AI for Smart Manufacturing

Nexus Materials & Odyssee

Date: June 2025

Agenda

I. The Big Picture

II. Nexus Materials

III. Odyssee

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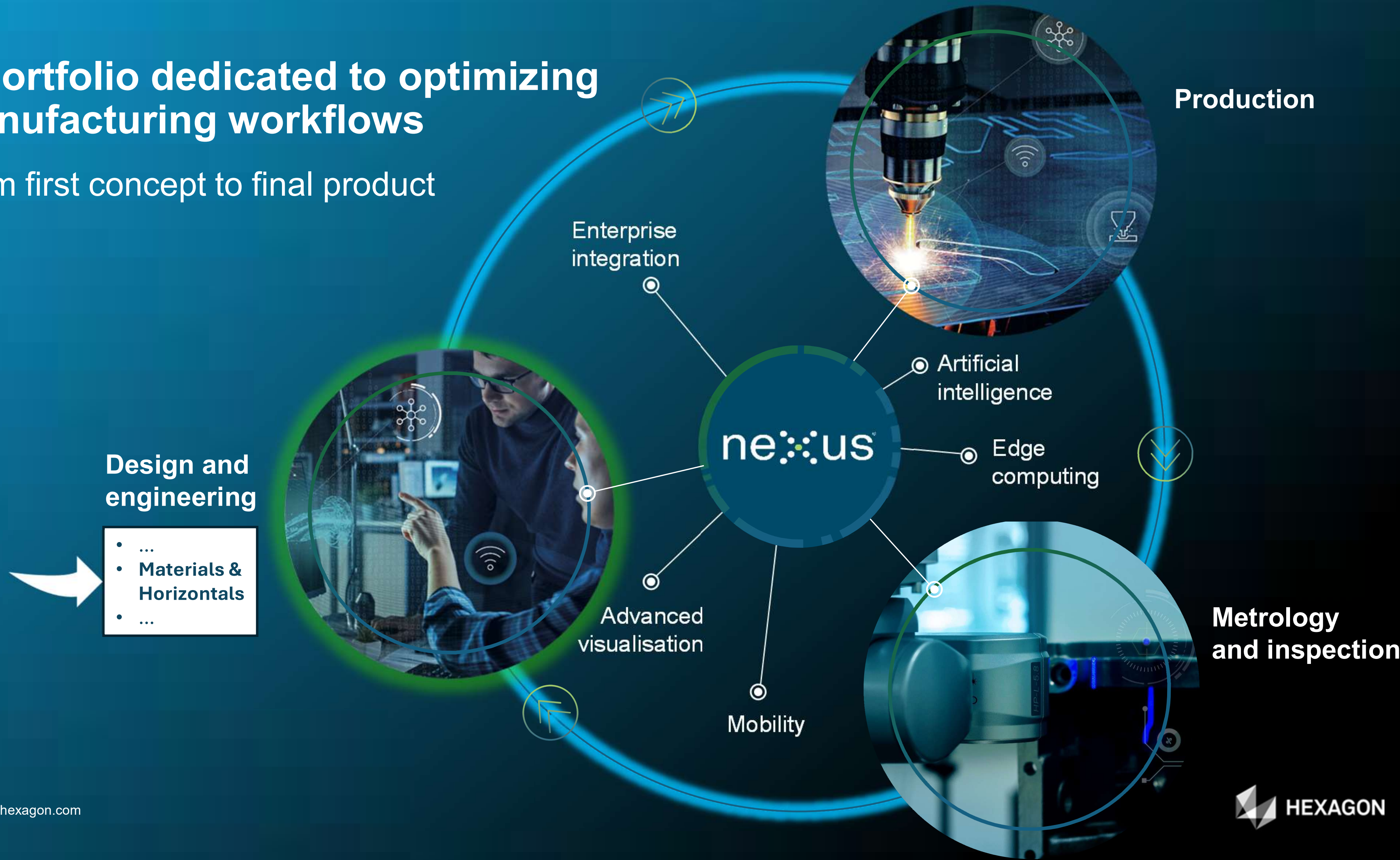
A portfolio dedicated to optimizing manufacturing workflows

From first concept to final product



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The 2 AI Solutions from D&E Presented Today

Nexus Materials & Odyssee

ODYSSEE

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I. Introduction to Nexus Materials

HxGN
Digital Materials

Hexagon's Digital Materials suite delivers material-focused solutions with a predictive edge to empower engineers to reduce prototypes, accelerate material innovation and improve product performance:

- Material Data Management
- Digital Materials Laboratory
- Materials Informatics
- Multiscale Simulations

HxGN
Digital Materials

Overview – Capabilities & Products

- Digimat MF
- Digimat FE
- Digimat MX
- Digimat VA
- Digimat MS
- Material Center
- Materials Connect
- Materials Enrich

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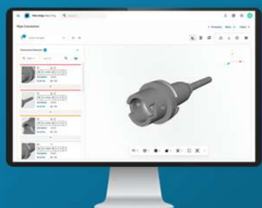
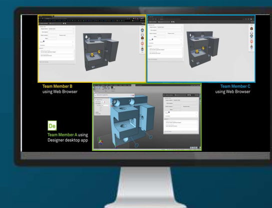
Nexus Overview

Nexus Apps



- Metrology Reporting (nexus APP)
- Materials Connect (nexus APP)
- Materials Enrich (nexus APP)

Nexus Solutions



Additive Manufacturing
nexus SOLUTION

Powered by Nexus

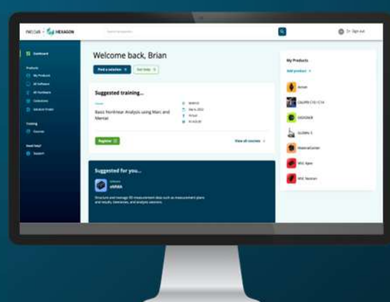
- APEX GD — Powered By **Nexus**
- PC-DMIS — Powered By **Nexus**
- Next-Gen CMM — Powered By **Nexus**

nexus

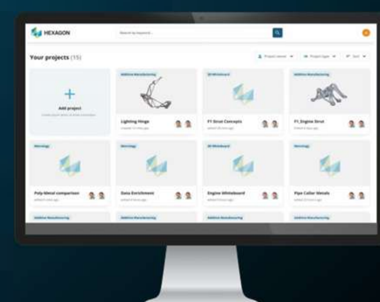
Portal

- Manage your products
- E-commerce
- Training Academy
- Product Documentation

…and more!



Core



- Project Collaboration
- Developer Kit
- AI
- Compute

…and more!

Nexus is an open platform that enhances digital engineering & manufacturing collaboration by connecting people, technologies and data, accelerating innovation and time to market.

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Manage
securely and accessibly

Consume
for design and simulations

Share
internally and externally

Enhance
with sustainable, fast and cost-effective and solutions

Nexus Materials

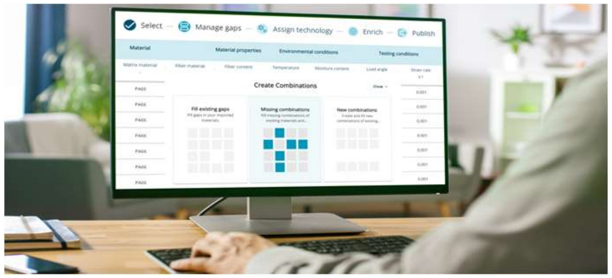
Materials Connect

A cloud-native *visualization* and *data management* solution that provides seamless access to and dissemination of *material data*.

Great for marketing & sales, manufacturing, designers, CAE engineers and materials engineers.

Materials Enrich

The top-tier solution combining *material modeling* and *machine learning* to *enrich material data*, eliminating costly and time-consuming experiments.



Great for designers, CAE engineers and materials engineers.

