



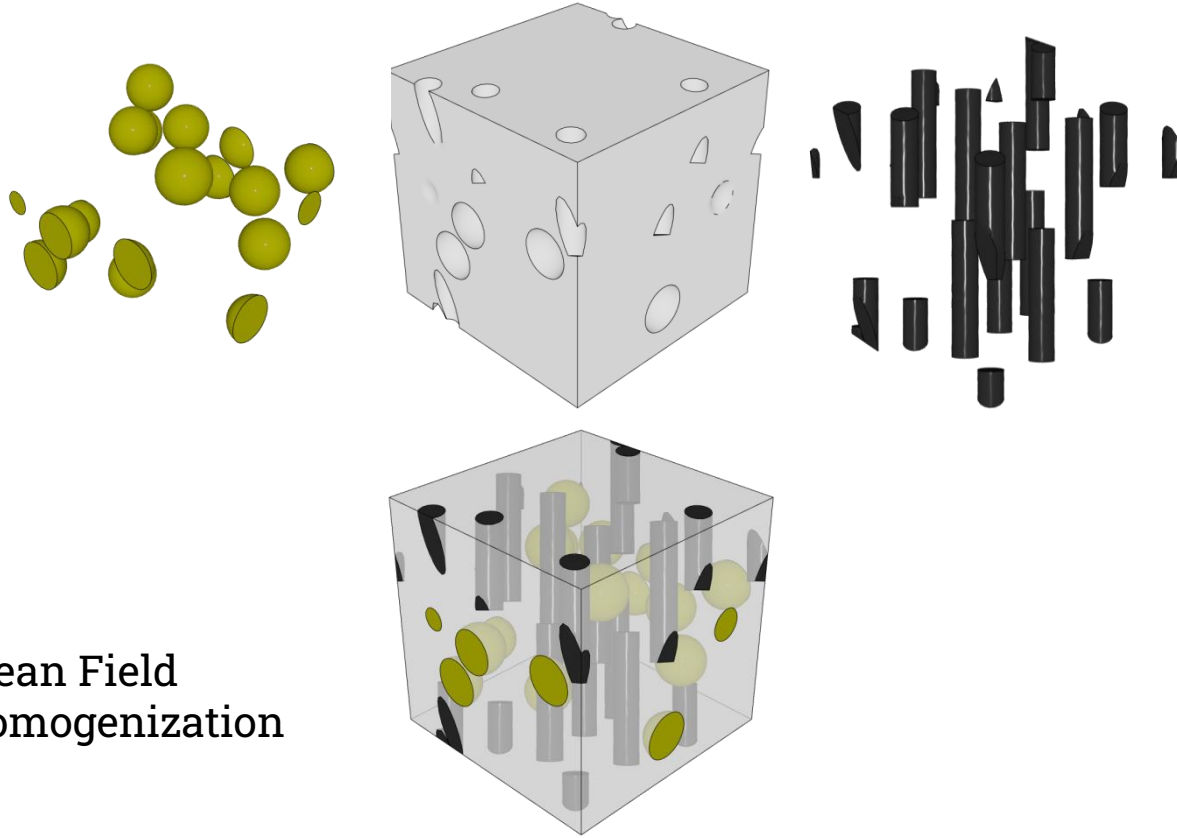
Ground breaking
Simulation Solutions

physics on screen

Non Linear Multi-scale Modeling of Composite Materials using ANSA tools

Eleftherios Tsivolas, Vangelis Palaiokastritis

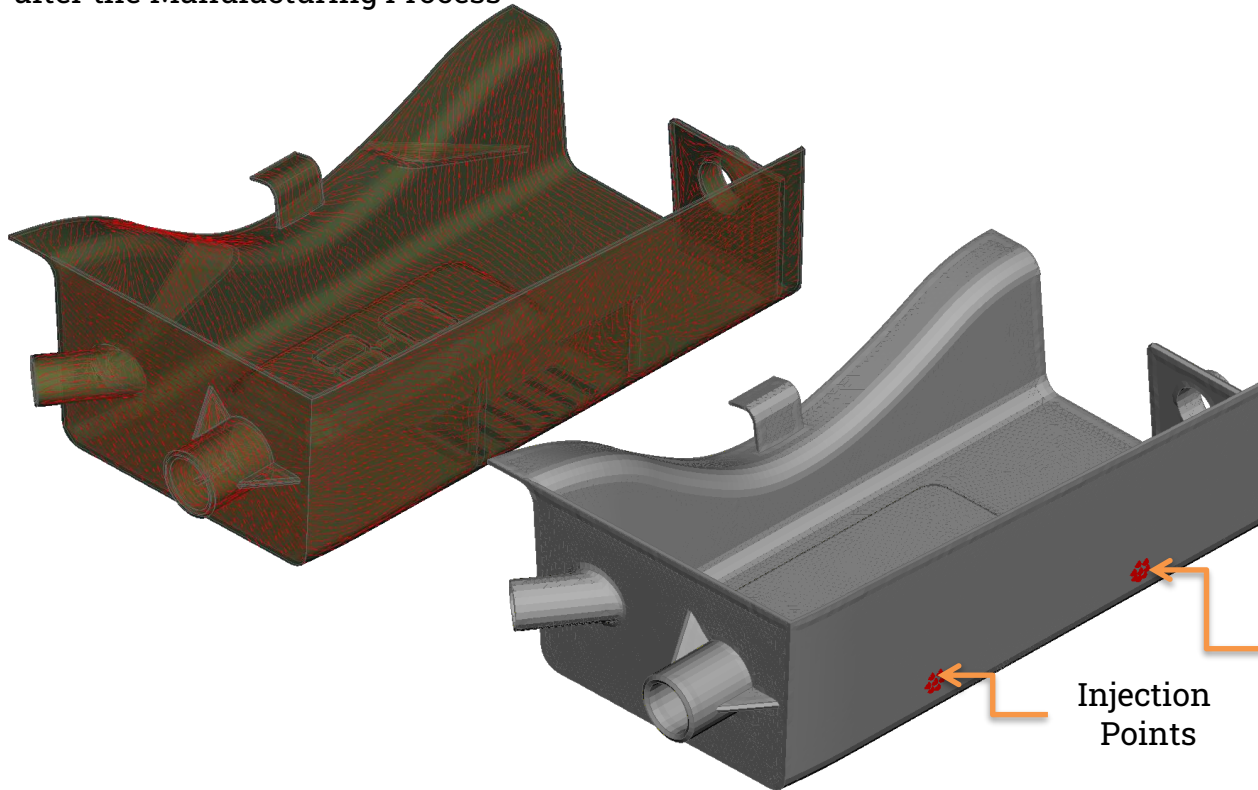
Composite Materials Modeling -Engineering challenges



- Multi-Scale Approach
- Manufacturing Process Simulation
- Macro & Micro Structural Analysis

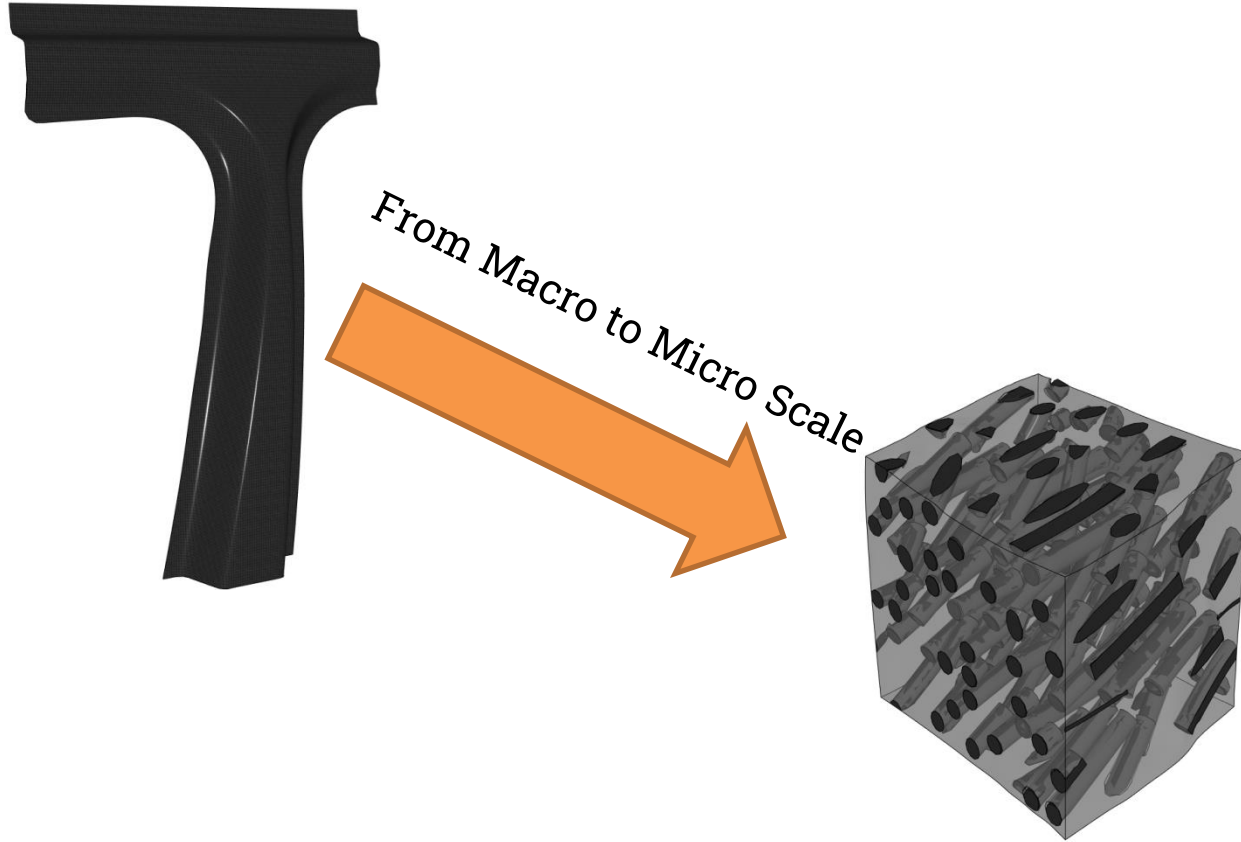
Composite Materials Modeling -Engineering challenges

