Ensuring product durability with FEA-based fatigue life prediction

nCode® DesignLife

Kurt Munson

Manager, Applications Engineering

Hi, I’m your host!

Kurt Munson is the engineering manager at HBK where he oversees software technical support, training, and engineering services activities.

He has 25 years’ practical experience in structural testing and analysis, specializing in durability, fatigue, and vibration analysis.

He holds a bachelor’s degree in mechanical engineering from Michigan Technological University and a master’s degree in mechanical engineering from the University of Washington.

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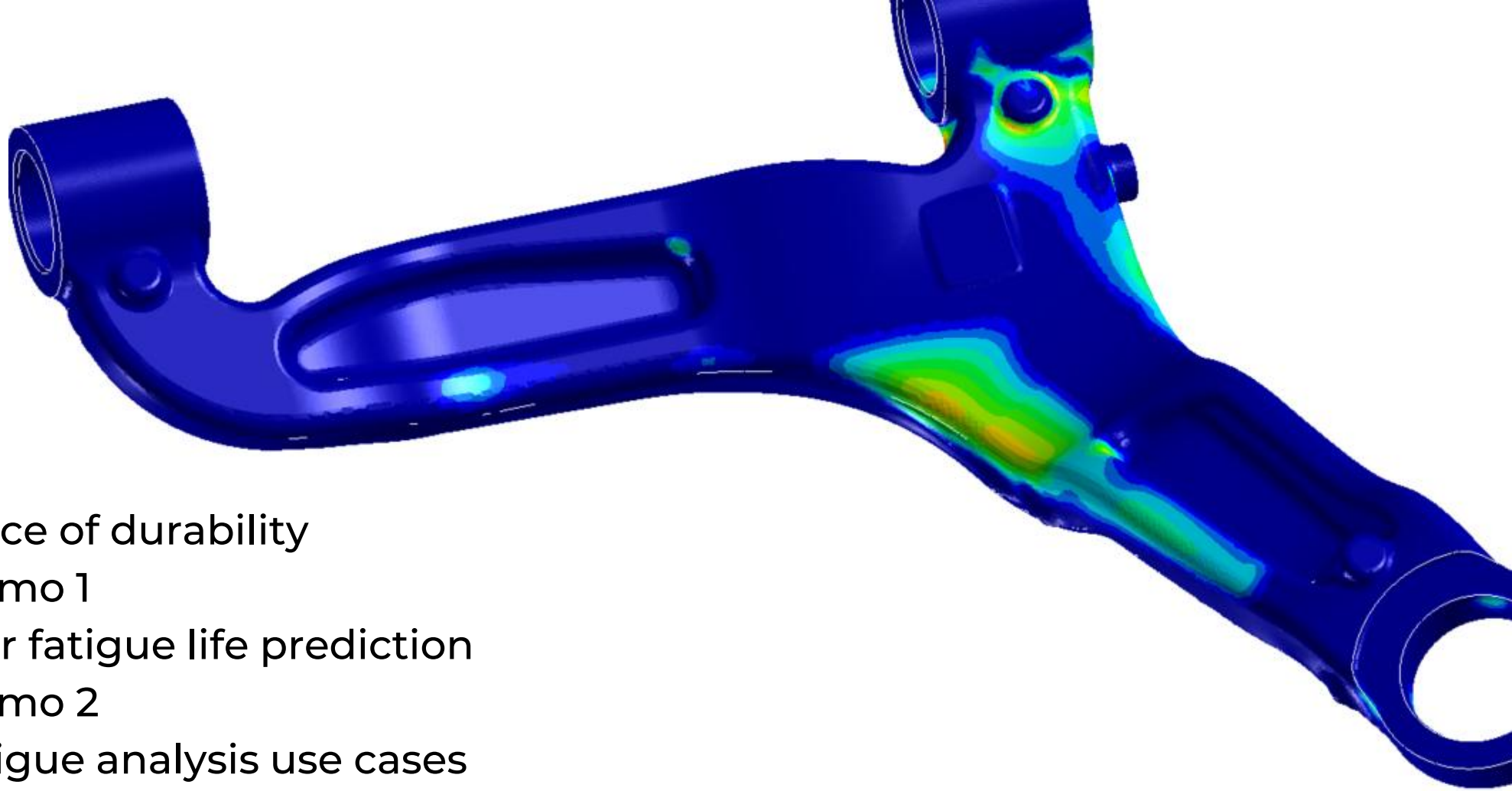
Agenda



- The importance of durability
  - Software demo 1
- A roadmap for fatigue life prediction
  - Software demo 2
- Advanced fatigue analysis use cases
  - Software demo 3
- Test-CAE correlation: connecting the physical and virtual worlds
- Summary

The importance of durability

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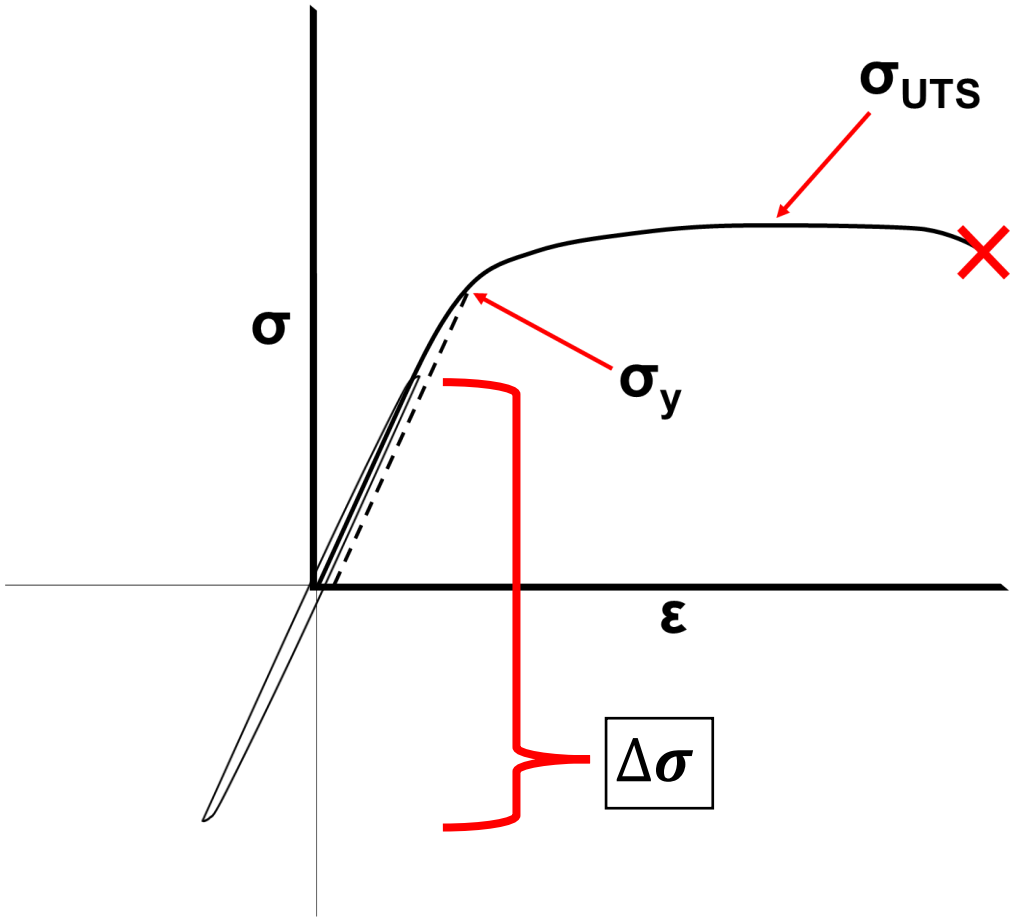
Fatigue as a failure mode

Initiation and subsequent growth of a crack, or growth from a pre-existing defect, until it reaches a critical size



Stress and strains are relatively small...

...but over time can be deadly!

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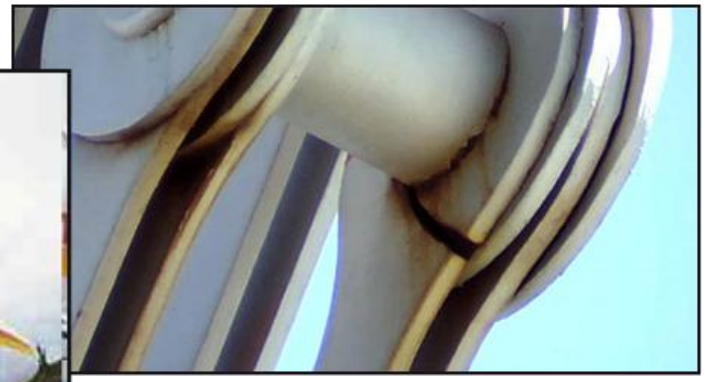

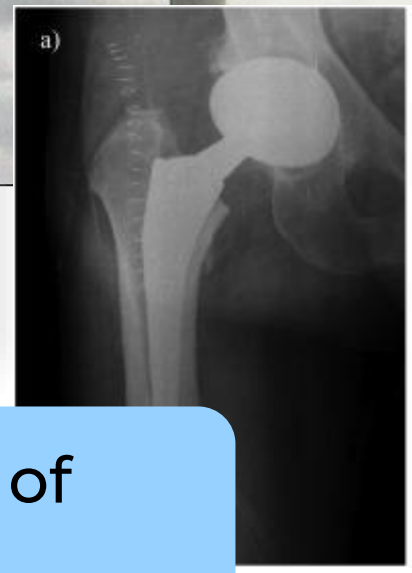

Costs include warranty, loss of reputation, loss of life, etc.