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State of the Art Solutions for Material Data Enrichment

3 Classical ways for solving this challenge

LAB TESTING

- ✓ Highly Trusted
- ✗ Very Costly

ADVANCED MATERIAL MODELING

- ✓ Reliable
- ✗ Complex

ARTIFICIAL INTELLIGENCE

- ✓ Efficient
- ✗ Data Dependent

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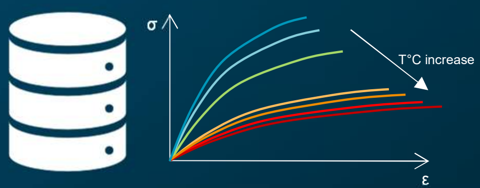
Nexus Materials Enrich

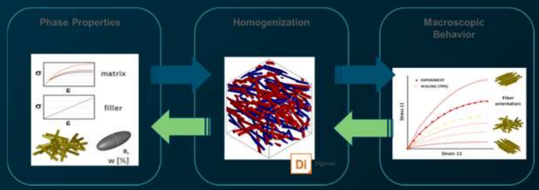
Integrative solution to address those challenges

Experimental Data



Trust of lab data

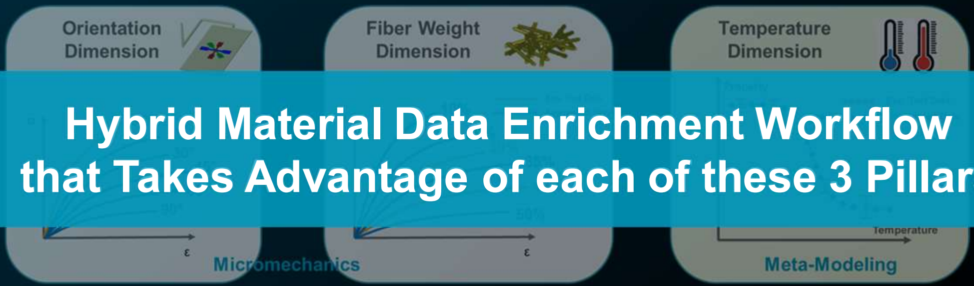
Digimat Micromechanics Modeling + Material Science/Models



Rigor of material science

AI with Relevant Physical Descriptors

Efficiency of AI



Hybrid Material Data Enrichment Workflow that Takes Advantage of each of these 3 Pillars

II. Deep Dive into & Demo of Nexus Materials Enrich

Nexus Materials Enrich

Motivation

Design Requirements

Simulations of fiber reinforced plastic parts material properties for various performances and test conditions

- Temperatures: -40, 23, 80, 120°C…
- Fiber contents: 30, 40, 50%...
- …

Available Material Data

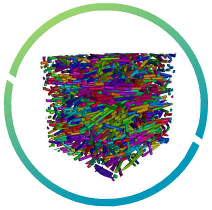
Only very few material properties are available

CAE Engineer

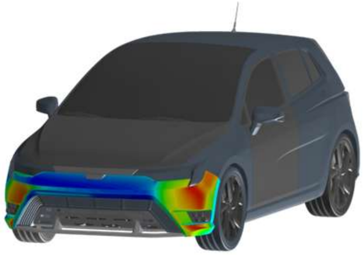
- I need additional material data to run FEA and ensure structural integrity.
- I am working against tight deadlines and cannot afford delays.

Material Engineer

- I have limited data available for this specific material grade.
- Generating more material data is time-consuming and costly.



Short fibre reinforced plastic



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Nexus Materials Enrich

Materials Enrich

Concept

Illustrated on QS Tensile Data

Let's consider PBT resin as an example to enrich the available data:

✓ Available material data = input

? Missing material data = output

	Mass fraction 30%	Mass fraction 40%	Mass fraction 50%
-40 °C	✓	?	?
23 °C	✓	✓	✓
40 °C	?	?	?
80 °C	?	?	?
100 °C	?	?	?
120 °C	✓	?	?

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Digital Materials

Materials Enrich

Materials Informatics – Materials Enrich

CAPABILITIES

- **Test campaigns:** define material test campaigns and identify lacking material properties and conditions
- **Data enrichment:** generate material data with accurate material modelling and machine learning (ML) predictions
- **Cloud-based environment:** facilitate access from any device and leverage computing resources

BENEFITS

- **Reduce cost, time and waste:** minimize lengthy and costly physical experimental tests
- **Accelerate product development:** deliver enriched material information and bring products to market faster
- **Democratise ML technologies:** enjoy an easy-to-use workflow without requiring advanced knowledge

Digimat MF | Digimat FE | Digimat MX | Digimat VA | Digimat MS | Material Center | Materials Connect | Materials Enrich

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Use Case #1

Time & Cost Savings

Your material data enrichment campaign

Running this campaign will save $ 18,000 and 11 days 2 hours of time compared to traditional experimental tests.

18 virtual tests | 1 minute 3 seconds

Pure AI (18) — 720 credits

Enriched property	Qty	Credits	Test subtotal
Quasi-static stress-strain curve	18	40	720

Pre-trained AI models (1) — 100 credits

	Credits
PA66	100

Total campaign cost :
820 credits

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Validation

Use Case #1

Material Engineer

How Materials Enrich is helping

Predict additional material behaviours across both temperatures and fiber weight fractions

Initial Data

Data points for PA66 GF35 %

- at room temperature of 23 °C
- at cold temperature of -40 °C
- at high temperature of 120 °C

at a weight fraction of 35 %

Objective

Predict additional material behaviours:

a) at 4 additional temperatures of 0 °C, 60 °C, 90 °C and 180 °C for the same weight fraction of 35%

b) at all 7 temperatures for additional weight fractions of 25% and 50%

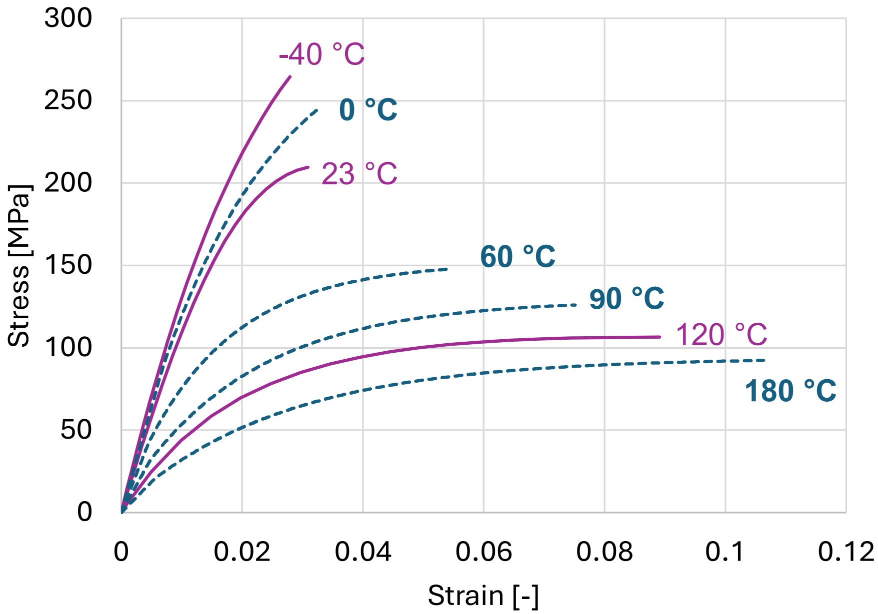
	25 %	35 %	50 %
-40 °C	?	✓	?
0 °C	?	?	?
23 °C	?	✓	?
60 °C	?	?	?
90 °C	?	?	?
120 °C	?	✓	?
180 °C	?	?	?

Time Savings **Cost Savings** **CO_2 Savings**

Use Case #1

(a) Let's enrich the data for PA66 **GF35 %** across the temperature range

Tensile curves of *experimental* (—) and *enriched* (---) material data:



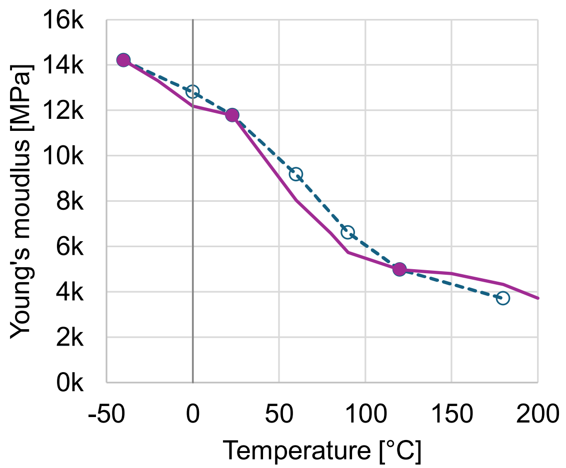
	25 %	35 %	50 %
-40 °C	?	✓	?
0 °C	?	?	?
23 °C	?	✓	?
60 °C	?	?	?
90 °C	?	?	?
120 °C	?	✓	?
180 °C	?	?	?