Material Orientation
after the Manufacturing Process



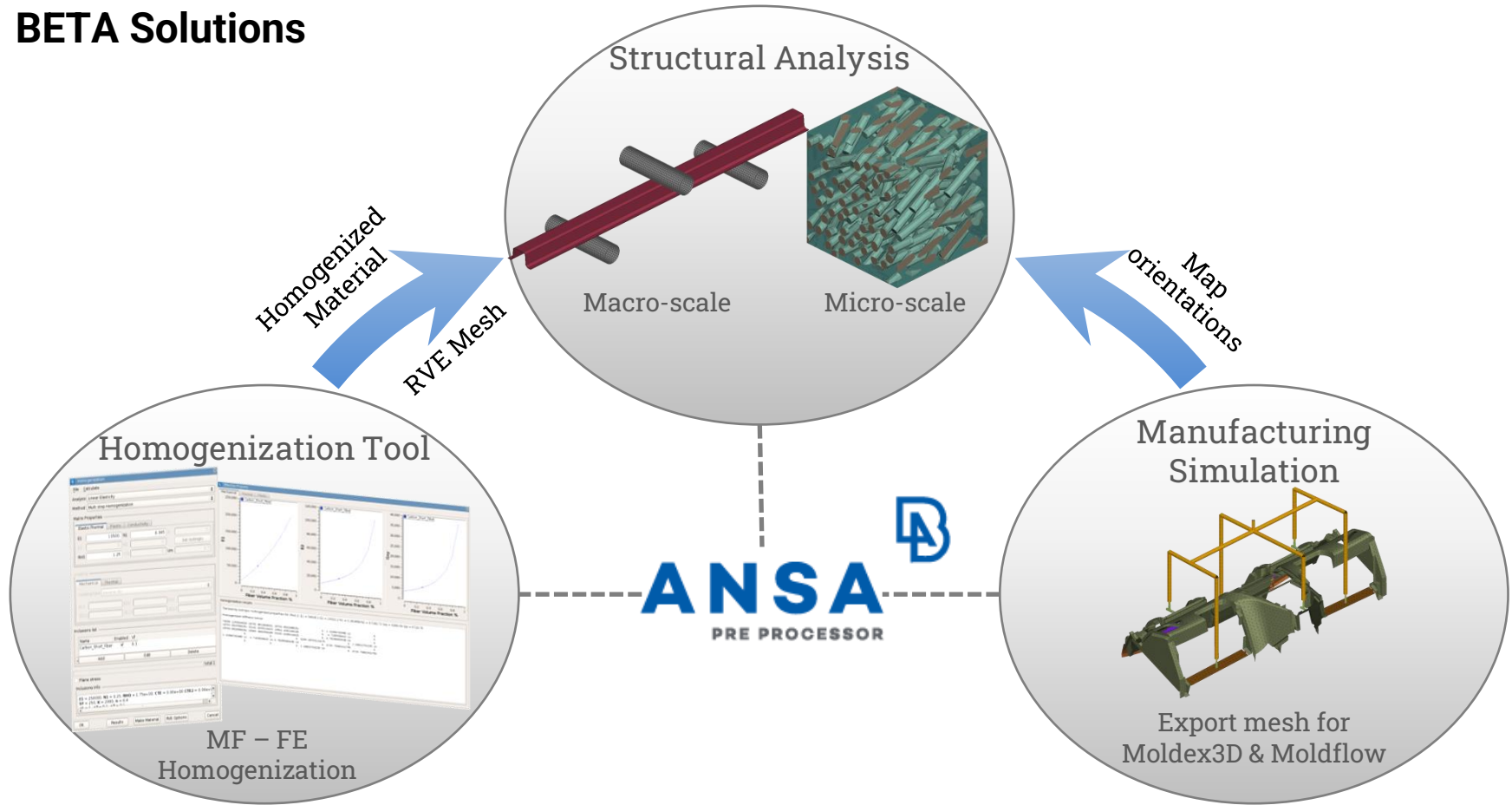
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Composite Materials Modeling -Engineering challenges

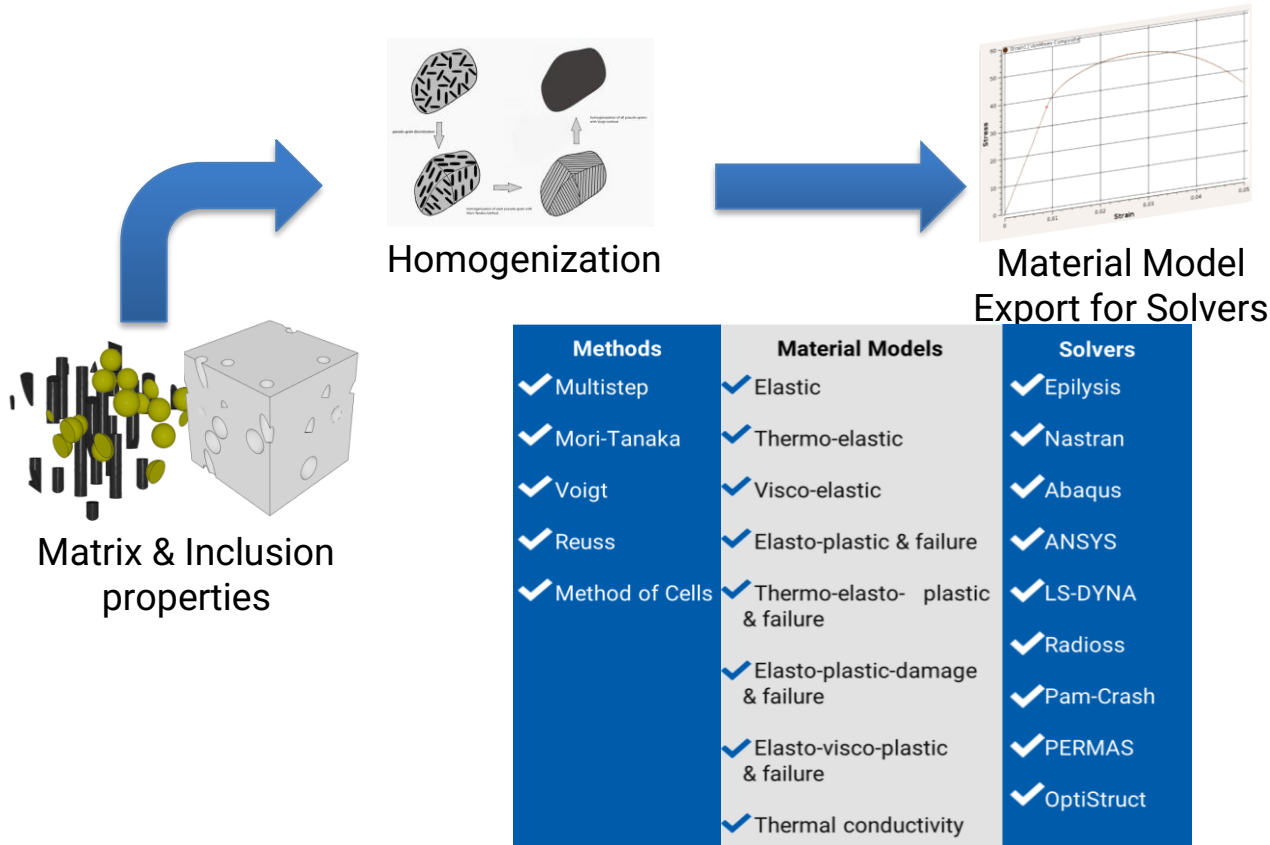


- Multi-Scale Approach
- Manufacturing Process Simulation
- Macro & Micro Structural Analysis

