As-Manufactured Structural Simulation of Fiber-Filled Plastics

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Class summary

In this class we will discuss the new capability to map fiber orientations and material properties from Simulation Moldflow software to structural finite element analysis (FEA). We will also cover how to use Simulation Composite Analysis software to simulate nonlinear material behavior of the fiber-filled material.

Key learning objectives

At the end of this class, you will be able to:

- Discover the new interface between Simulation Composite Analysis software and Simulation Moldflow software
- Understand the nonlinear material behaviors supported by Simulation Composite Analysis software
- Understand how to use Simulation Composite Analysis software for fiber-filled materials
- Learn how to confidently interpret results from Simulation Composite Analysis software for fiber-filled materials

We may make statements regarding planned or future development efforts for our existing or new products and services. These statements are not intended to be a promise or guarantee of future availability of products, services or features but merely reflect our current plans and based on factors currently known to us. These planned and future development efforts may change without notice. Purchasing decisions should not be made based upon reliance on these statements.

These statements are being made as of 12/4/2014 [the date of this presentation], and we assume no obligation to update these forward-looking statements to reflect events that occur or circumstances that exist or change after the date on which they were made.

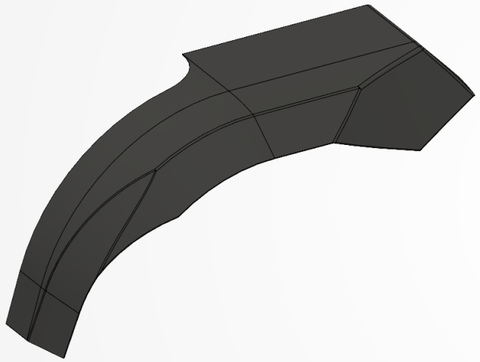
If this presentation is reviewed after 12/4/2014 [the date of its original publication], these statements may no longer contain current or accurate information.

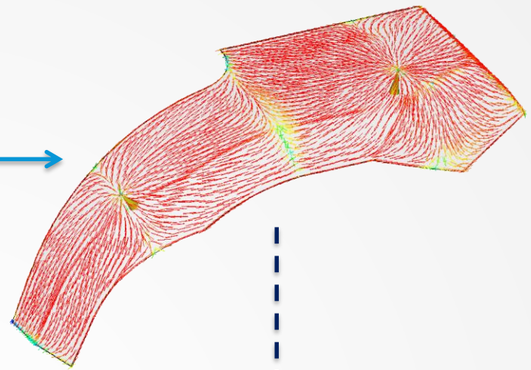
Agenda

- Advanced Material Exchange
  - Aligning models
  - Determining mesh suitability
- Material Nonlinearity
  - Theory
  - Application
- Case study
  - Static structural
  - Warpage
- Future directions

Moldflow Simulation

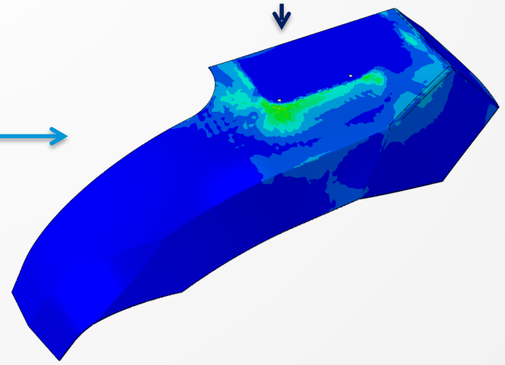
Pre-Processor





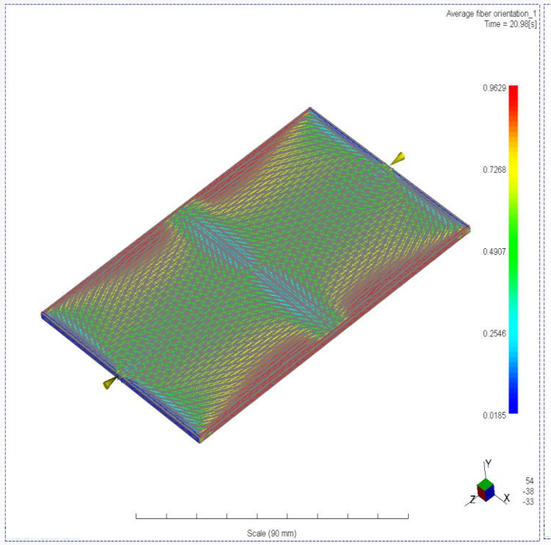
CAE Simulation

Pre-Processor

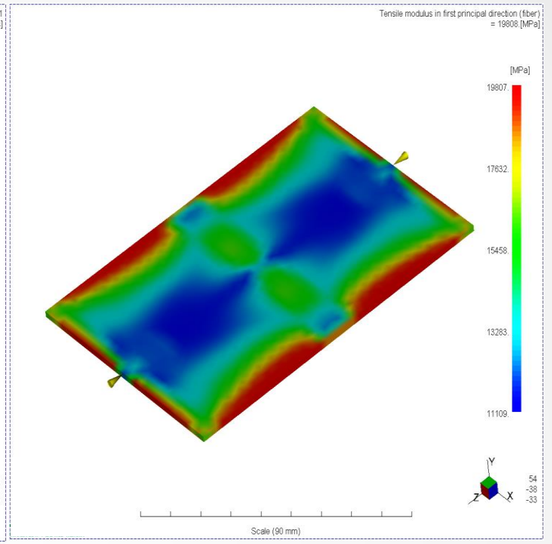


AMSA

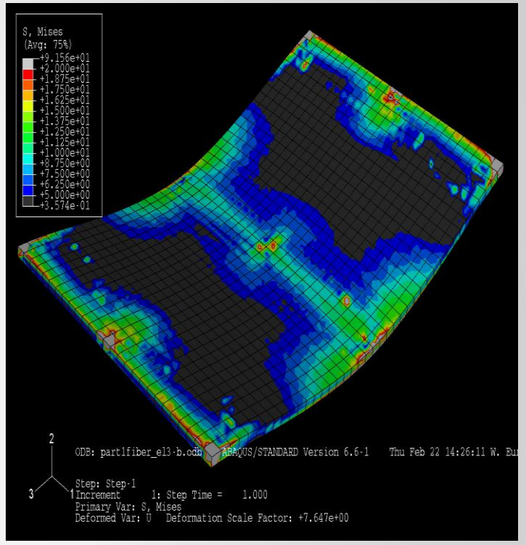
- FEA Platforms
  - Abaqus
  - ANSYS
- Supported Mappings
  - Dual Domain to solid
  - 3D to solid
- Maps:
  - Mechanical properties
  - CTE
  - Residual stresses
  - Crystallinity induced anisotropy



