Simulating Additive Manufacturing Material Extrusion Processes with Short Fiber-Reinforced Polymer Materials

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Simulating Additive Manufacturing Material Extrusion Processes with Short Fiber-Reinforced Polymer Materials

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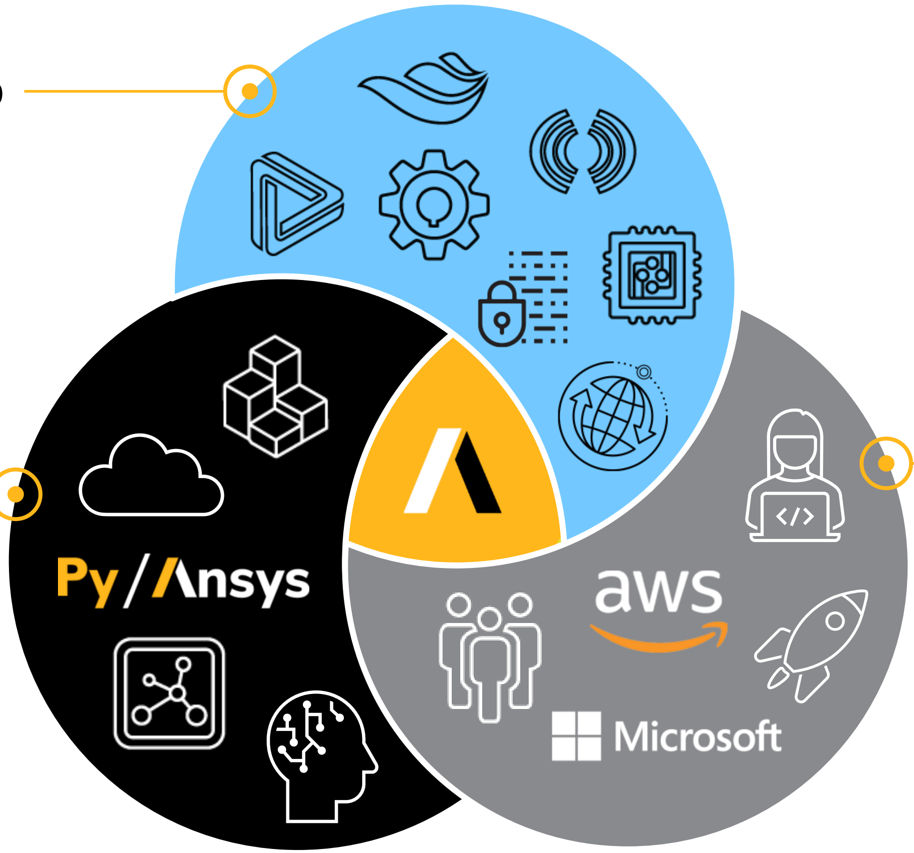
Synopsys:

- Thomas Hirche, Lead Application Engineer
- Haoliang Yu, Senior R&D Engineer
- Javier Vique, Team Lead Application Engineer

Redefining "Simulation"

The unique **combination** of the Ansys product **portfolio, platform and ecosystem** is redefining simulation in ways that enable people in every industry to **change the world**.



Product Portfolio

Industry leading simulation products across physics, systems, safety and missions

Platform

Intelligent, open, agile platform that enhances, extends and amplifies the value of the Ansys portfolio

Ecosystem

Broad ecosystem of developers and partners enabling unprecedented innovation

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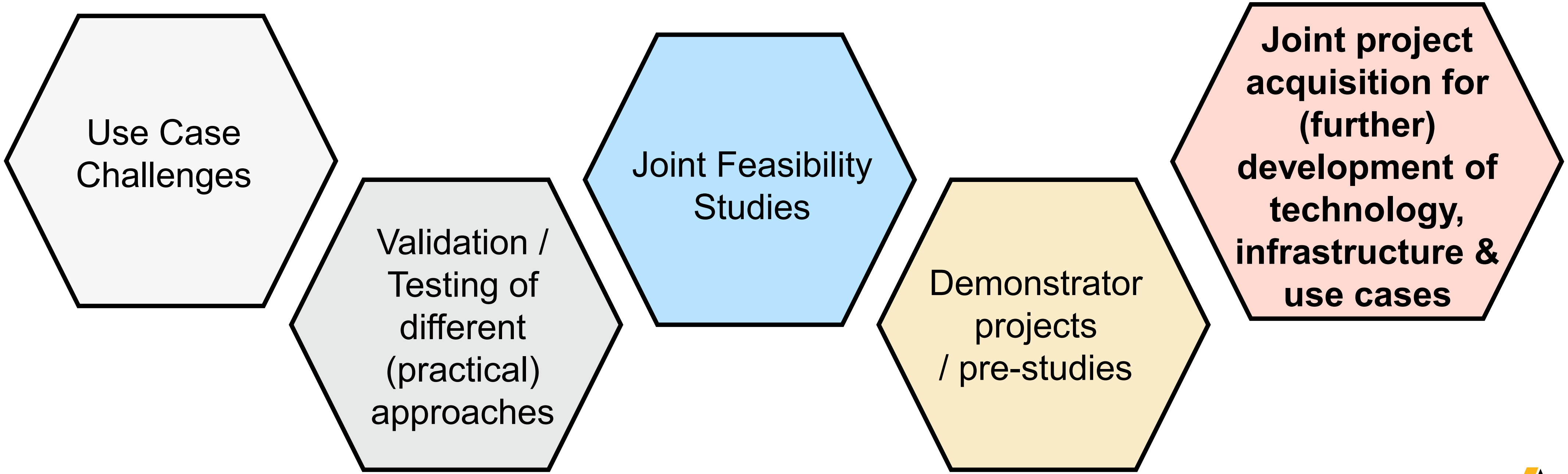
EmpowerAX is…

… a place where we can try out together almost everything,
what drives the technology, infrastructure & use cases forward
and makes it accessible to the broad industry…