Use Case #1

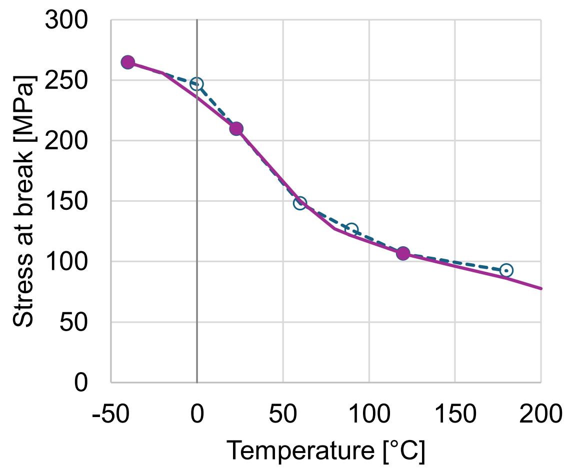
(a) Let’s enrich the data for PA66 **GF35 %** across the temperature range

Master curves of *experimental* ( ) and *enriched* ( ) material data:

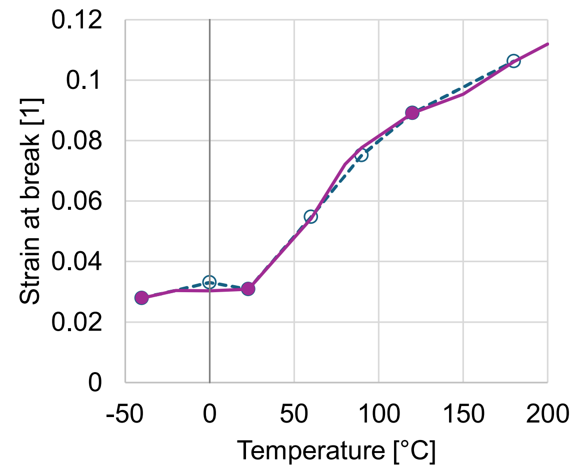
Young’s modulus



Stress at break



Strain at break



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Use Case #2

CAE Engineer

Optimizing Input Efficiency

Determine the minimum number of inputs required for accurate predictions

Initial Data

Data points for PPA GF

- at room temperature of 23 °C for three mass fractions of 30 %, 40 % and 50 %
- at three temperatures of -40 °C, 23 °C and 180 °C at a mass fraction of 30 %

Objective

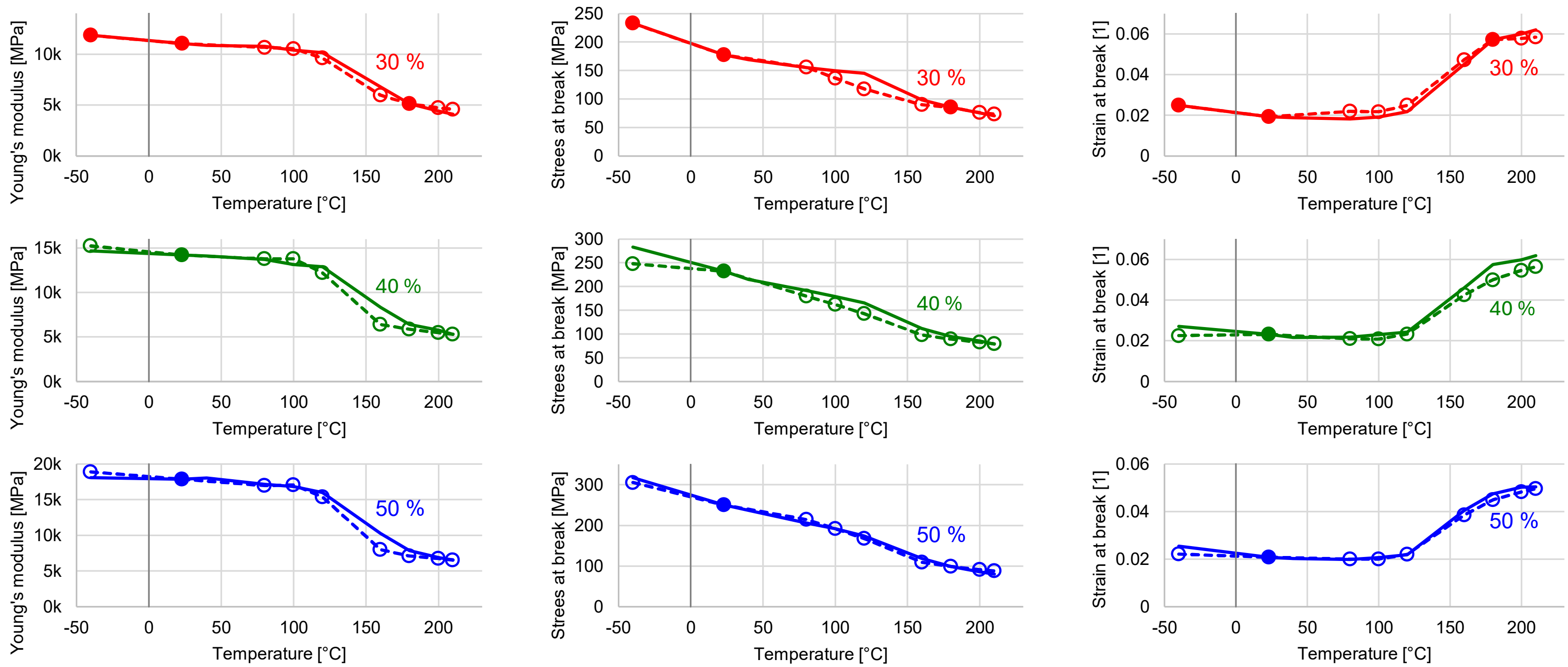
- Predict additional material behaviours across various temperatures and mass fractions
- Assess the quality of predictions with a reduced number of inputs

	30 %	40 %	50 %
-40 °C	✓	?	?
23 °C	✓	✓	✓
40 °C	?	?	?
80 °C	?	?	?
100 °C	?	?	?
120 °C	?	?	?
160 °C	?	?	?
180 °C	✓	?	?
200 °C	?	?	?
210 °C	?	?	?

Use Case #2

Master curves of *imported* (●), *experimental* (—), and *enriched* (-⊖-) material data

Young's modulus | Stress at break | Strain at break



Core Concepts Behind Nexus Materials Enrich

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Nexus Materials Enrich

Enrichment technology – Pure AI

1 → 2 → 3 → 4

Translate

Translate a stress strain curve into constitutive features

Train

Train an AI to predict the constitutive features as function of input parameters

Predict

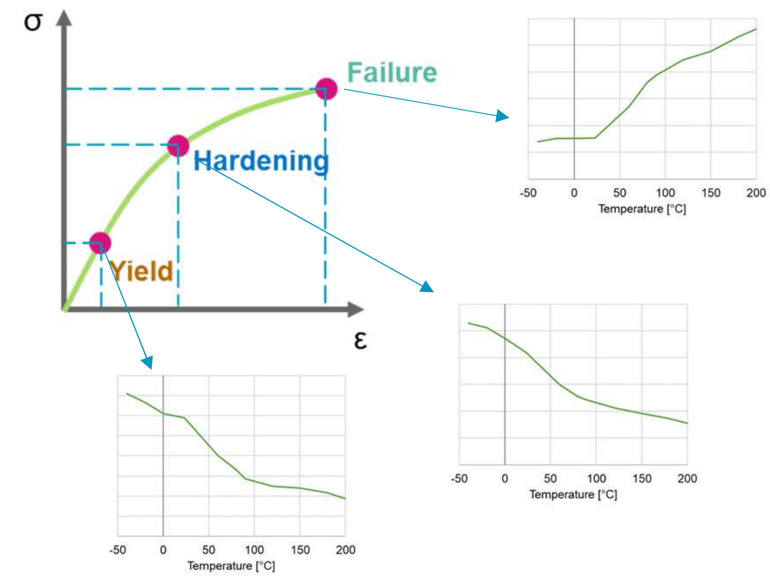
Predict the constitutive features for a new set of input values

Rebuild

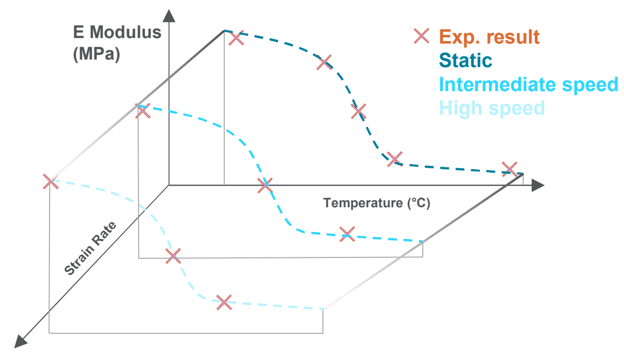
Rebuild the stress strain curve using the predicted constitutive features

What is a Pretrained Model

Pretrained Models refer to Pretrained Master Curves or Pretrained AI (Neural Networks) Models



Master curves are mathematical functions that describe the evolution of material constitutive law parameters as function of conditions e.g. temperature, strain rate, humidity etc.



Master curves should be understood as multidimensional functions rather than 2D functions.

The **master curves** are also called **pretrained master curves** or **pretrained AI models** interchangeably in Materials Enrich, depending on how they are assessed using whether **mathematical equations** or **neural networks**. Let's group them under the term of **Pretrained Models**.