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Durability requirements

[redacted] ENGINEERING STANDARDS [redacted]

3.4 Test Plan Development. The test-flow shown in this document represents the cumulative global experience and knowledge gained from many products over many years. The strategy underlying this series-parallel test-flow is based on the concepts of "physics of failure" with correlation to field usage. The correlation to field usage is established from many years of

wear out failure mechanisms as well as the electrical input-output usage cycles. For an electronic module, wear out will be due to thermal- and vibration-induced fatigue. The DUT typically is exercised for the required number of 1-life electrical operational cycles during the Power–Temperature-Cycling (PTC) test. When there is inadequate time during PTC to

'Product must be free of visible cracks after 150,000 miles of use'

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Improving durability

‘Product must be free of visible cracks after 150,000 miles of use’

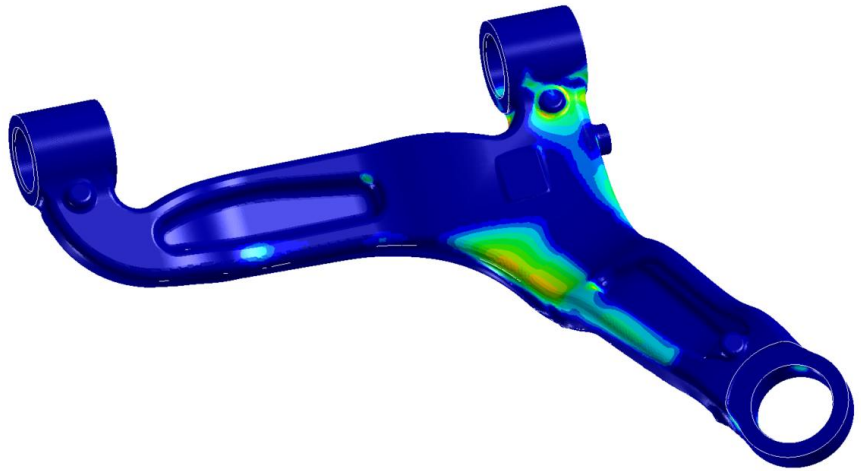
Physical testing

- Historically proven
- Necessary for validation
- Slow and expensive

Photo credit: Pursuit Cycles

Virtual testing

- Fast and agile
- Ideal for optimization
- Requires correlation



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nCode DesignLife:
The virtual fatigue analysis solution

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35,000 CUSTOMERS SERVED

800+
CUSTOMER FACING EMPLOYEES

300+
EMPLOYEES WORKING IN R&D

INNOVATION FOR MORE THAN
80 YEARS

3,500+
EMPLOYEES

CUSTOMERS IN
50+
COUNTRIES WORLDWIDE

Empowering innovation across test, measurement, simulation and analysis

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Durability and fatigue analysis

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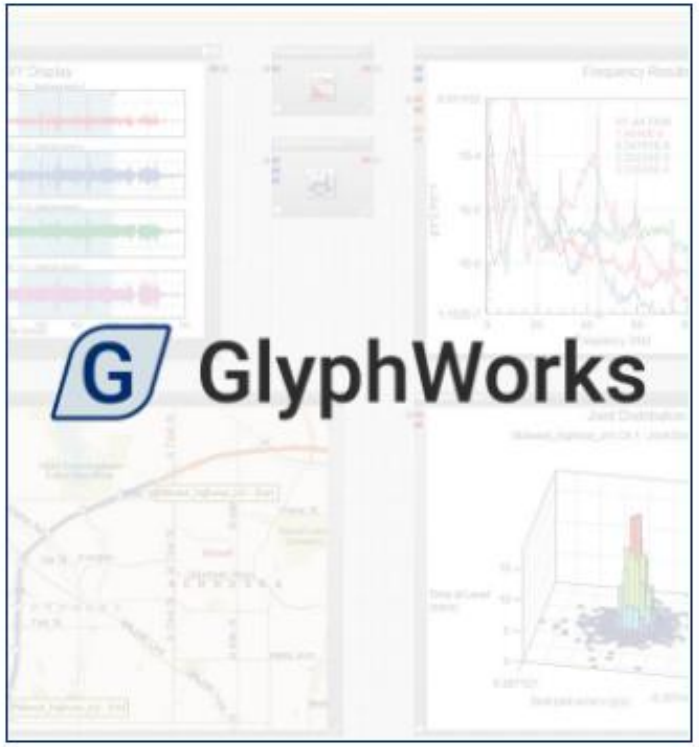
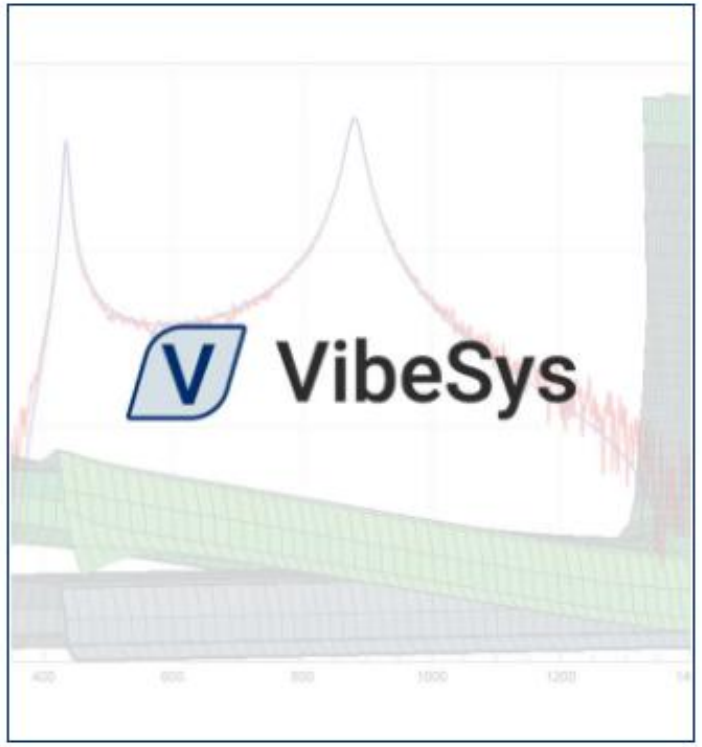
nCode Desktop Product Range





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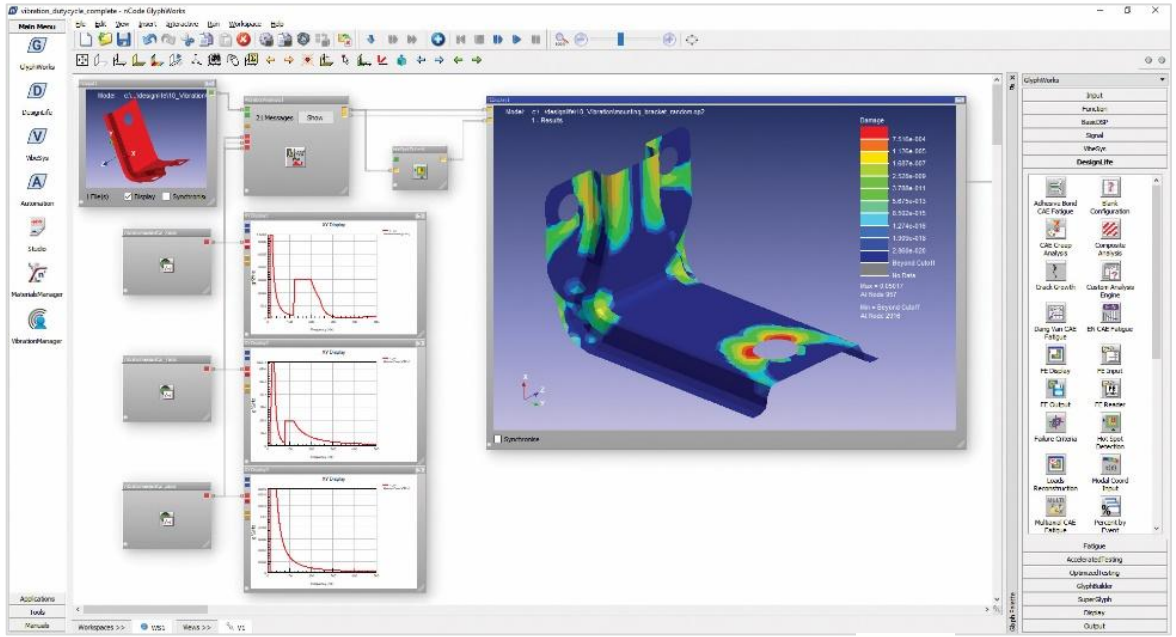
DesignLife