BETA Solutions



Homogenization Tool: Mean Field Homogenization

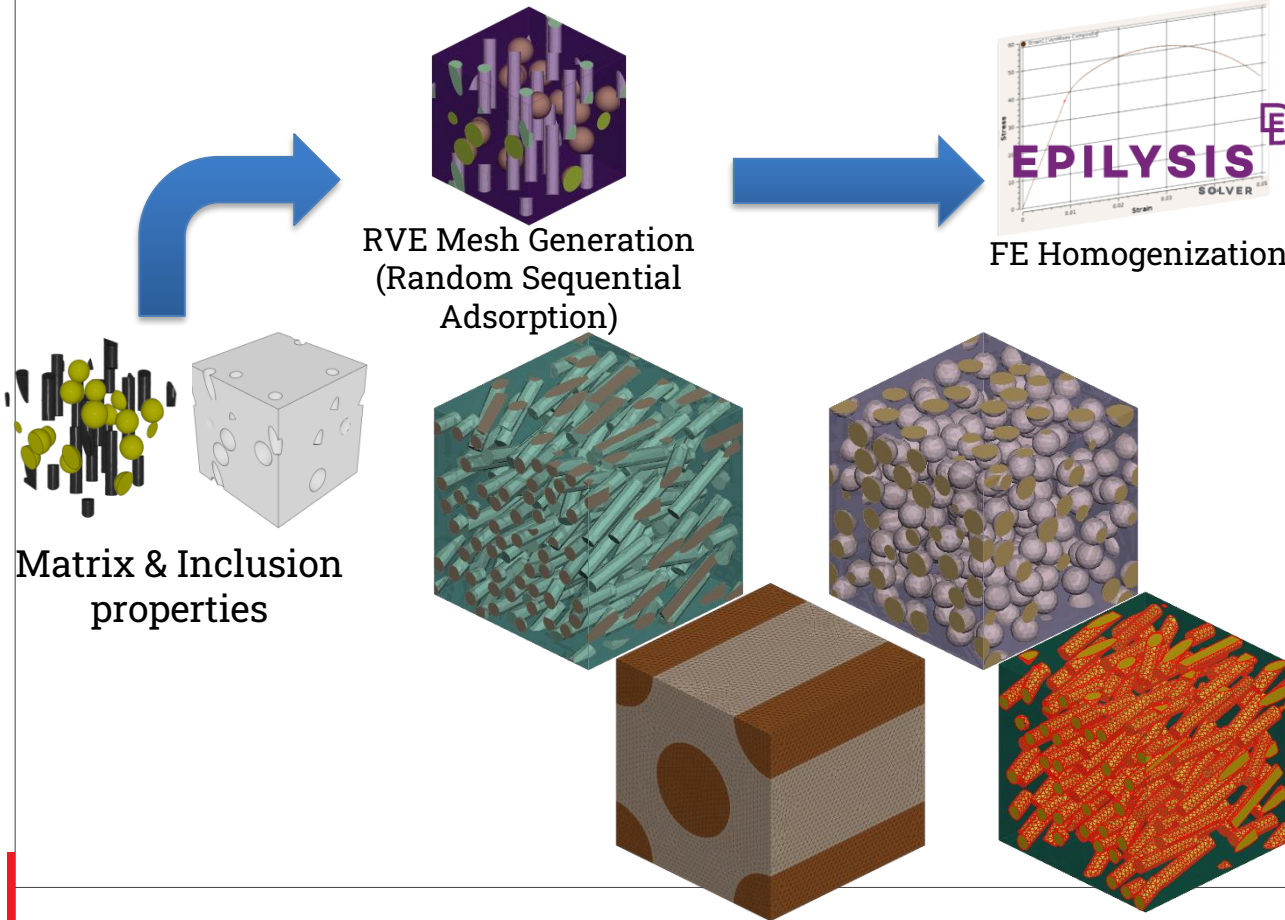


- Homogenization Methods

- Material Models

- Material Output for multiple solvers

Homogenization Tool: Representative Volume Element (RVE) Mesh Generation



- Microstructure:
 - Short fiber
 - Long fiber
 - Sphere Particles
 - Multiple Inclusions
 - Cohesive Interface
- FE Homogenization with Epilysis

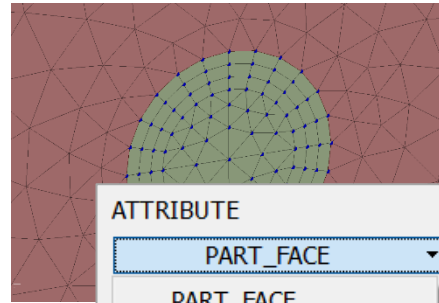
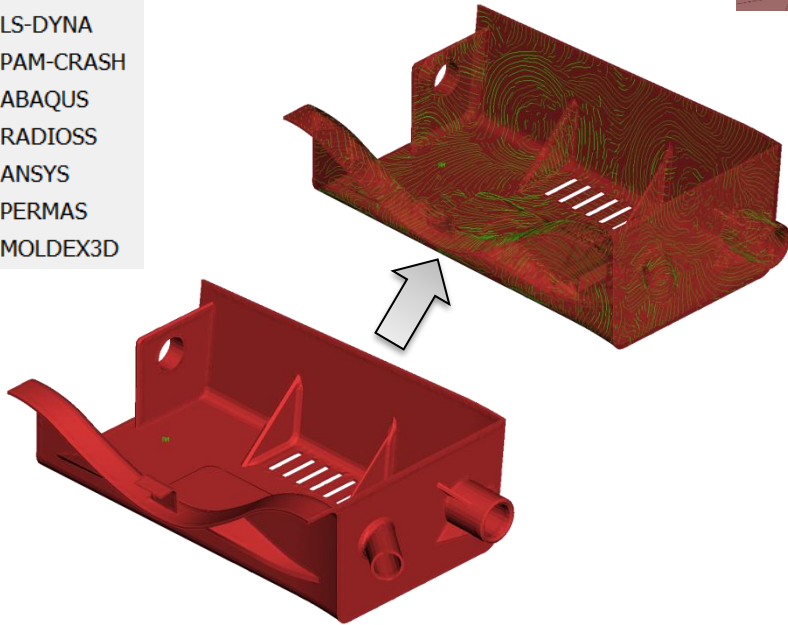
Molding Analysis Supported Decks:

