April 27, 2017

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AUTODESK® MOLDFLOW®

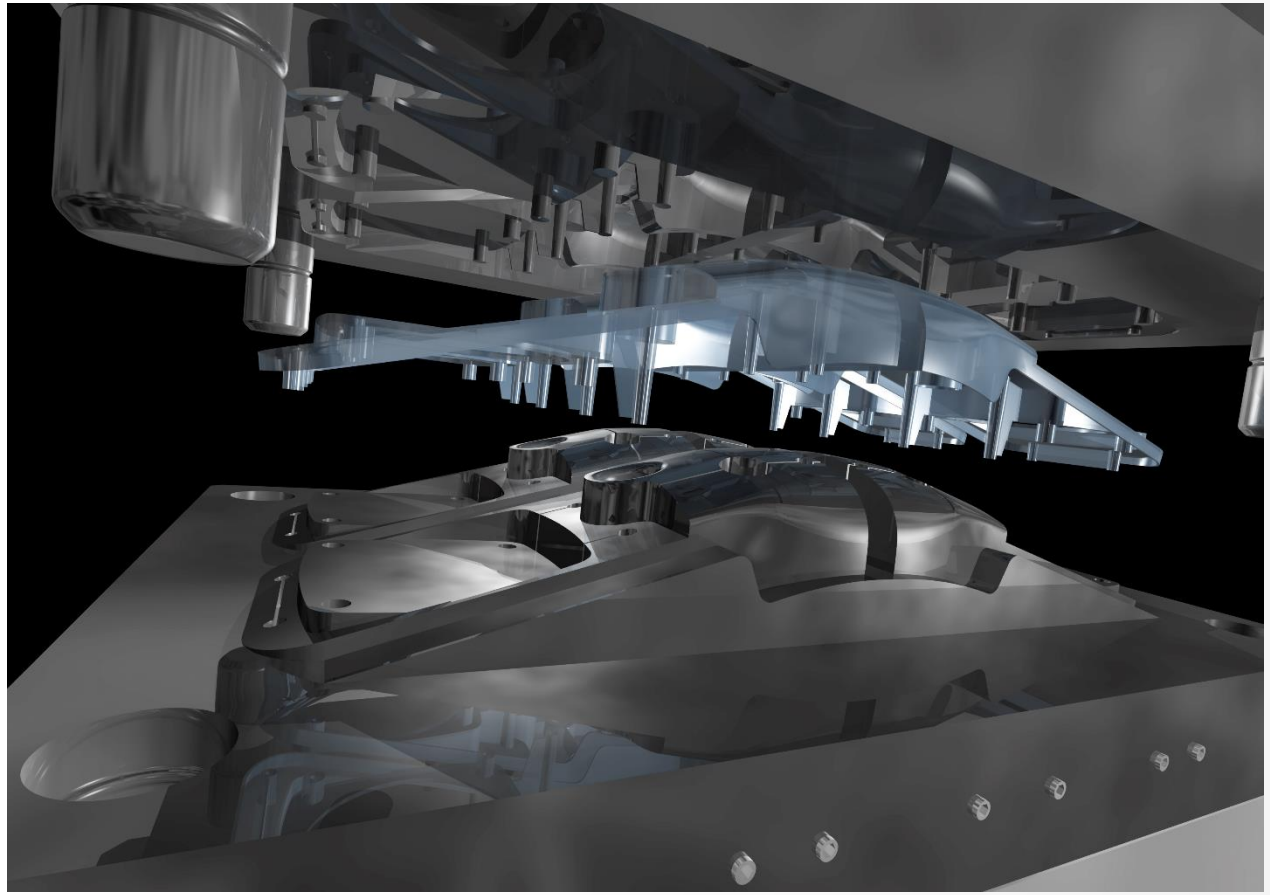
Autodesk Manufacturing Simulation Stops the Guess Work