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How is a Pretrained Model used to generate data in Materials Enrich

User Action | **Automated by Materials Enrich**

1 → 2 → 3 → 4 → 5

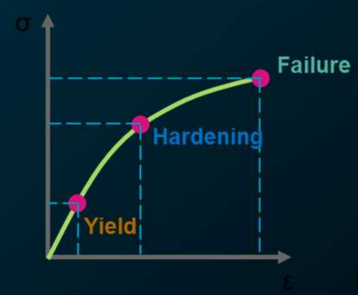
1. Input
The user provides at least one input data point

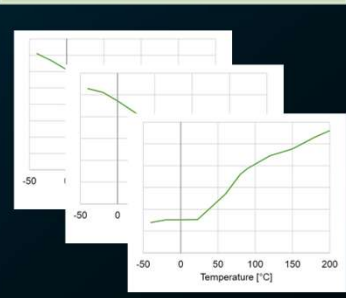
2. Translate
Translate a stress strain curve into constitutive features

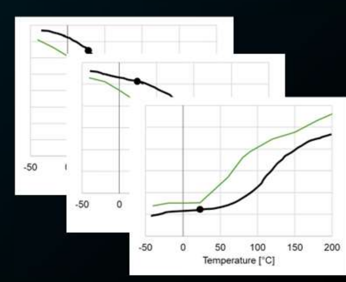
3. Load
Load the adequate pretrained models

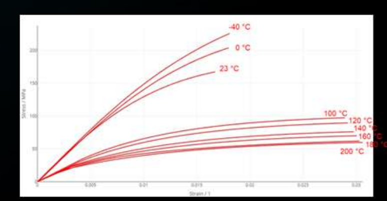
4. Retrain
Retrain the pretrained models w.r.t. the provided input data

5. Output
Compute the output based on the retrained models









Adding Pretrained Models on the top of the 3 Enrichment Technologies

Pretrained Models make it possible to generate exhaustive data out of very few input data

Pretrained models

- The pre-trained models can be used in combination with any of the Pure AI, Physics Informed AI and Digital Test technologies.
- Pre-trained models are available for several matrix systems.
- Pretrained models are retrained with the current data of the user for more accuracy.

Digital Test

- Uses micromechanics
- Does not use AI
- Operates at micro level i.e. Matrix level

Pretrained Master Curves at Micro level

Pure AI

- Does not use micromechanics
- Uses AI
- Operates at macroscopic level i.e. SFRP level

Pretrained AI at Macro level

Physics Informed AI

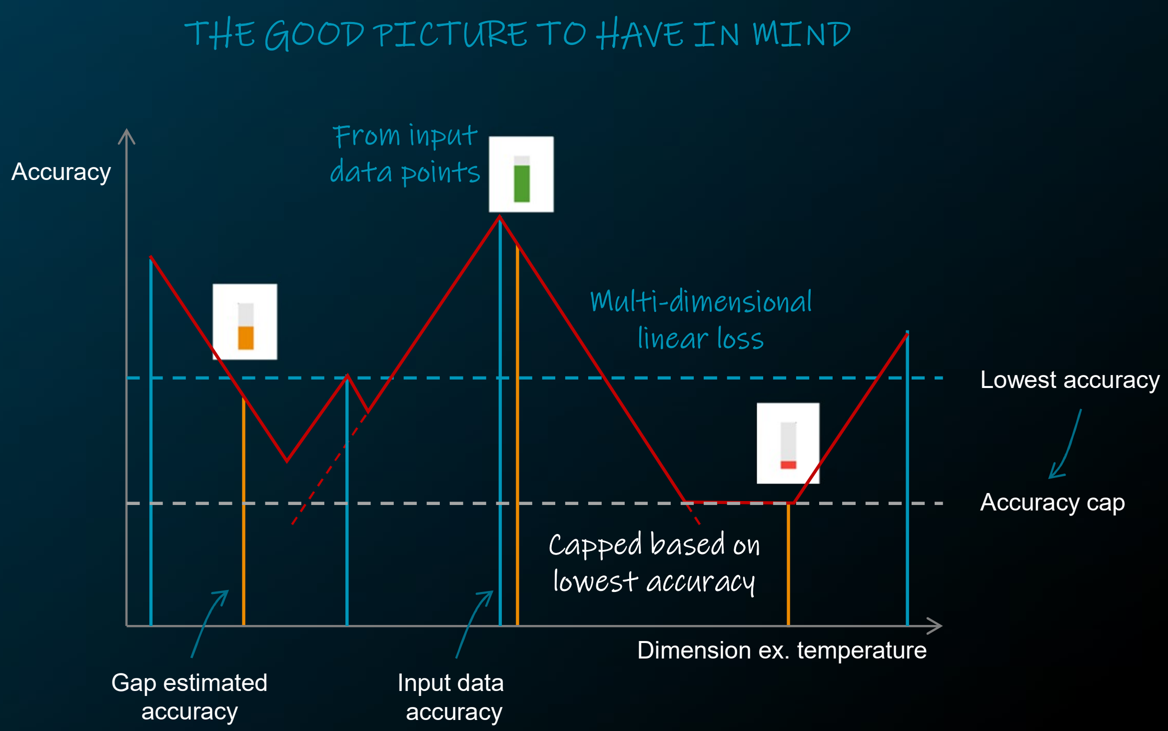
- Uses micromechanics
- Uses AI
- Operates at micro level i.e. Matrix level

Pretrained AI at Micro level

How is accuracy estimated

Enrichment related – Accuracy estimate

Estimation of accuracy along interpolation dimensions



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Hexagon's AI/ML Solution

ODYSSEE

Enhancing Engineering through
Machine Learning & Artificial Intelligence

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Overview of the Horizontal Enablers – ODYSSEE

ODYSSEE CAE

- Real-time predictions within DoE boundaries
- Evaluation of wide array of scenarios & rapid turnaround once unknow scenario takes place
- Sensitivity analyses, Robustness studies and Optimization performed in real time
- Faster design to stress iterations, resulting in faster design cycles
- Export FMU models (limited or unlimited)
- Export Nastran/Marc sub-models

ODYSSEE A-Eye

- Image-based prediction
- CAD-based prediction
- Sound-based prediction
- Tailor-made applications enabling non-experts to leverage machine learning methods and/or predict results in lieu of simulation Prediction: labels, integer/real, curves, Image

ODYSSEE Solver

- Enabling Digital Twin, Multiphysics, Virtual prototyping, Health monitoring projects
- Co-Simulation through FMU model exchange
- Embedded CAE Software & Electronics (FMU or Smart Superelements)
- Data Mining
- Optimization
- Possibility to create own scripts (Quasar/Python)
- Integration into SimManager, Cradle, Marc, Apex, Digimat…)

ODYSSEE Explore

- Data pre & post-processing enabling thorough analysis and mining
- Process & analyse data to setup machine learning projects
- Enabling troubleshooting of machine learning models, understand prediction deviances

ODYSSEE FMU Builder
ODYSSEE FMU RunTime

- ODYSSEE FMU Builder & ODYSSEE FMU Runtime are products without interface to respectively create and run FMU model.
- These one can be integrated into FEA models, electronics....
- The versions integrated into Marc call respectively Mentat FMU Builder & Marc FMU Runtime