*.msh

*.mfe

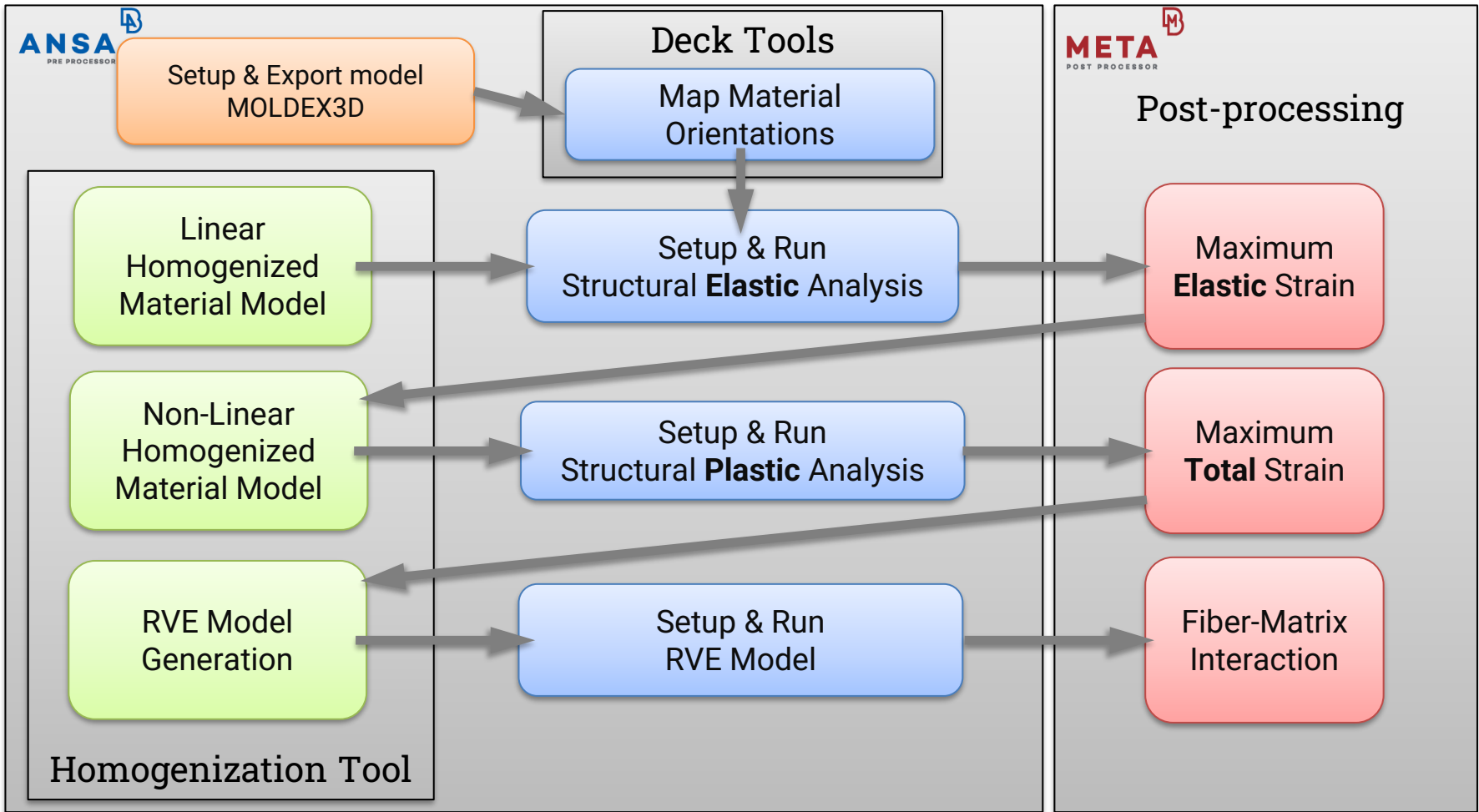
*.udm

- NAS NASTRAN
- LS-DYNA
- PAM PAM-CRASH
- ABAQUS
- RADIOSS
- ANSYS
- PERMAS
- MOLDEX3D



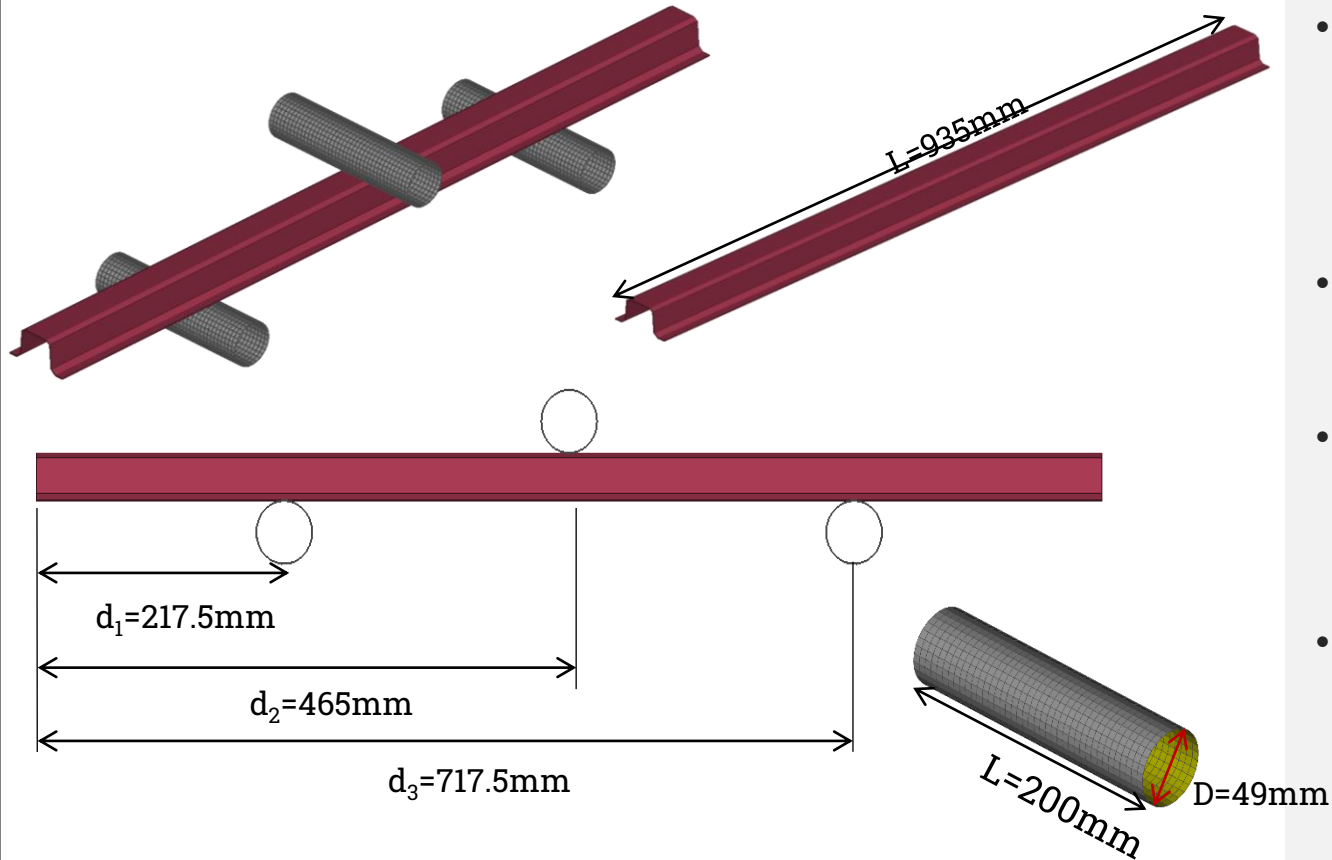
- ATTRIBUTE
- PART_FACE
 - PART_FACE
 - MOLDBASE_FACE
 - PART_INSERT_FACE
 - MOLD_INSERT_FACE
 - GAS_FLOW_FACE

- I/O Moldex3d and Moldflow files
- Special molding environment
- Solver Entities:
 - Point attributes
 - Face & Pipe attributes
 - Wizard for pipes creation
- Interoperability between decks
 - Map Orientations & Homogenization



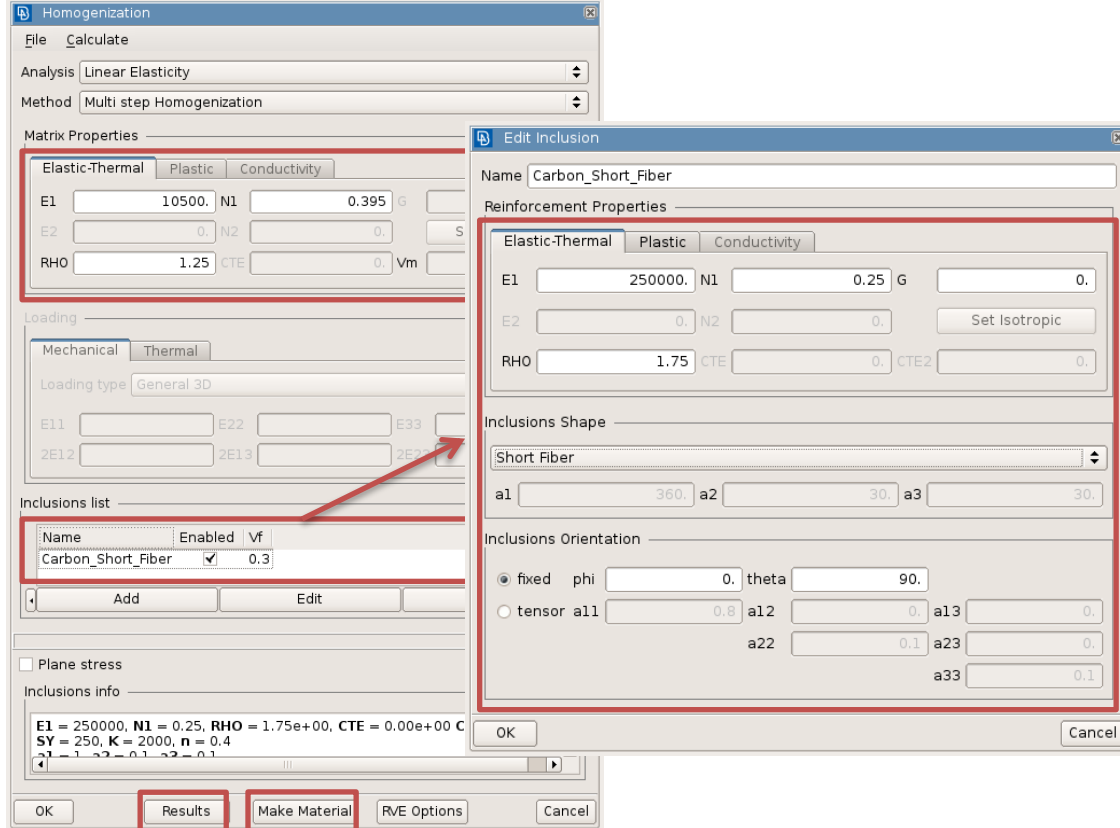
Workflow for multi-scale analysis of Composite components

Case Study: Geometry – FE Model



- Beam model:
Solid mesh
40392 HEXAs
Thickness = 1mm
- Subjected into:
3 Point Bending Test
- Aluminium Material:
 $E = 68.9\text{ GPa}$
 $\text{Rho} = 2.7\text{ kg/m}^3$
- Bending Jigs:
3D Rigid Body