Fiber Orientation

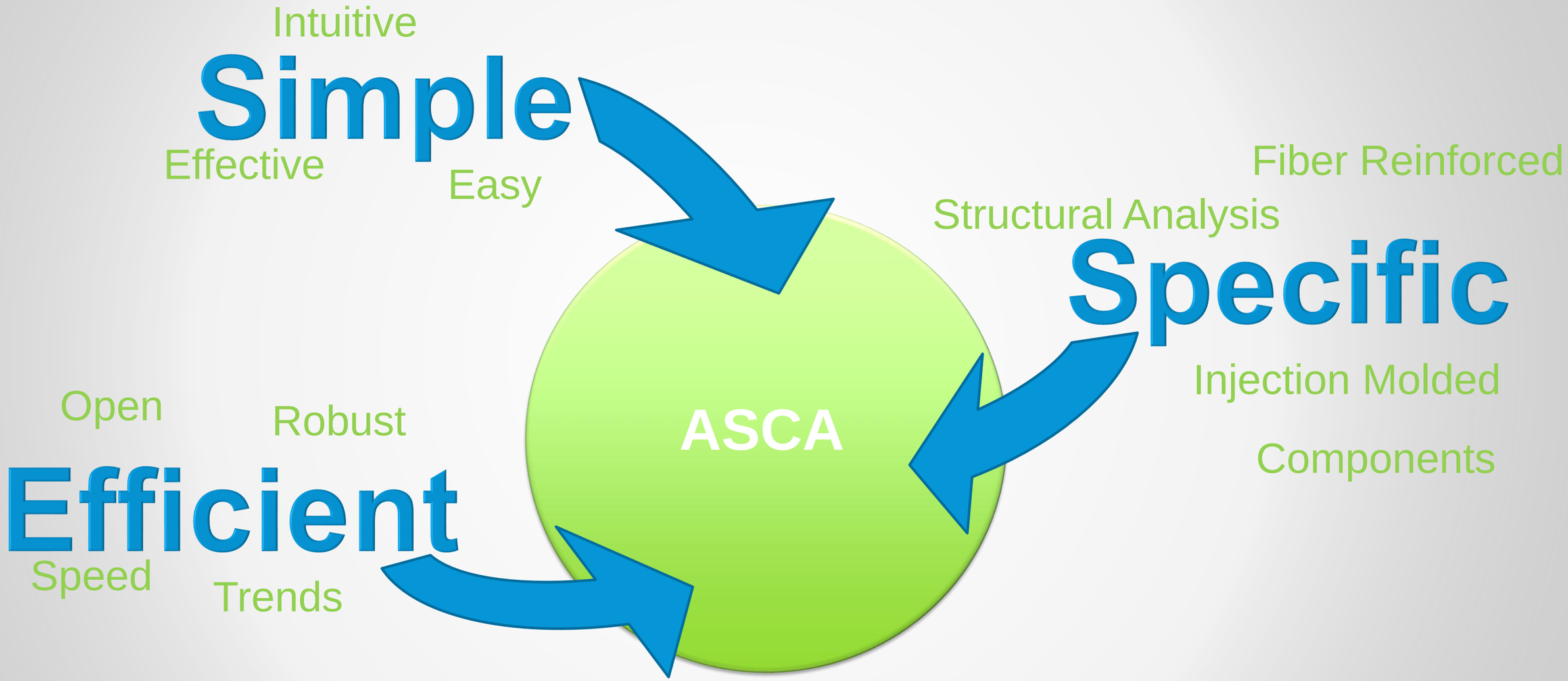


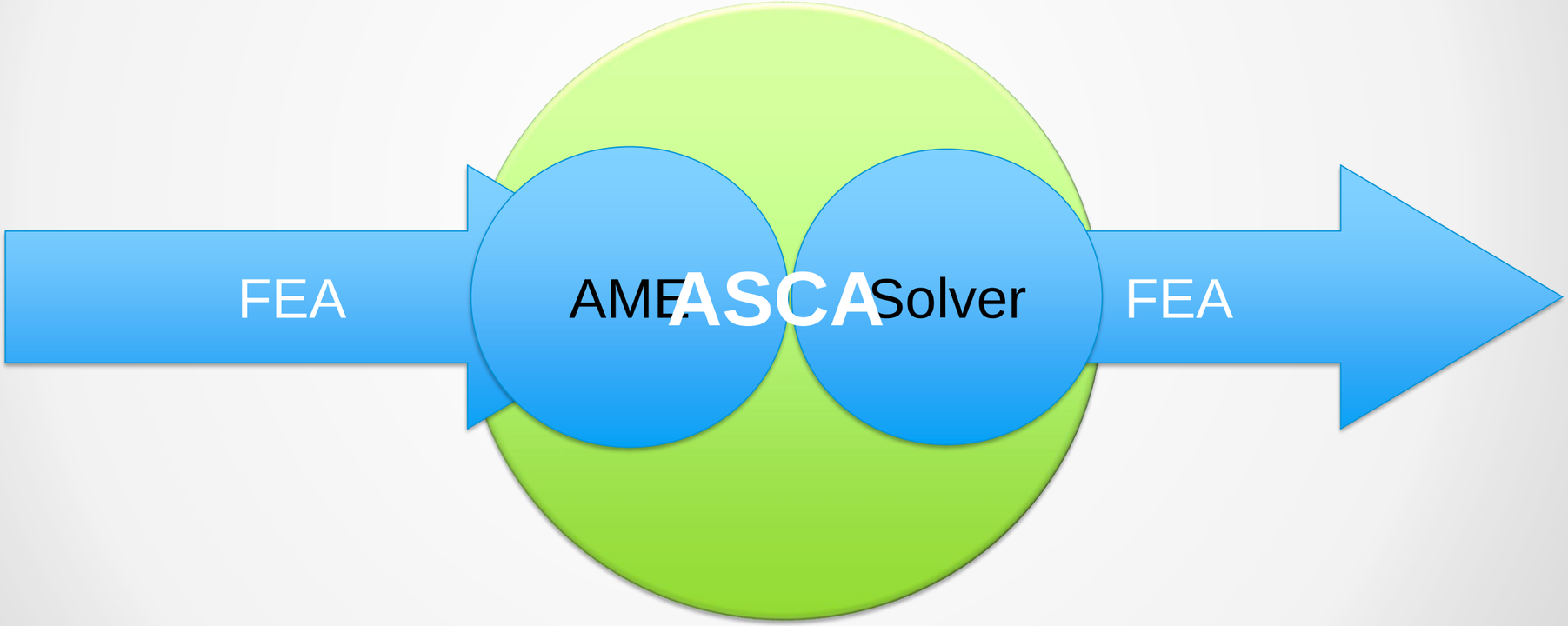
Mechanical Properties



Structural Analysis

Linear

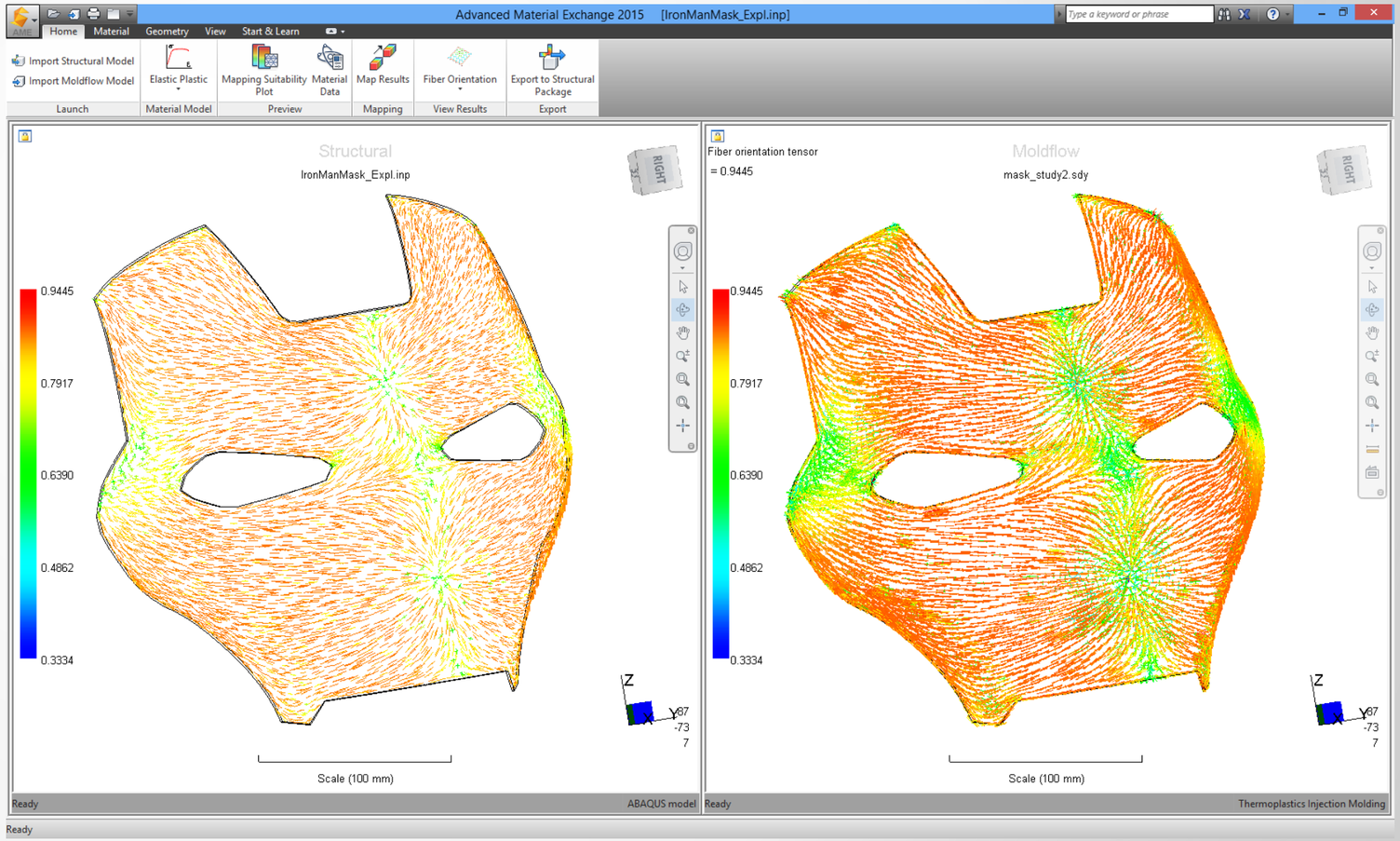

Intuitive
Simple
Effective
Easy
Fiber Reinforced
Structural Analysis
Specific
Injection Molded
Components
Open
Robust
Efficient
Speed
Trends
ASCA


FEA
AMEA
ASCA
Solver
FEA

Advanced Material Exchange

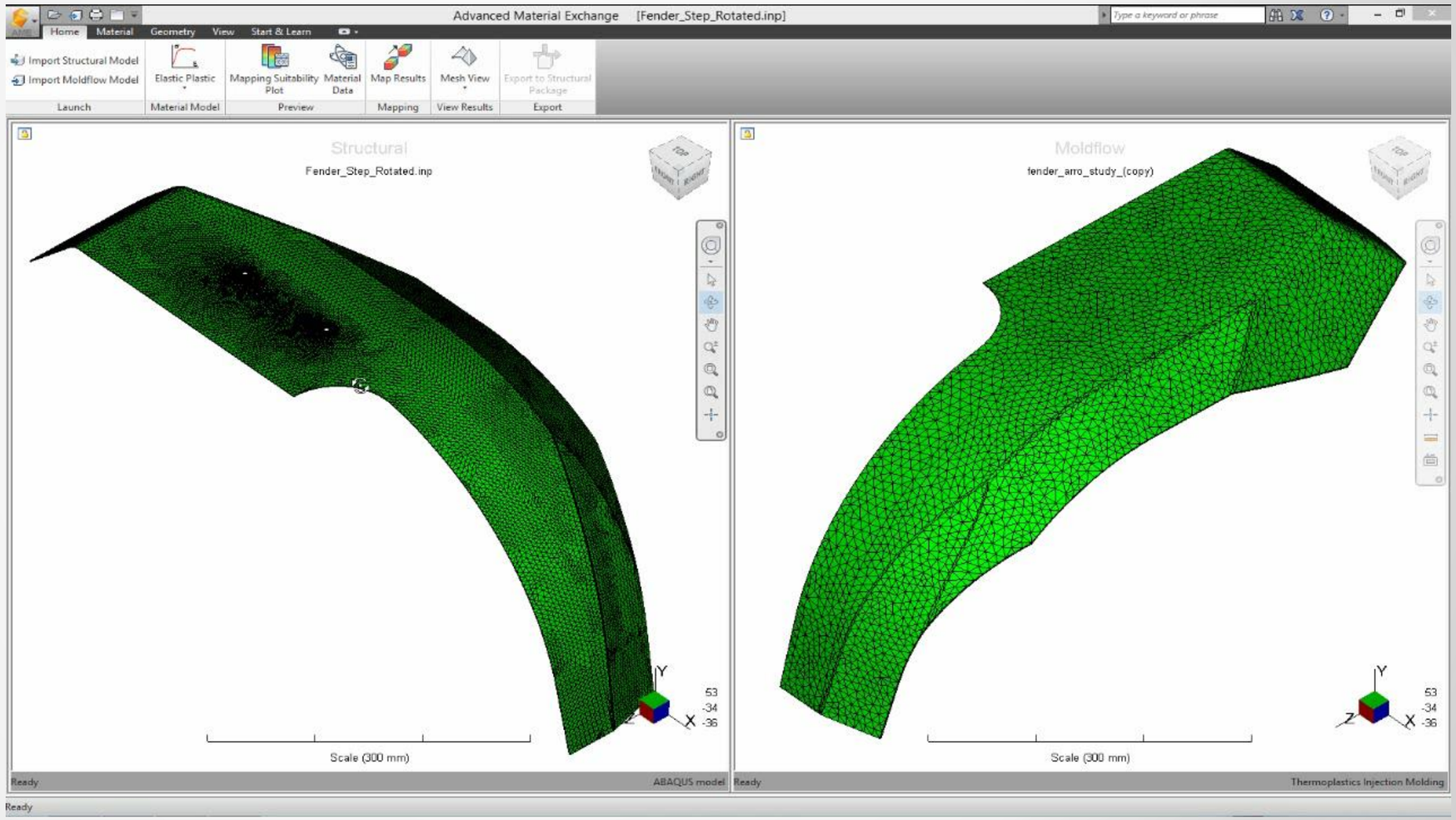
Advanced Material Exchange

- Map results from Moldflow to Abaqus
  - Material Properties
  - Fiber orientations
  - Residual stress/strain



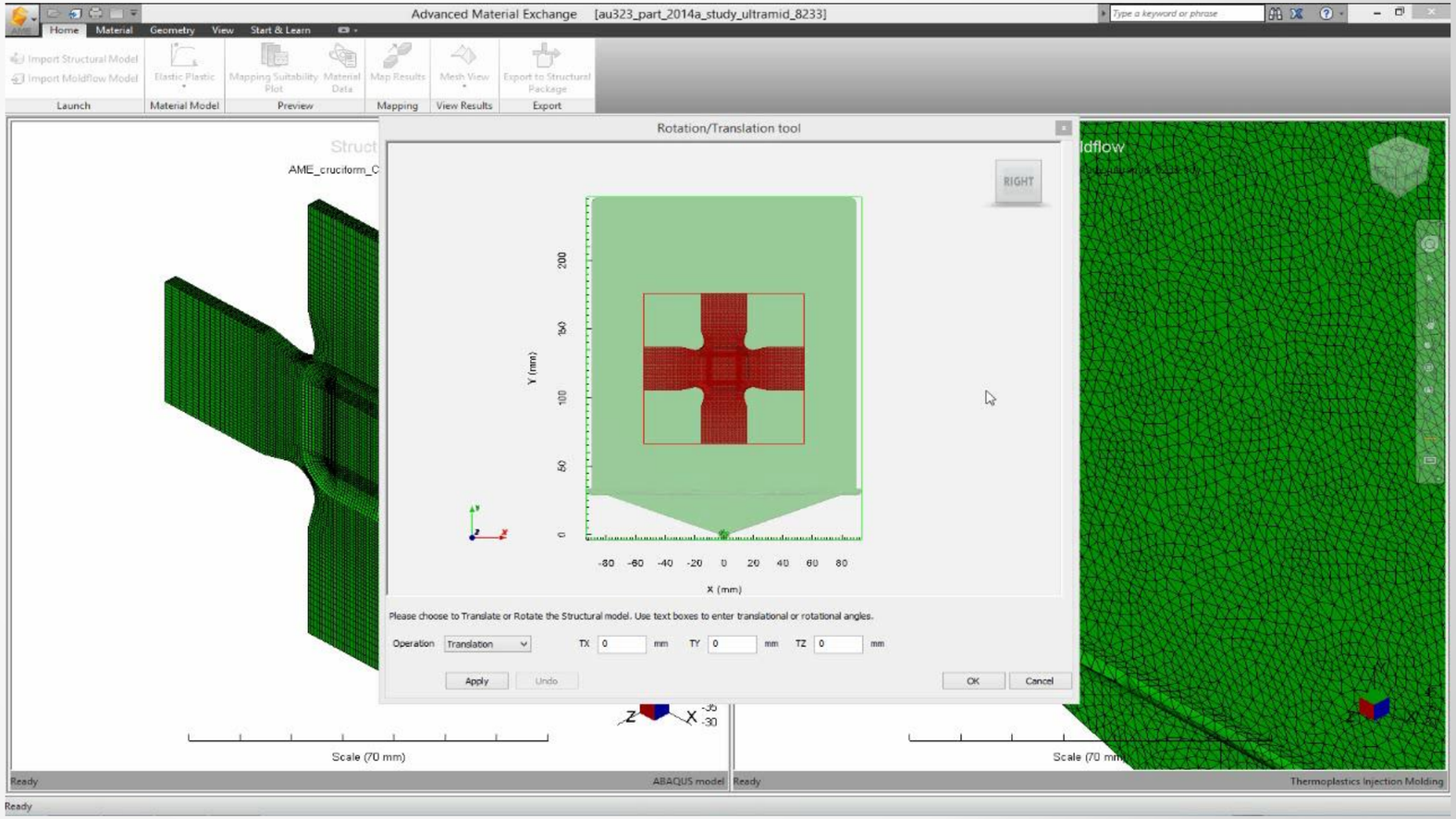
Problem - Models are not the same!