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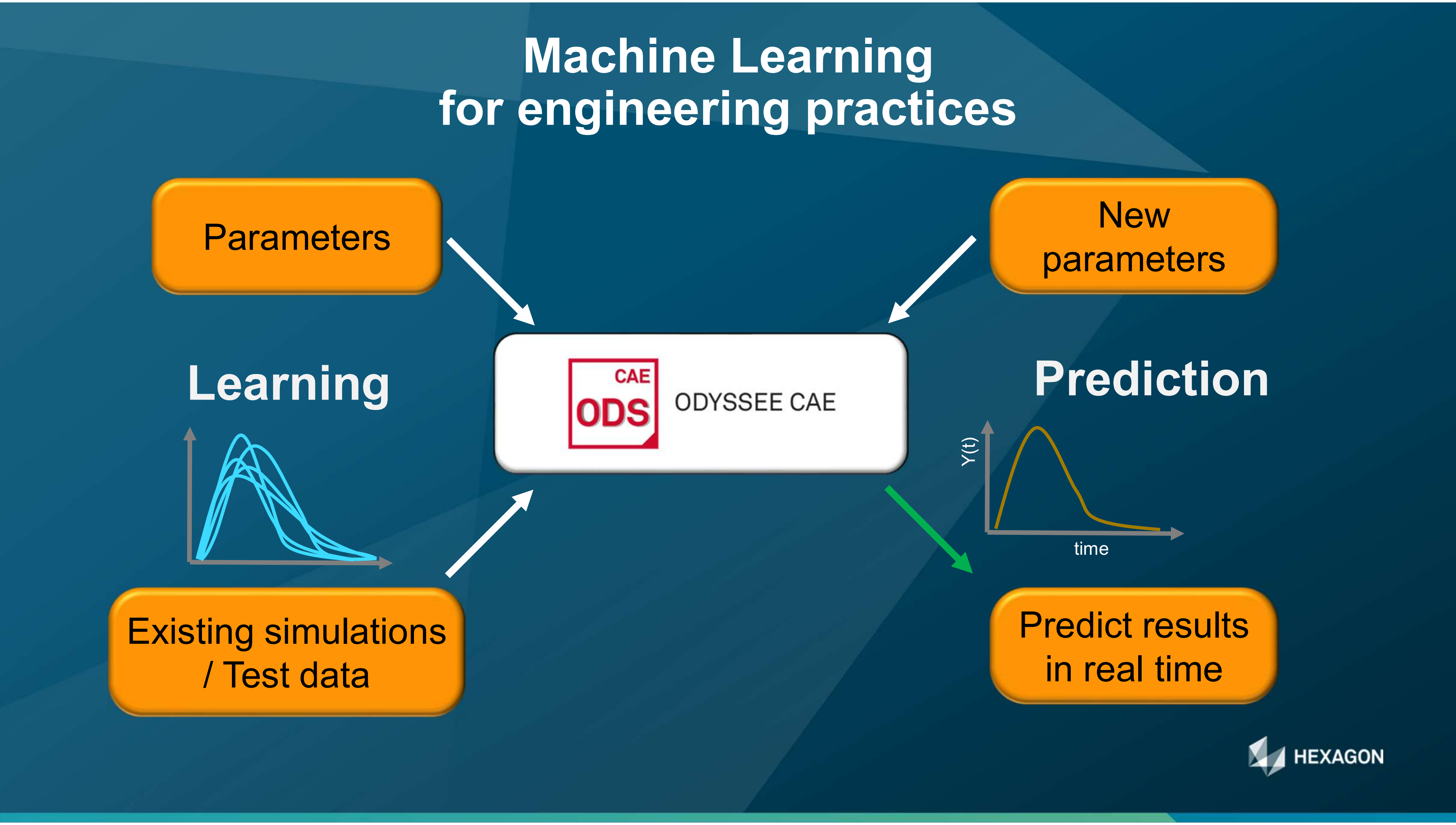
Real-Time predictive modeling and optimization

With ODYSSEE CAE


Machine Learning
for engineering practices
Parameters
New
parameters
Learning
CAE
ODS
ODYSSEE CAE
Prediction
Y(t)
time
Existing simulations
/ Test data
Predict results
in real time
HEXAGON

Image/CAD based learning and prediction

With ODYSSEE A-Eye

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Machine Learning
for Images and production

Images / CAD models

Database Results

Learning

ODS AI ODYSSEE A-Eye

New Images / CAD models

Predict results in real time

Prediction

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Why ODYSSEE as AI/ML Solution for Material / Process / CAE

Needs less data

POD/ROM based (vs Deep Learning, Neural Networks and classic Machine Learning)

Needs little CPU Power

Data Security (On Premise Solution)

Cutting edge image/morphology to performance feature (A-Eye)

User Experience (UX) and CAE oriented mindset > Easier deployment

Compatible with the MSC-One licensing system

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ODYSSEE CAE – Case Studies

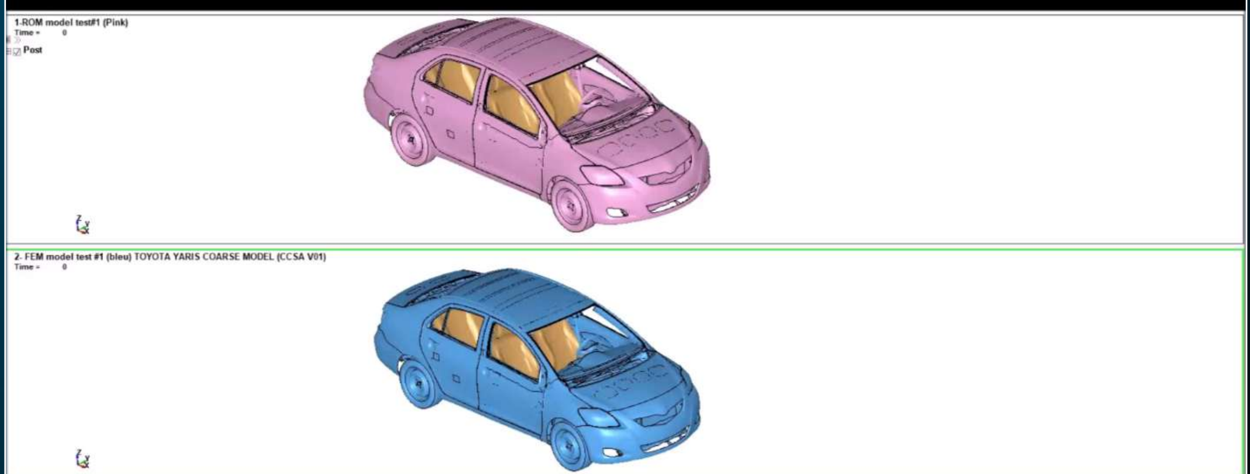
Explicit Analysis – Crash – *Front Crash in Real-time*

ODYSSEE CAE & FMU Export

ODYSSEE A-Eye

ODYSSEE Solver & FMU Run

ODYSSEE Explore



Pink car : Lunar simulation (few seconds) / Blue car : FEM simulation (3h)

Challenge

- Crash/safety configurations depend on many parameters.
- Investigating them or optimising the design requires multiple simulations.
- Explicit FEM simulations typically require hours and design exploration studies can take days.

Solutions

- By first identifying the most sensitive variables, ODYSSEE enables design optimisation using very few evaluations of the model. Ultimately, ODYSSEE can be used to find the best design.
- Design exploration studies can be performed in minutes.

Benefits

- Using ODYSSEE allows engineers to determine the most sensitive parameters first and then evaluate different scenarios (in a few seconds instead of hours) with historical curves and animations with elemental info (stress, strain…)
- Finally, ODYSSEE can perform optimisation (multi constraint), multi objective) and generate optimal responses (curves and field data) in a few seconds.

Fluid Dynamics | Acoustics | Structural | Thermal Analyses | Multi-Body Dynamics | Manufacturing | **Explicit Analysis**

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ODYSSEE CAE – Case Studies

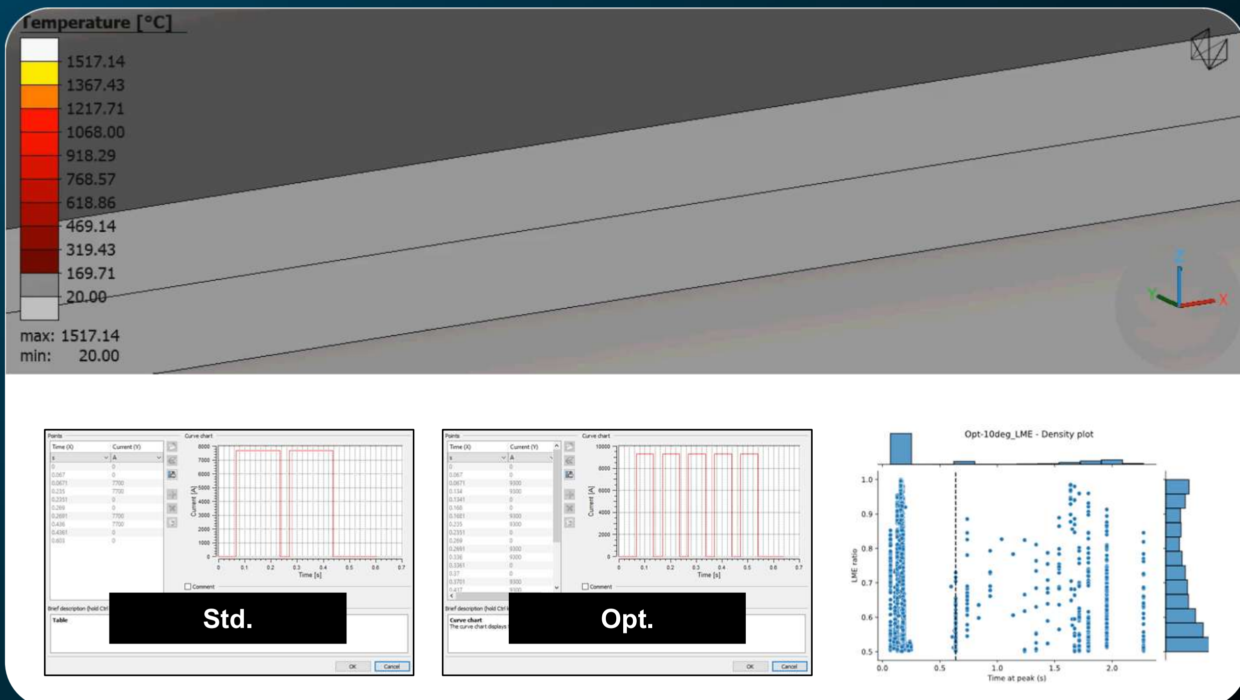
Manufacturing – *Resistance Spot Welding*

ODYSSEE CAE & FMU Export

ODYSSEE A-Eye

ODYSSEE Solver & FMU Run

ODYSSEE Explore



Challenge

- RSW is a widely used process in the automotive industry and requires extensive knowledge on material and joining parameters to be well executed.
- Very often it requires hundreds of tests to define a robust welding schedule for a specific material stack up.
- This task involves welding coupons and then performing tensile tests ensuring the desired strength is obtained.