- Fatigue analysis technology for FEA
- Fast, configurable, and scalable

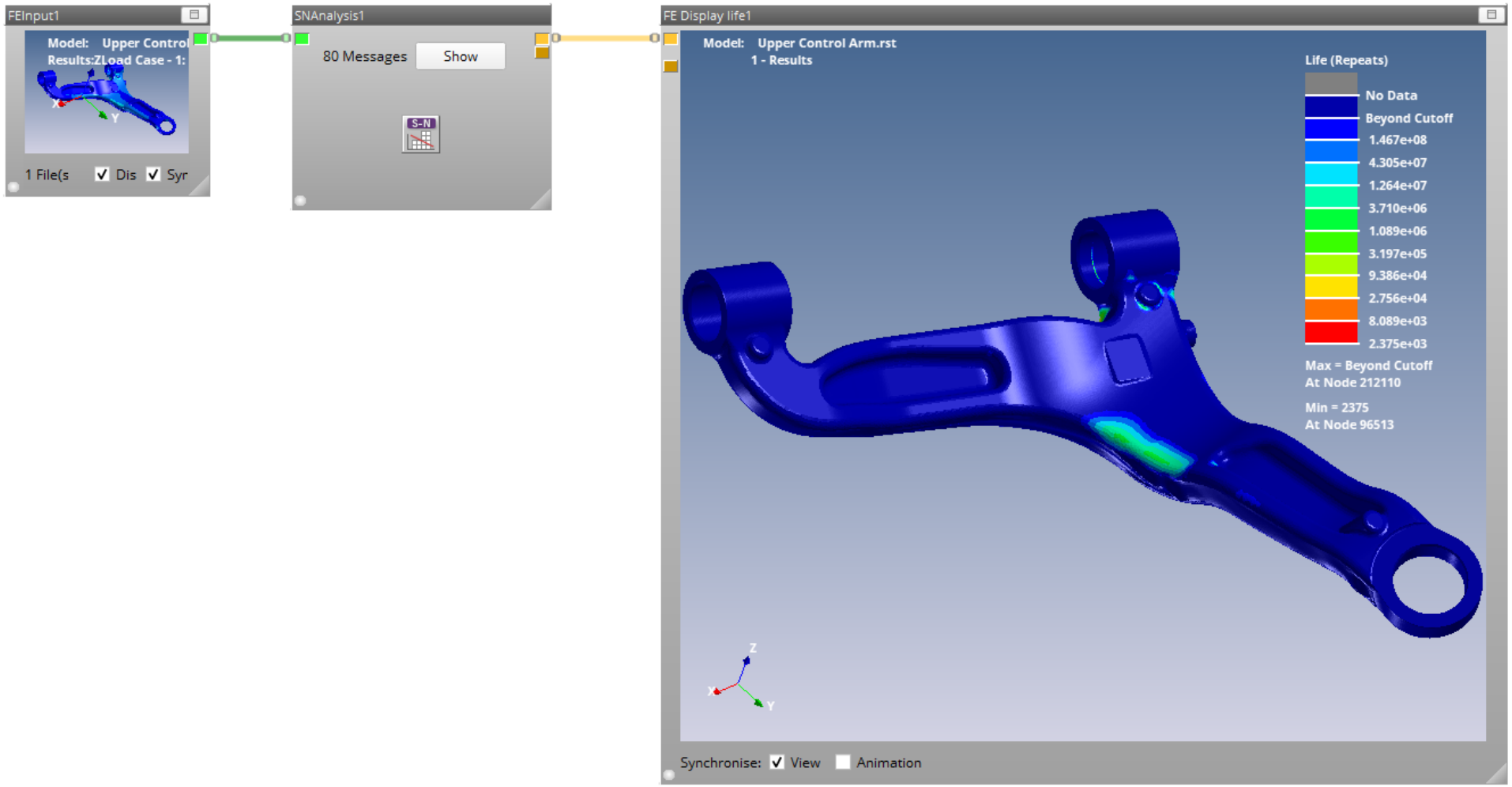
nCode DesignLife is an up-front design tool that calculates durability and fatigue life from leading finite element (FE) results for both metals and composites.

- **Stress-life and strain-life analysis** accounting for mean stress, temperature, plasticity, stress gradients
- **Advanced technology** including thermo-mechanical, composites, adhesive bonds, multiaxial, welds, vibration, crack growth…
- **Fast results** with multi-threaded and distributing processing
- Support stress results from **ANSYS, Nastran, Abaqus, LS-Dyna, Altair OptiStruct** and others



Ansys ALTAIR SIMULIA ABAQUS MSC Nastran HBK HOTTINGER BRÜEL & KJÆR

DesignLife software demo 1



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A deeper look at nCode DesignLife

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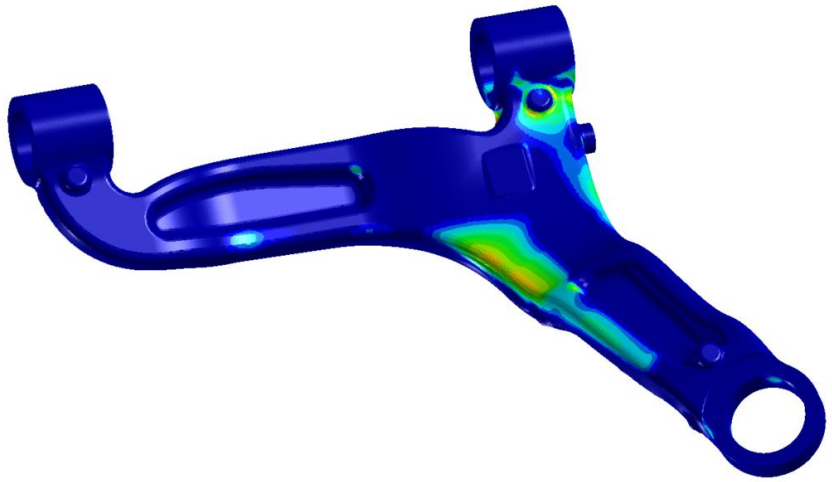
Fatigue analysis process