- Position
- Geometry
- Mesh



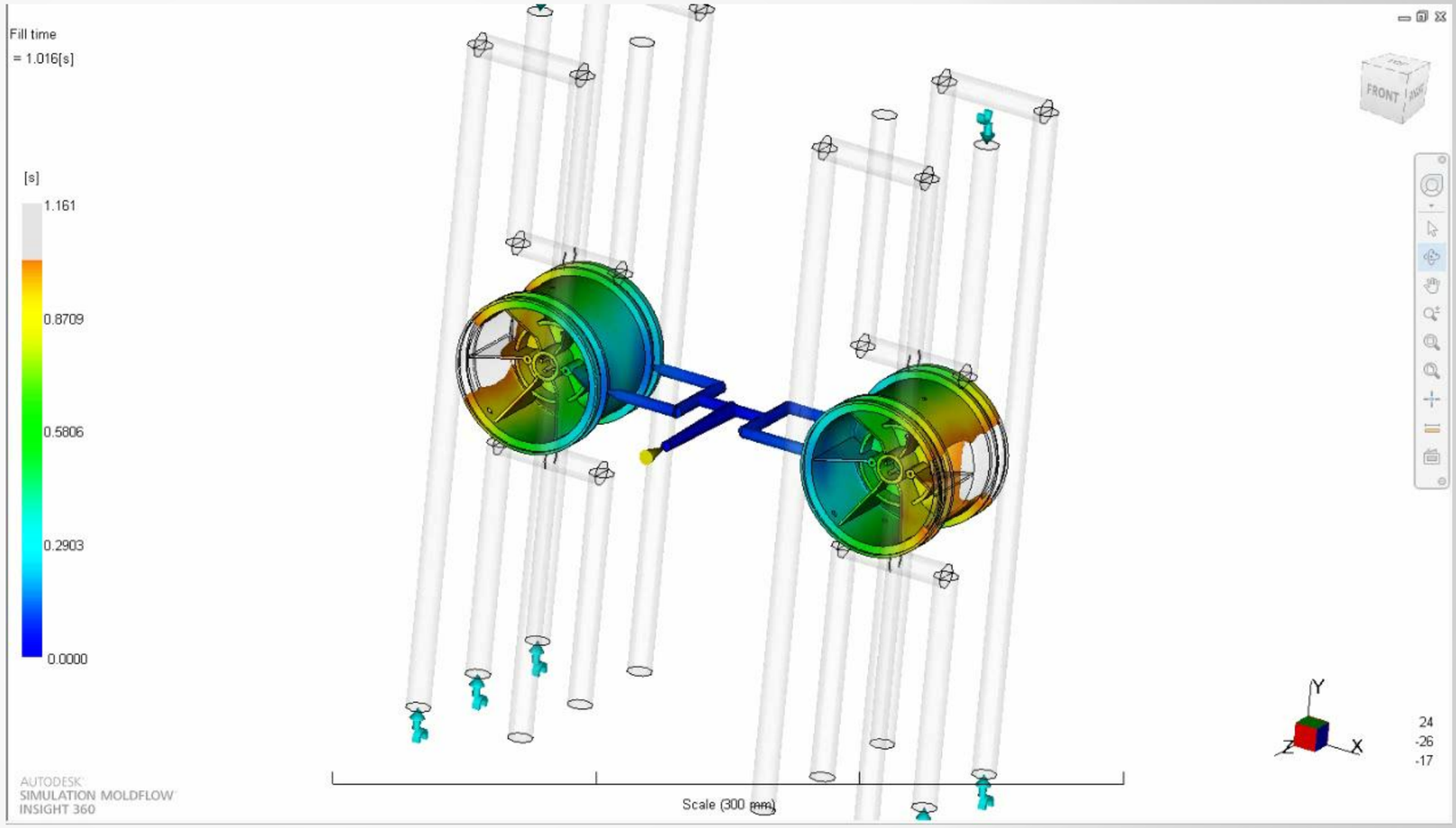
Model Alignment

- Automatic
- Interactive

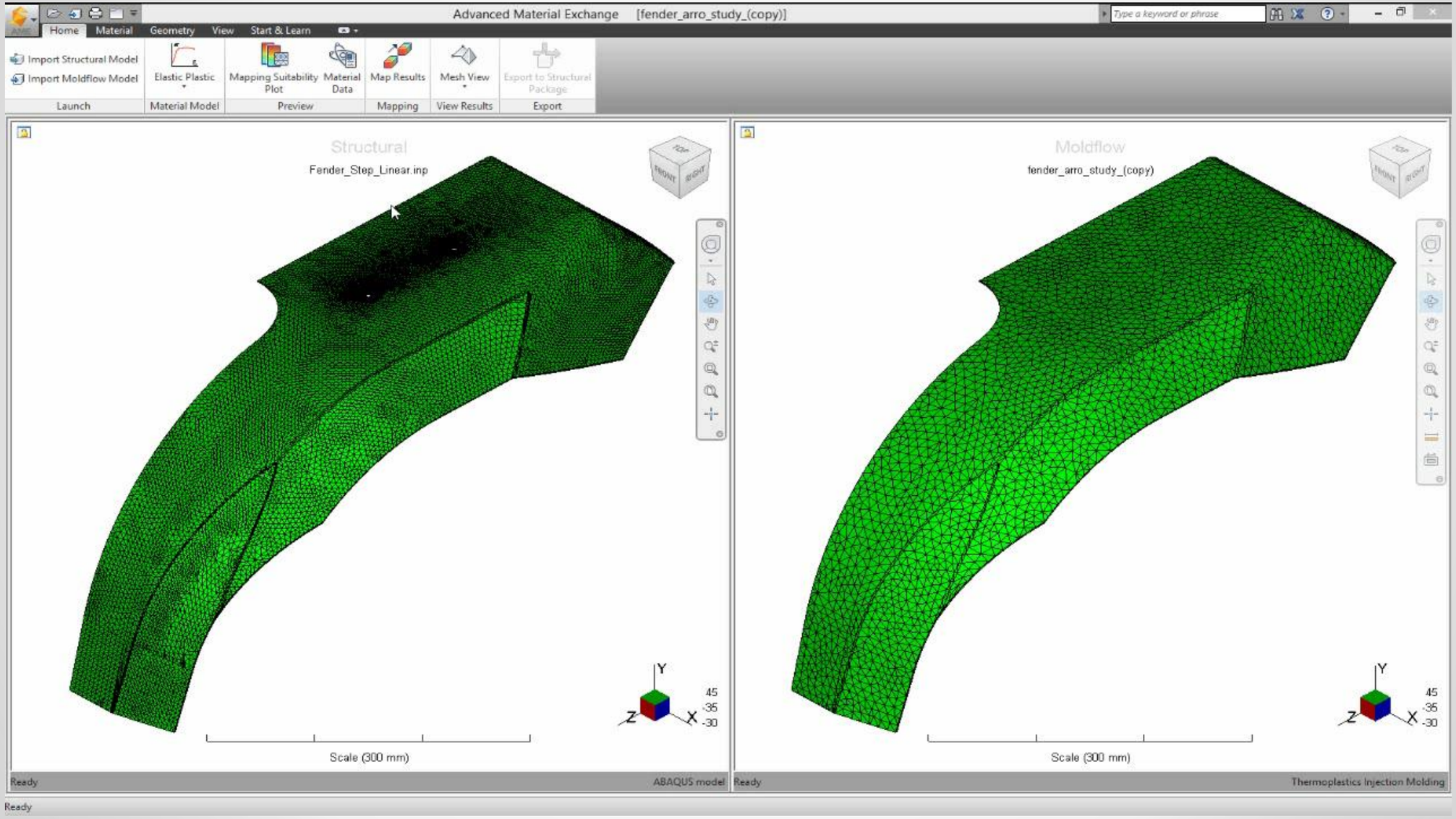


Dissimilar Geometries

- Different geometry
- Ignores:
  - Runners
  - Cooling lines
  - Molds
- Imports short shots