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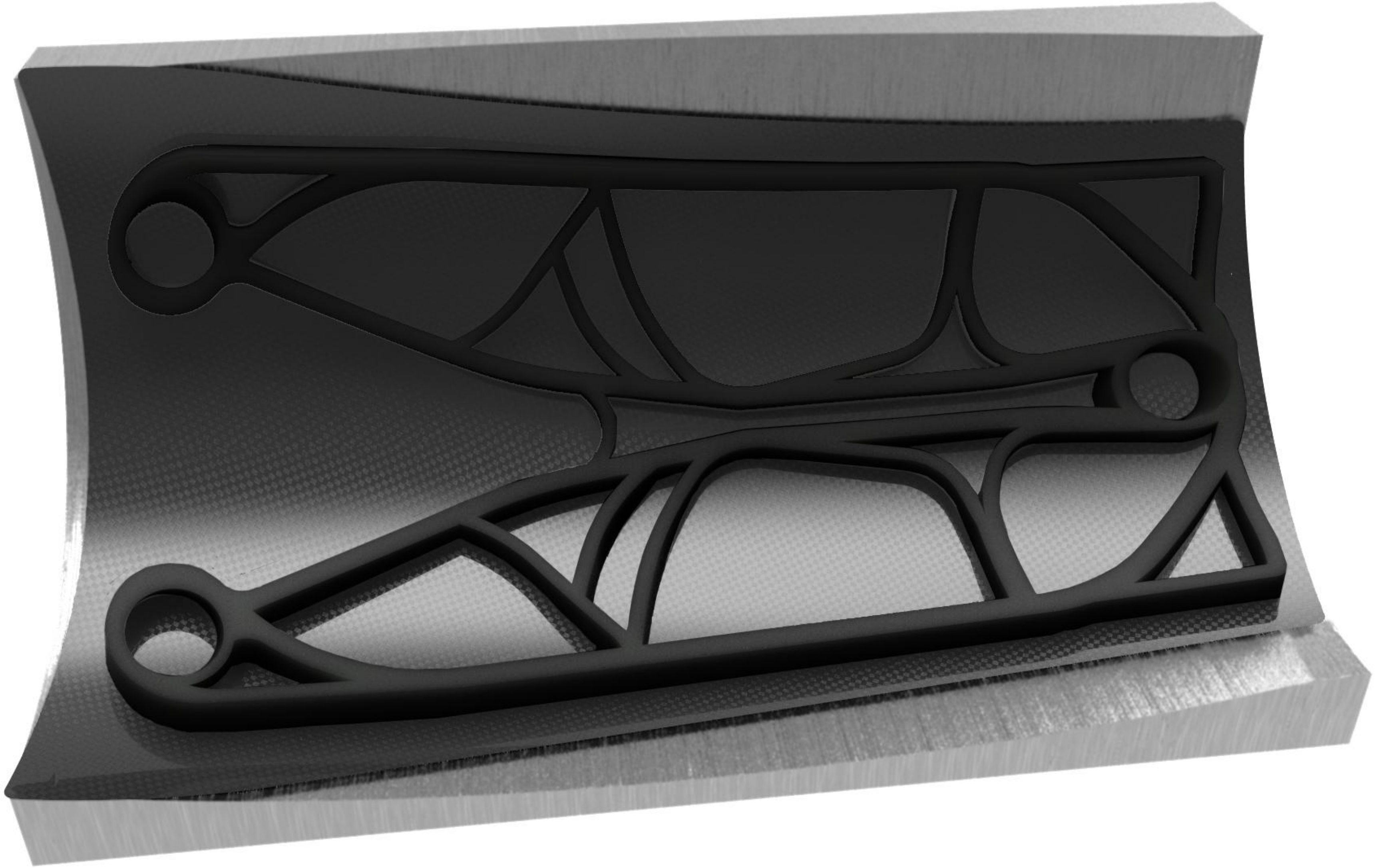
EmpowerAX Demo Part

Experimental data courtesy of the German Aerospace Center (DLR)



https://empowerax.dlr.de/

Experimental data courtesy of the German Aerospace Center (DLR)

EmpowerAX Demo Part
The Basic Idea

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EmpowerAX Demo Part

The Basic Idea

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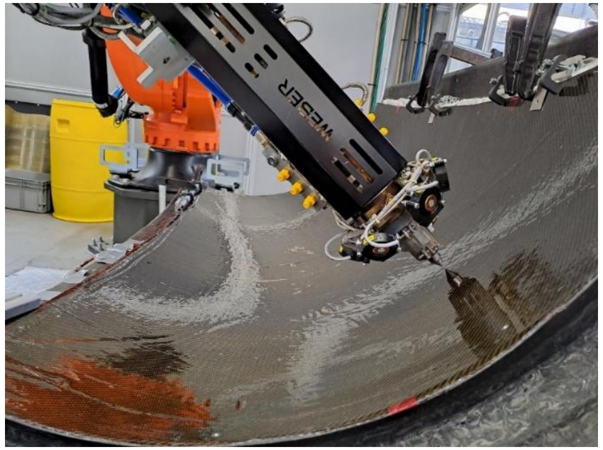
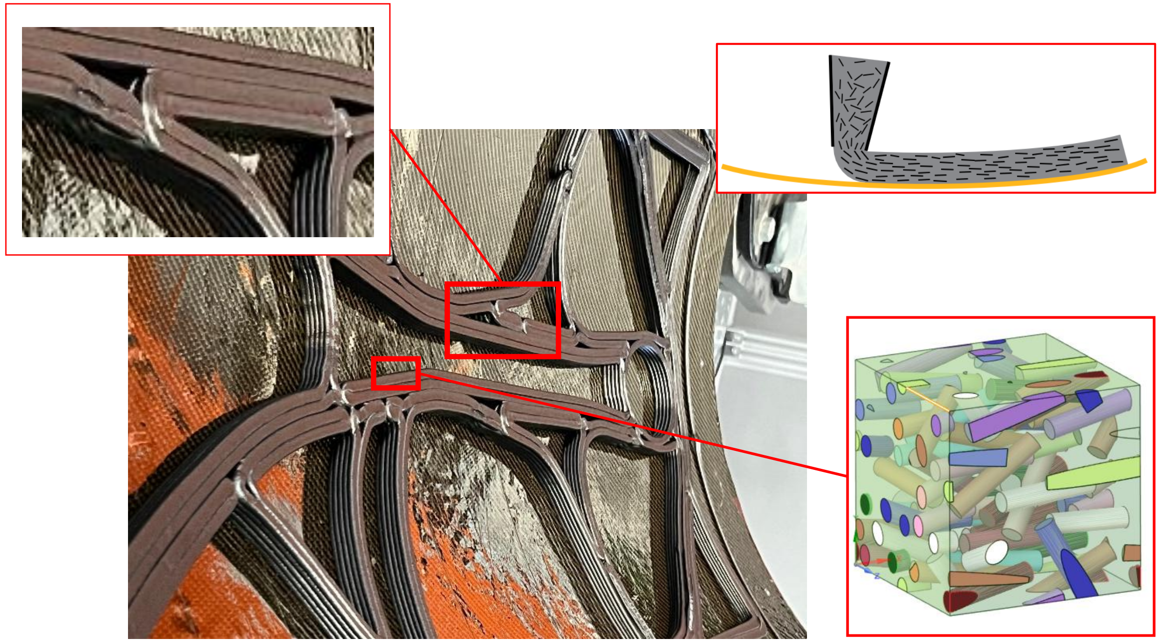


Simulation Challenges

Experimental data courtesy of the German Aerospace Center (DLR)

Ansys partnered with the DLR Innovation Lab EmpowerAX, which drives the adoption of Multi-Axis AM with fiber reinforced materials. The goals are:

- Simulate printed **geometry as manufactured** – it often does not match designed geometry.
- Enable print path **trajectories in 3D space**.
- Consider the **anisotropic properties** of Fiber-reinforced materials. These influence thermal and structural response of parts and affect geometric tolerances.