FE stresses

Loading - time or frequency domain

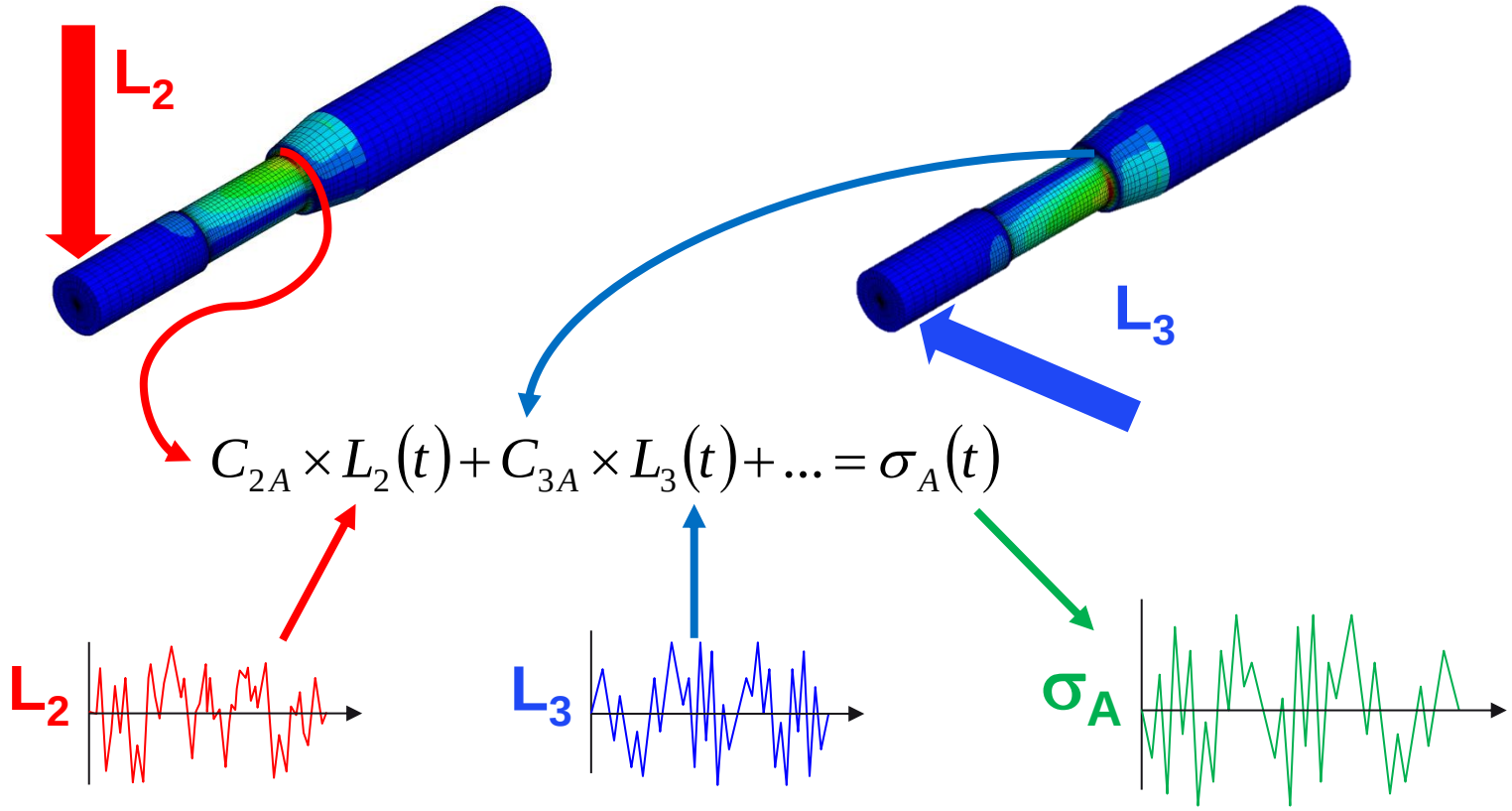
Material fatigue properties

Fatigue analysis

Predicted fatigue life

Variable amplitude loading

- Define fatigue cycles with time or frequency domain loading
- Individual FE load cases for each DOF are paired with measured loading to generate stress or strain histories
- Linear superposition of stress tensors for multiple load cases



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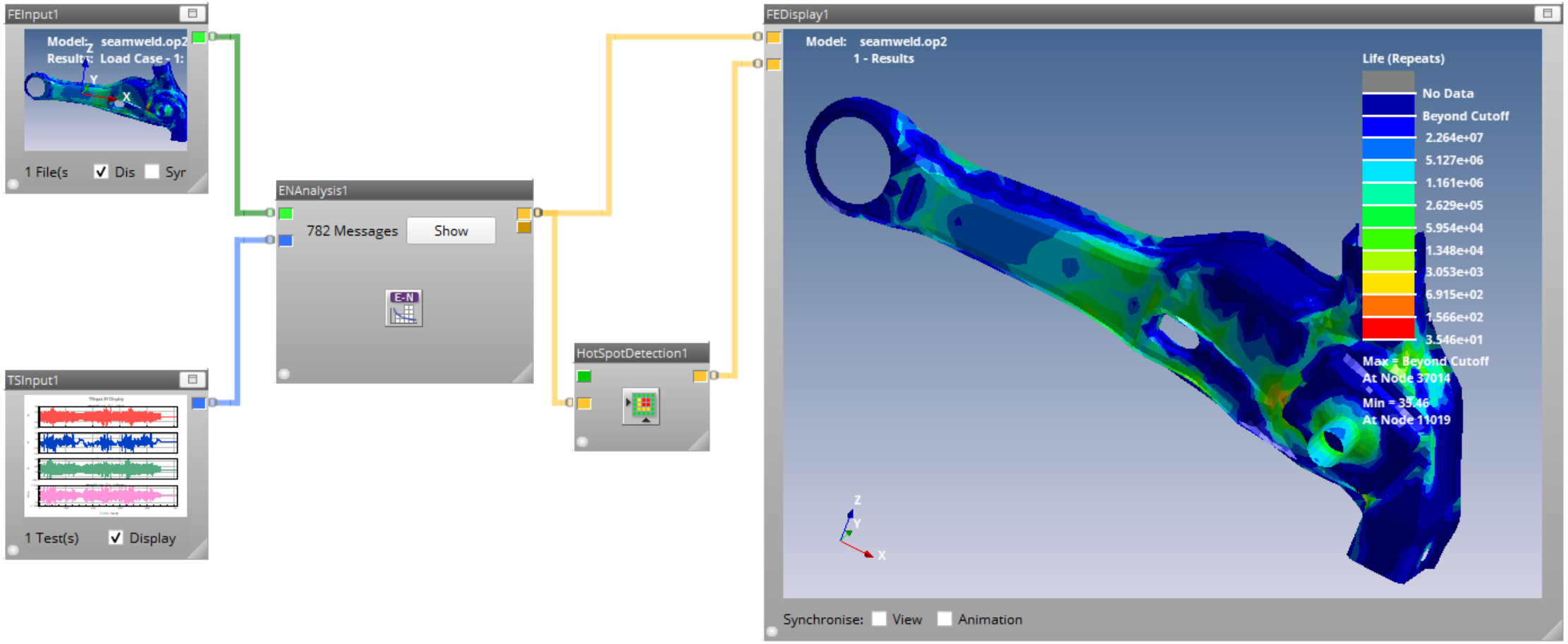
DesignLife software demo 2



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Advanced fatigue analysis use cases

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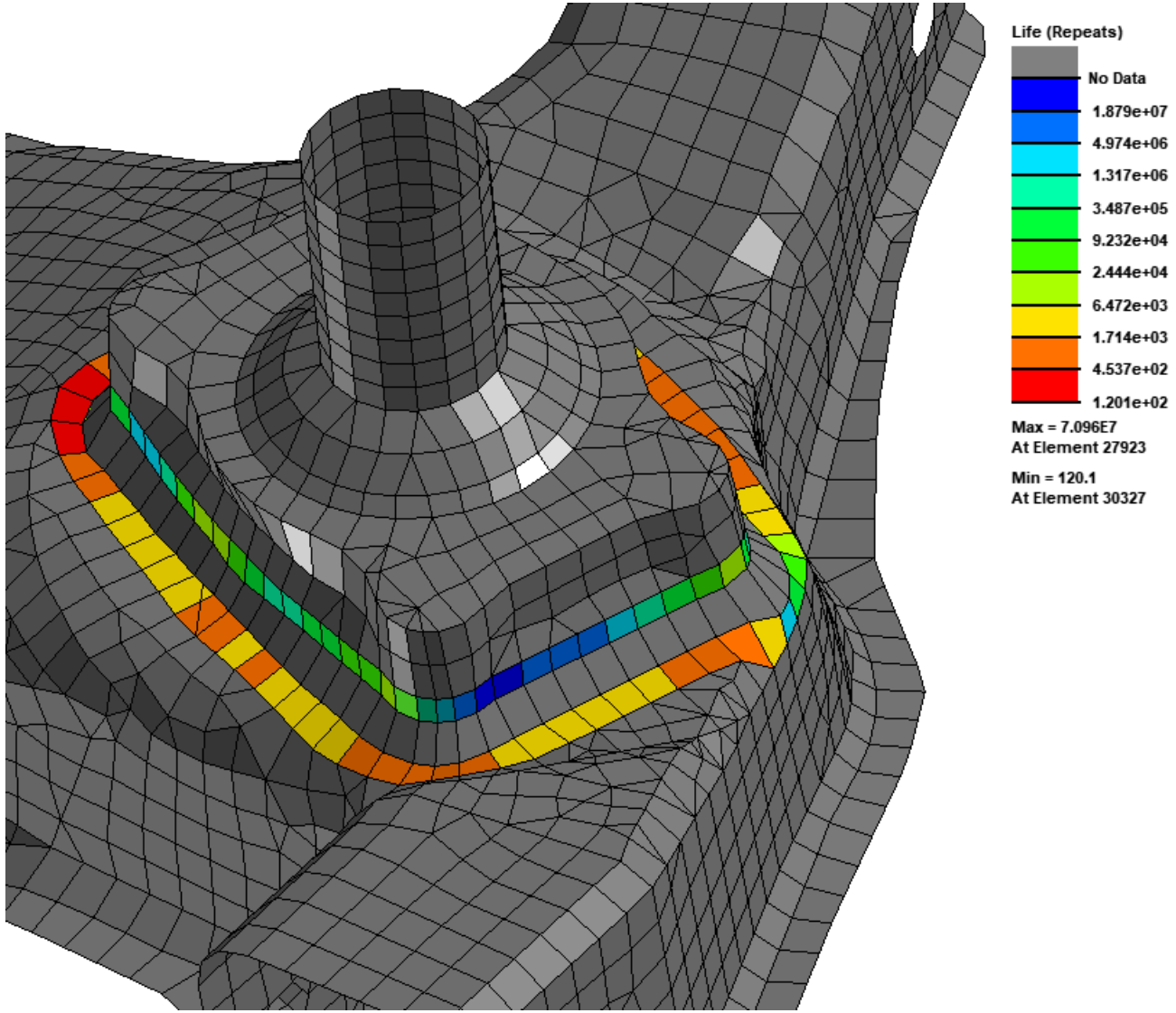
Seam Weld Fatigue

