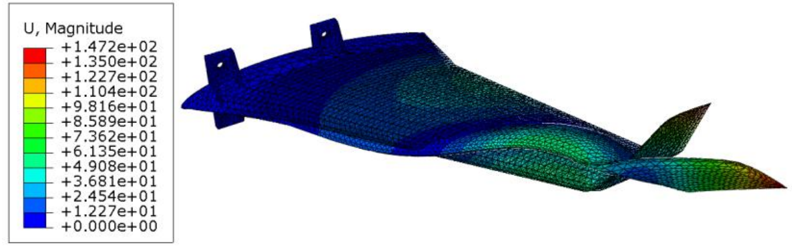
Mode 1 – 116 Hz



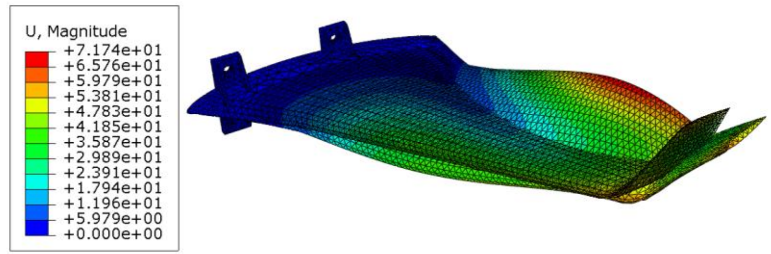
Mode 2 – 405 Hz



Mode 3 – 633 Hz



Mode 4 – 761 Hz



Mode 5 – 822 Hz

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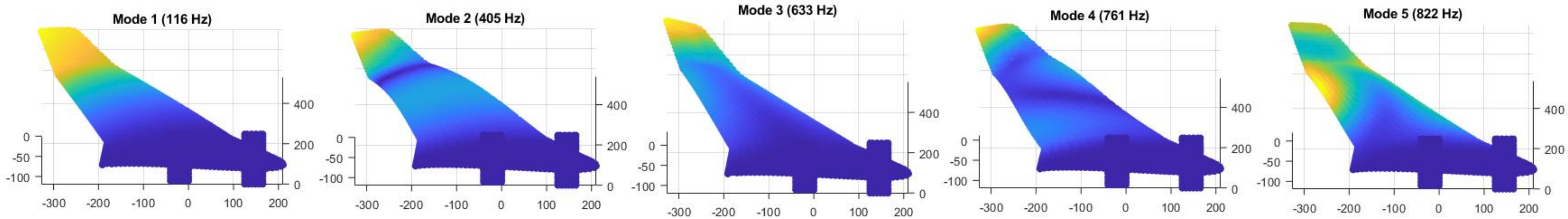
Application of a scaling factor on each mode