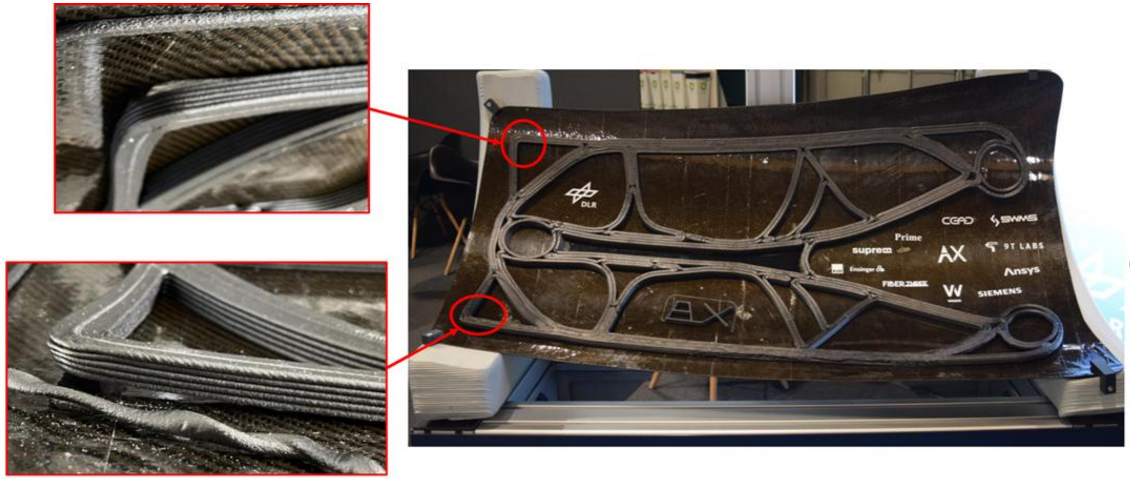


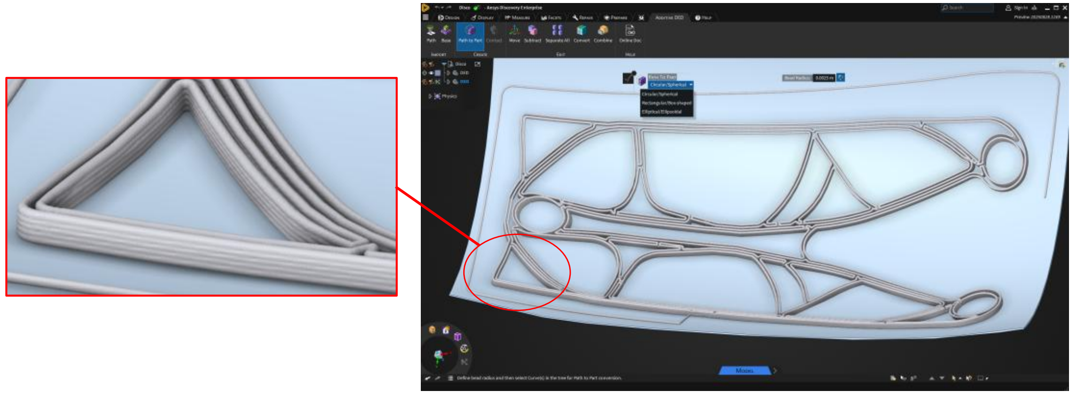
Approach taken – From G-Code to CAD Model

Experimental data courtesy of the German Aerospace Center (DLR)

Additive DED in Ansys Discovery – Path to Part Modeling allows to generate geometry models directly from G-code for your simulations.

- Print bead cross sections and deposition volumes with greater accuracy in the simulation model (Available in 25R2)
- G-Code is the common data format for manufacturing and simulation processes. Differences between manufactured part and simulated part significantly decreased.