- Variety of approaches provided, for thin and thick welds
- Primary method based on the ‘Volvo’ method (SAE paper 982311) and validated through years of use on vehicle chassis and body development projects
- Uses stresses either from FE models (shell or solid elements), or stresses from grid point forces or displacements at the weld
- Seam welded SN curves are provided



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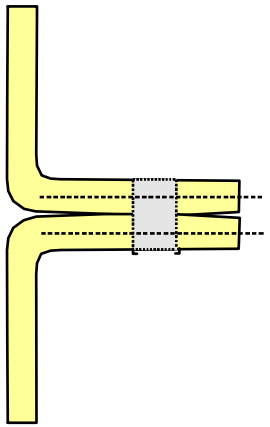
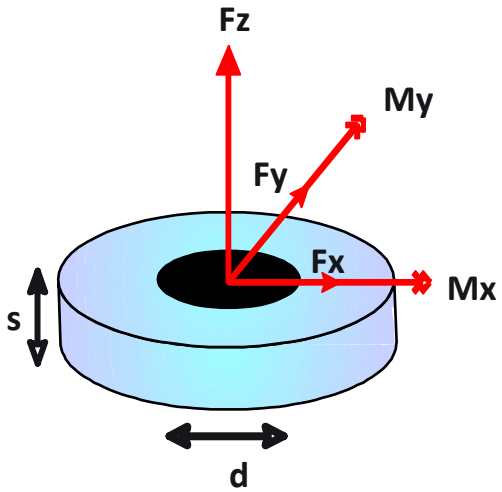
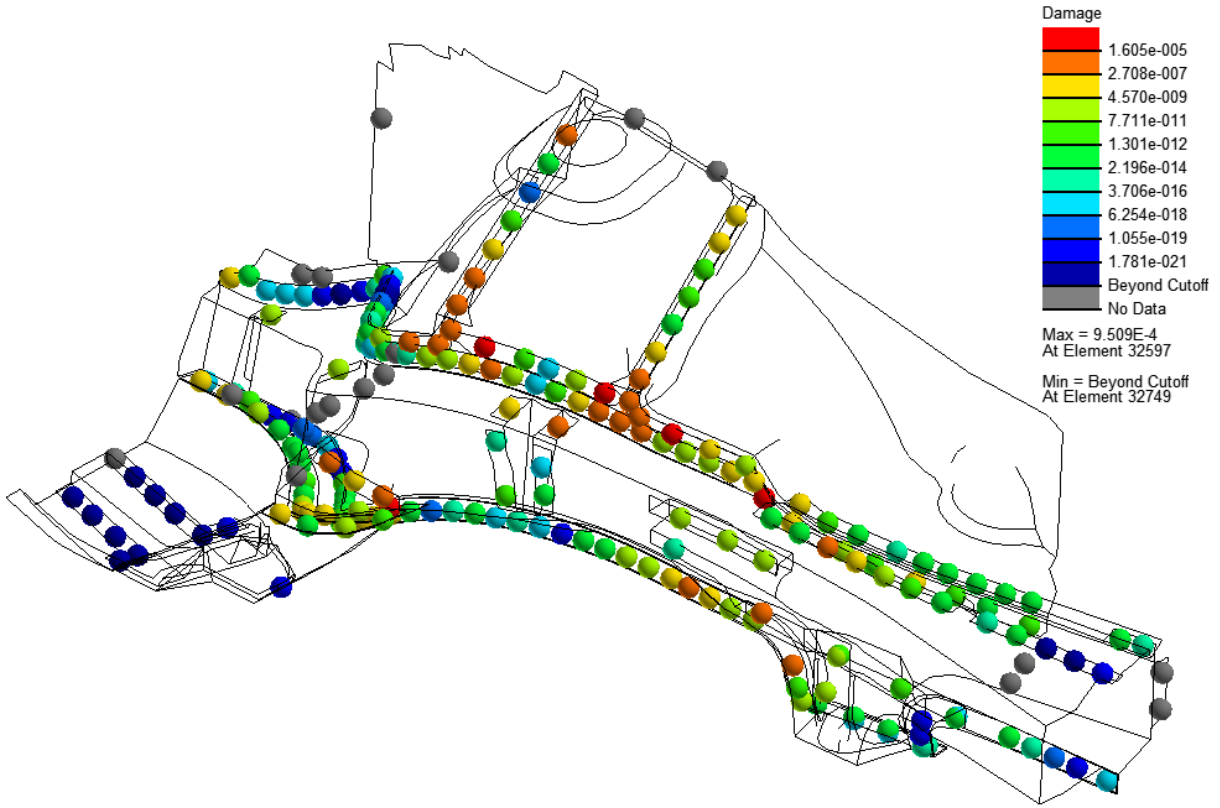
Spot Weld Fatigue

- Based on the ‘LBF’ method (SAE paper 950711)
- Spot welds modelled by beam elements or area contact method
- Cross-sectional forces and moments are used to calculate structural stress around the edge of the weld spot
- Spot welded SN curves are provided