Case Study: Calculate Linear Elastic Composite Material



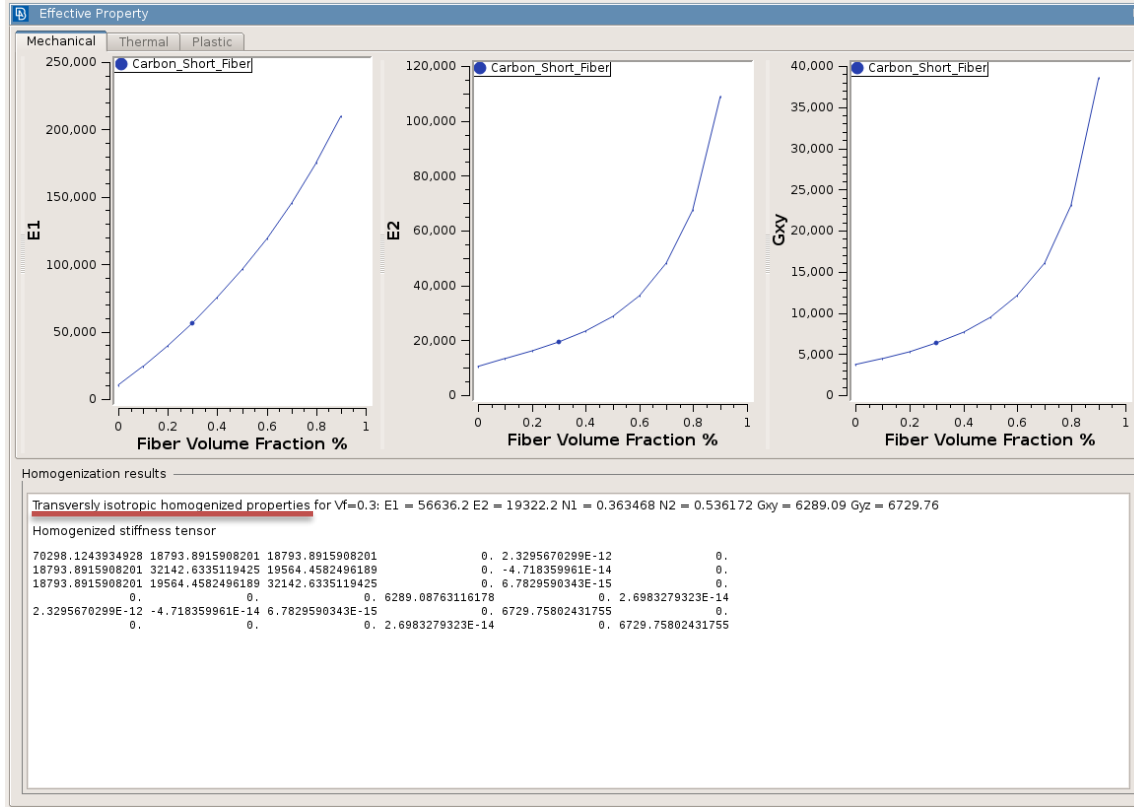
- Target Modulus
 $E_{\text{alumin}} = 68.9 \text{ GPa}$
 $\text{Rho}_{\text{alumin}} = 2.7 \text{ kg/m}^3$

- Constituents
Resin Epoxy:
 $E_{\text{matrix}} = 10.5 \text{ GPa}$
 $\text{Rho}_{\text{matrix}} = 1.25 \text{ kg/m}^3$

- **Short Carbon Fibers:**
 $E_{\text{fiber}} = 250 \text{ GPa}$
 $\text{Rho}_{\text{fiber}} = 1.75 \text{ kg/m}^3$
aspect ratio = 12
 $v_f = 30\%$

- **Composite's Properties**
 $E_{1\text{comp}} = 56.6 \text{ GPa}$
 $\text{Rho}_{\text{comp}} = 1.4 \text{ kg/m}^3$

Case Study: Calculate Linear Elastic Composite Material



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Case Study: Calculate Linear Elastic Composite Material

MATERIAL [MATERIAL]

Name: Carbon_Epoxy_Homogenized_Composite

FROZEN_ID: NO, FROZEN_DELETE: NO, DEFINED: YES

MID	Elasticity	Plasticity (Rate Indep.)	Plasticity (Rate Dep.)	RTOL
2	ELASTIC	PLASTIC	CREEP	

*DENSITY: YES, DEP_DENS: NO, DENS: 1.4

*EXPANSION: NO

*ELASTIC: YES, MODULI: , DEP_ELAST: NO, ELASTIC_TYPE: ENG CONST

E1	E2	E3	v12	v13	v23	G12	G13
56636.1547	19322.2366	19322.2366	.363468355	.363468355	.536171679	6729.75802	6729.75802

G23: 6289.08763

Carbon_Epoxy_Homogenized_Composite

OK ColorEdit Cancel

- Target Modulus
 $E_{\text{alumin}} = 68.9 \text{ GPa}$
 $Rho_{\text{alumin}} = 2.7 \text{ kg/m}^3$

- Constituents
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 $E_{\text{matrix}} = 10.5 \text{ GPa}$
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 $E_{\text{1comp}} = 56.6 \text{ GPa}$
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Setup & Export model
MOLDEX3D

Deck Tools

Map Material
Orientations

Setup & Run
Structural **Elastic** Analysis

Setup & Run
Structural **Plastic** Analysis

Setup & Run
RVE Model

Linear
Homogenized
Material Model

Non-Linear
Homogenized
Material Model

RVE Model
Generation

Homogenization Tool

Post-processing

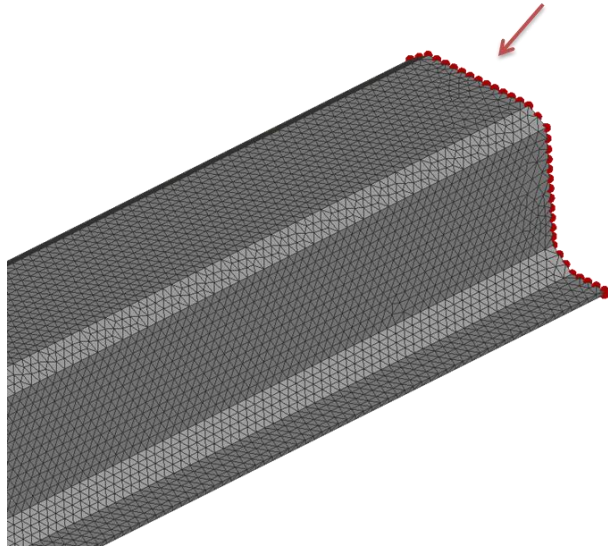
Maximum
Elastic Strain

Maximum
Total Strain

Fiber-Matrix
Interaction

Case Study: Setup Moldex3D Analysis and Mapping

Assign Point Attribute: Melt Entrance

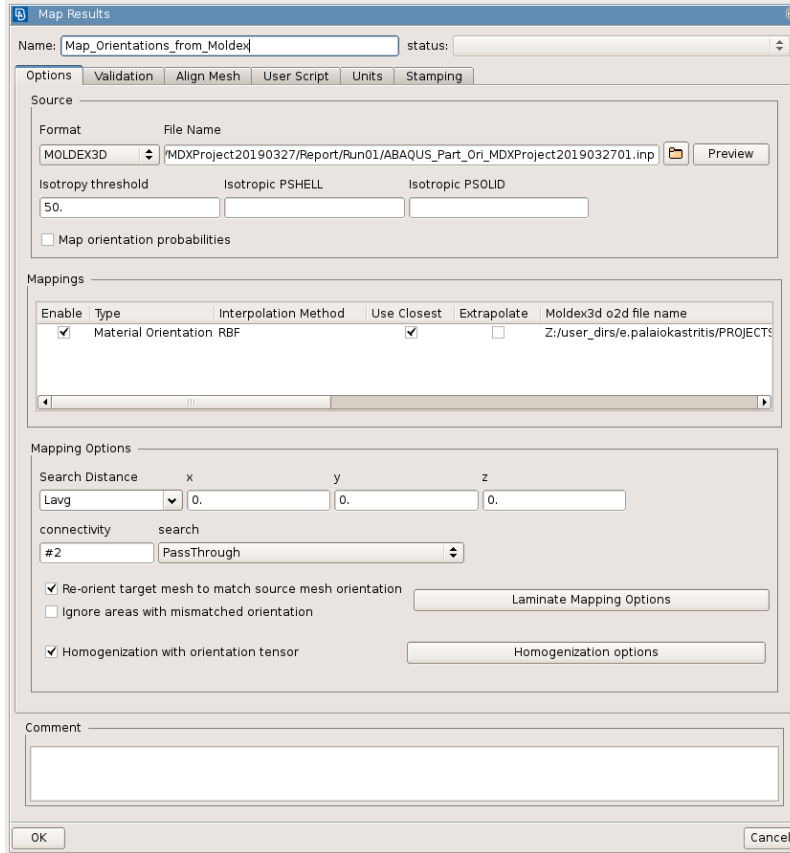
A screenshot of the 'MOLDEX3D Output Parameters' dialog box. The dialog is titled 'MOLDEX3D Output Parameters' and has a close button (X) in the top right corner. It is divided into several sections:

- File format Options:** Contains two radio buttons: 'SHELL' (unselected) and 'SOLID' (selected). There is also a checkbox for 'Fast Cool' which is unchecked.
- Output Options:** Contains a dropdown menu for 'Output' with 'Model' selected.
- Pre Output Script:** Contains two text input fields: 'Pre func name' and 'Pre func args'.
- Post Output Script:** Contains two text input fields: 'Post func name' and 'Post func args'.
- Pre-Output Model Check:** Contains a checkbox for 'Pre-Output Model Check' which is unchecked. Below it is a 'Template:' dropdown menu and a checked checkbox for 'Do not output if error occurs'.