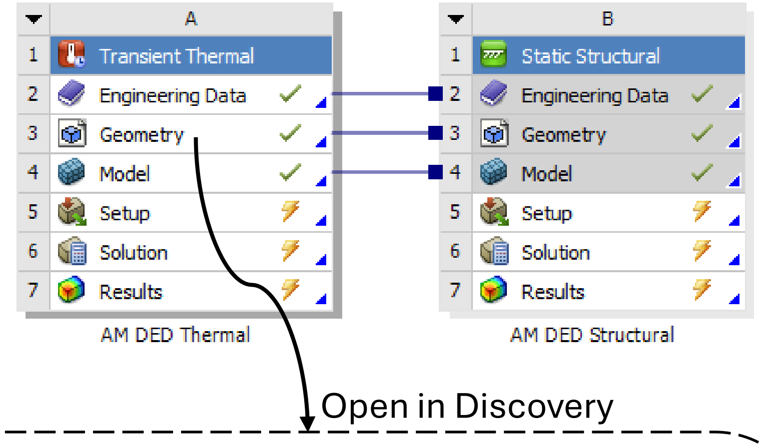


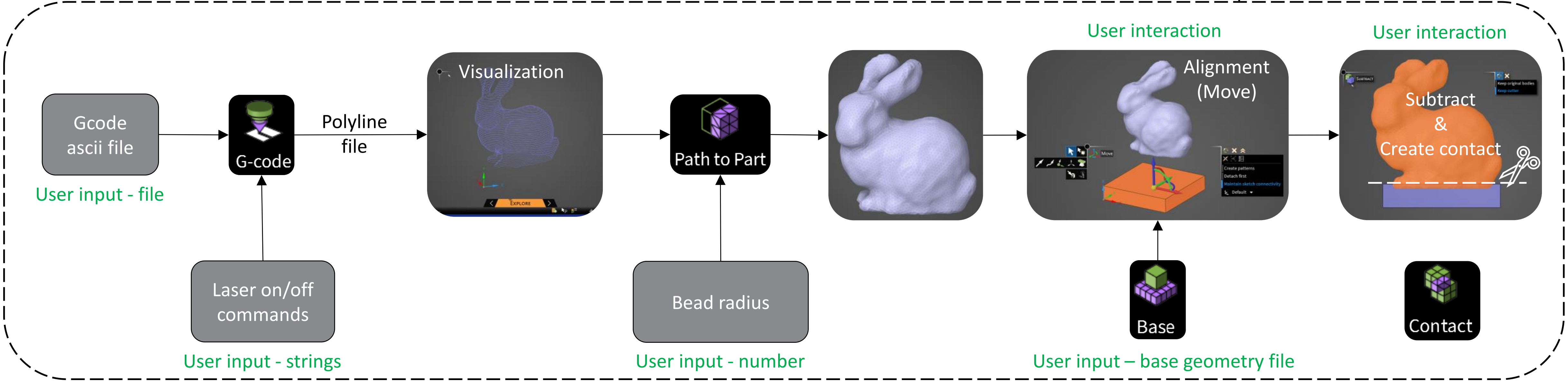
Path-based Geometry Generation Tool in Ansys Discovery

A new workflow in Ansys Discovery which considers:

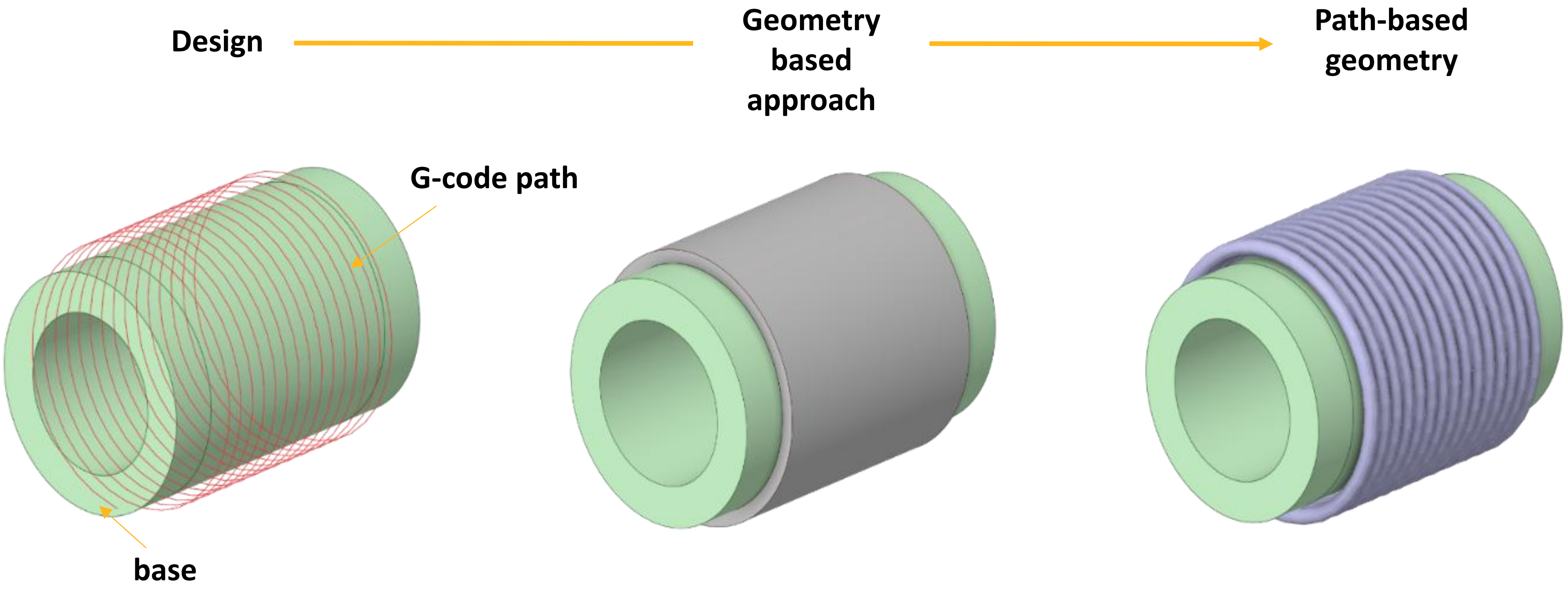
- Different Laser On & Off command
- Various bead radii
- Part and base alignment
- Part and base contact generation for WB Additive simulations