Scaling factor 0.002

Scaling factor 0.001

Scaling factor 0.00067

Scaling factor 0.0005

Scaling factor 0.0004

Applied displacement magnitudes

EikoTwin DIC

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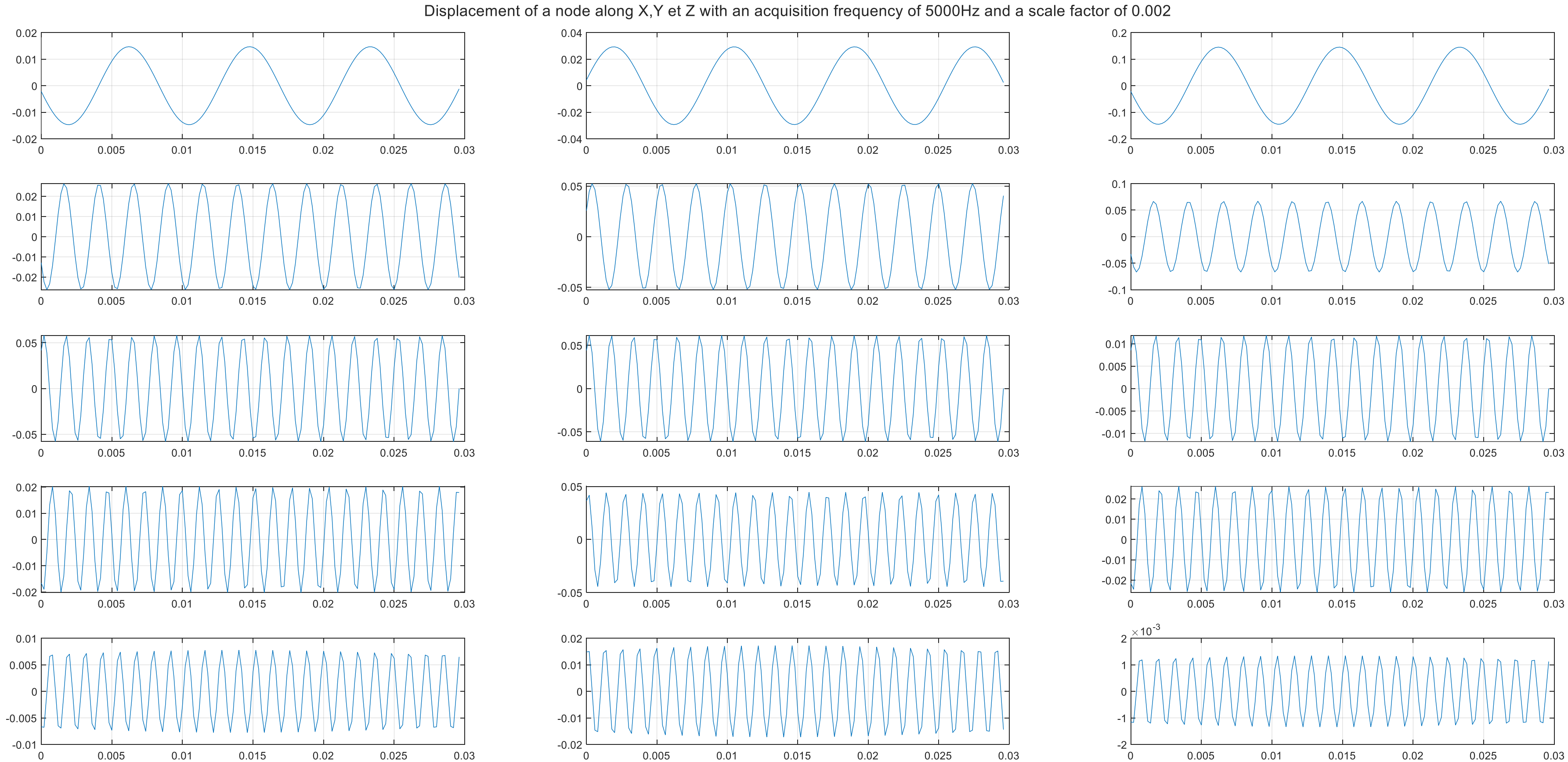
Generation of a 5000 Hz signal during 30 ms



Creation of sinusoids for each mode

Sum of mode displacements at each node and each time value

EikoTwin DIC

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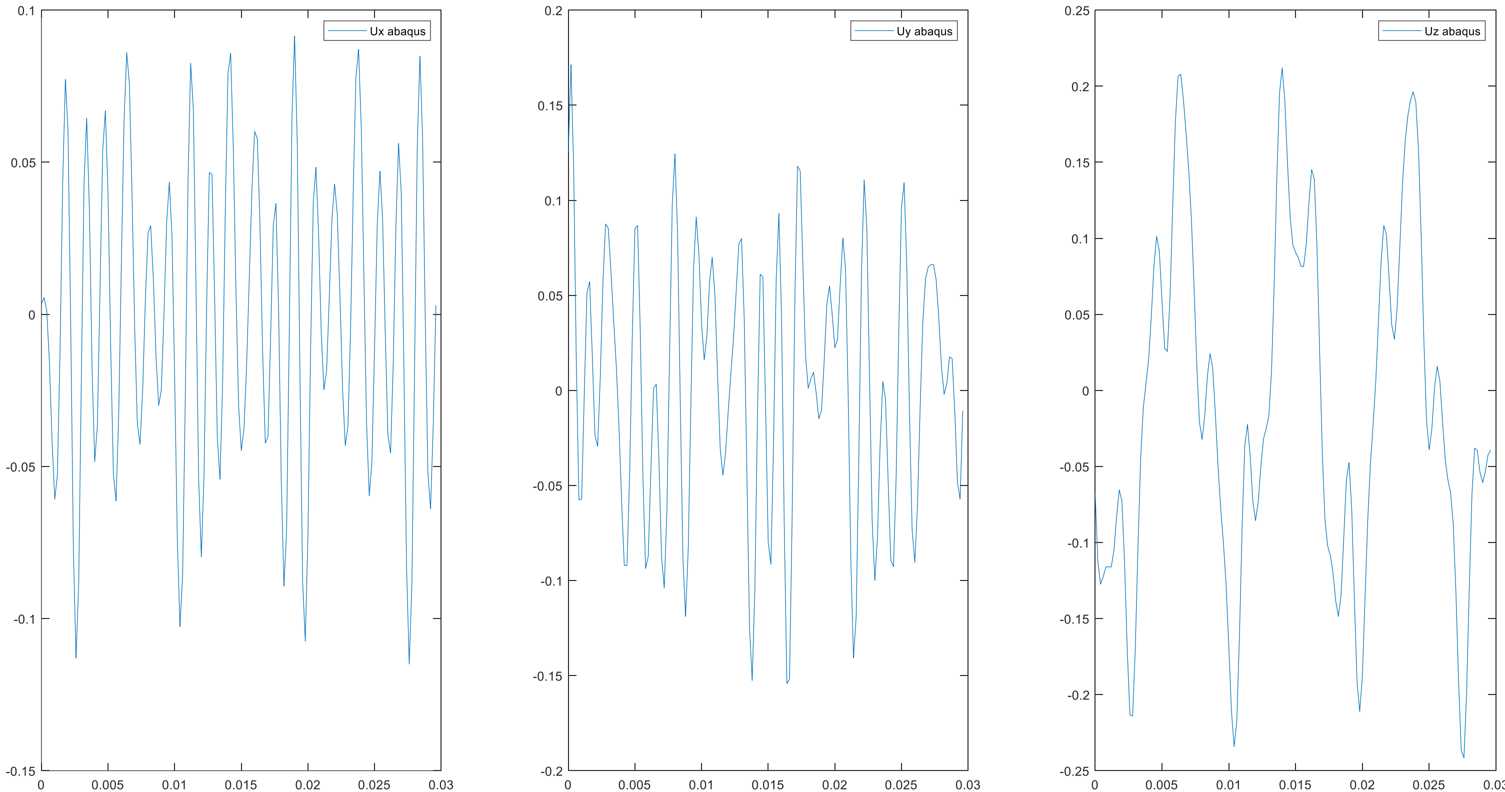
Generation of a 5000 Hz signal during 30 ms