At the bottom of the dialog are 'OK' and 'Cancel' buttons.

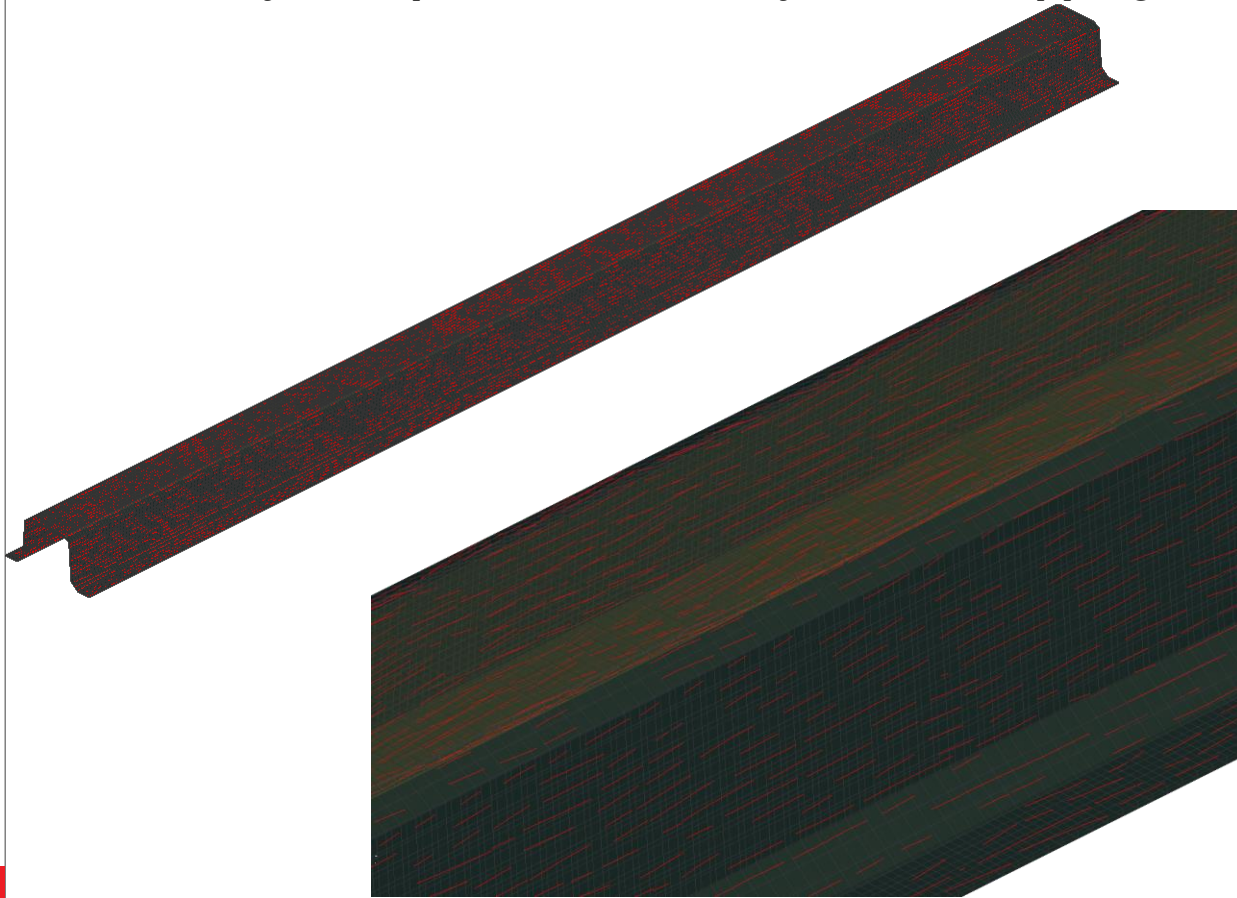
- Setup Point Attributes
Melt Entrance
- Export Mesh for
Moldex3D
- Run molding Analysis
Get the material
orientations file (*.o2d)
- Map Orientations

Case Study: Setup Moldex3D Analysis and Mapping



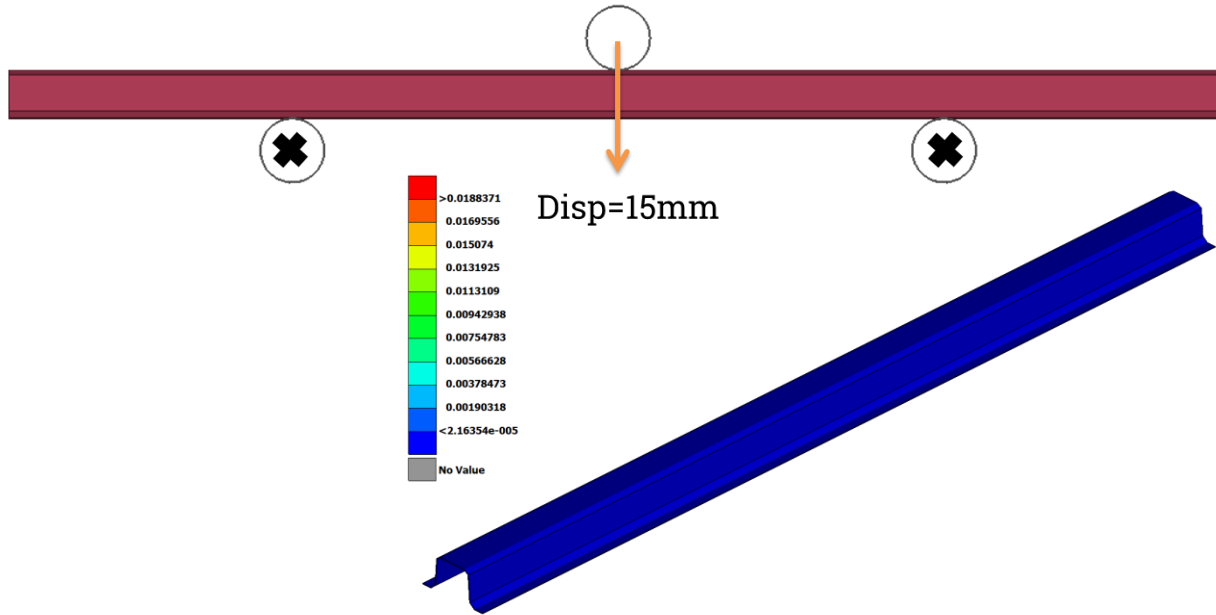
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Case Study: Setup Moldex3D Analysis and Mapping



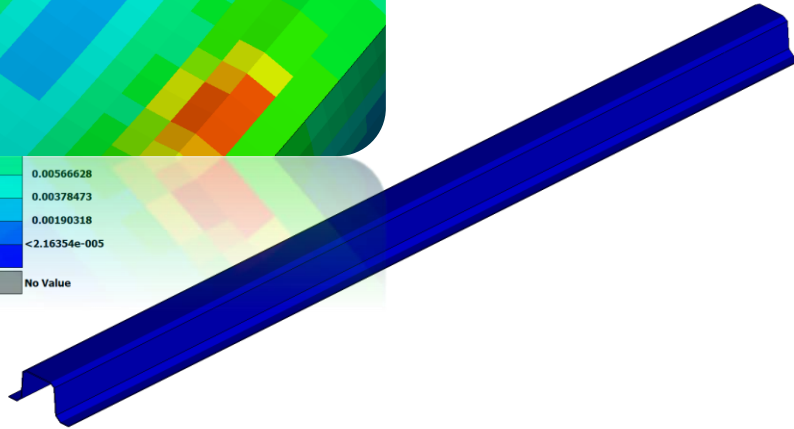
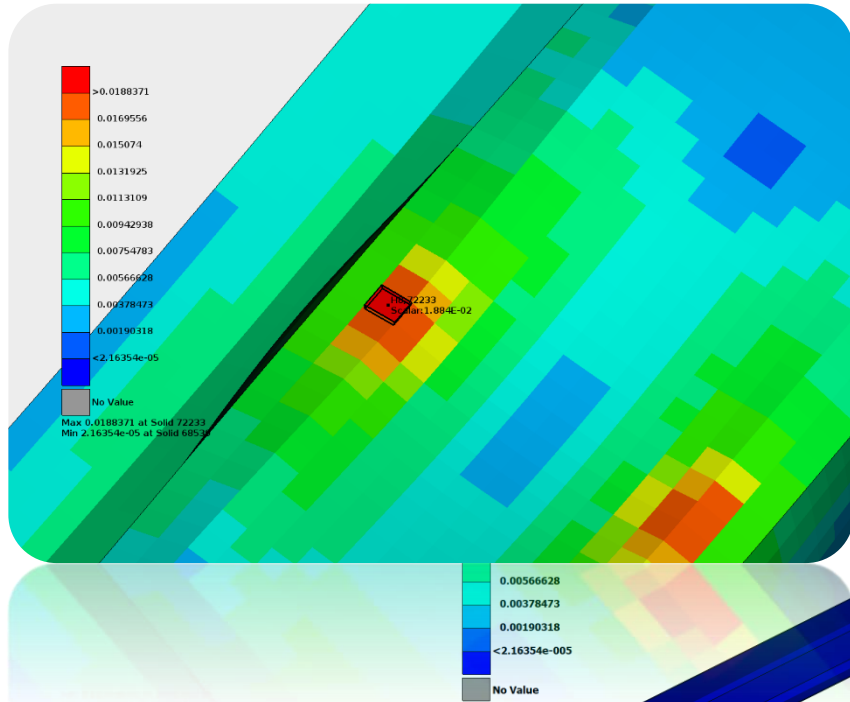
- Setup Point Attributes Melt Entrance
- Export Mesh for Moldex3D
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Case Study: Solve Linear Elastic Model