Jeff Higgins

Technical Specialst – Detroit, MI

Agenda

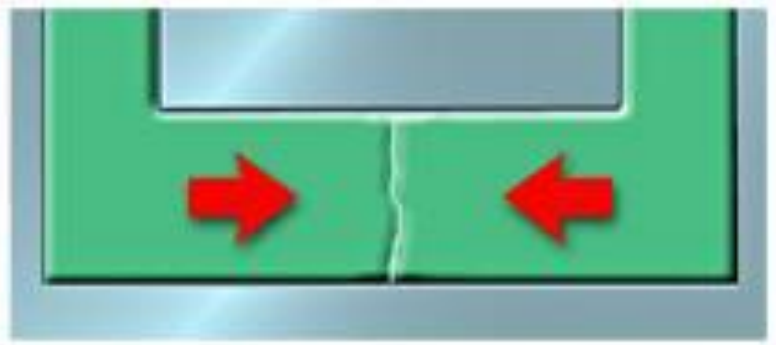
- Weld Line Introduction
- As-manufactured Simulation
- Material Testing
- Weld Surface Strength Reduction
- Summary
- Future Work
- Q&A



Weld Line Introduction

What is a Weld or Knit Line?

- Regions where separated melt fronts recombine



- Separation due to:
  - Obstacle such as a core pin
  - Geometrical features of part
  - Multiple injection locations
  - Jetting