Schematic in Workbench





Path-based Geometry Generation Tool in Ansys Discovery

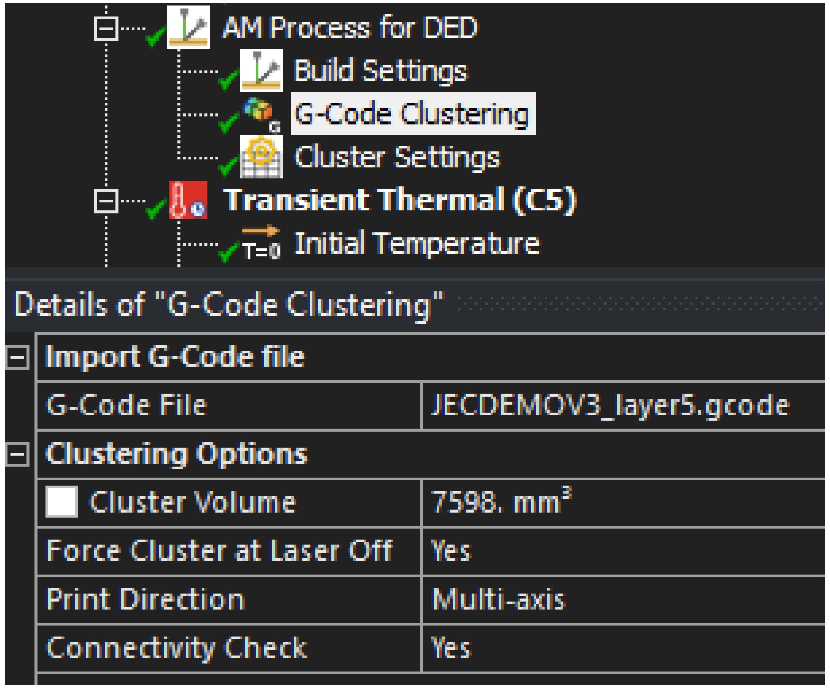


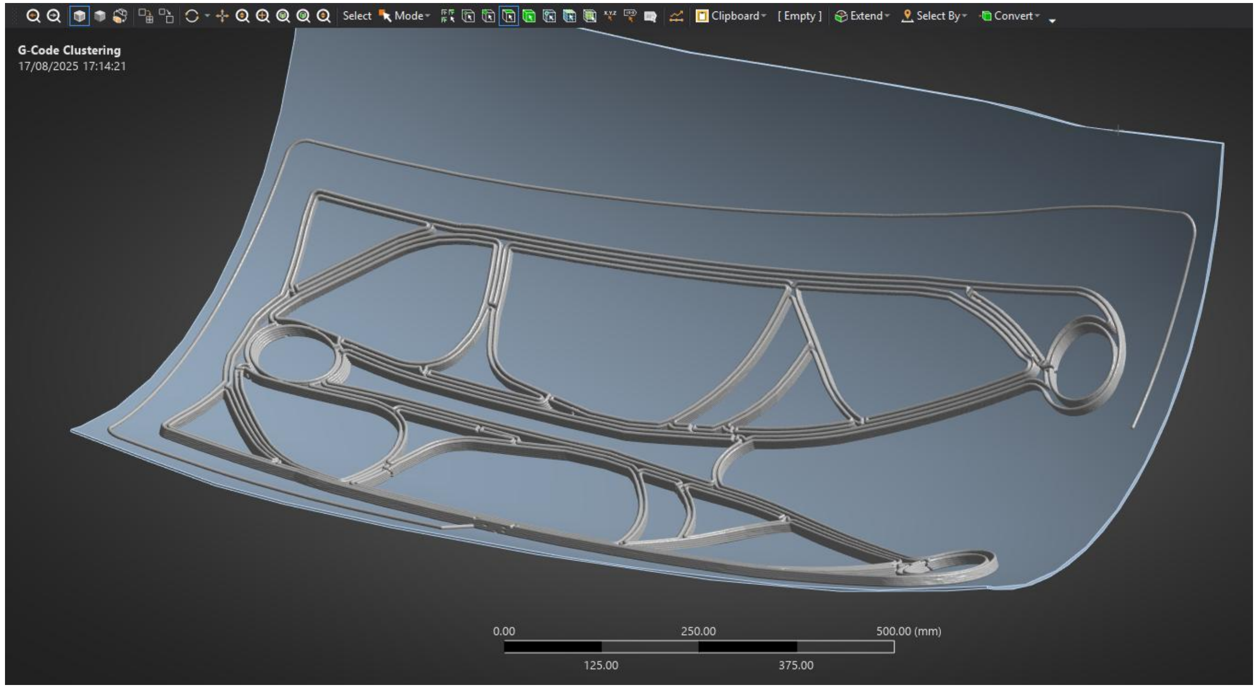
Path-based Geometry Generation Tool in Ansys Discovery

Approach taken – Multi Axis Material Deposition

Ansys Mechanical AM Process for DED – Allows Multi-Axis printing processes

- Print head translates and rotates taking into account the curved print base. The 5-Axis G-code file contains required information.

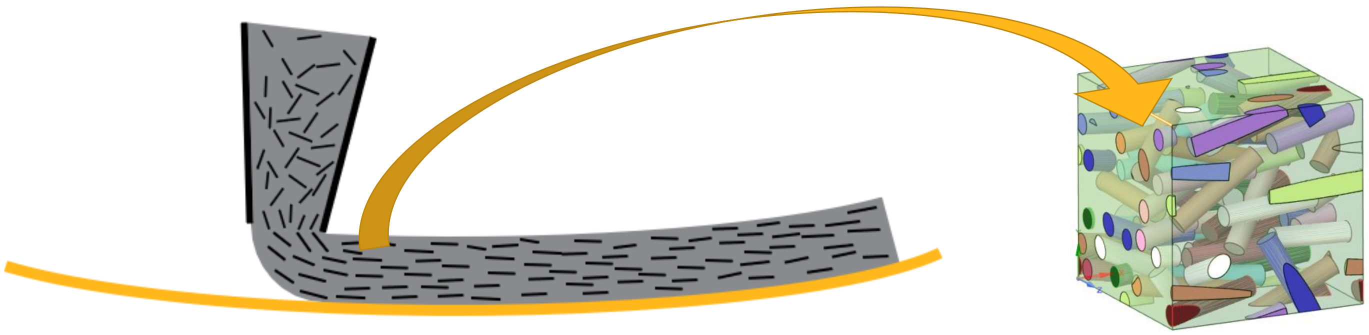


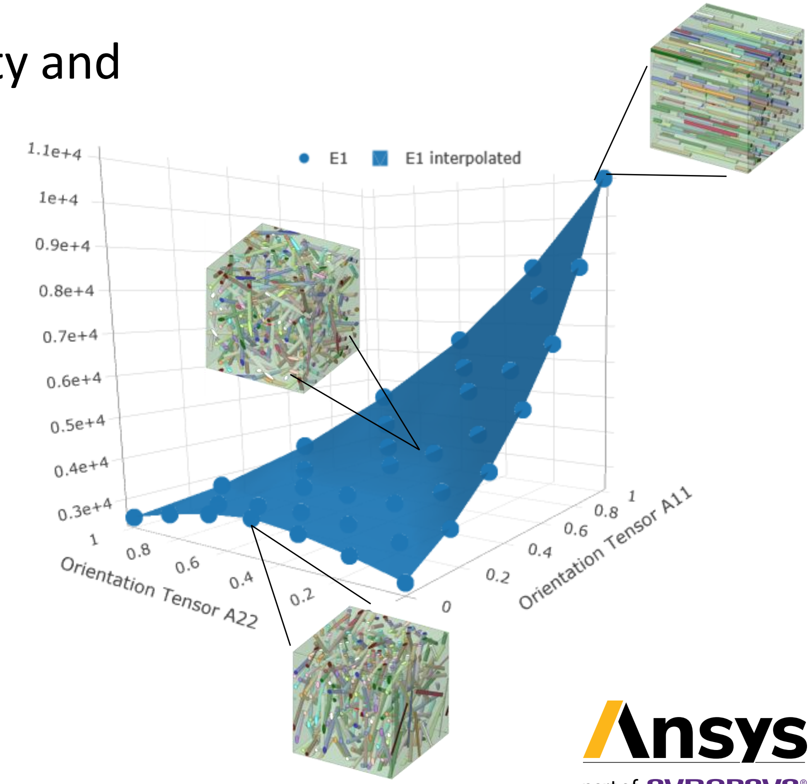


Approach taken – From G-Code to Material Anisotropy

Ansys Material Designer – Calculates Material Anisotropic Properties

- Research shows specific alignment pattern of fibers when passing through print head nozzle*
- Material properties are calculated based on commonly assumed Orientation Tensors for Short fiber materials e.g. A11=0.8.
- Anisotropic Elastic Properties, Thermal Expansion, Thermal Conductivity and Specific Heat.