EikoTwin DIC



Example for a node on the winglet (X, Y, Z)

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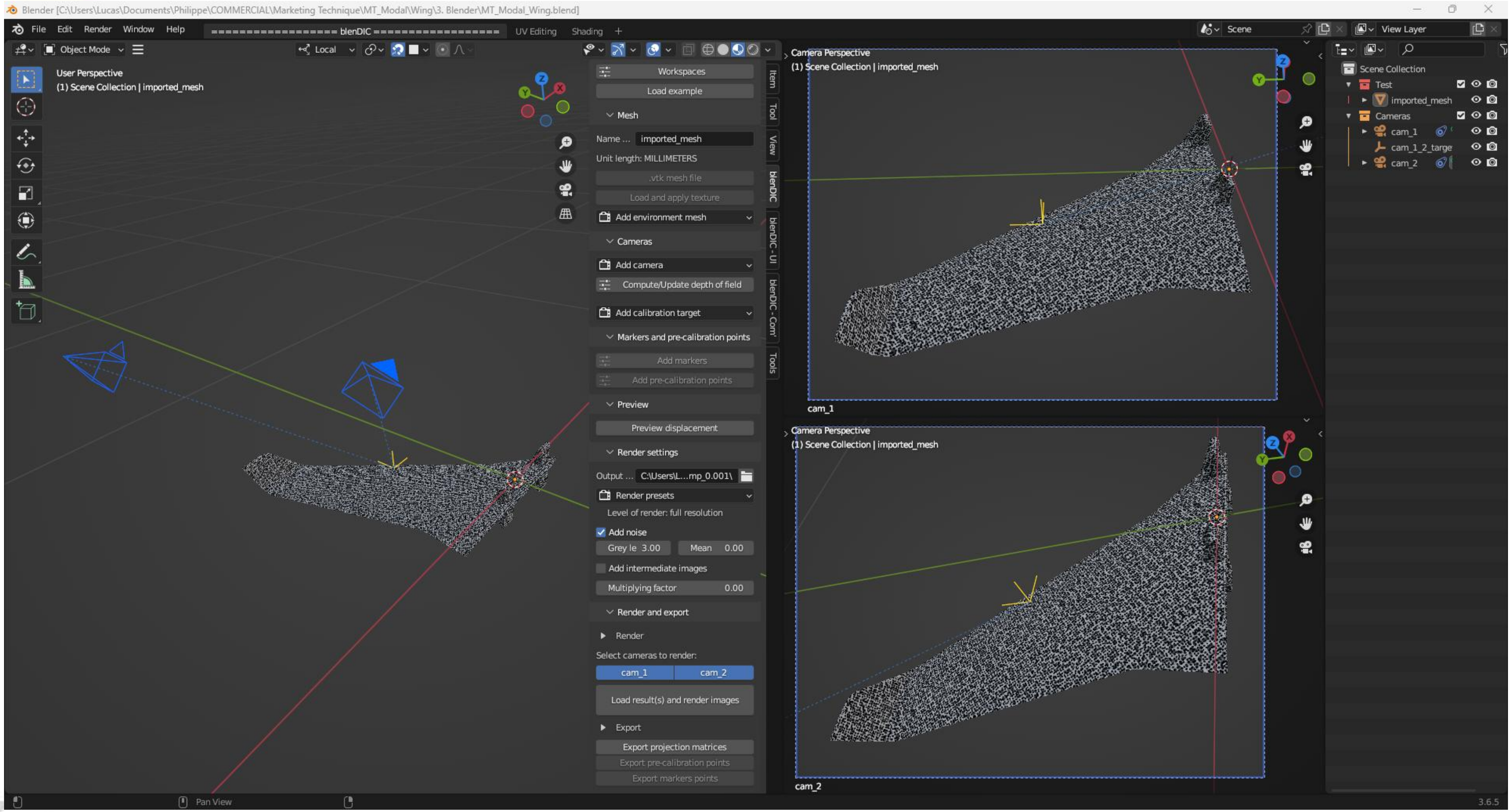
Use of EikoTwin Virtual to generate virtual images