- Solve with Abaqus:
Linear Elastic Material,
Non Linear Geometry
- Isolate element with
Max Strain:
Use this Strain Tensor
for calculation of the
Elasto-plastic material
model

Case Study: Solve Linear Elastic Model



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Maximum
Total Strain

RVE Model
Generation

Setup & Run
RVE Model

Fiber-Matrix
Interaction

Homogenization Tool

Case Study: Calculate the Elasto-Plastic Composite Material

The screenshot shows the 'Homogenization' software interface. The 'Analysis' is set to 'Elasto-plasticity' and the 'Method' is 'Multi step Homogenization'. The 'Matrix Properties' section includes tabs for 'Elastic-Thermal', 'Plastic', 'Damage', 'Failure', 'Viscous', and 'Conductivity'. The 'Elastic-Thermal' tab is active, showing properties: E1 = 10500, N1 = 0.395, E2 = 0, N2 = 0, RHO = 1.25, CTE = 0, and Vm = 1. A 'Set Isotropic' button is present. The 'Loading' section is highlighted with a red box and includes tabs for 'Mechanical' and 'Thermal'. The 'Mechanical' tab is active, showing 'Loading type' as 'General 3D' and a table of loading parameters:

Parameter	Value	Parameter	Value	Parameter	Value
E11	0.0167874929	E22	0.0046173073	E33	0.0146624545
2E12	8.10032806344285E-5	2E13	0.0065503604	2E23	0.0038473822
Loading Time	1				

Below the loading section is an 'Inclusions list' table:

Name	Enabled	Vf
Carbon_iso	<input checked="" type="checkbox"/>	0.3

Buttons for 'Add', 'Edit', and 'Delete' are located below the table. At the bottom of the interface, the 'Results' and 'Make Material' buttons are highlighted with red boxes.

- Homogenization Tool Elasto-plasticity Strain Tensor for Loading
- Homogenized Material's behaviour: Elasto-plastic stress-strain curve
- Create the material entity: Abaqus material with *PLASTIC

Case Study: Calculate the Elasto-Plastic Composite Material

Homogenization

File Calculate

Analysis Elasto-plasticity

Method Multi step Homo

Matrix Properties

Elastic-Thermal Pla

E1

E2

RHO

Loading

Mechanical Thermal

Loading type General

E11

2E12 8.1C

Loading Time

Inclusions list

Name	Enabled
Carbon_iso	<input checked="" type="checkbox"/>

Add

Plane stress

Inclusions info

OK Results Make Material RVE Options Cancel

Effective Property

Mechanical Thermal Plastic

Choose curve type

VonMises Strain11 Add curve Export curve

Macro scale-Composite

X	Y
1	0. 0.
2	0.000067 2.128659
3	0.000134 4.257318
4	0.000201 6.385977
5	0.000269 8.514636
6	0.000336 10.643295
7	0.000403 12.771954
8	0.00047 14.900613
9	0.000537 17.029272
10	0.000604 19.157931
11	0.000671 21.28659
12	0.000739 23.415248
13	0.000806 25.543907
14	0.000873 27.672566

Stress

Strain

strain11VonMises-composite

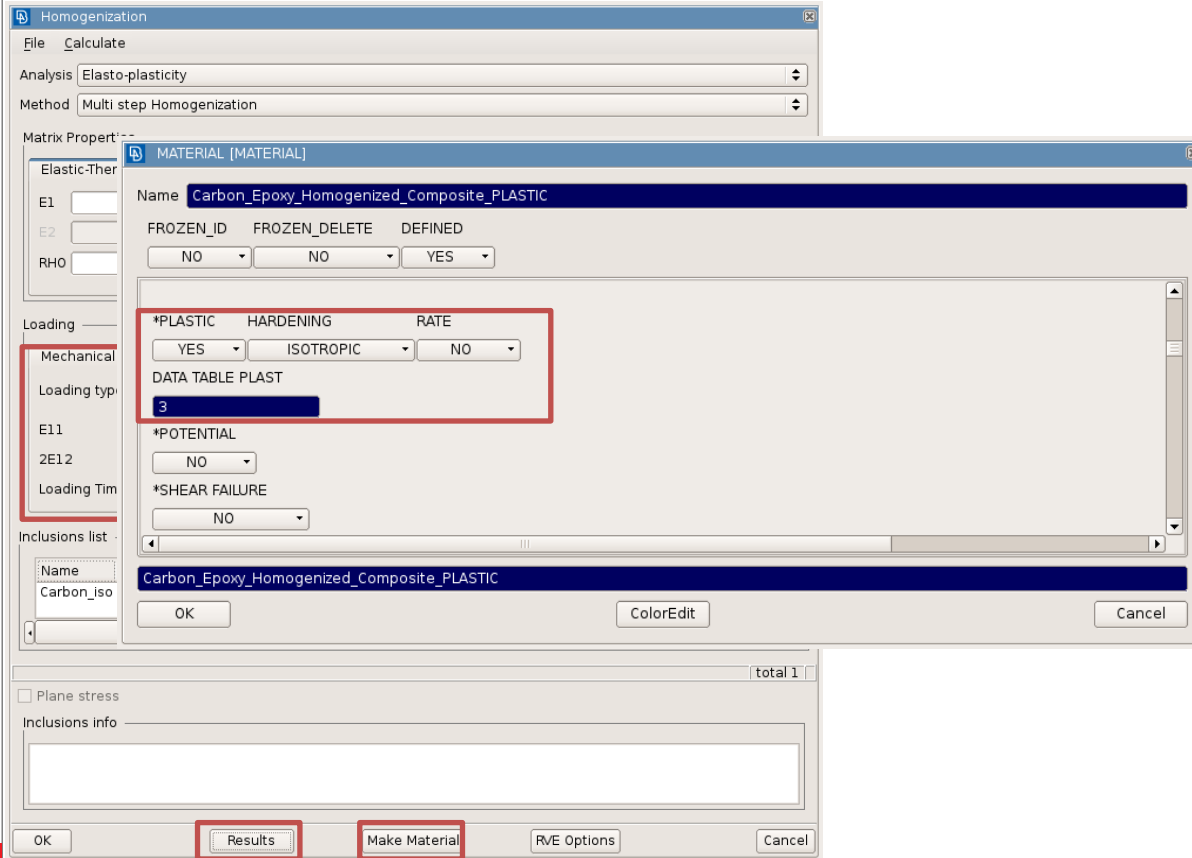
Homogenization results

Homogenized stiffness tensor

```
54105.8948564917 23337.1329613565 21464.5164159488 -150.91508852875 1478.39522464204 1345.29970761151
23337.1329613565 33412.7519060577 19797.7361887552 -58.141059621555 296.035303099402 449.063229754083
21464.5164159488 19797.7361887552 32170.4560502256 -41.97614102063 356.28584341005 144.531387598966
-150.91508852875 -58.141059621555 -41.97614102063 6448.09150768736 78.7821418267711 88.6657693294138
1478.39522464204 296.035303099402 356.28584341005 78.7821418267711 7576.69927139779 73.7722534384993
1345.29970761151 449.063229754083 144.531387598966 88.6657693294138 73.7722534384993 7704.89213788326
```