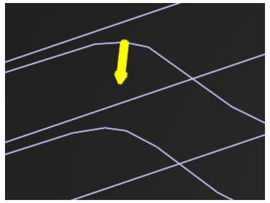


The stiffness and strength of the material depend largely on the fiber orientation with respect to the loading direction, due to the anisotropic nature of the fibers.

* "Foundational Investigation on the Characterization of Porosity and Fiber Orientation Using XCT in Large-Scale Extrusion Additive Manufacturing", Tagscherer et al., 2022

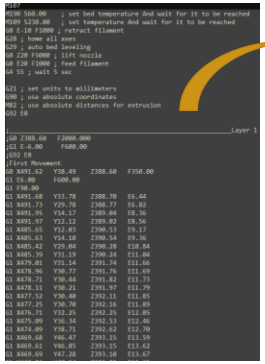
Approach taken – From G-Code to Material Orientation

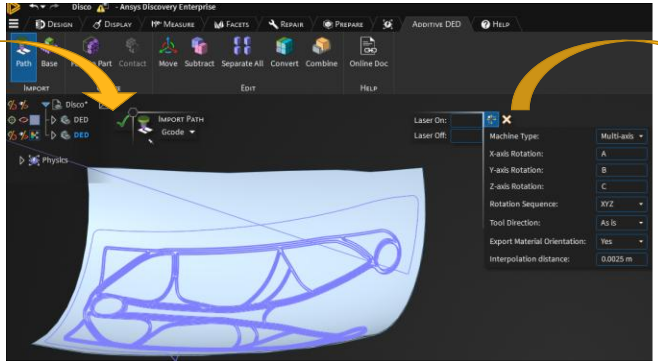
Tool position

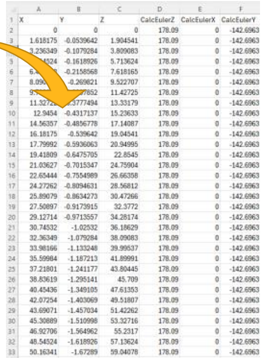


Additive DED-addin in Ansys Discovery – Material Orientation

- Material orientations aligned with print head movement direction. Therefore, the G-Code file is used to calculate material orientations.
- It also improves data point resolution to enable accurate mapping in Mechanical.

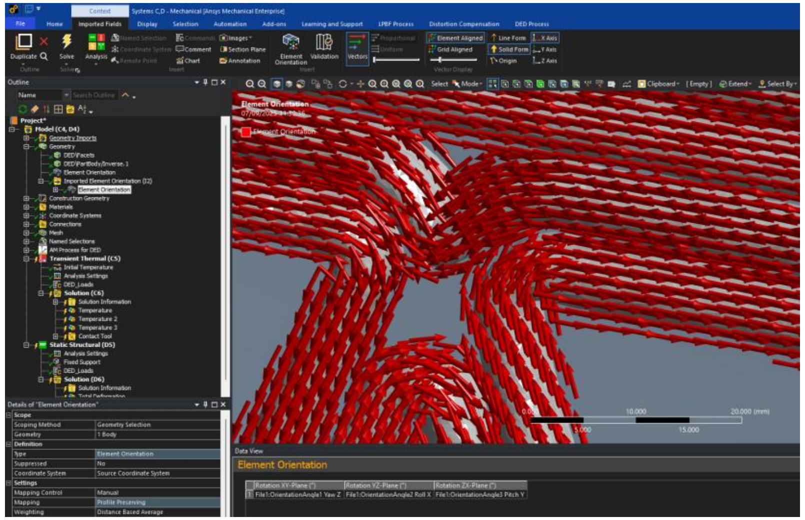






Ansys Mechanical + External Data – Orientation Mapping

- Material Orientation file is imported into Ansys Mechanical AM DED simulation model.
- Material Orientations file contains Euler Angles and is mapped to a Finite Element Mesh.



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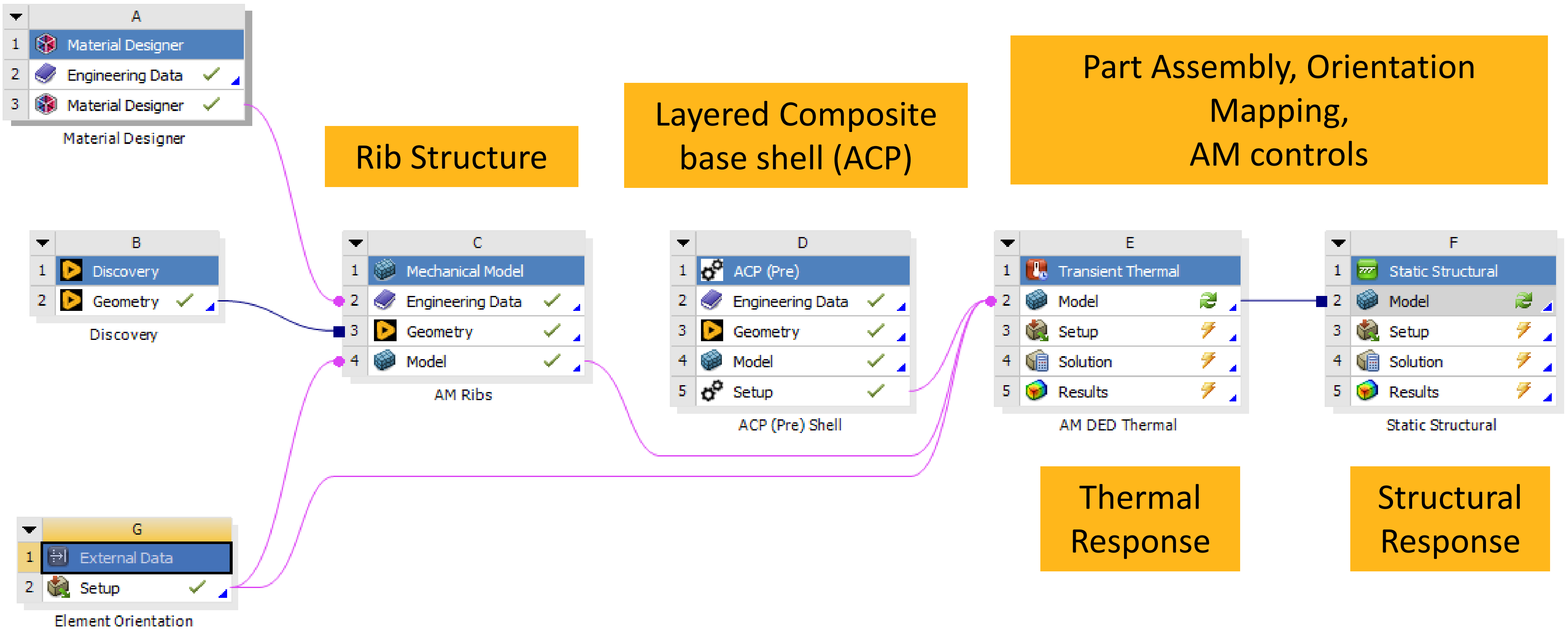
Approach taken – Ansys Workflow Details