- Generation of synthetic images with standard levels of image noise
- Input of the FE mesh+fields, output of images

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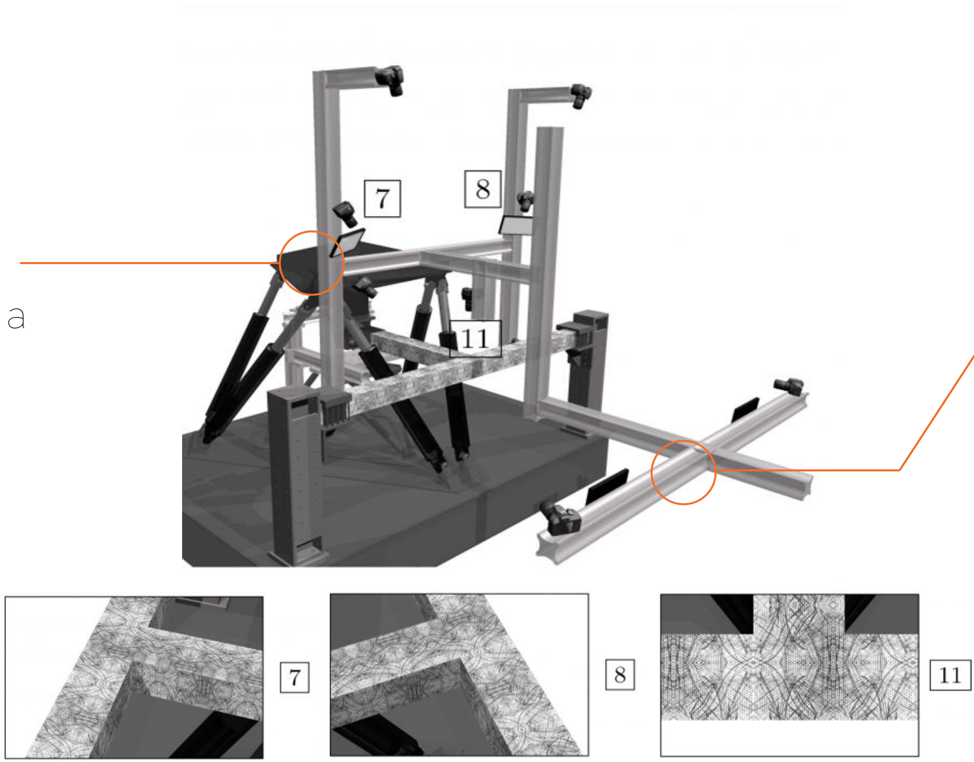
EikoTwin Virtual: consistant test specification

EikoTwin Virtual

Anticipate and solve experimental pain points

- Visualize the test scene in a virtual setup
- Ensure cameras are positioned adequately for optical measurements



Design the optimal setup

- Select the most relevant locations for both cameras and sensors
- Deform the structure virtually to estimate measurement errors
- Create an instrumentation map to ensure a fast preparation phase