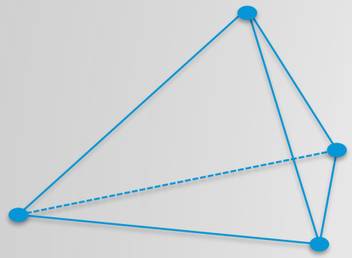


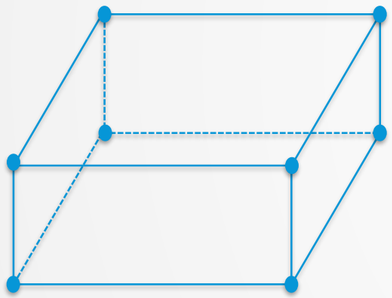
Mapping Suitability



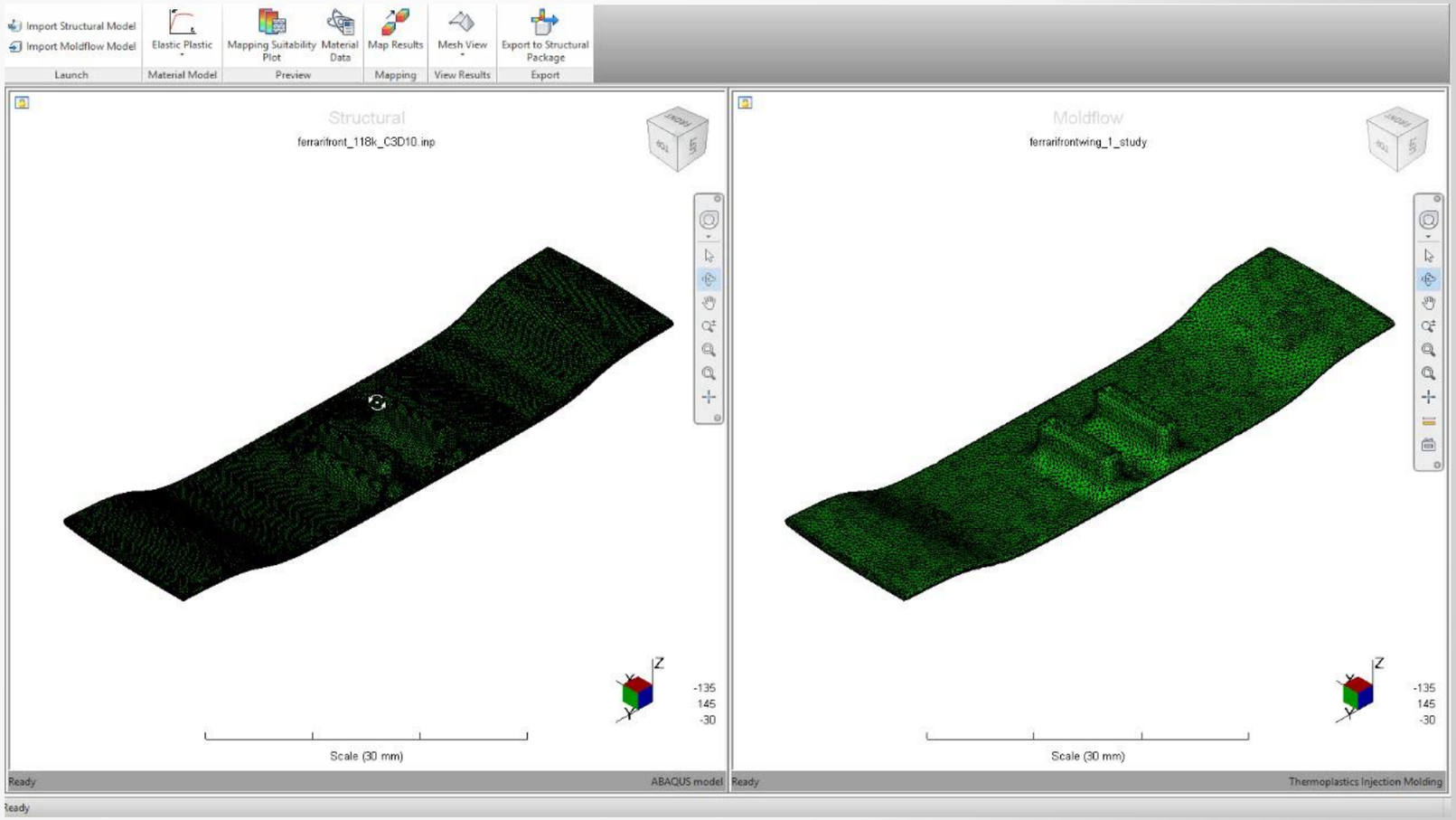
Supported Mappings & Elements

- Supported mappings:
  - Solid – solid



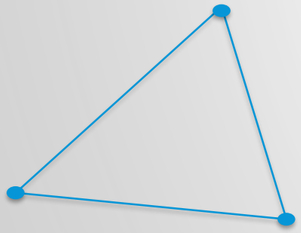


Tets	Bricks
C3D4	C3D8
C3D10	C3D8R

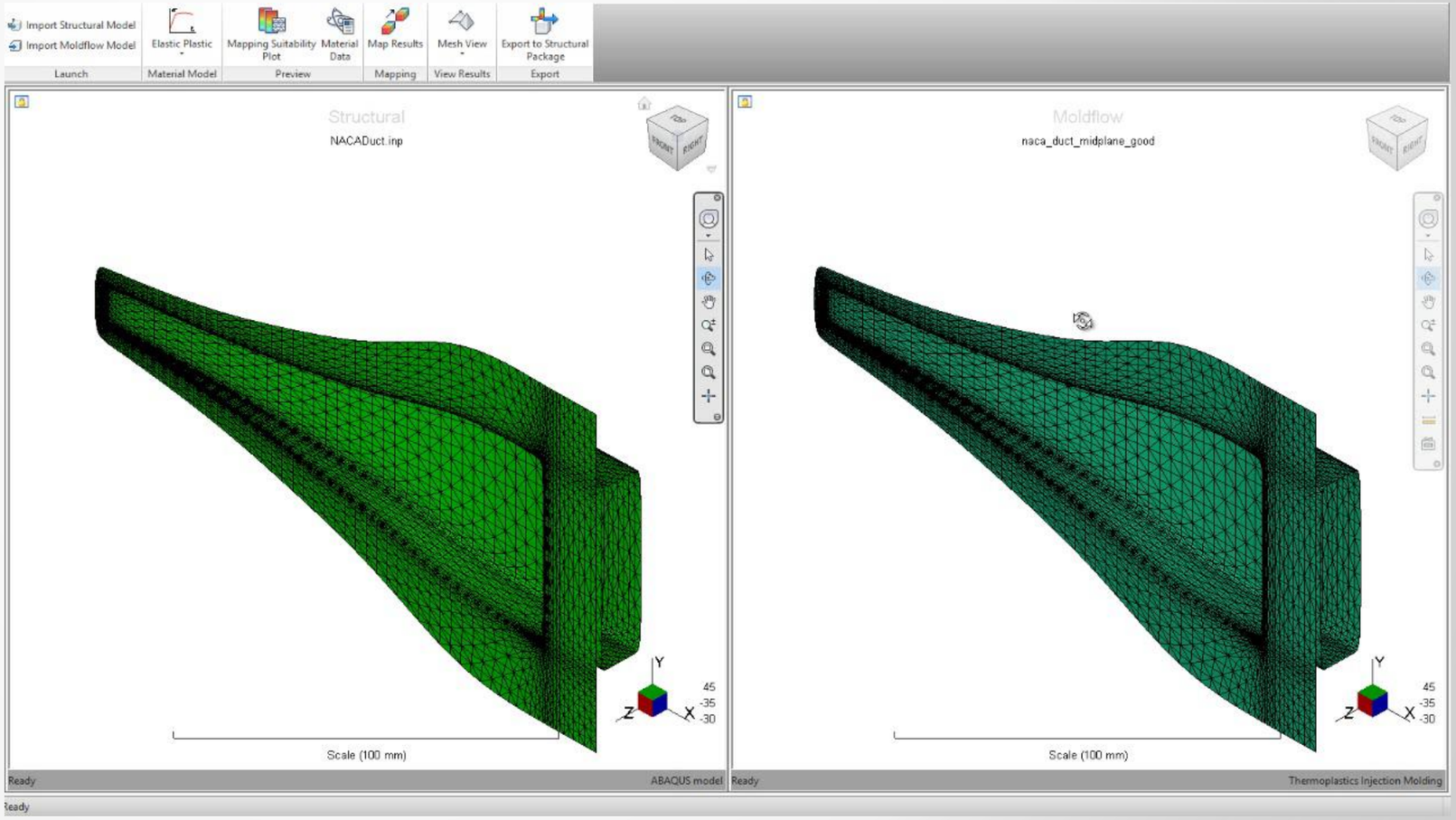


Supported Mappings & Elements

- Supported mappings:
  - Solid – solid
  - Midplane – shell



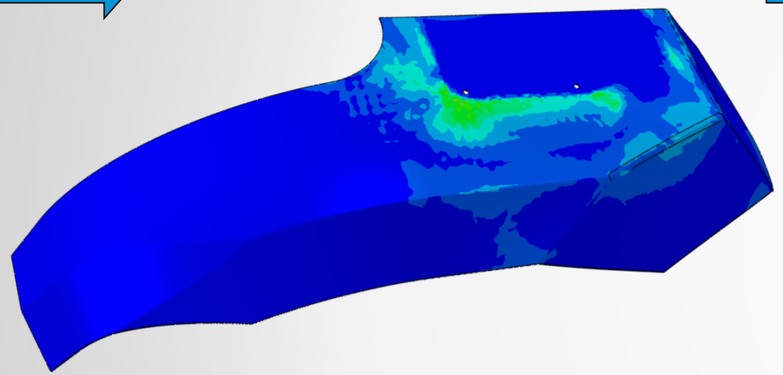
Shell
S3
S4
S4R



Working With the Solver

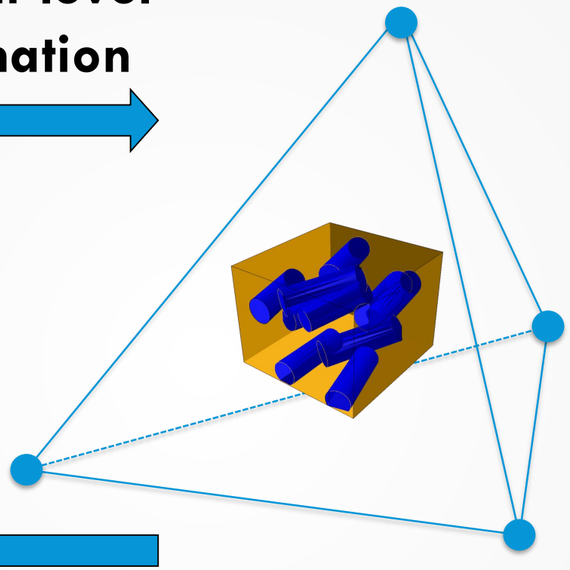
How it Works

Global loads



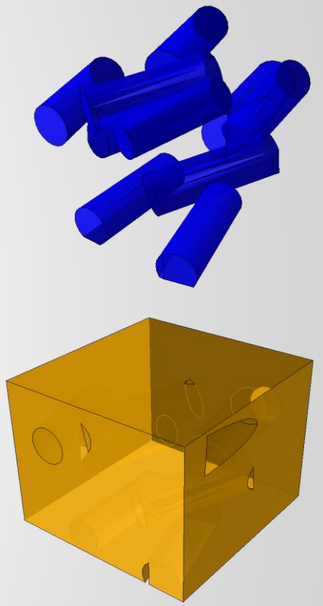
Global Response

Element-level Information



Physical Response of Composite

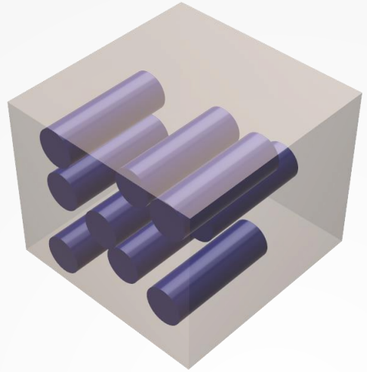
Constituent Information



Physical Response of Constituent

Acquiring Information

$\Delta\boldsymbol{\varepsilon}$

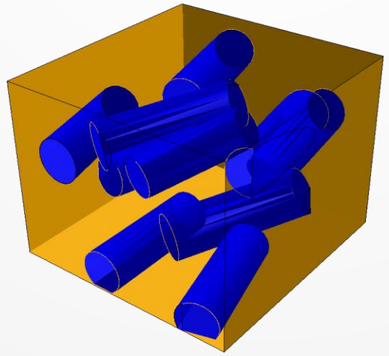


Orientation Averaging

$\Delta\boldsymbol{\sigma}_f, \Delta\boldsymbol{\varepsilon}_f$

$\Delta\boldsymbol{\sigma}_m, \Delta\boldsymbol{\varepsilon}_m$

$\Delta\boldsymbol{\varepsilon}$

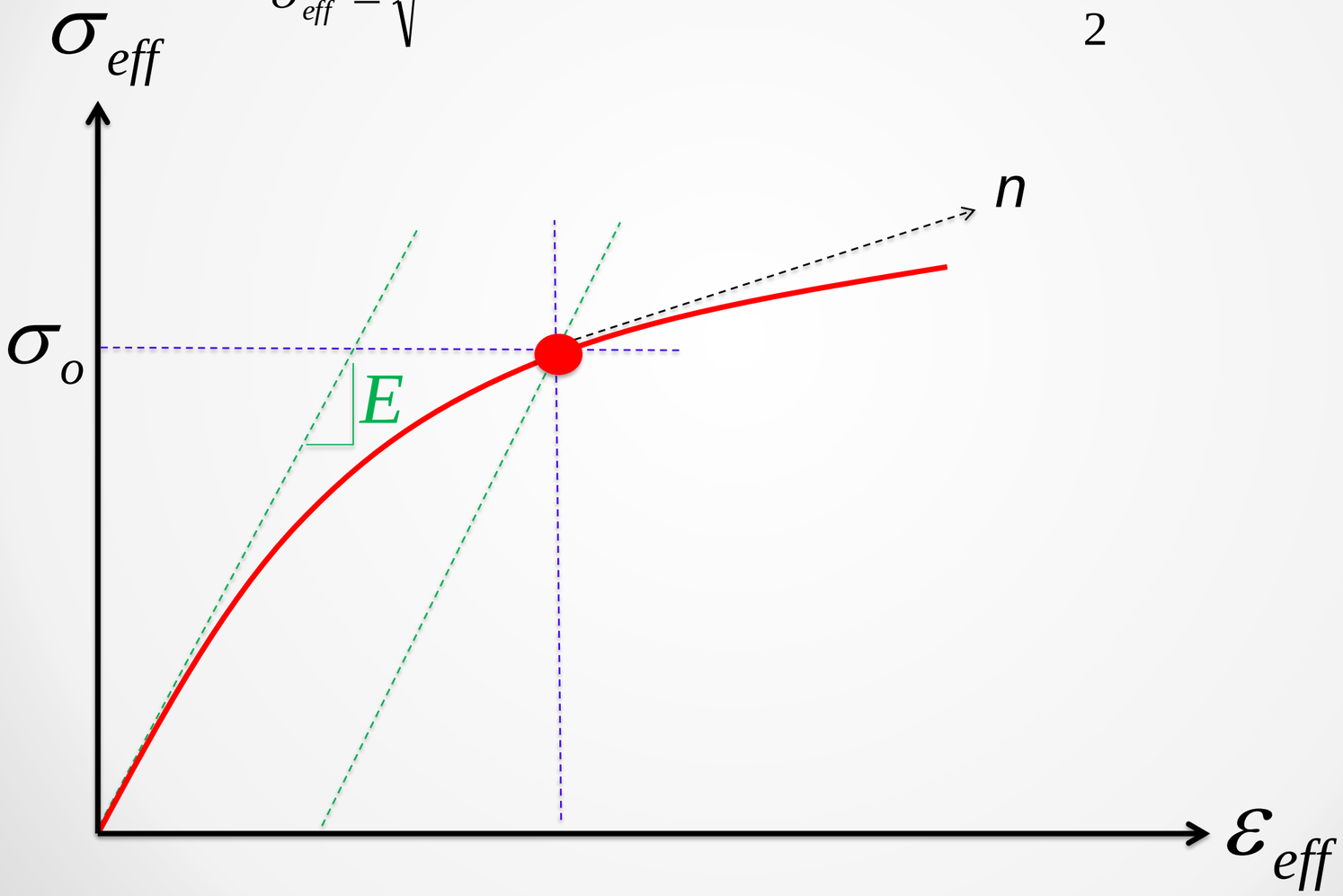


$\Delta\boldsymbol{\sigma}_f, \Delta\boldsymbol{\varepsilon}_f$

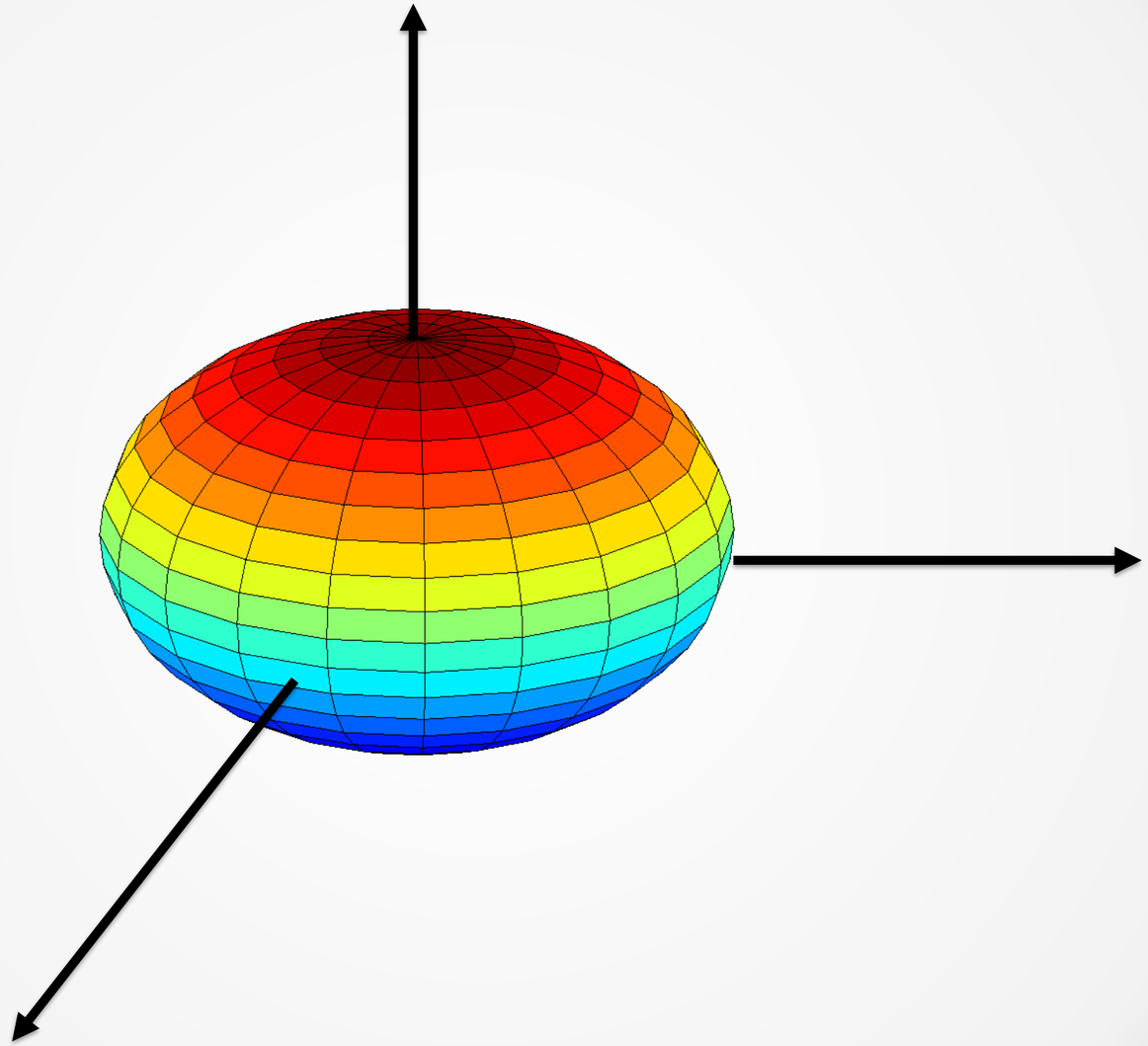
Mori-Tanaka Decomposition

Matrix Plasticity – Ramberg Osgood

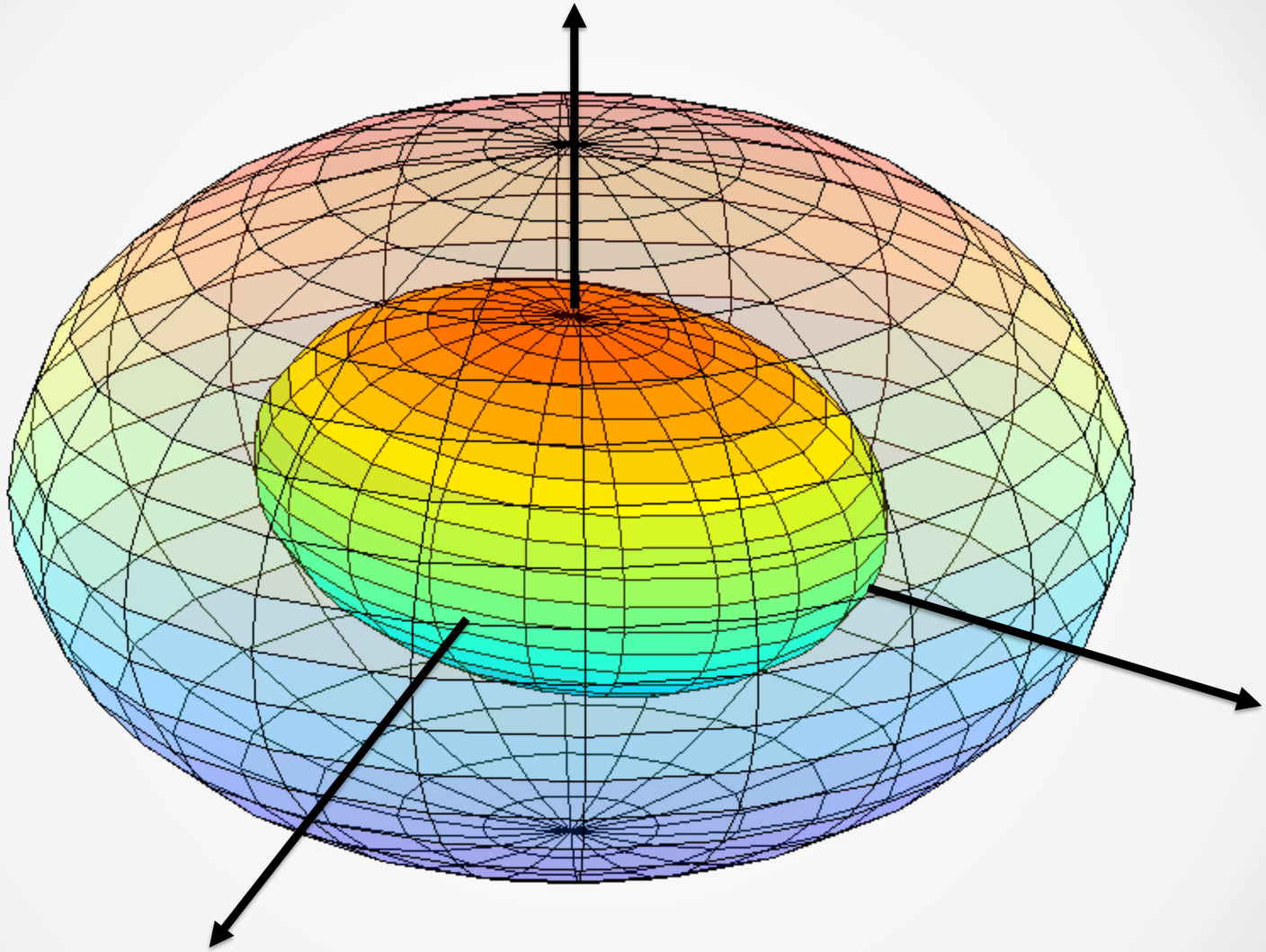
$$\sigma_{eff} \equiv \sqrt{\frac{(\sigma_{11}-\sigma_{22})^2+(\sigma_{22}-\sigma_{33})^2+(\sigma_{33}-\sigma_{11})^2+6[(\sigma_{12})^2+(\sigma_{23})^2+(\sigma_{31})^2]}{2}}$$