Solutions

- Combining ODYSSEE with Simufact Welding, the VMC team is augmenting welding simulations by identifying patterns in the results that can be used to derive optimised welding schedules by controlling weld current, number of pulses and electrode force.

Benefits

- Interpolated data generated from ODYSSEE is utilised to create an optimised RSW schedule.
- Schedule is implemented on new welds with different materials.

Fluid Dynamics | Acoustics | Structural | Thermal Analyses | Multi-Body Dynamics | **Manufacturing** | Explicit Analysis

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ODYSSEE A-Eye – Case Studies

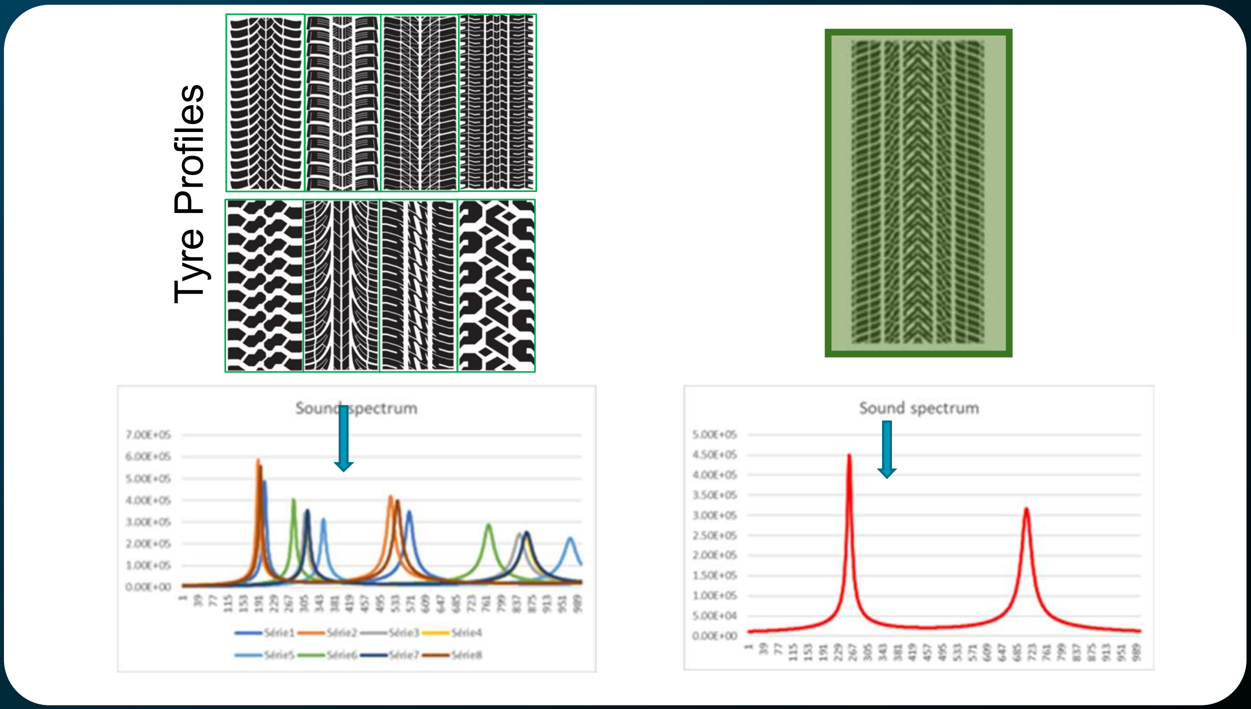
Acoustics – *Sound spectrum prediction from images*

ODYSSEE CAE & FMU Export

ODYSSEE A-Eye

ODYSSEE Solver & FMU Run

ODYSSEE Explore



Challenge

- Capability to predict results as curves based on design images (simulation & experiments).
- Quickly predict the sound spectrum over the entire frequency range (experimental or simulation) from a tire tread design image.

Solutions

- ODYSSEE A-Eye: image-based prediction (you can create a customisation dedicated for this application and this can be used by non-experts (technicians & designers)
- In this case, 8 known tire tread design images with the associated sound spectrum are used as the learning database.
- For a new tire tread design, the customisation can predict the sound spectrum.

Benefits

- The ODYSSEE approach needs few images to predict accurate results.

Fluid Dynamics | **Acoustics** | Structural | Materials | Quality Production

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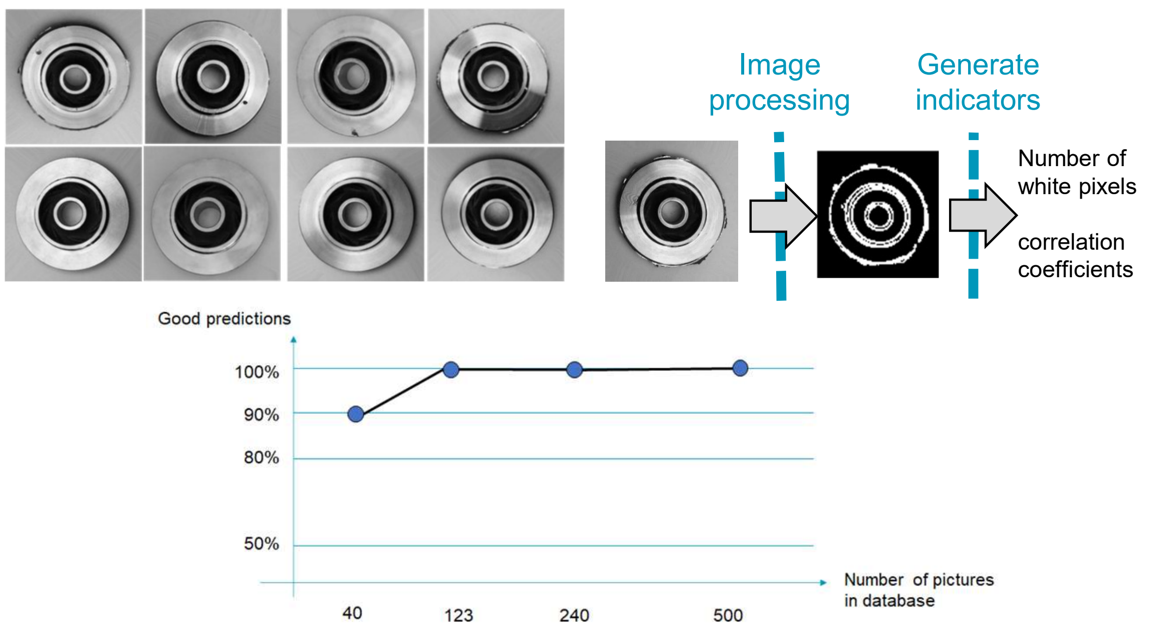
ODYSSEE A-Eye – Case Studies

Quality Production – *Casting parts quality assessment (from production pictures)*



*Source: https://www.kaggle.com/ravirajsinh45/real-life-industrial-dataset-of-casting-product

Challenge

- The objective is to verify if the cast metal parts are valid or defective.
- There are many types of defects in casting like blow holes, pinholes, burr, etc.
- With Volume Graphics, it is possible to predict the quality in 3D. Is it possible to have a complement solution in 2D?

Solutions

- Use ODYSSEE A-Eye to predict if a new cast part is valid or not.
- Compare database sizes of 500, 240, 123 and 40 images.
- Image processing is applied on the images to extract 5 features for each correlation coefficients to reference images.
- Finally, a predictive method is applied on the features database.

Benefits

- Works for a database with only 123 images.
- Automatic inspection process with 100% success.
- Ready for industrial production deployment.