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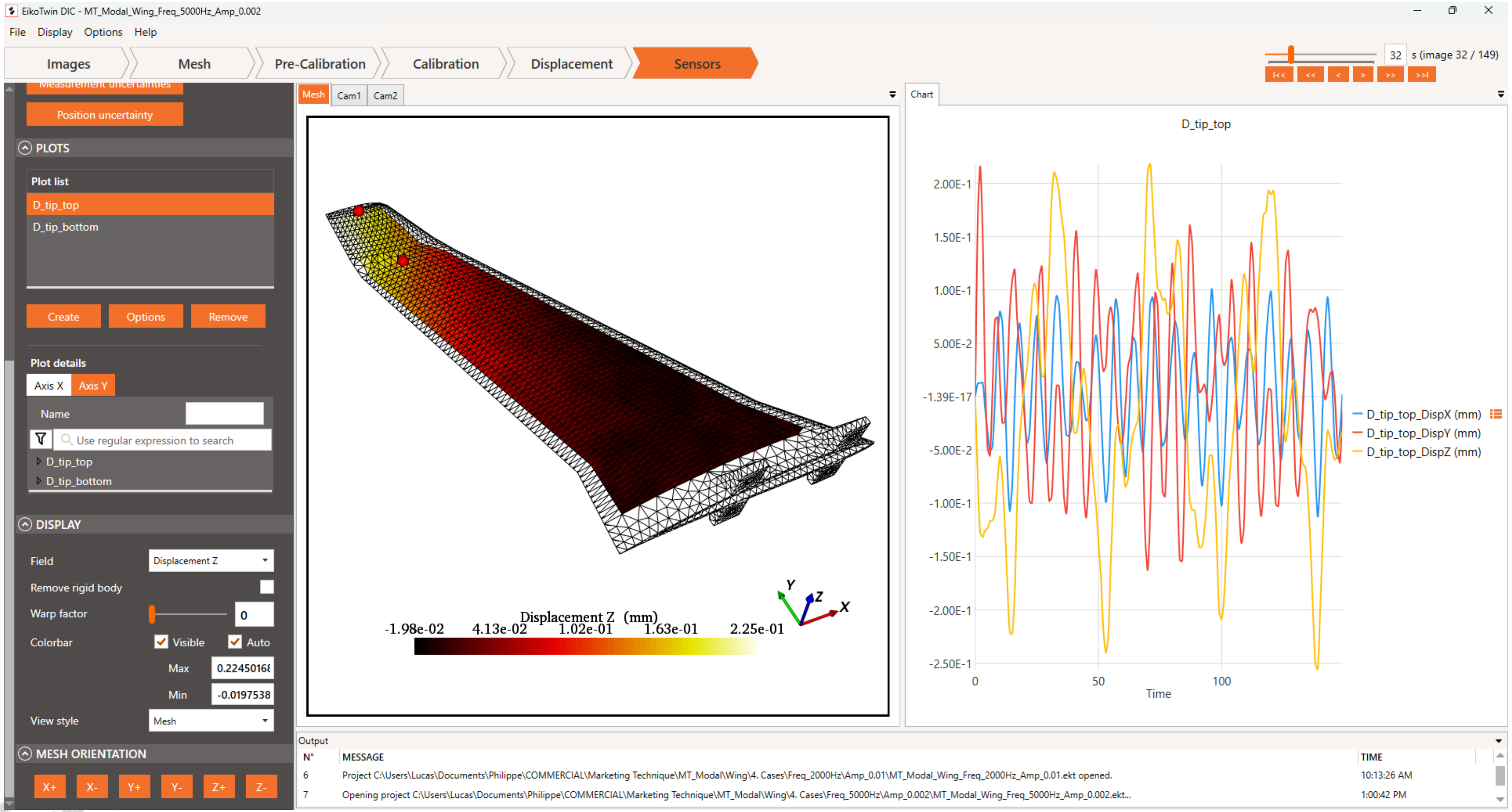
Use of EikoTwin DIC to process the images