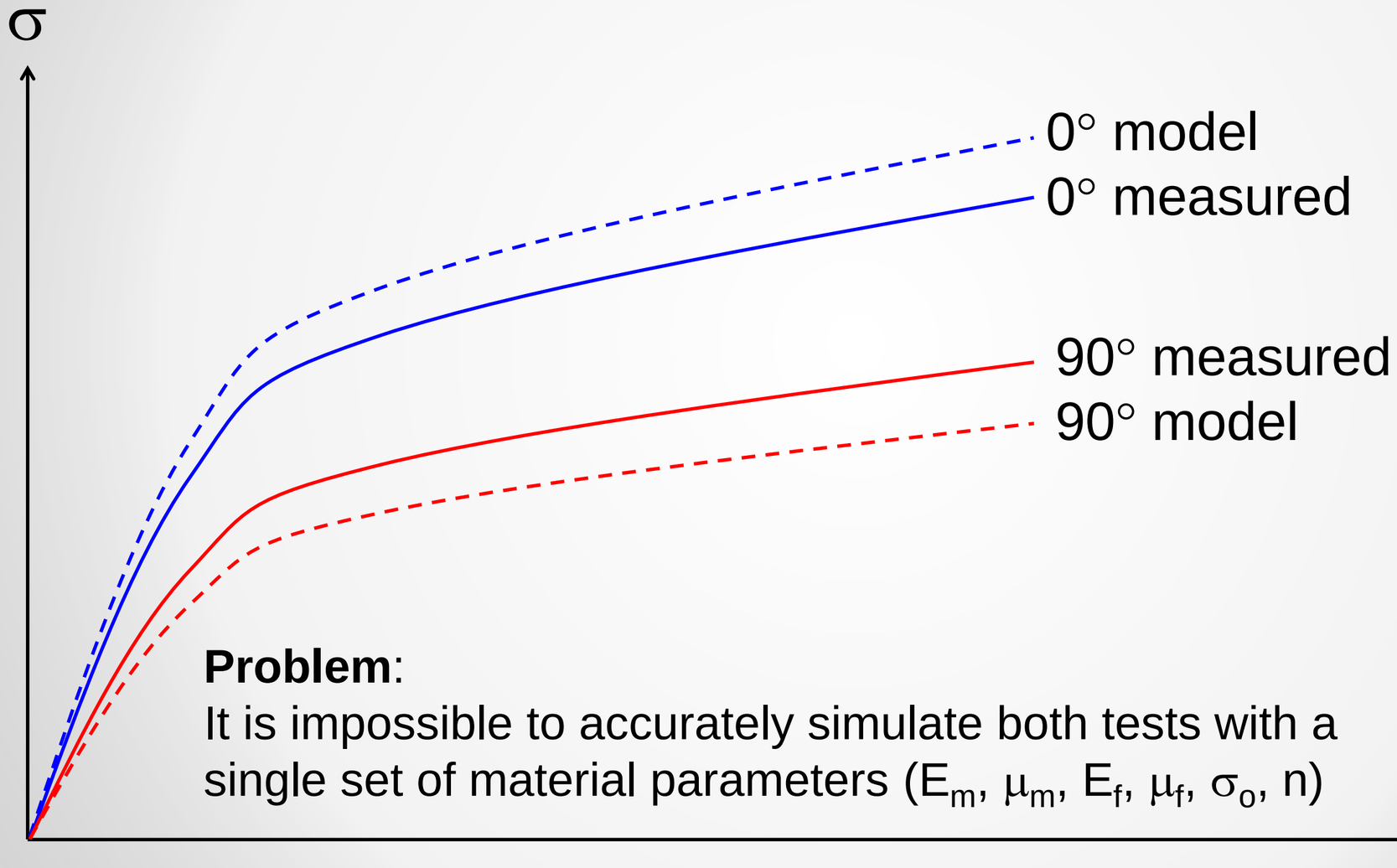
Material Plasticity – Ramberg Osgood

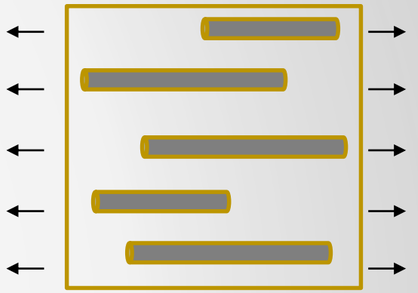


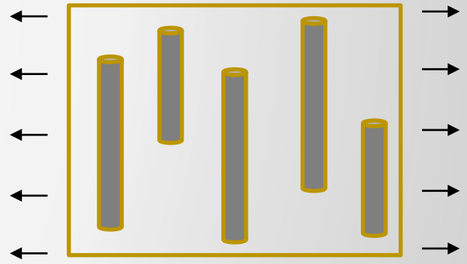
Material Plasticity – Ramberg Osgood



Directional Dependence



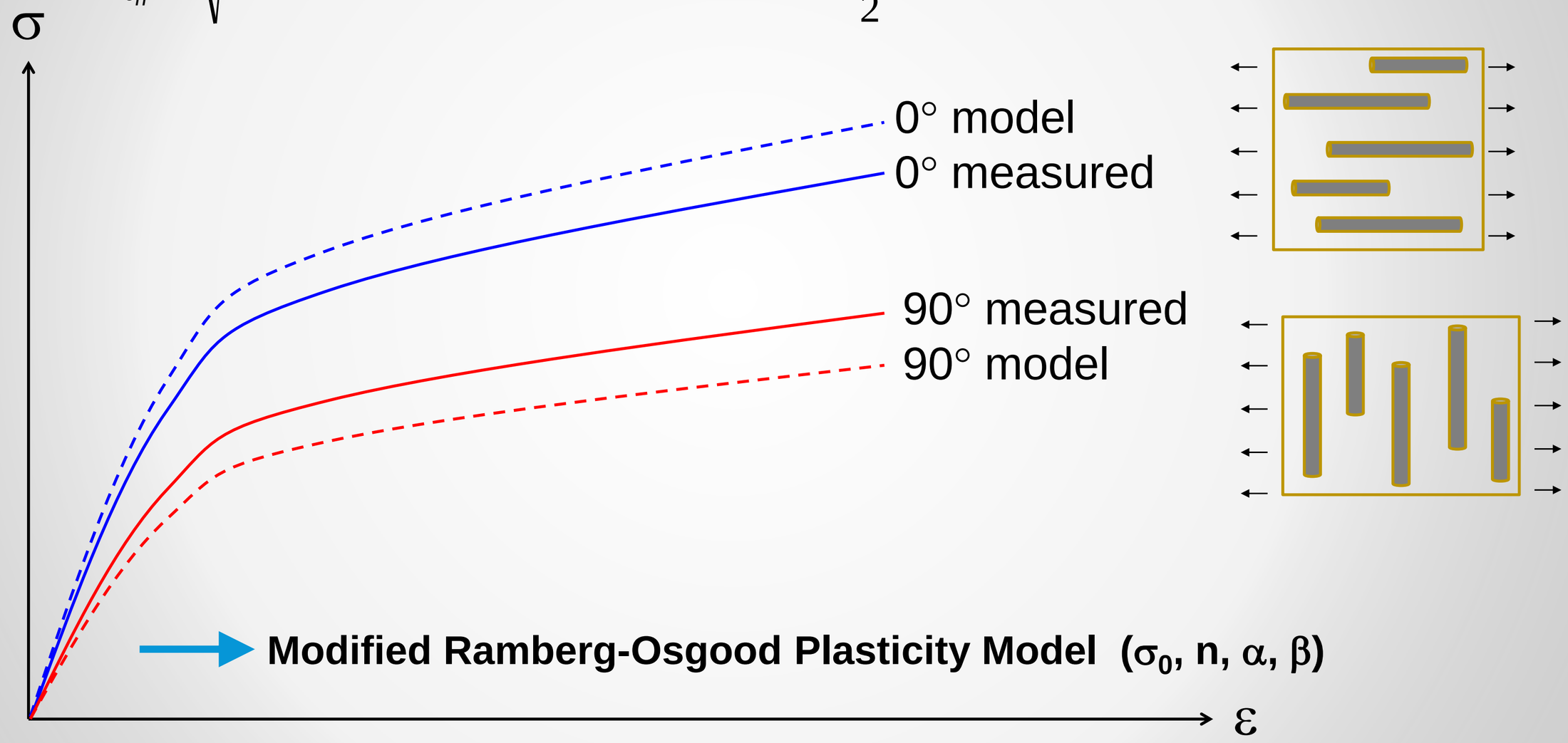




Problem:
It is impossible to accurately simulate both tests with a single set of material parameters (E_m, μ_m, E_f, μ_f, σ_o, n)

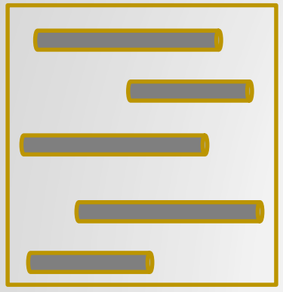
Directional Dependence

$$\sigma_{eff}^{m} \equiv \sqrt{\frac{(\alpha\sigma_{11}-\beta\sigma_{22})^2+(\beta\sigma_{22}-\beta\sigma_{33})^2+(\beta\sigma_{33}-\alpha\sigma_{11})^2+6[(\sigma_{12})^2+(\sigma_{23})^2+(\sigma_{31})^2]}{2}}$$



Impact of Fiber Orientation

Perfectly Aligned



$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$\alpha \neq \beta$$

Mostly Aligned

$$\begin{bmatrix} 0.836 & -0.056 & -0.018 \\ -0.056 & 0.098 & 0.129 \\ -0.018 & 0.129 & 0.066 \end{bmatrix}$$

$$\alpha \neq \beta$$

2-D Random

$$\begin{bmatrix} 0.5 & 0 & 0 \\ 0 & 0.5 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$\alpha = \beta$$