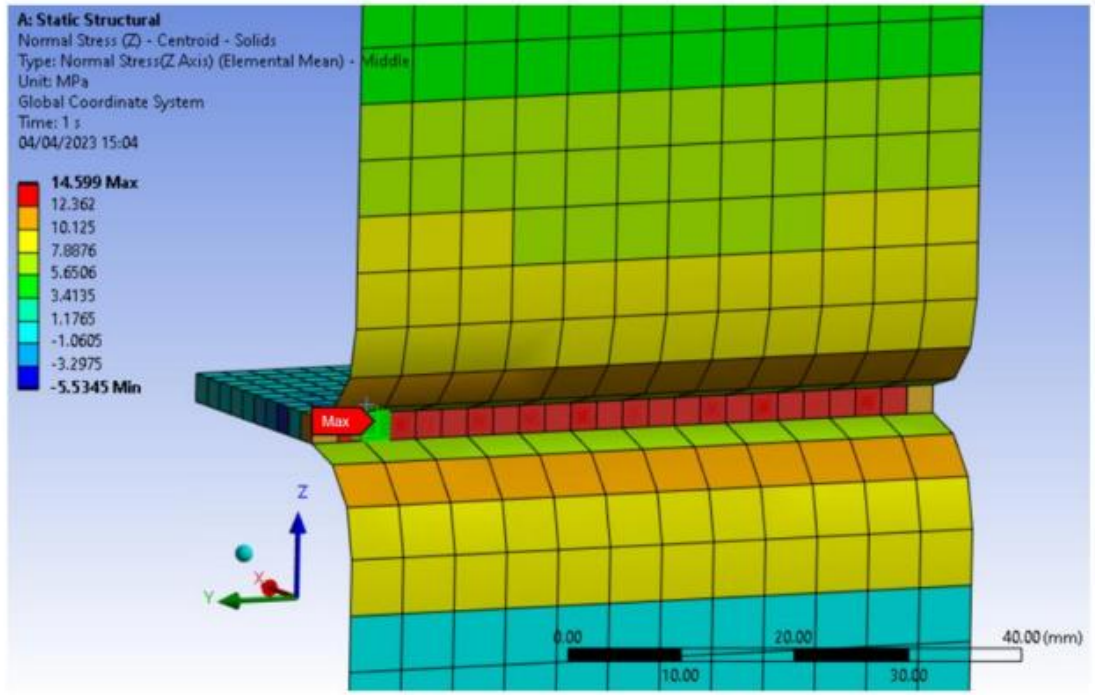


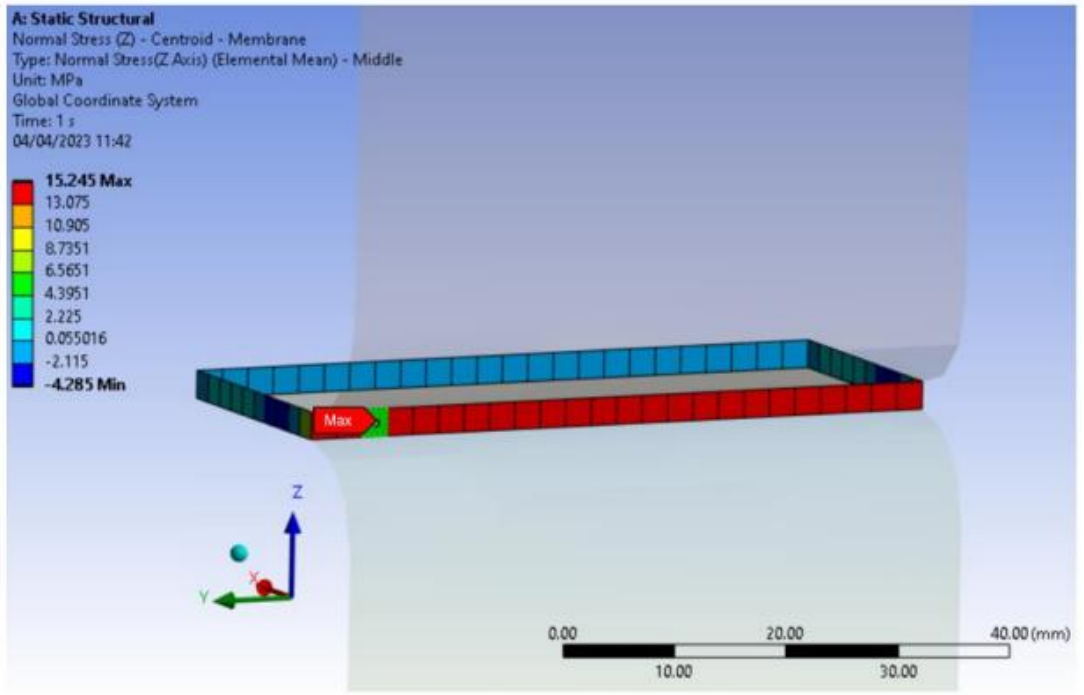




Adhesive Bond Fatigue

- Predict life of an adhesive joint or an adhesive + mechanical joint
- Sheet metal and adhesive mesh do not have to match
- Adhesive can be solid or cohesive elements
- Stress recovered at edge perimeter in the through thickness direction of the adhesive





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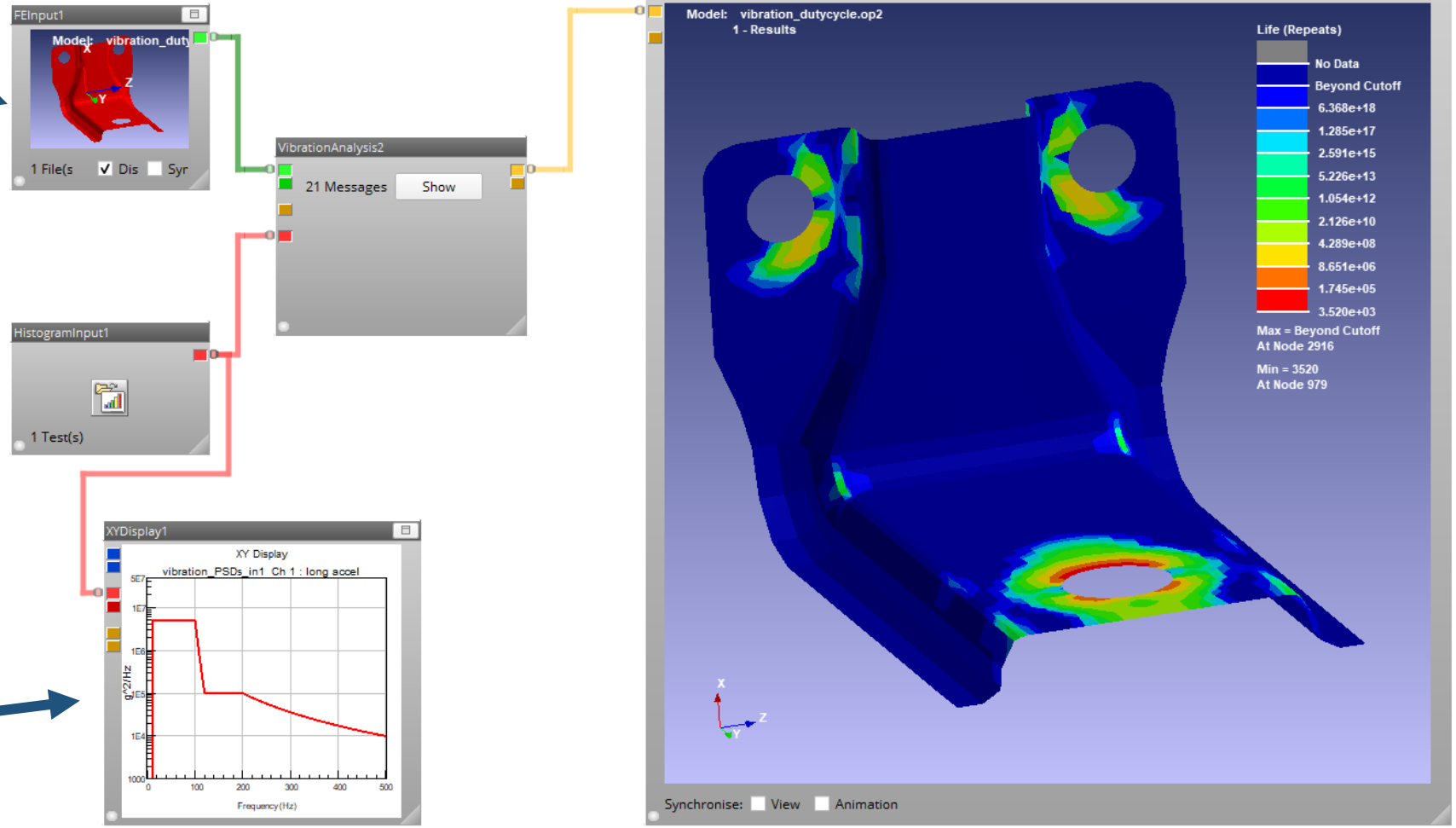
Vibration and frequency domain