EikoTwin DIC

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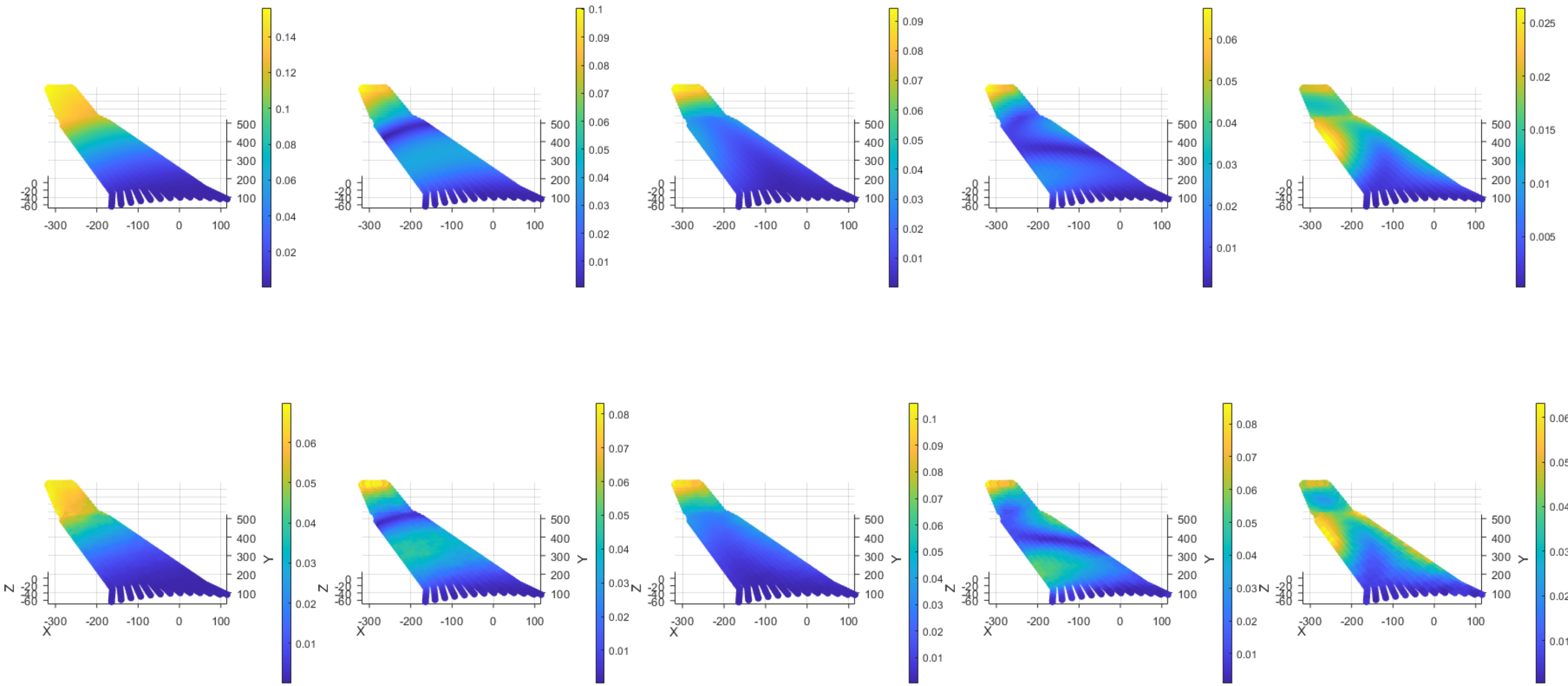
Determination of mode shapes by SVD