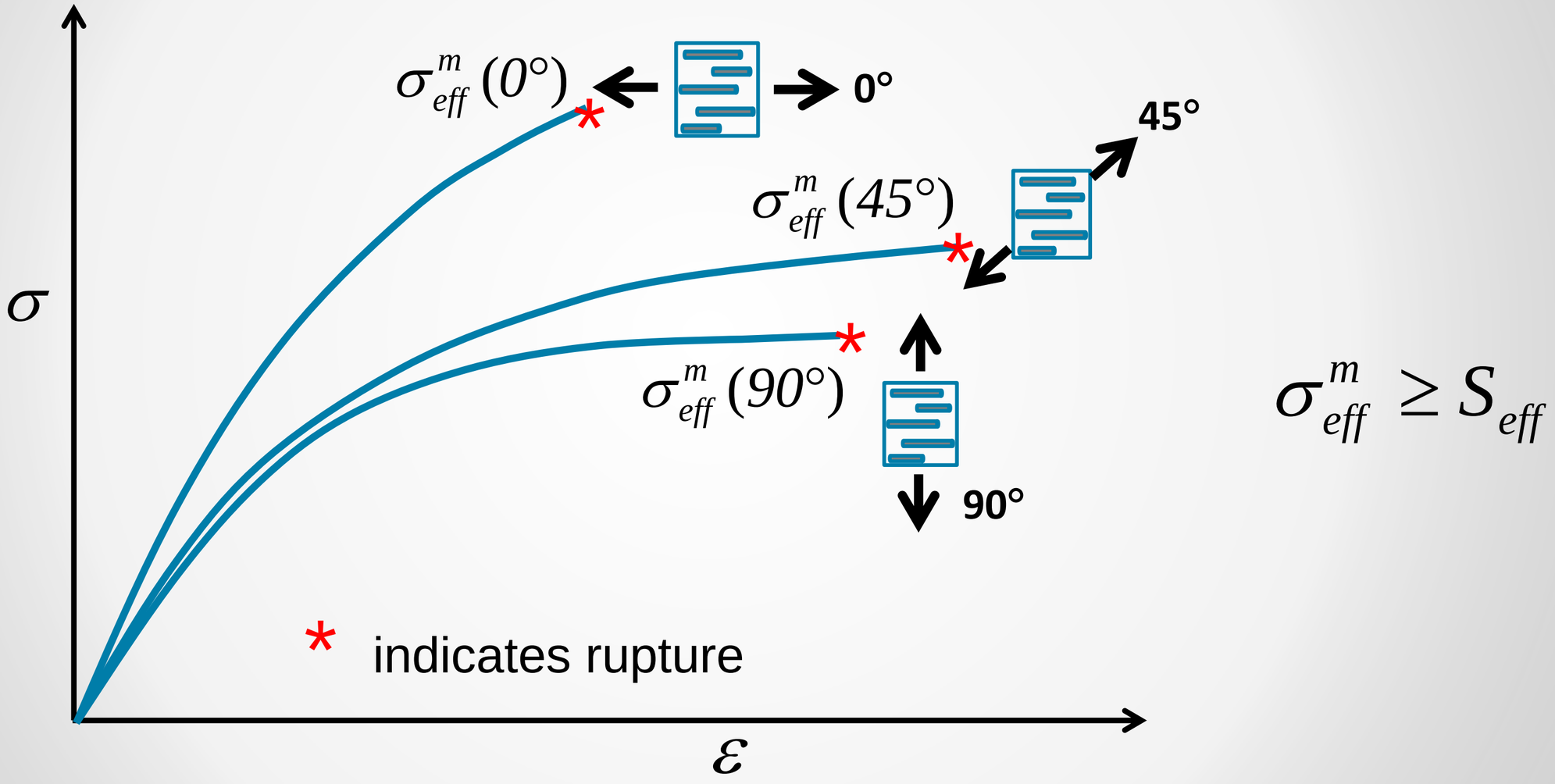
3-D Random

$$\begin{bmatrix} 1/3 & 0 & 0 \\ 0 & 1/3 & 0 \\ 0 & 0 & 1/3 \end{bmatrix}$$

$$\alpha = \beta$$

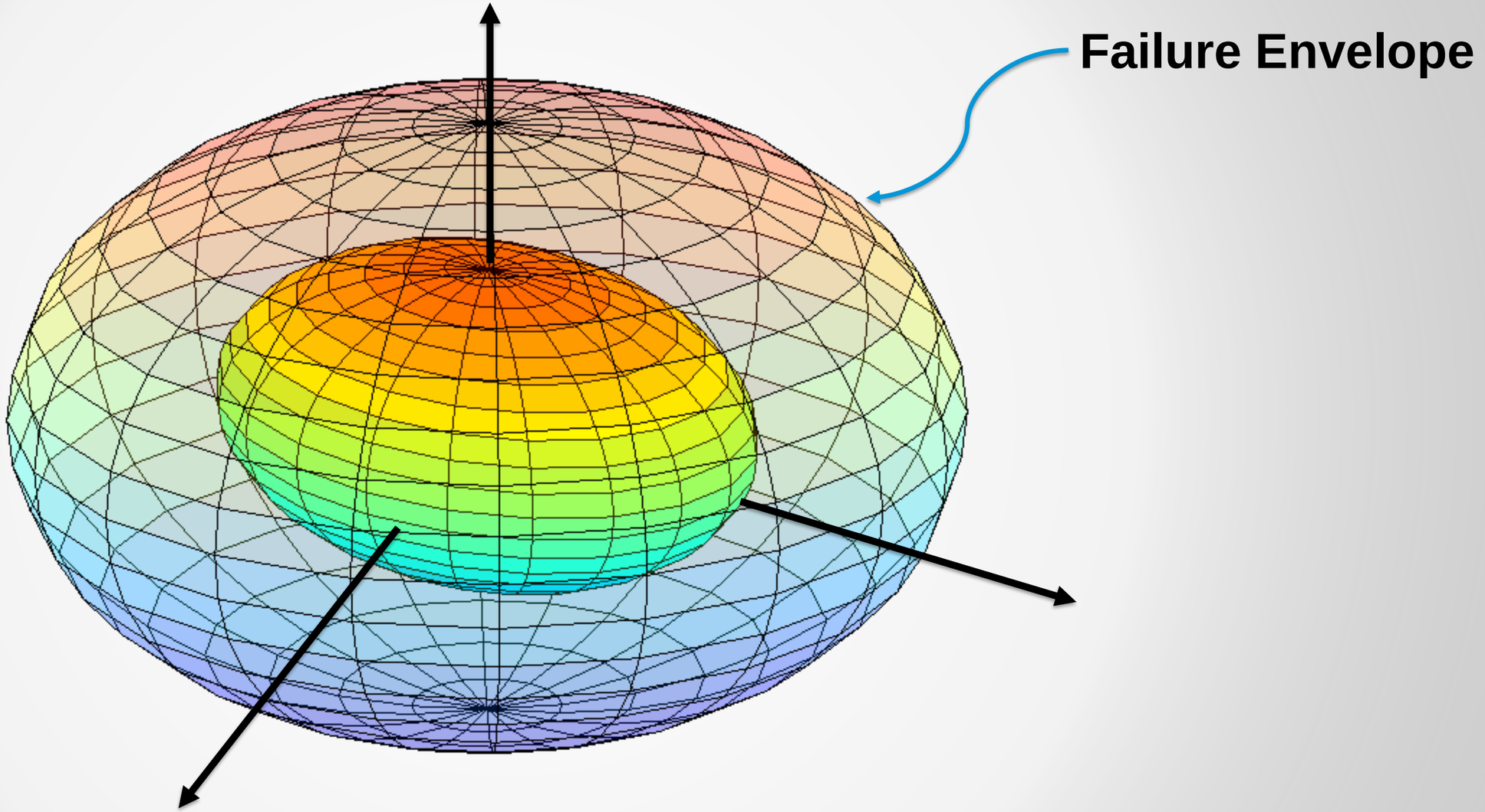
$$\alpha = f(\lambda_I) \qquad \beta = f(\lambda_I)$$