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ODYSSEE CAE – Case Studies

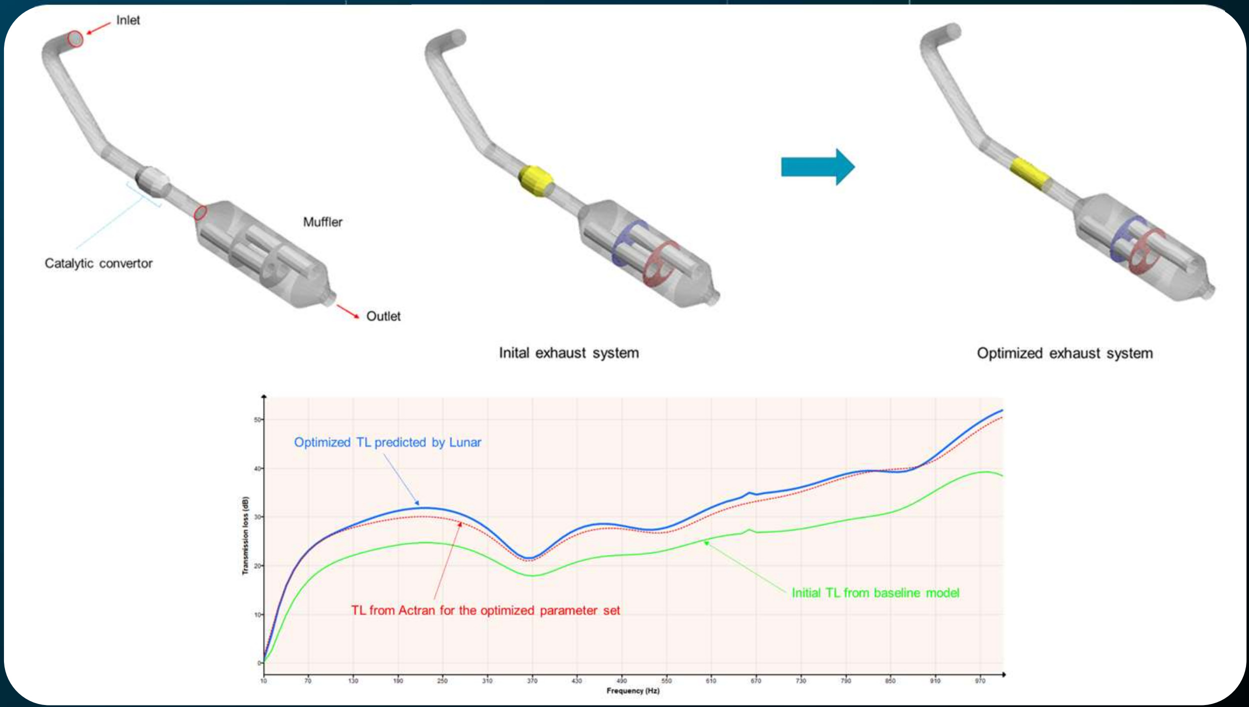
Acoustics – *Transmission loss optimization of a motorcycle exhaust*

ODYSSEE CAE & FMU Export

ODYSSEE A-Eye

ODYSSEE Solver & FMU Run

ODYSSEE Explore



Challenge

- Exhaust systems are important for the attenuation of the engine noise in motorcycles.
- The sound transmission loss is used to measure the sound attenuation through the system.
- Transmission loss needs to be maximised across the frequency spectrum in order to ensure quieter operation.

Solutions

- Combining Actran acoustic simulations with ODYSSEE creates a ROM and enables rapid performance optimisation to maximise the transmission loss of the exhaust system.
- The geometric parameters of the muffler and the catalytic converter are optimised.

Benefits

- Accelerated optimisation of a motorcycle exhaust system via the use of a ROM.
- This process optimises the system faster as no simulations of the system are performed during the optimisation process.

Fluid Dynamics | **Acoustics** | Structural | Thermal Analyses | Multi-Body Dynamics | Manufacturing | Explicit Analysis

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ODYSSEE CAE – Case Studies

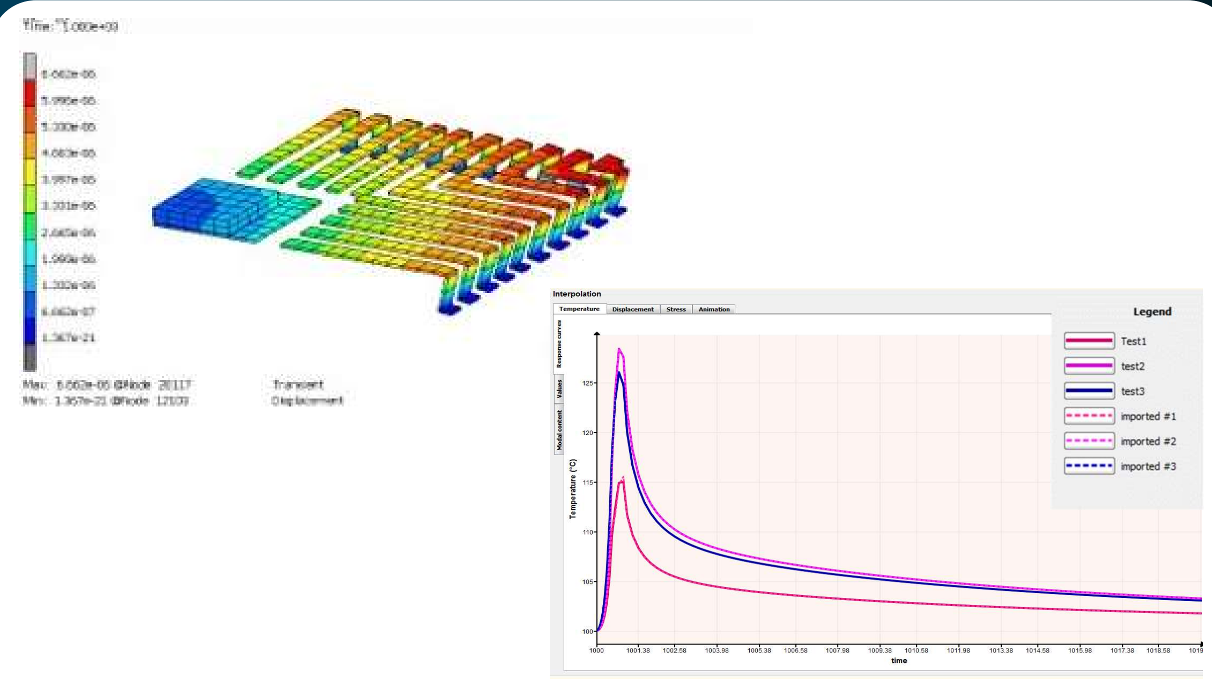
Thermal Analysis – *Circuit Board Analyse*

ODYSSEE CAE & FMU Export

ODYSSEE A-Eye

ODYSSEE Solver & FMU Run

ODYSSEE Explore



Challenge

- When there are 1s overpower peaks on the chip:
  - How to control the heat dissipated?
  - How to limit the thermal expansion of the microchip?
  - How to limit the high stress in the leads of the microchip? (no failure in weld)

Solutions

- MARC: Prepare a data base of results associated with each overpower peaks tested.
- ODYSSEE CAE used for prediction in real time:
  - Parameters = 3 (Amplitude of the overpower peak, “curvature” of the loading step, “curvature on the unloading step).
  - Output: Temperature on the chip, Stress in leads and displacement measured on the case.

Benefits

- Know the parameter effects on the result.
- Save user time: ODYSSEE CAE results are obtained in a few seconds against MARC simulations that take 2 min.

Fluid Dynamics | Acoustics | Structural | **Thermal Analyses** | Multi-Body Dynamics | Manufacturing | Explicit Analysis

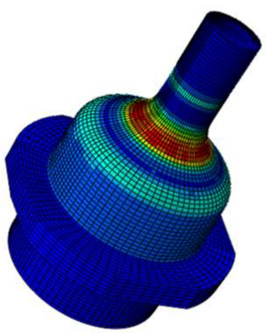
HEXAGON

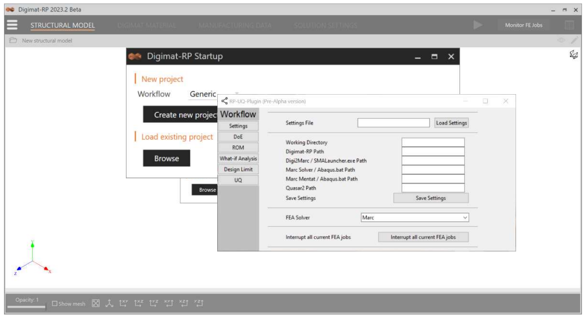
ODYSSEE Solver – Application

Digimat-MS – *UQ based design for reinforced plastics*

SIMULIA ABAQUS

Marc Digimat-MS Odyssee





BOSCH

- Hexagon’s products and services provide excellent support to our daily business with innovative simulation methods for holistic virtual engineering of plastic components. It’s great to collaborate with such a professional and knowledgeable team.