EikoTwin
DIC

Input

DIC



Mode 1 | Mode 2 | Mode 3 | Mode 4 | Mode 5

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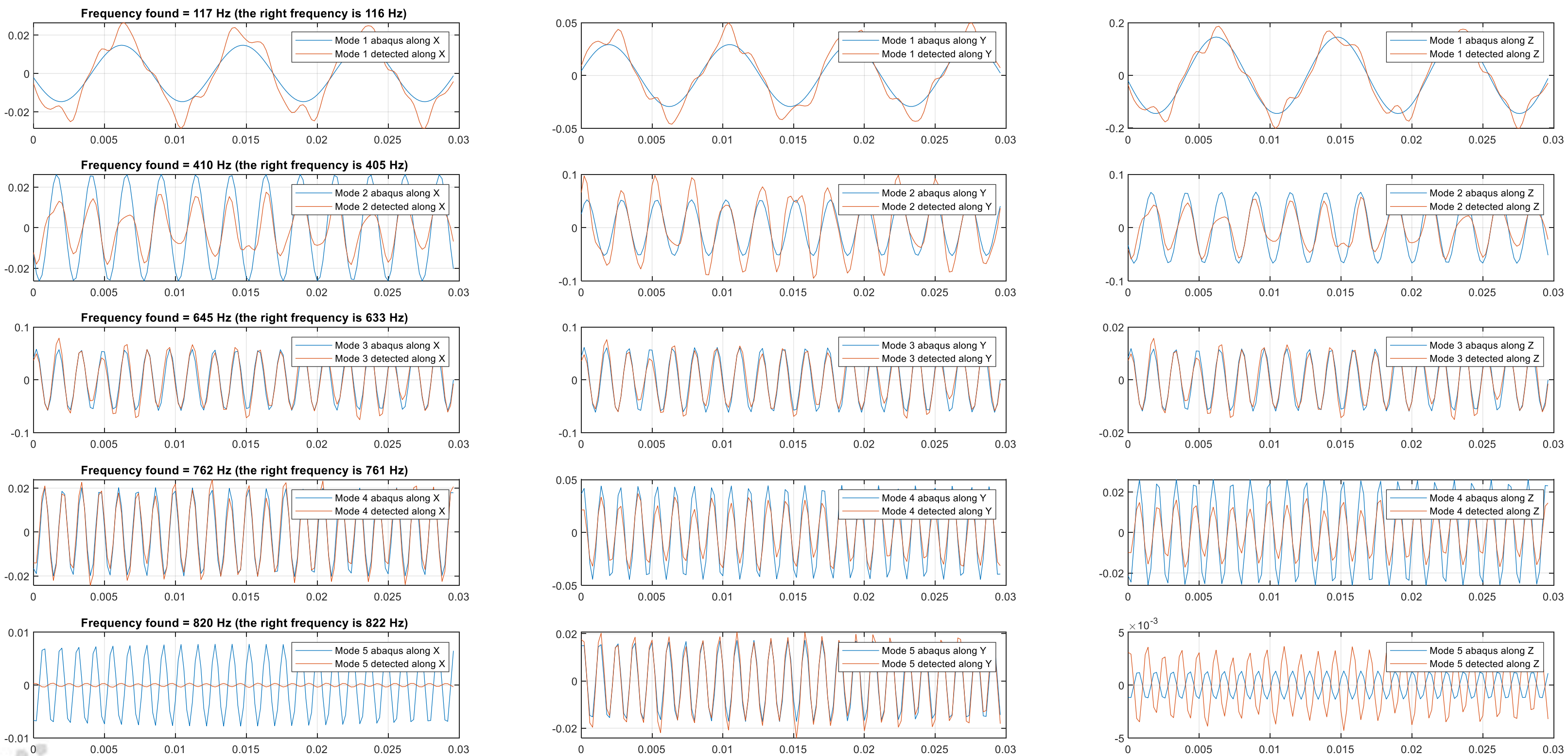
Determination of mode frequencies (FFT)

Displacement of a node along X,Y et Z with an acquisition frequency of 5000Hz and a scale factor of 0.002