Matrix Rupture

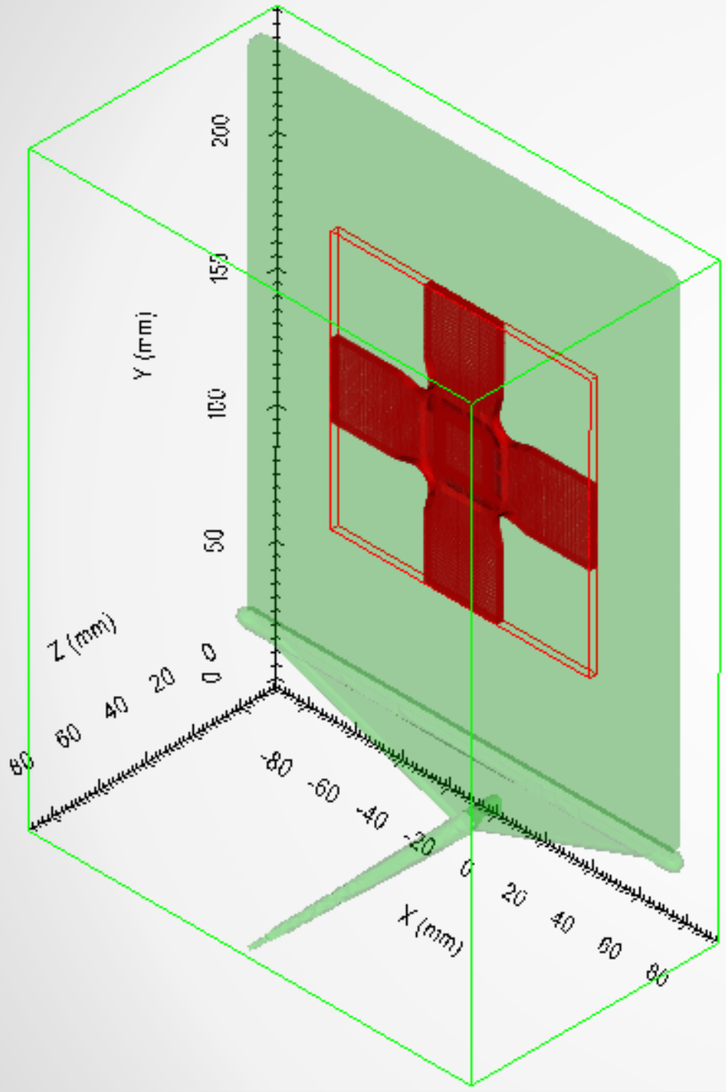


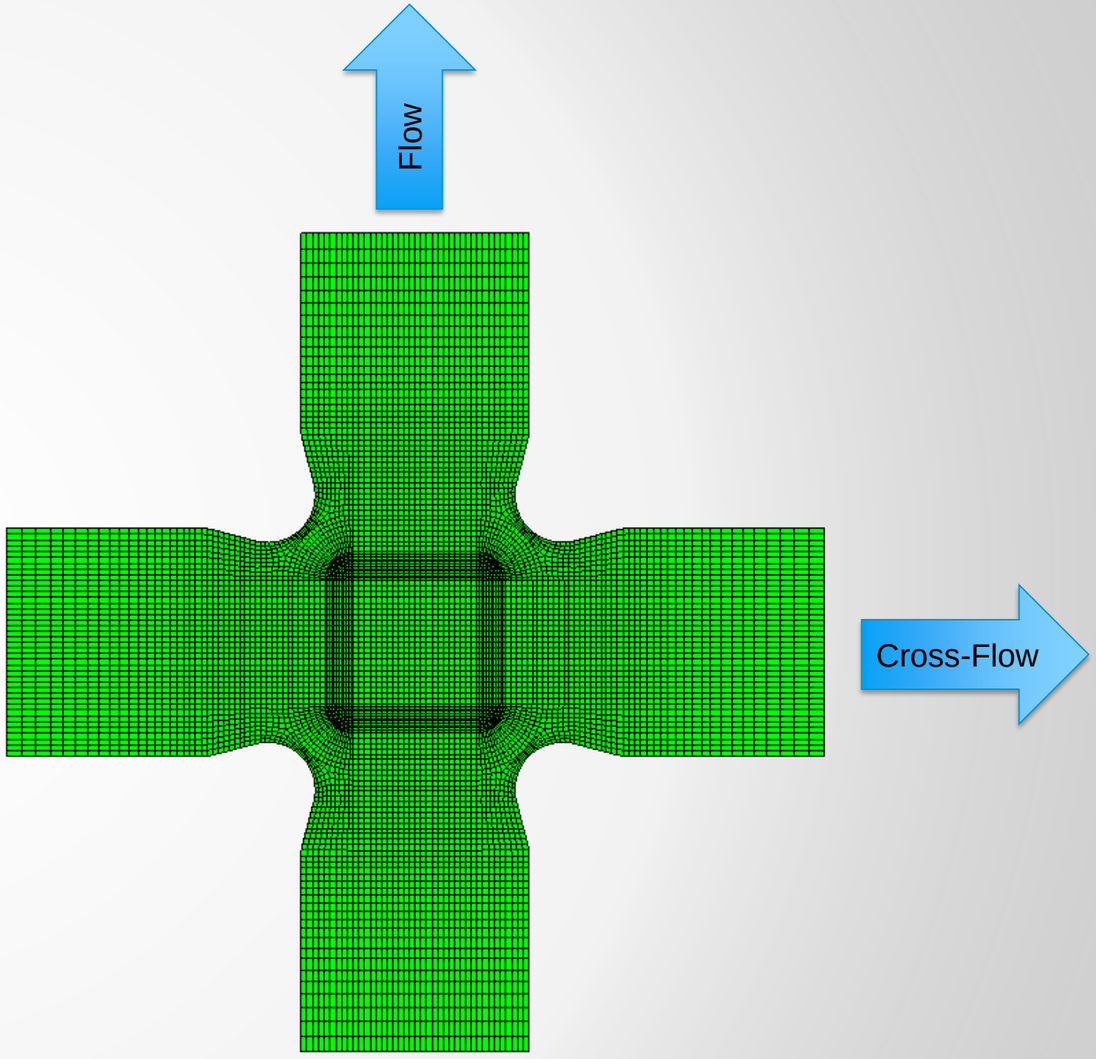
$$\sigma^m_{eff} \geq S_{eff}$$

Material Rupture



Validation – Biaxial Coupons





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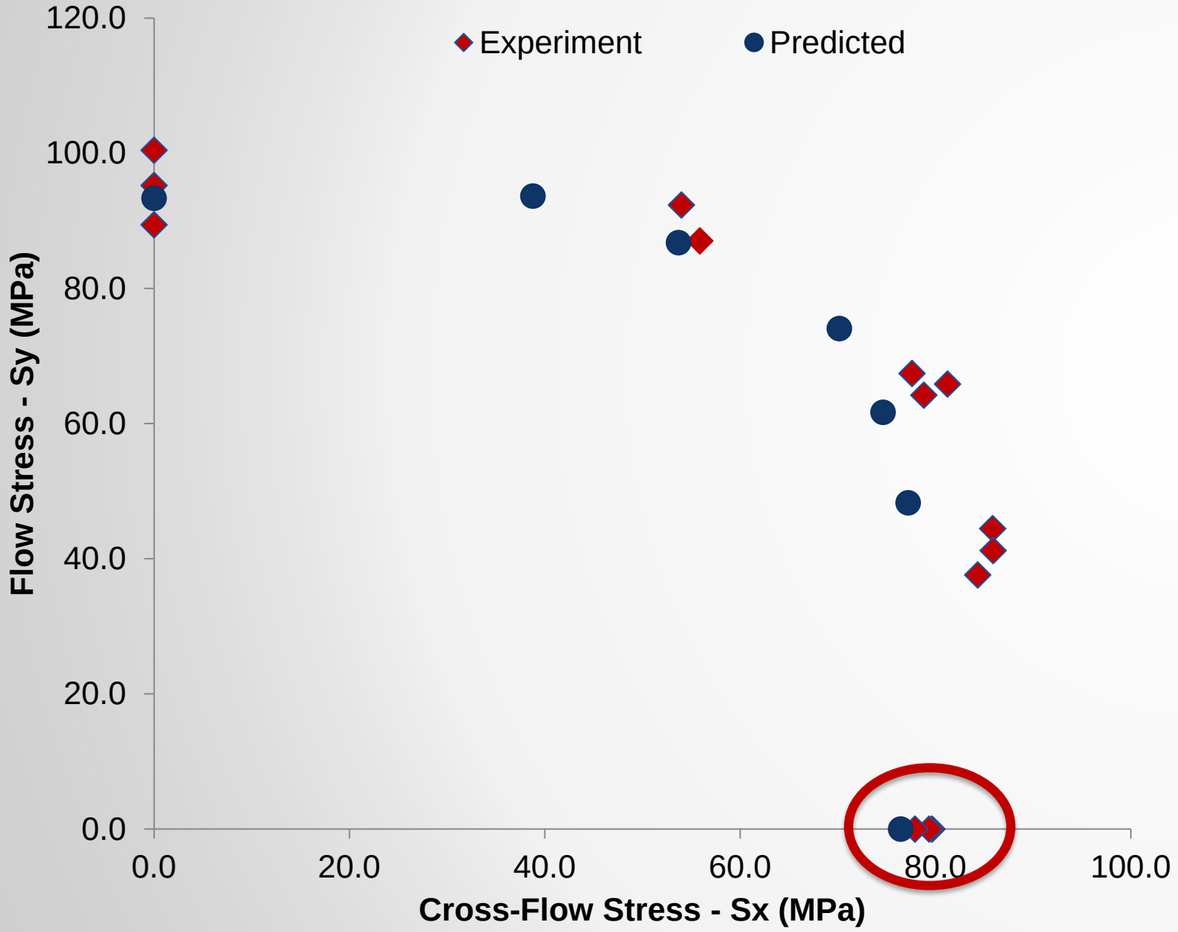
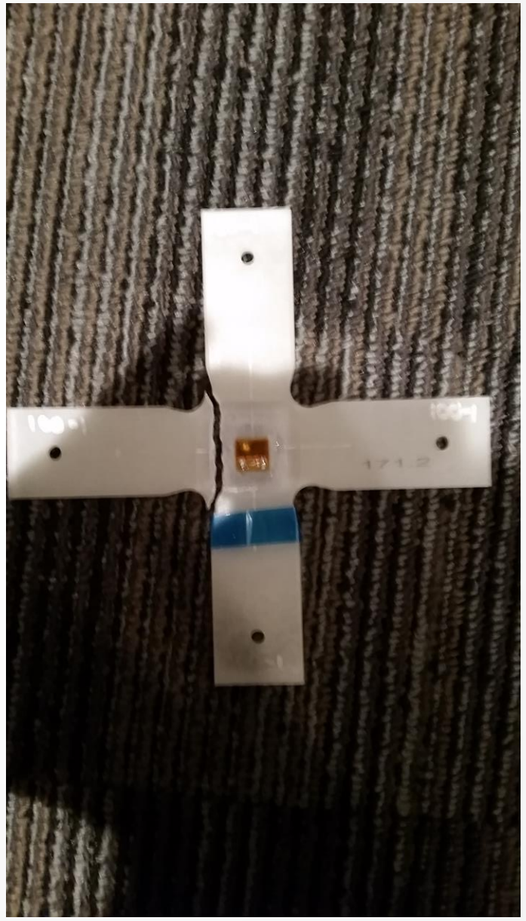
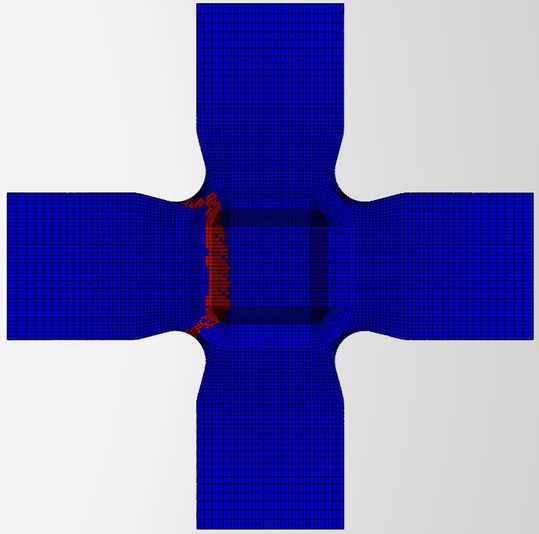
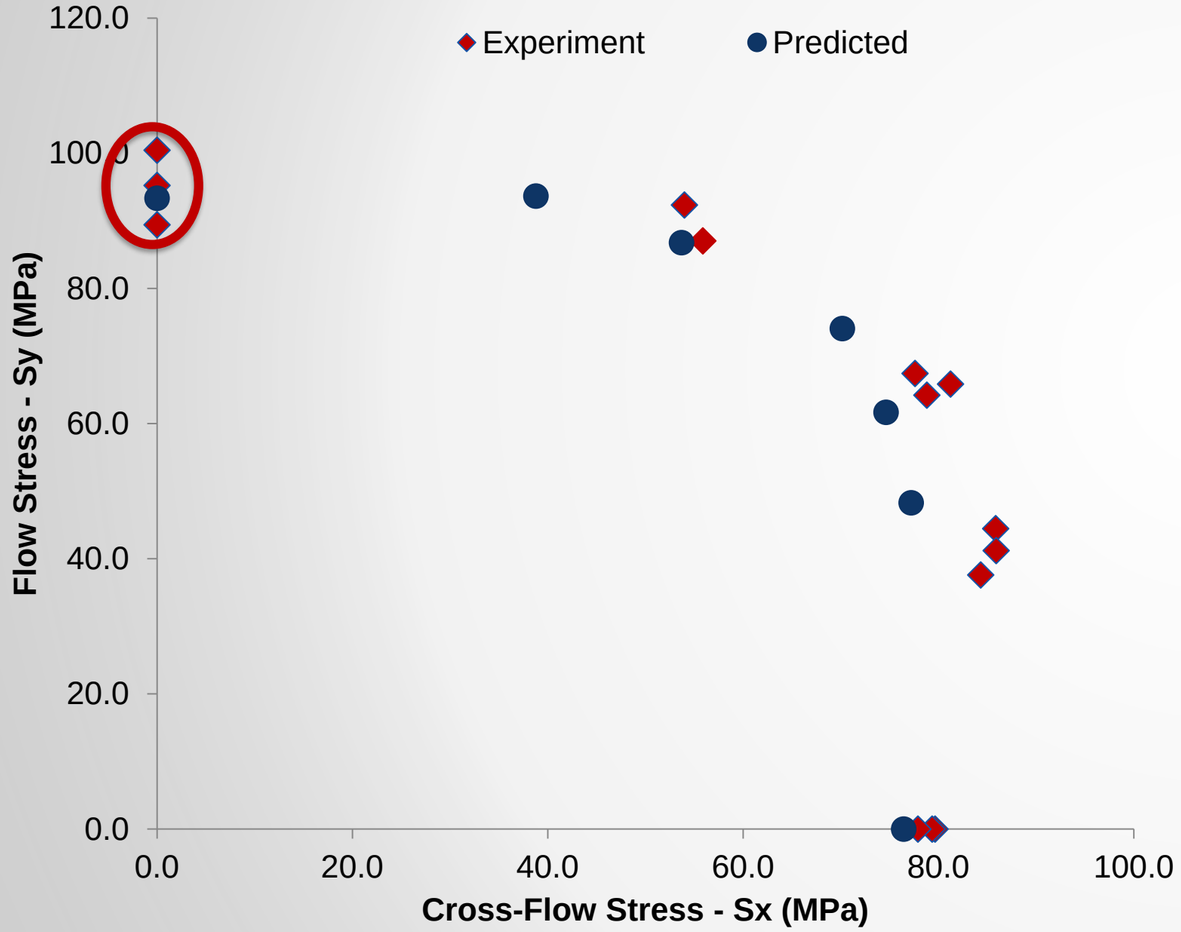
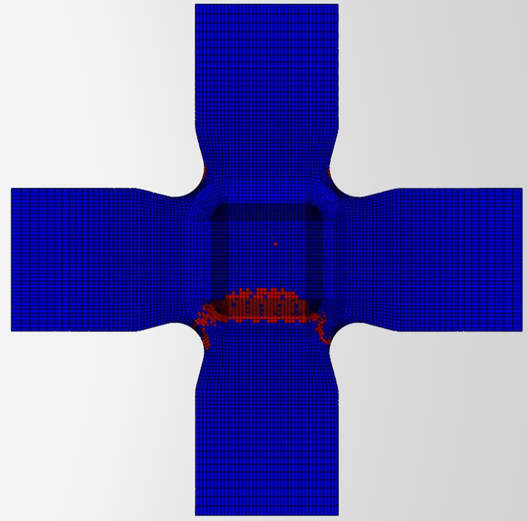