Anisotropic Material Properties

Rib Structure

Layered Composite base shell (ACP)

Part Assembly, Orientation Mapping, AM controls



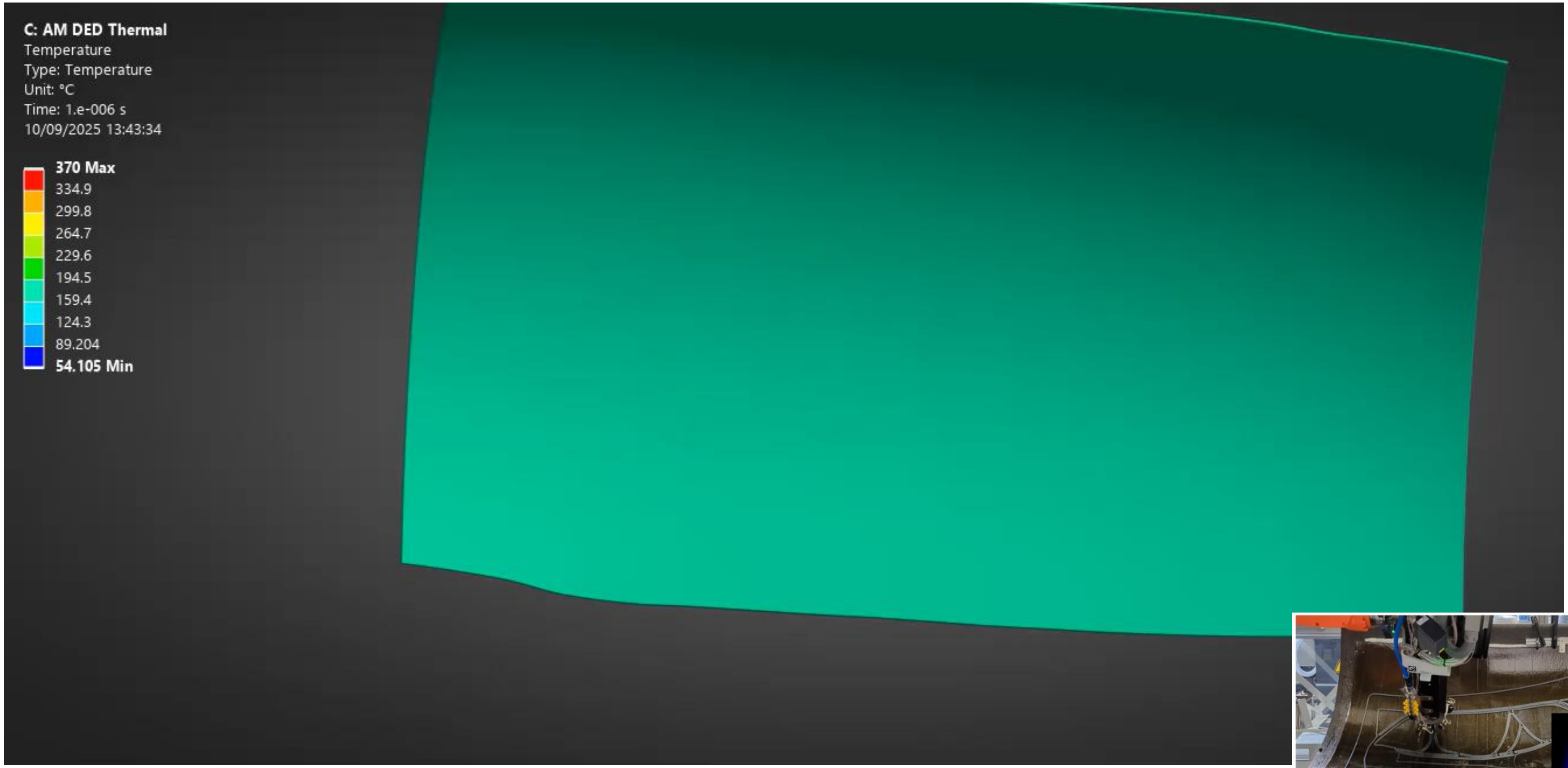
Thermal Response

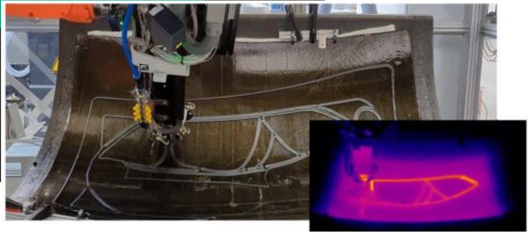
Structural Response

Field dependent Euler Angles

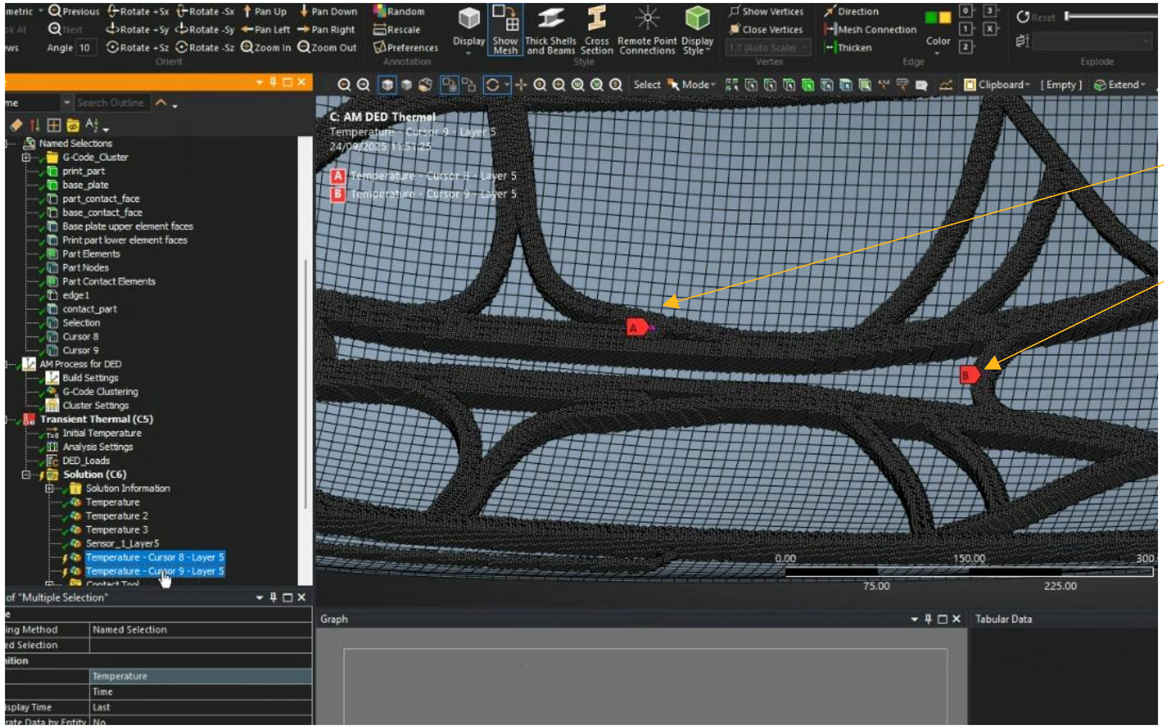
Ansys AM DED – Printing fiber reinforced polymer rib structure on a curved composite shell.

Experimental data courtesy of the German Aerospace Center (DLR)



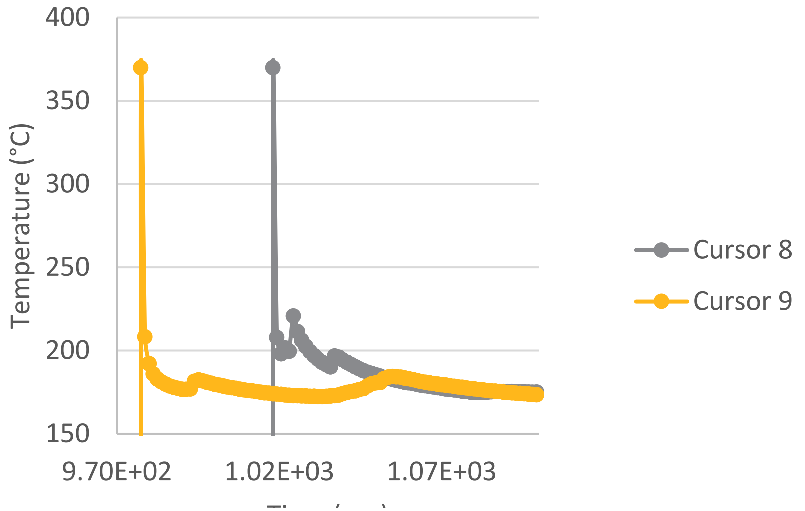


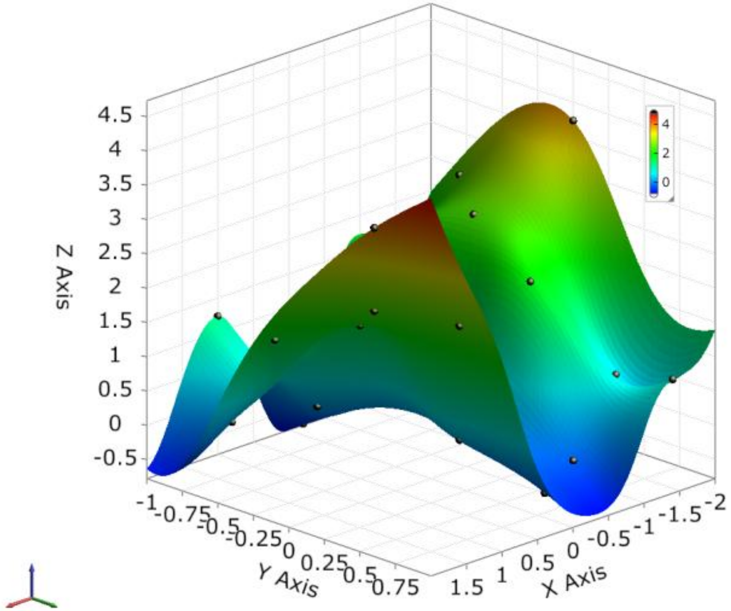
Sensor data and calibration



Cursor 8

Cursor 9