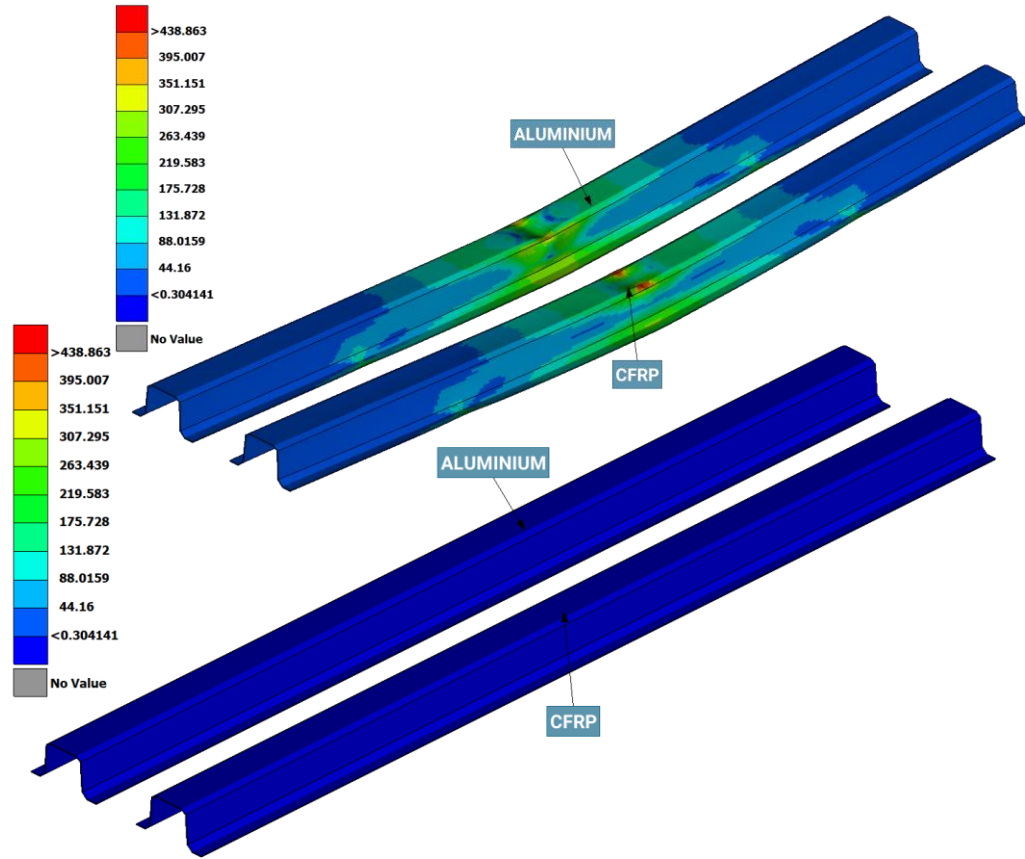
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Case Study: Calculate the Elasto-Plastic Composite Material



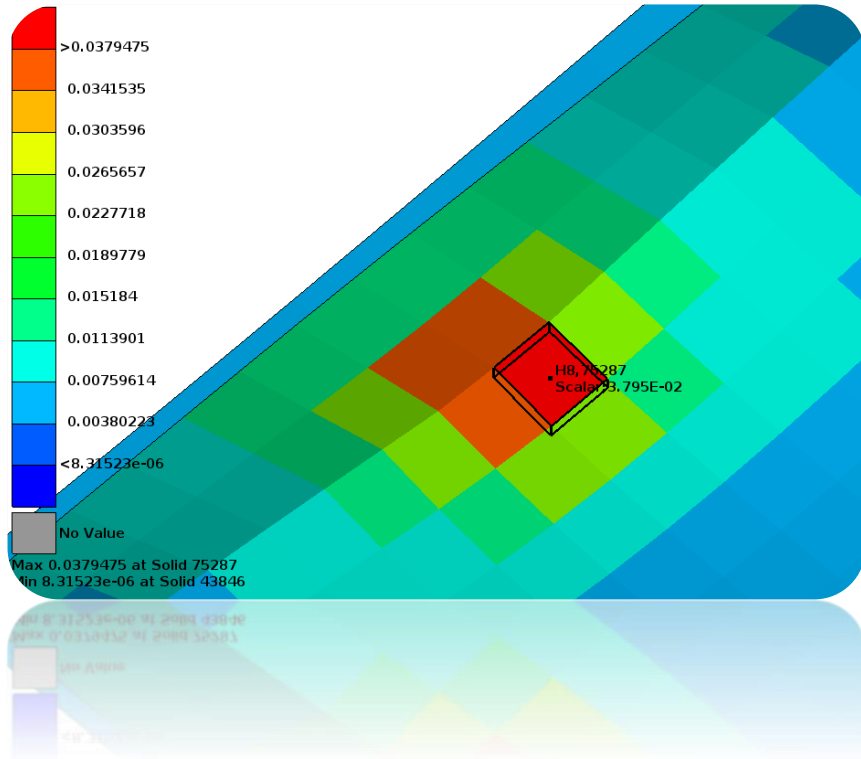
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Case Study: Solve Plastic Model



- Solve with Abaqus:
Elasto-plastic Material,
Non Linear Geometry
- Aluminium vs CFRP:
 $\text{MaxStress}_{\text{alum}} = 327 \text{ MPa}$
 $\text{MaxStress}_{\text{comp}} = 438 \text{ MPa}$
Weight Reduction $\cong 48\%$
- Isolate element with
Max Strain :
Use this strain in the
RVE Model

Case Study: Solve Plastic Model



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Non Linear Geometry
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MOLDEX3D

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Orientations

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Structural **Elastic** Analysis

Setup & Run
Structural **Plastic** Analysis

Setup & Run
RVE Model

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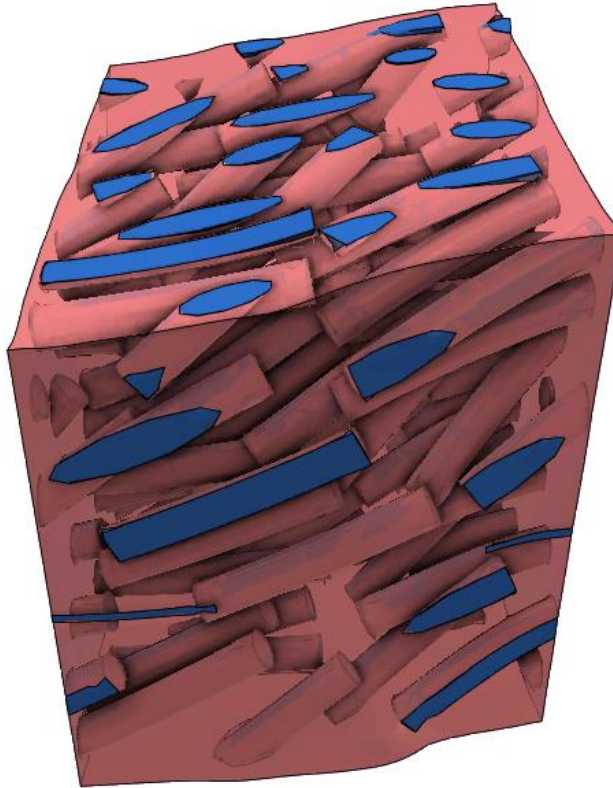
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RVE Model
Generation

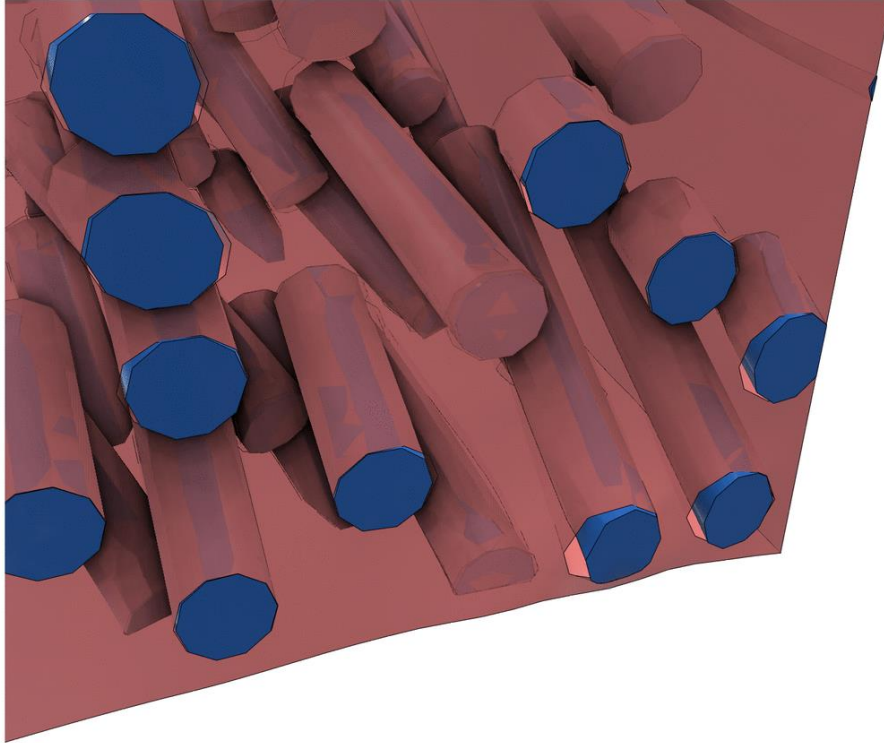
Homogenization Tool

Case Study: RVE Model - Analysis



- RVE Mesh Generation:
Contacts at the interface of fiber-matrix
- Subject it to the strain loading
- Examine the behavior of the interface
Debonding
Fiber-pull out

Case Study: RVE Model - Analysis



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Contacts at the interface of fiber-matrix
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Debonding
Fiber-pull out

Bridge Multi-scale Modeling, Manufacturing Simulation, Structural Analysis

Solutions provided in the multi-disciplinary environment of ANSA

Facilitate material design process

Automation capabilities with ANSA API.



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