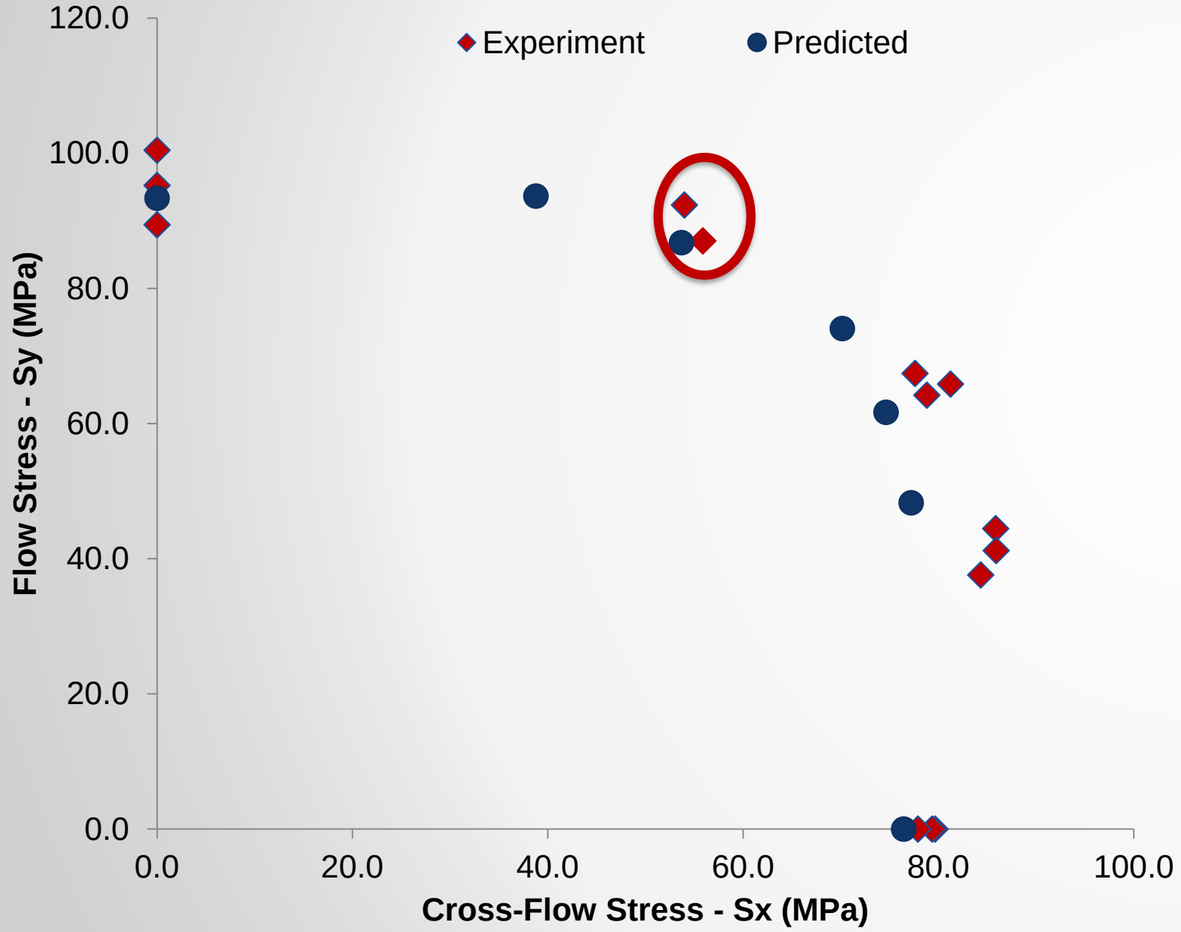


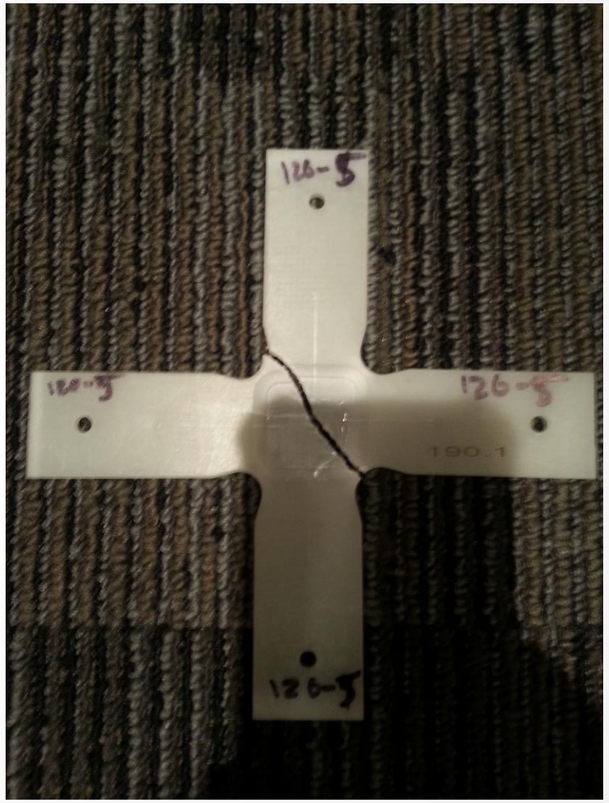
Validation – Biaxial Coupons

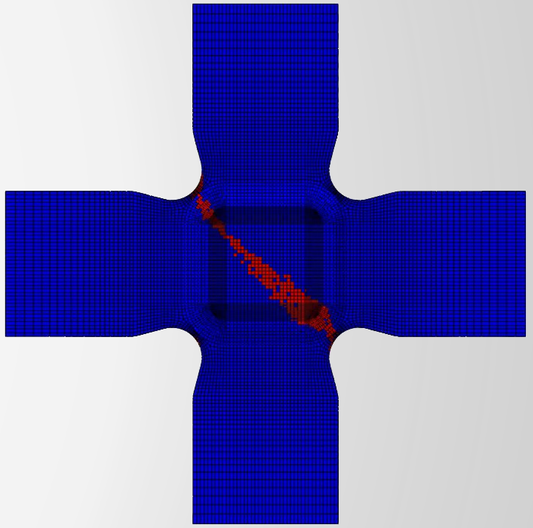




Validation – Biaxial Coupons

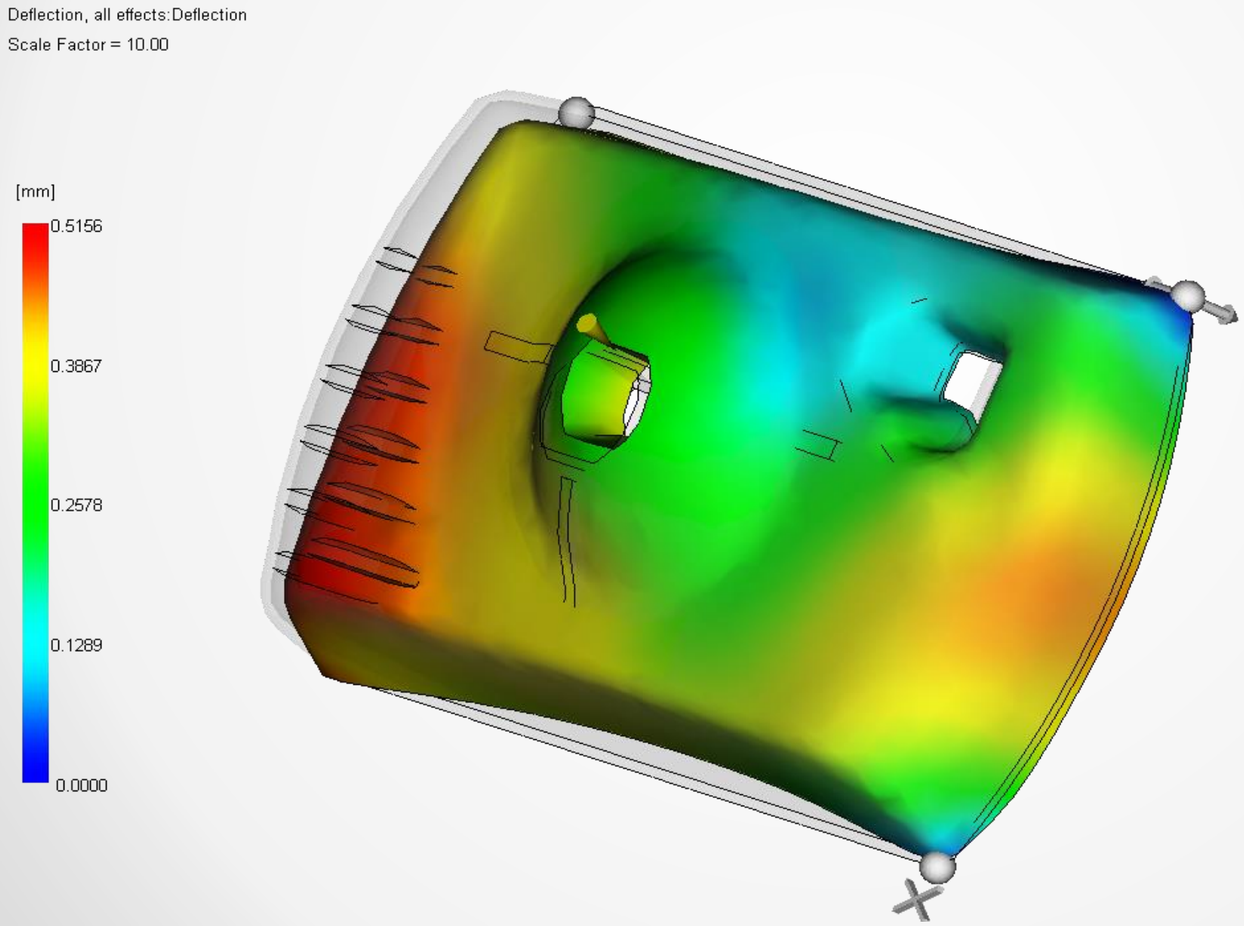






Residual Stresses/Strains

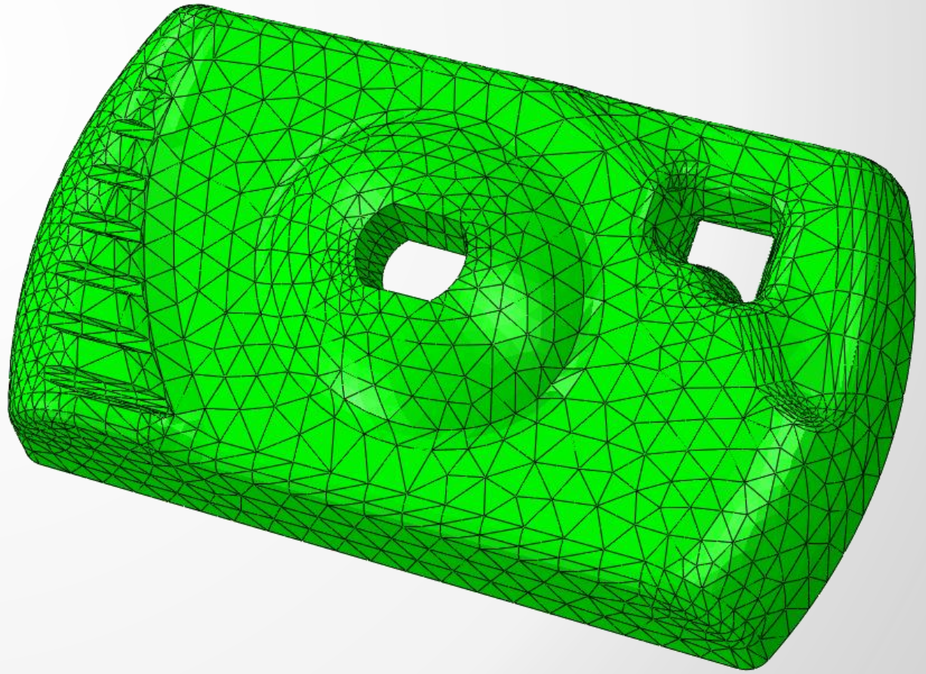
- What are residual strains? $\sigma = C(\varepsilon + \varepsilon_r)$



Residual Stresses/Strains

- What are residual strains? $\sigma = C(\varepsilon + \varepsilon_r)$
- How software typically handles this:

```
*INITIAL CONDITION,
TYPE=STRESS
1, 1.1e2, 1.5e2, 1.2e1, 4, 9, 8
2, 1.6e2, 1.3e2, 1.4e1, 4, 4, 8
3, 1.7e2, 1.9e2, 1.8e1, 4, 3, 8
4, 1.3e2, 1.2e2, 1.2e1, 5, 7, 9
…
10000, 1.5e2, 2.e2,4.e1, 3, 1, 5
```



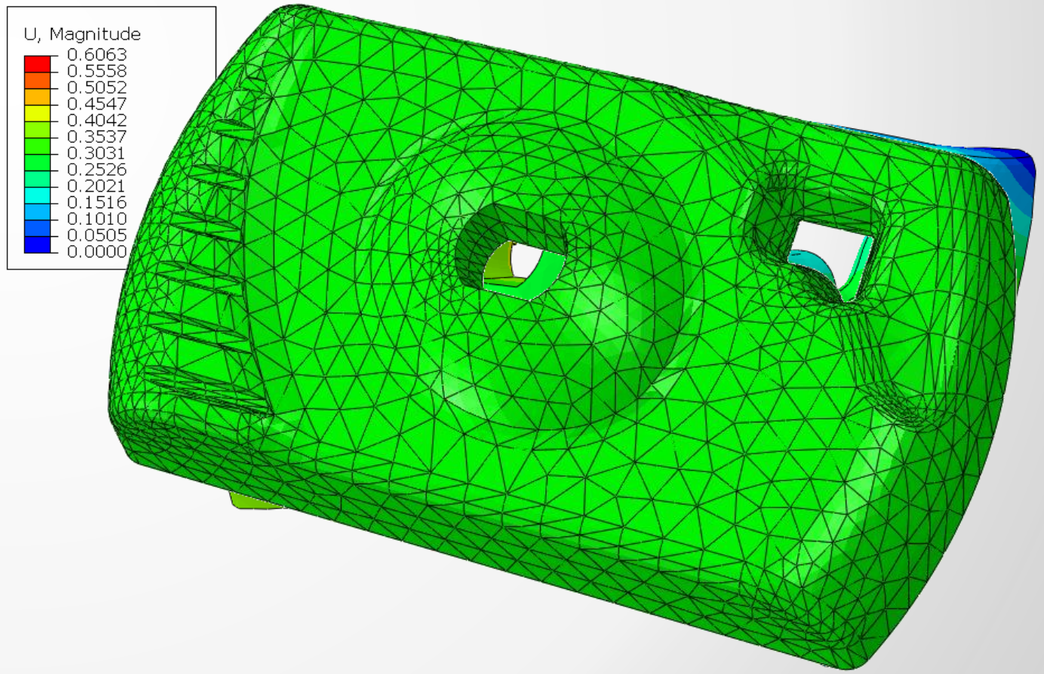
Residual Stresses/Strains

- What are residual strains? $\sigma = C(\varepsilon + \varepsilon_r)$
- How software typically handles these:
- How ASCA handles these:

$$\sigma = C\varepsilon$$

$$\sigma \neq C\varepsilon$$

$$\sigma = C(\varepsilon + \varepsilon_r)$$

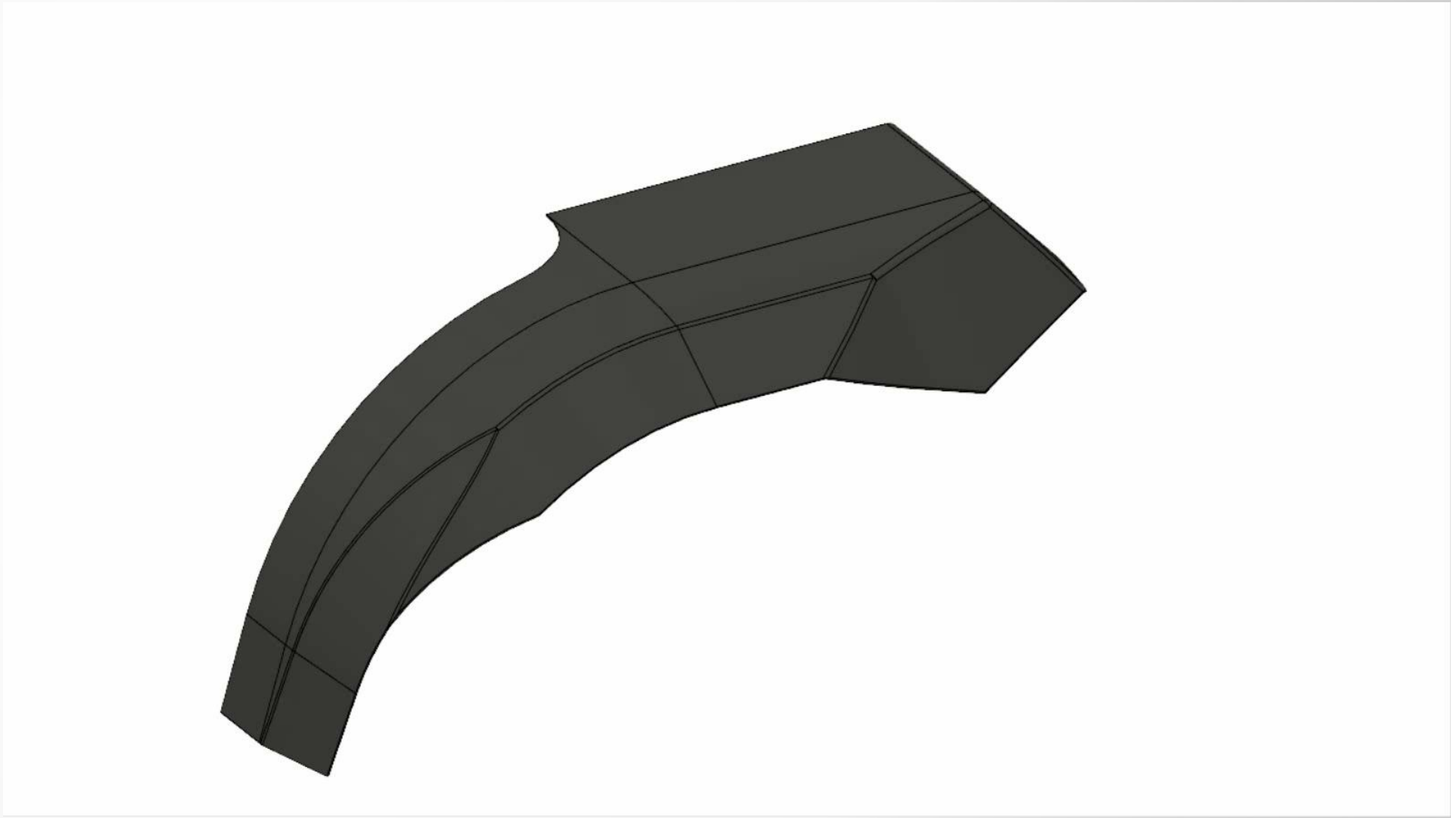


Use Case

Injection Molded Fender

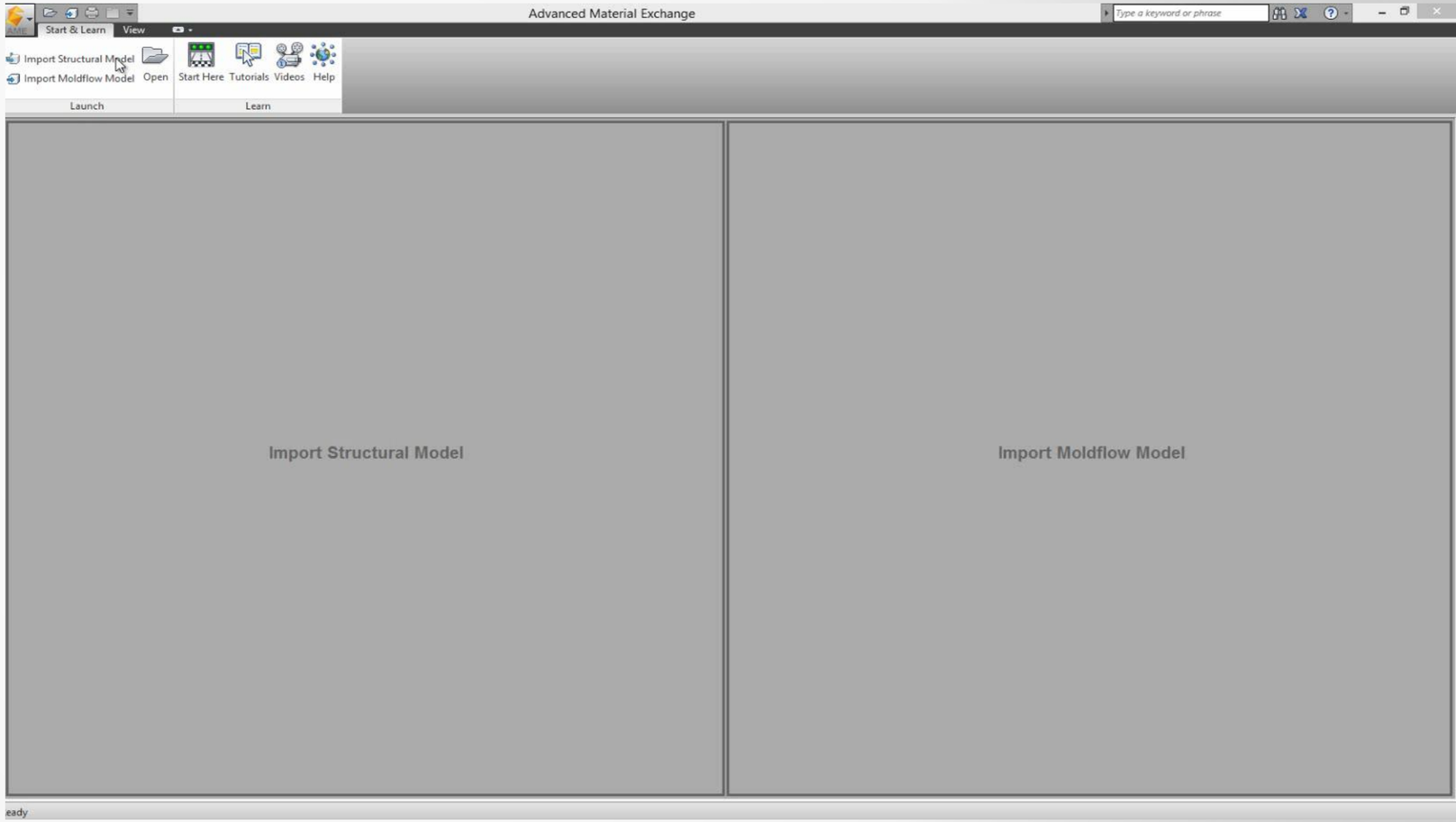
Abaqus Setup

- Load
  - Pressure loading to simulate stepping on fender
- Boundary Conditions
  - Fixed at bolt locations
  - Pinned through thickness on contact surface
- 10 node tetrahedral elements



Advanced Material Exchange

- Material:
  - BASF 8233G HS
- Map:
  - Fiber orientations
  - Residual stress/strian
  - All available material data
- Export new input file
  - Run w/ Abaqus
  - Cluster analyses supported



Abaqus Results