Optimization models can be used to fit FEA model parameters to experimental data.

Want to know more…

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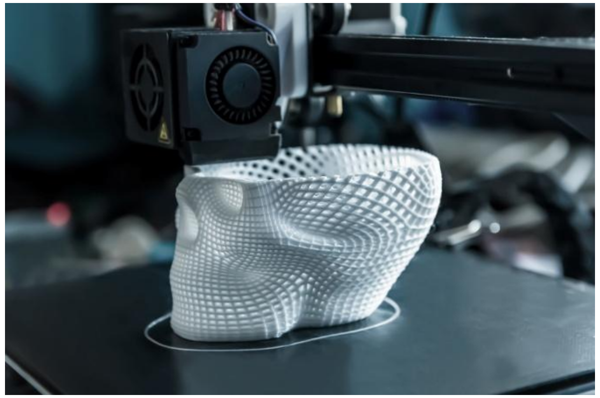
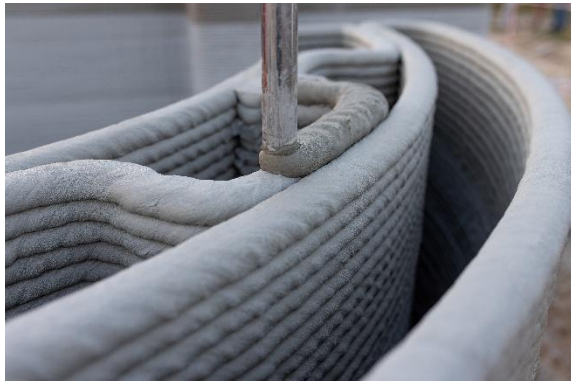
Summary

Further developments includes:

- Perform simulation validations based on thermal sensor data and structural analysis
- Enhance simulation workflows (meshing types, material models, etc)
- There is more than reinforced polymers …Expand the use of this technology to other anisotropic manufacturing Additive Manufacturing processes that also depend on path deposition sequence





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