Harmonic stresses

Frequency domain excitation



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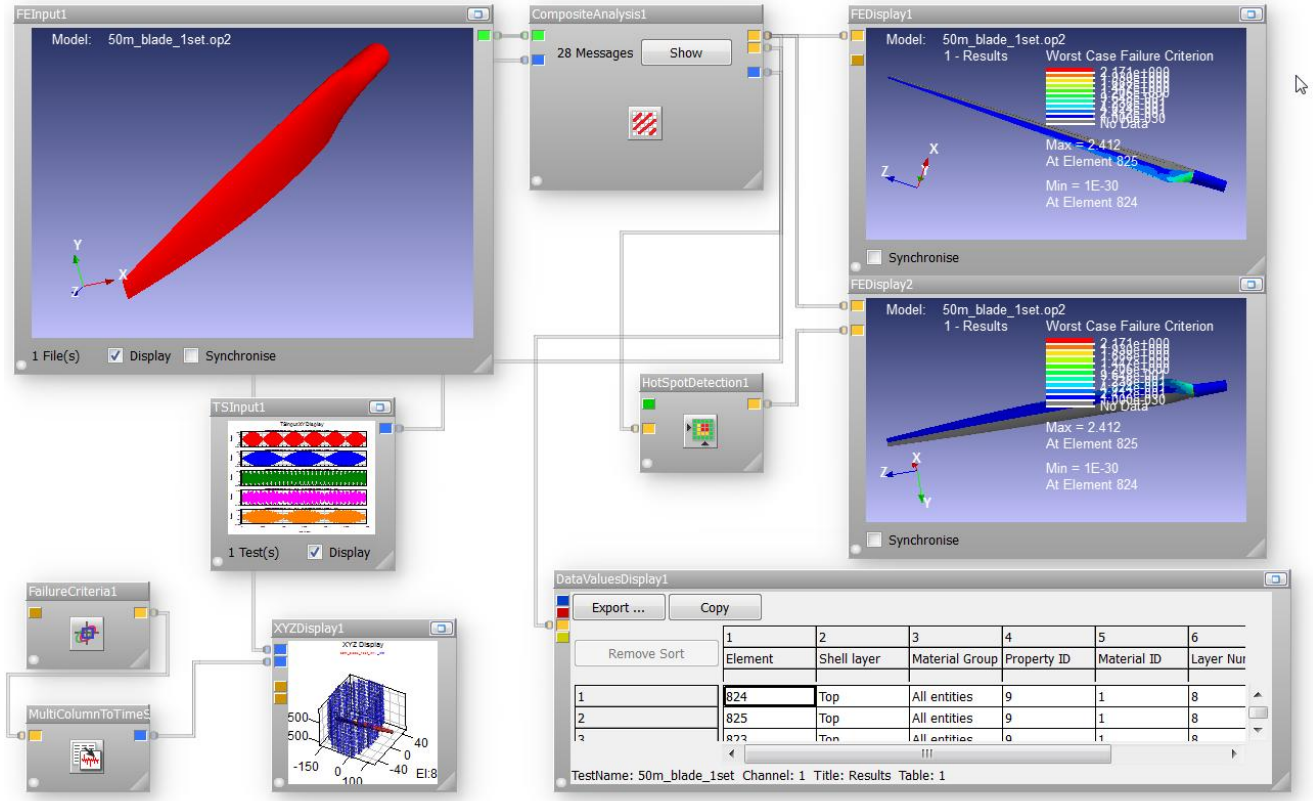
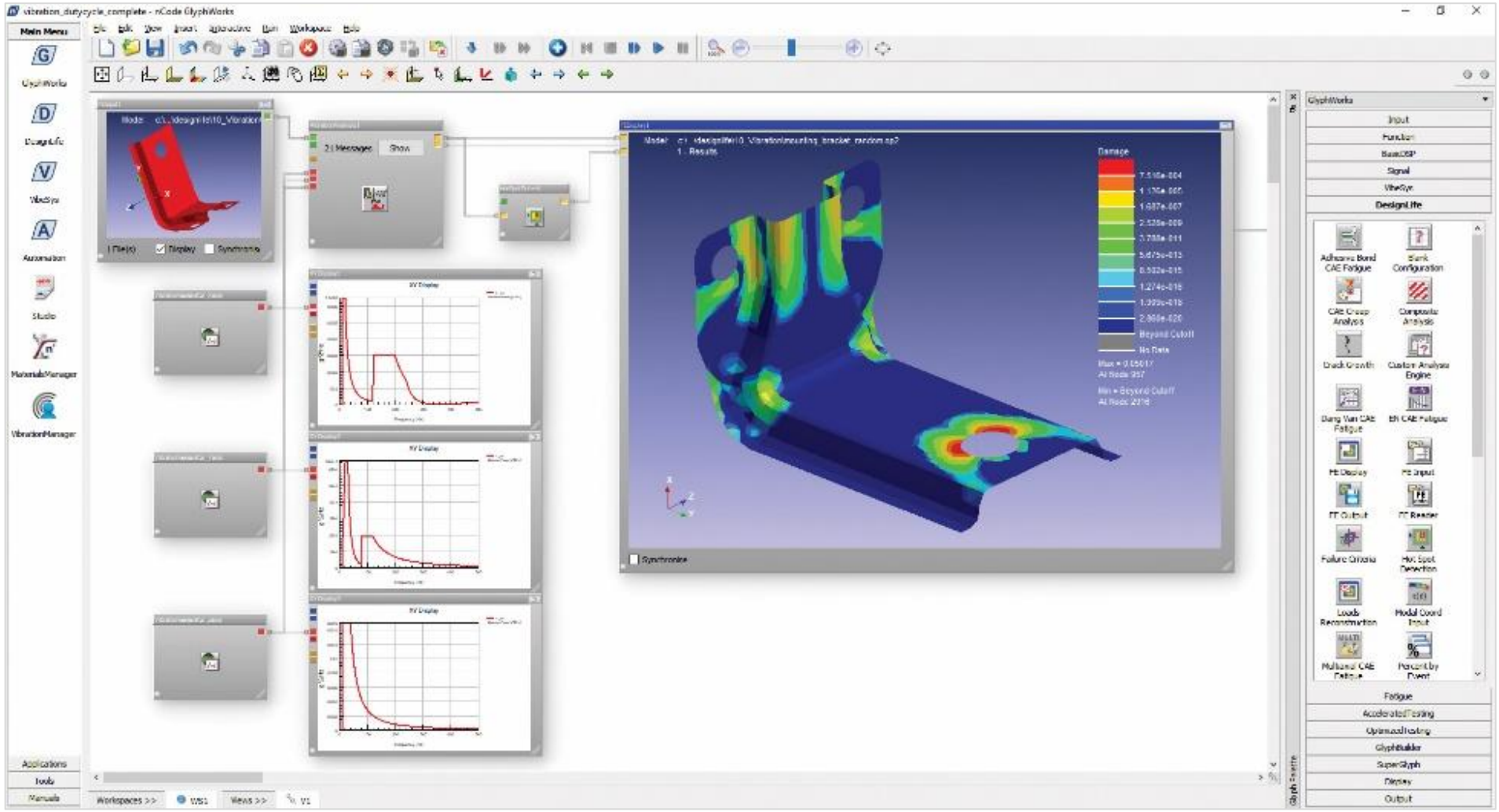
Fatigue of composites

- Static and fatigue failure criteria
- Applies to short fiber, unidirectional long fiber, and woven composites
- 14 different failure criteria supported
- BENEFIT: Enables complete duty cycles of complex loading to be assessed



DesignLife software demo 3



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Correlation between virtual and physical

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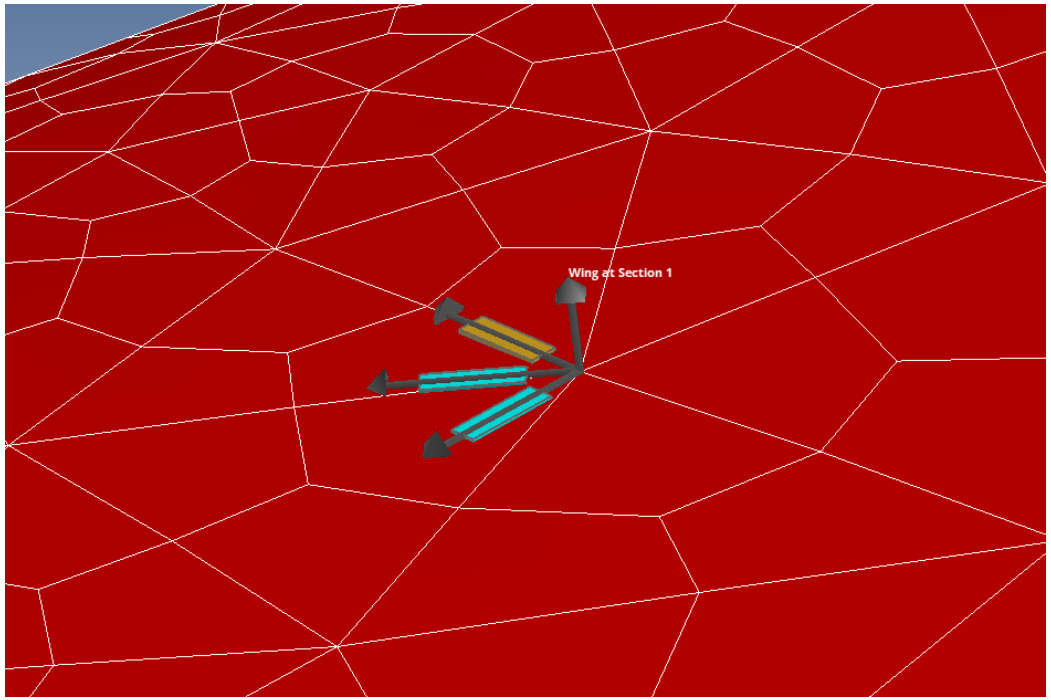
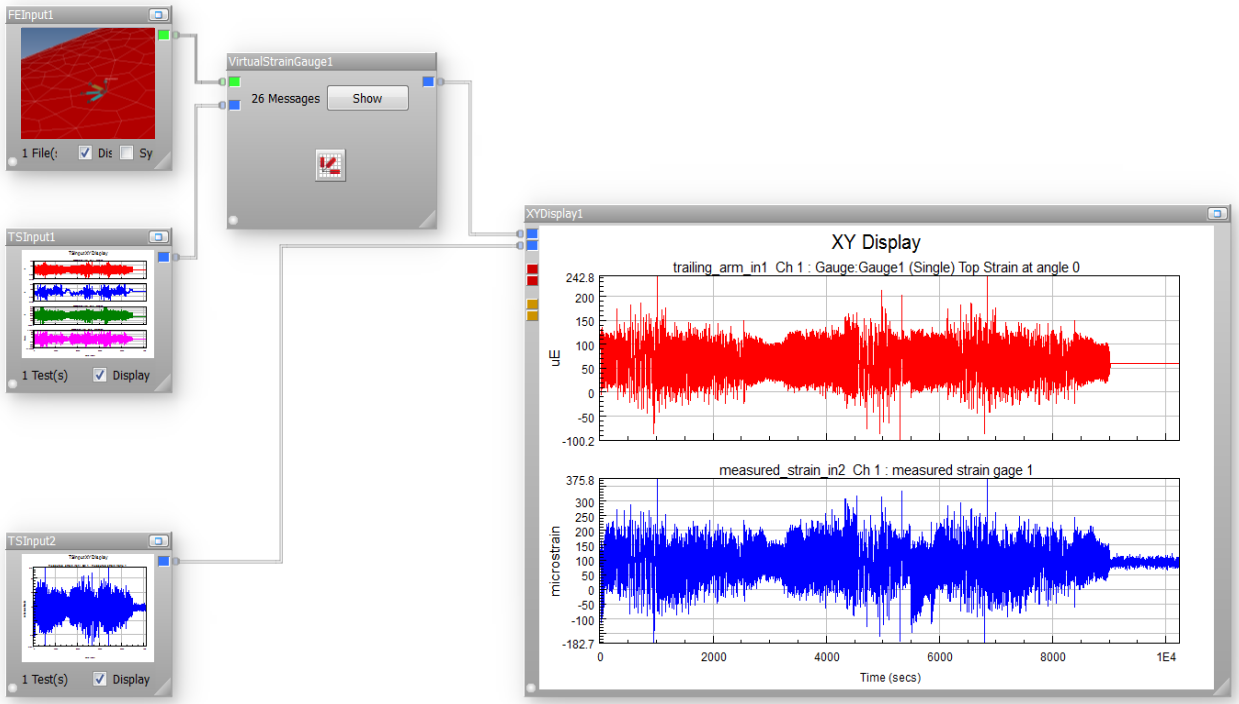
Virtual strain gauges