Challenge

- Material properties such as stiffness and strength, and injection moulding predictions are sources of uncertainties.
- These uncertainties provide an additional challenge in multiscale simulation to validate the robustness of a given design.
- Most of the virtual designs are deterministic and ignore these numerous sources of uncertainties.

Solutions

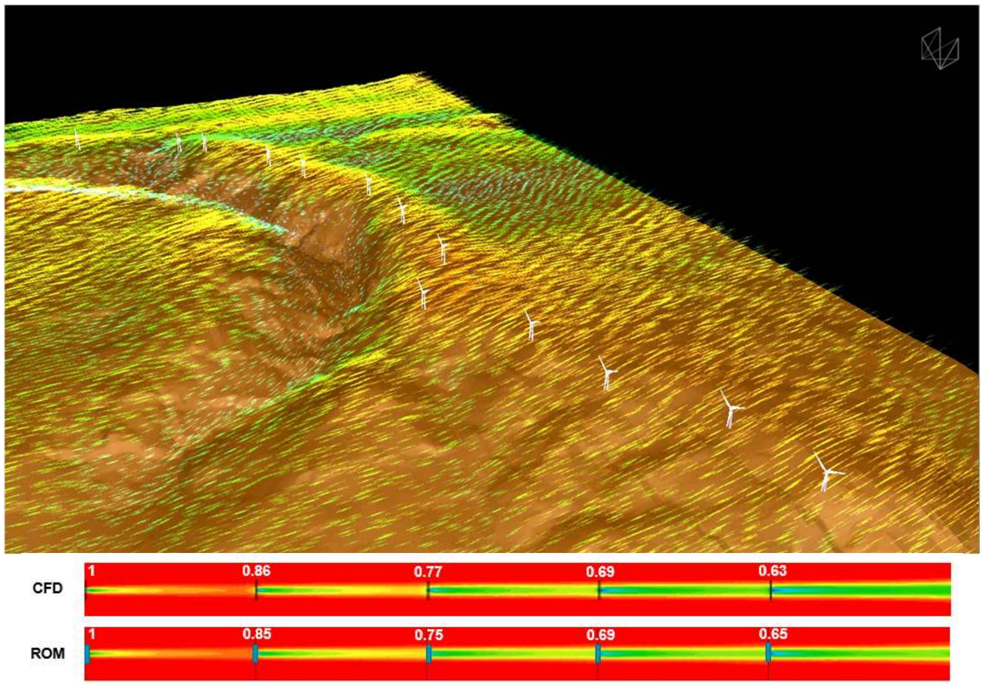
- Digimat offers a simplified workflow that performs multiscale material modelling from the manufacturing process to the structural analysis.
- The workflow also integrates artificial intelligence (AI) and uncertainty quantification (UQ) to account for material properties uncertainties.
- A UQ plugin is available to prepare and run high fidelity design of experiments (DoE) using Digimat-MS simulations.

Benefits

- The reliability of the studied structural analysis can be evaluated by considering the propagation of different sources of uncertainties.
- The automated workflow embeds advanced expertise in material science, AI and UQ.
- Prescriptive solution allows to enhance the product quality by considering the numerical uncertainties.

ODYSSEE Solver – Applications

Cradle – *Wind Turbine Field Positioning*



Challenge

- Need placement design to minimise the impact of wind turbine wakes.
- Millions of elements are required for each turbine.
- Unrealistic data size makes CFD simulation difficult for practical design works.

Solutions

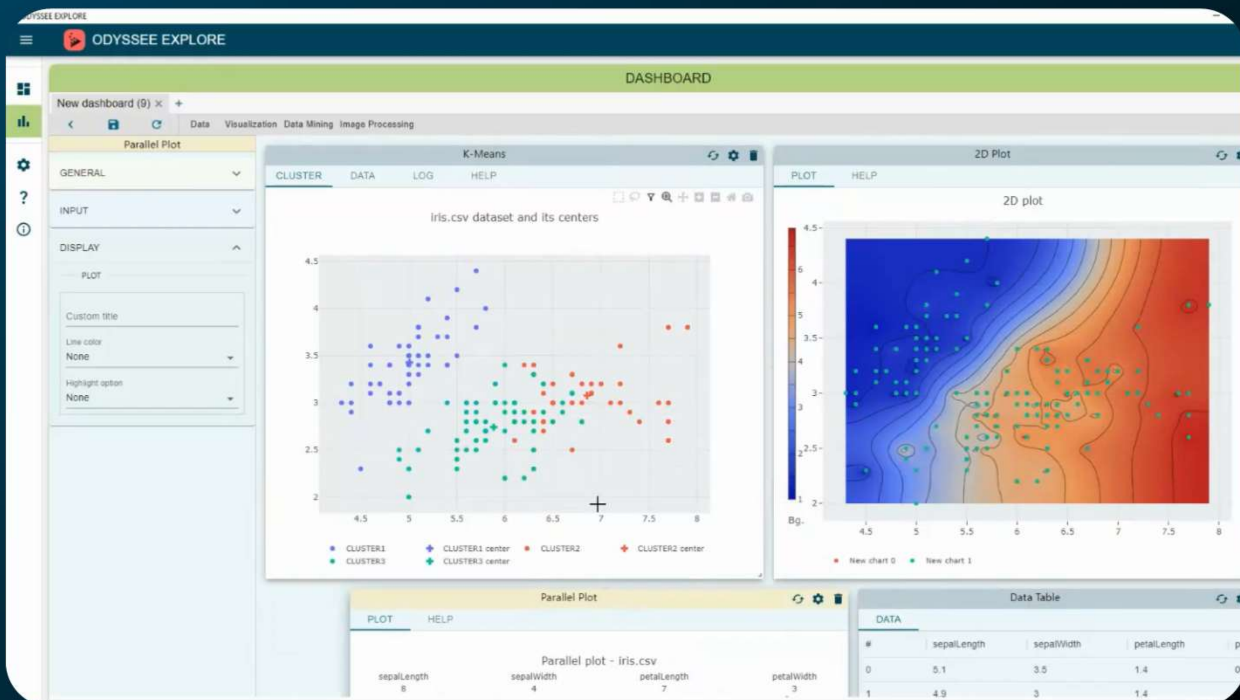
- Cradle scFLOW: CFD simulation of a pair of wind turbines with real 3D shape
- ODYSSEE: Wind turbine wakes prediction results by ROM (Reduced Order Model).
- Design variable (20 cases): Wind velocity, Reference velocity ratio Results: 3D flow field around the back rotor. Combination of different ROMs.

Benefits

- Instantaneous Cradle / ODYSSEE large scale field modelling using ROMs (every wind turbine is an ODYSSEE ROM)
- Accelerated simulation for wind farm validation and optimisation.

ODYSSEE Explore

Data analysis and data mining



CAPABILITIES

- ODYSSEE Explore is an application for data mining and AI techniques:
  - allows to analyse the inputs and understand if the data is ready to be exploited by the Machine Learning software.
  - helps to interpret the output show why there are difficulties to predict some cases.

BENEFITS

- Customisable Dashboards display multiple visuals simultaneously, aiding data analysis and Machine Learning insights. Visuals within Dashboards are interconnected for cohesive exploration.
- The Data Mining tab offers tools for data analysis, behaviour understanding, and data quality assessment: Covariance/Correlation, K-Means, PCA, PCoA, and Dendrogram.

FEATURES

- Data Management: data uploading and transformation.
- Visualisation allows to make some basic plots to show relations, behaviour,…(1D plot, 2D plot, Heatmap and Parallel plot.)

Appendix

AI for Smart Manufacturing: The big picture

1 Predictive Maintenance
AI algorithms can analyze machine data to predict when equipment is likely to fail, enabling timely maintenance and reducing downtime.

2 Quality Control
AI-powered image recognition systems can identify defects in real-time, ensuring high-quality and minimizing defects.

3 Supply Chain Optimization
AI can analyze supply chain data to optimize inventory levels, streamline logistics, and enhance overall supply chain efficiency.

4 Production Planning
AI algorithms can analyze historical data and market trends to optimize production and schedules

5 Energy Management
AI systems can monitor energy usage in real-time, identifying patterns and suggesting ways to optimize energy consumption.

6 Robotics and Automation
AI-driven robots and automation systems can handle complex tasks, increasing efficiency and reducing the need for human intervention in dangerous or repetitive tasks.

7 Customization and Personalization
AI can enable mass customization by analyzing customer data and preferences, allowing manufacturers to tailor products as needed.

8 Supply Chain Risk Management
AI can analyze various factors such as geopolitical events, weather patterns, and market trends to predict potential risks in the supply chain.

9 Human-Robot Collaboration
AI can facilitate safe collaboration between humans and robots in manufacturing processes, enhancing productivity and safety.

10 Waste Reduction
AI systems can optimize production processes, minimizing raw material wastage and reducing environmental impact.

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