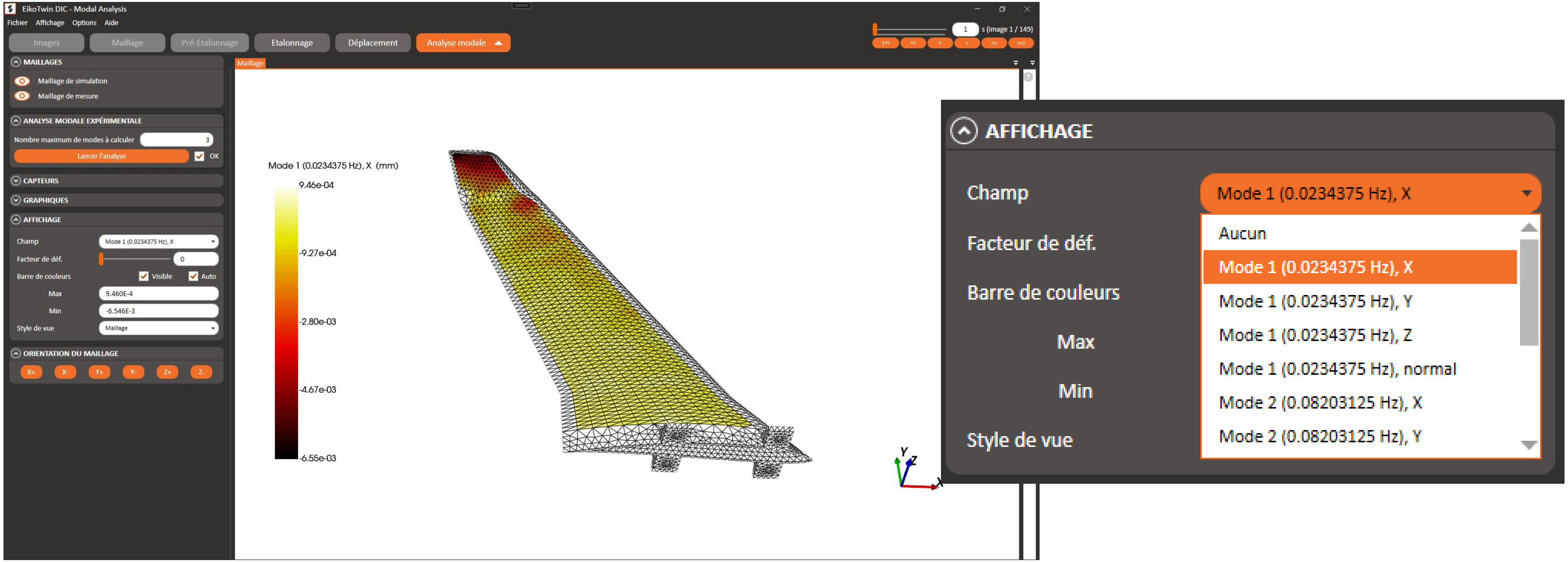


Mode	Input (Hz)	DIC (5000 Hz)	*DIC (2000 Hz)*
1	116	117	*125*
2	405	410	*406*
3	633	645	*656*
4	761	762	*781*
5	822	820	*844*

Applied mode

Detected mode

Integration



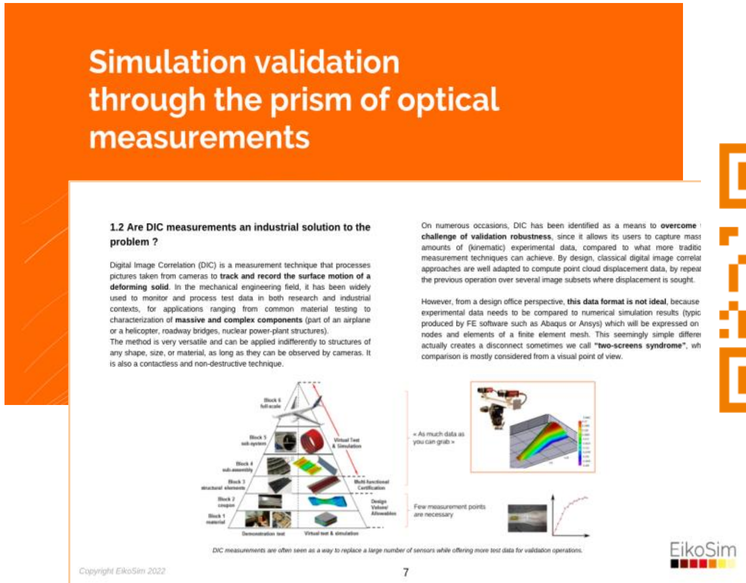
- Integration currently being done in EikoTwin DIC
- Probable release end of 2025

Conclusion & next steps

- DIC is able to measure displacement over the whole surface of the sample, for 3D shapes, at high speed
- We confirmed SVD+FFT was able to find mode shapes and frequencies with acceptable accuracy
- Accuracy is dependent on amplitudes and we can determine beforehand
  - Maximum amplitude based on usual measurement accuracies
  - A probable limit frequency
- Integration work is currently being done in EikoTwin DIC – we're looking for use cases!

Questions?

Download our White Paper !



Simulation validation through the prism of optical measurements

1.2 Are DIC measurements an industrial solution to the problem ?

Digital Image Correlation (DIC) is a measurement technique that processes pictures taken from cameras to **track and record the surface motion of a deforming solid**. In the mechanical engineering field, it has been widely used to monitor and process test data in both research and industrial contexts, for applications ranging from common material testing to characterization of **massive and complex components** (part of an airplane or a helicopter, roadway bridges, nuclear power-plant structures).
The method is very versatile and can be applied indifferently to structures of any shape, size, or material, as long as they can be observed by cameras. It is also a contactless and non-destructive technique.

On numerous occasions, DIC has been identified as a means to **overcome** **challenge of validation robustness**, since it allows its users to capture mass amounts of (kinematic) experimental data, compared to what more traditio measurement techniques can achieve. By design, classical digital image correlat approaches are well adapted to compute point cloud displacement data, by repeat the previous operation over several image subsets where displacement is sought.

However, from a design office perspective, **this data format is not ideal**, because experimental data needs to be compared to numerical simulation results (typic produced by FE software such as Abaqus or Ansys) which will be expressed on nodes and elements of a finite element mesh. This seemingly simple differe actually creates a disconnect sometimes we call **"two-screens syndrome"**, wh comparison is mostly considered from a visual point of view.

DIC measurements are often seen as a way to replace a large number of sensors while offering more test data for validation operations.

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