Gain confidence and improve virtual stress analysis

- Virtual strain gauges are placed on finite element model in nCode
- DesignLife generates **virtual strain** for comparison with **measured strain**
- DesignLife has a wide range of signal processing tools for correlation





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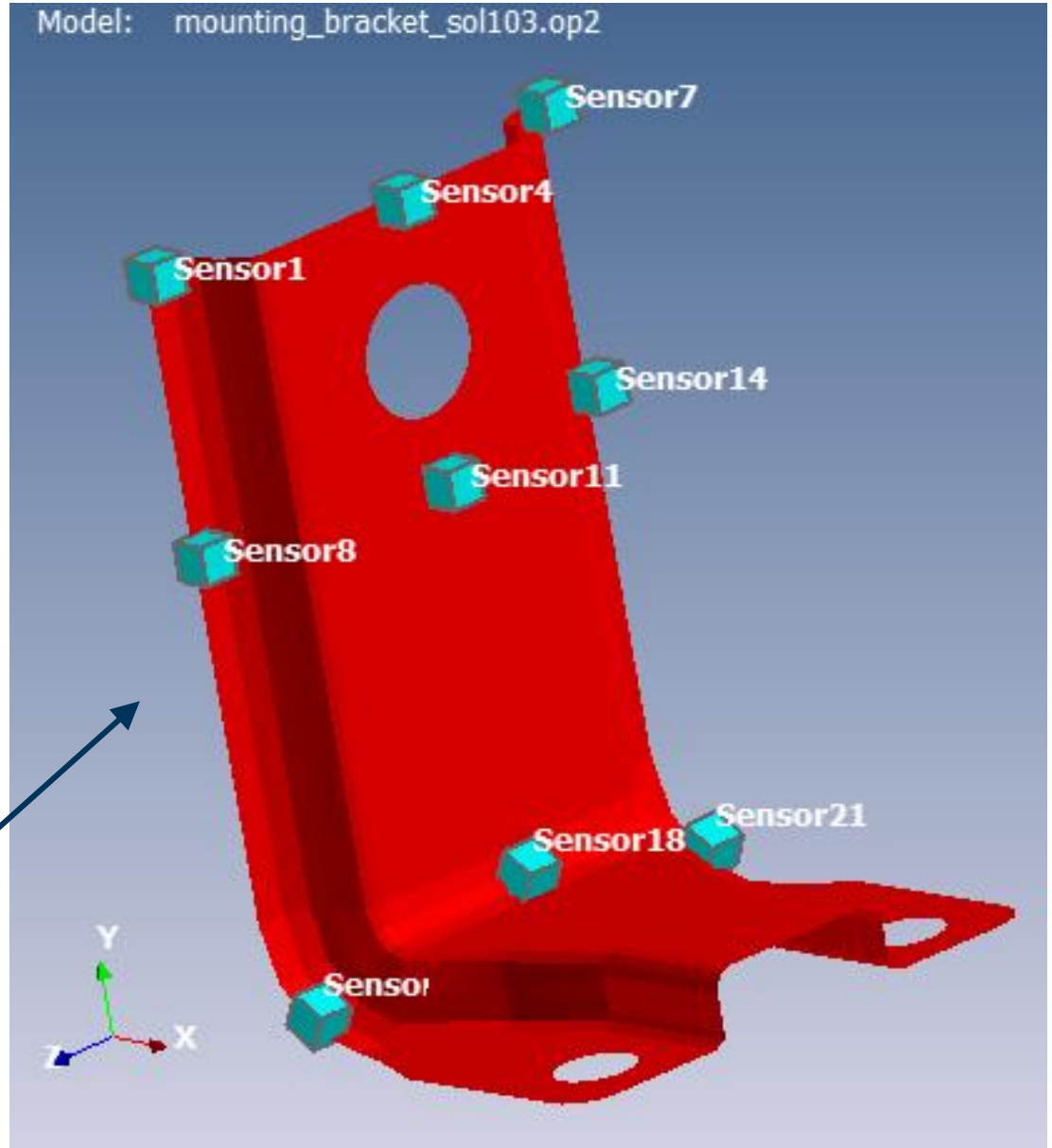
Virtual sensors

- Virtual sensors are applied to the FE model in nCode
- Virtual sensors can capture displacement or acceleration in addition to strain
- Recover virtual vibration in time or frequency domains
- Applications include statics and dynamics, include modal vibration



9 virtual accelerometers

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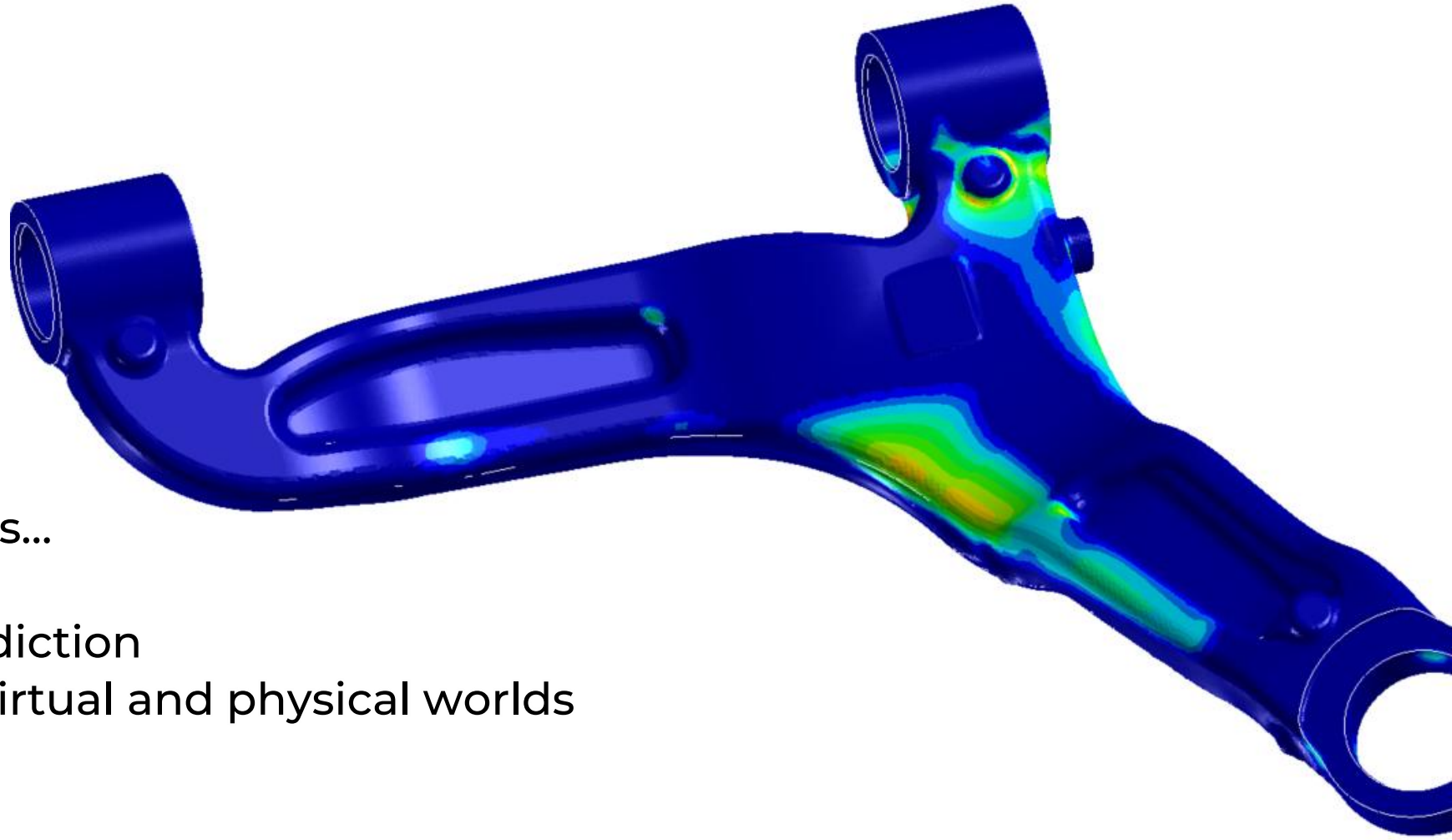
Summary



nCode DesignLife enables...

- Virtual fatigue life prediction
- Correlation between virtual and physical worlds

...in order to...

- Develop products faster, cheaper, and better
- Reduce the risk of failure

Thank you!

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