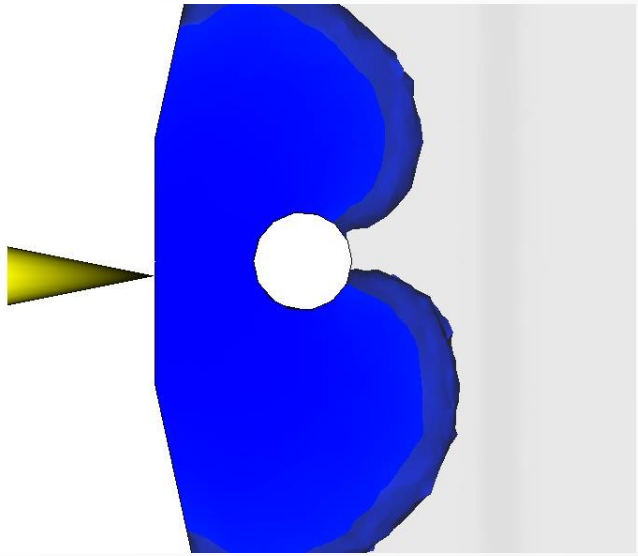


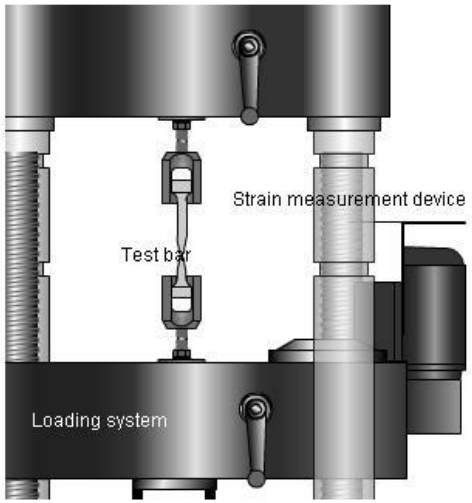
Image Source: PlasticsToday

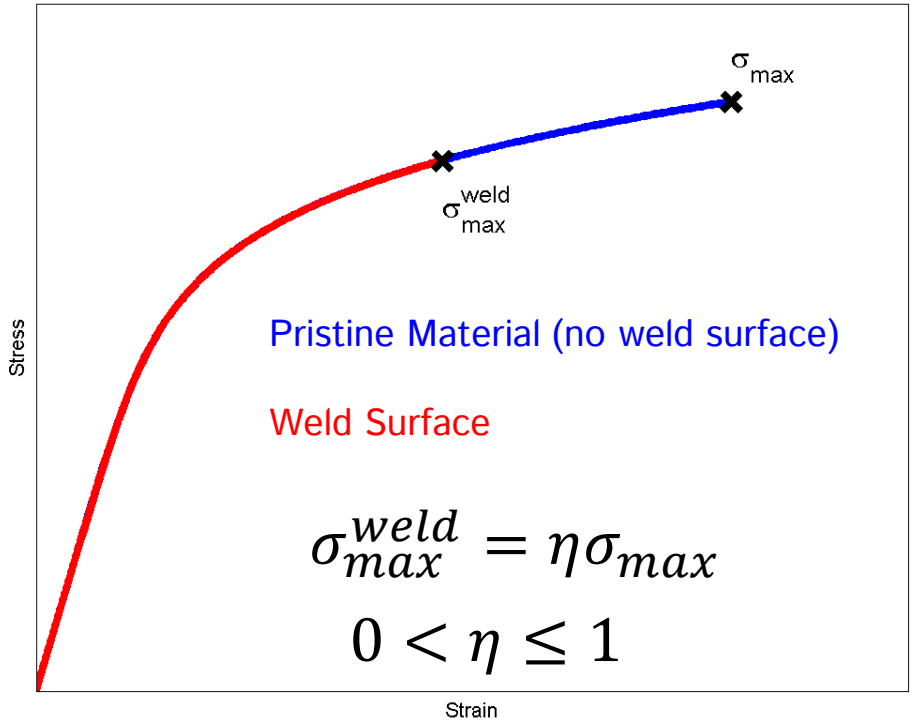
Weld Line Strength Testing

- Weld line retention

$$\eta = \frac{F_w}{F_b} or \frac{\sigma_w}{\sigma_b}$$

- Tensile Testing
  - ASTM-D647
  - Notch sensitive
  - Rate & temperature dependent





Why We Care About Weld Lines...

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Amorphous Resin	Reinf.	%	Filler	%	η % (UTS)	Crystalline Resin	Reinf.	%	Filler	%	η % (UTS)
PC	-	-	-	-	99	PA66	-	-	-	-	97
PC	GF	10	-	-	90	PA66	GF	10	-	-	93
PC	GF	30	-	-	65	PA66	GF	30	-	-	61
PC	GF	40	-	-	55	PA66	GF	40	-	-	52
PC	-	-	Milled Gl	30	92	PA66	LGF	30	-	-	58
PC	GF	30	PTFE	15	60	PA66	CF	30	-	-	47
SAN	-	-	-	-	80	PA66	-	-	Glass Bd	30	95
SAN	GF	30	-	-	40	PP	-	-	-	-	86
SAN	GF	30	Flame Ret	10	45	PP	GF	30	-	-	34
PSU	-	-	-	-	100	PPS	-	-	-	-	83
PSU	GF	30	-	-	62	PPS	GF	40	-	-	20

Reference: Cloud et al., "Reinforced Thermoplastics: Understanding Weld-Line Integrity", Plastics Technology, 22, 48, (1976).

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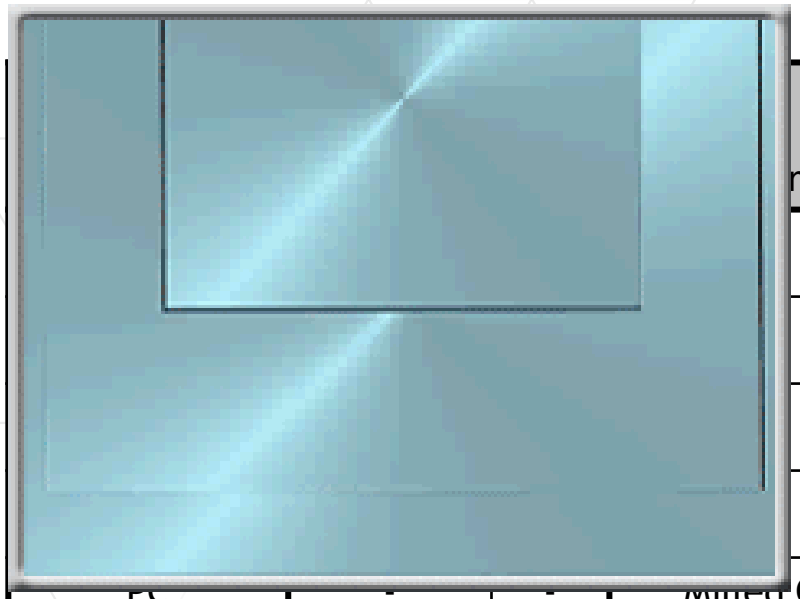

			r	%	η % (UTS)	Crystalline Resin	Reinf.	%	Filler	%	η % (UTS)
				-	99	PA66	-	-	-	-	97
				-	90	PA66	GF	10	-	-	93
				-	65	PA66	GF	30	-	-	61
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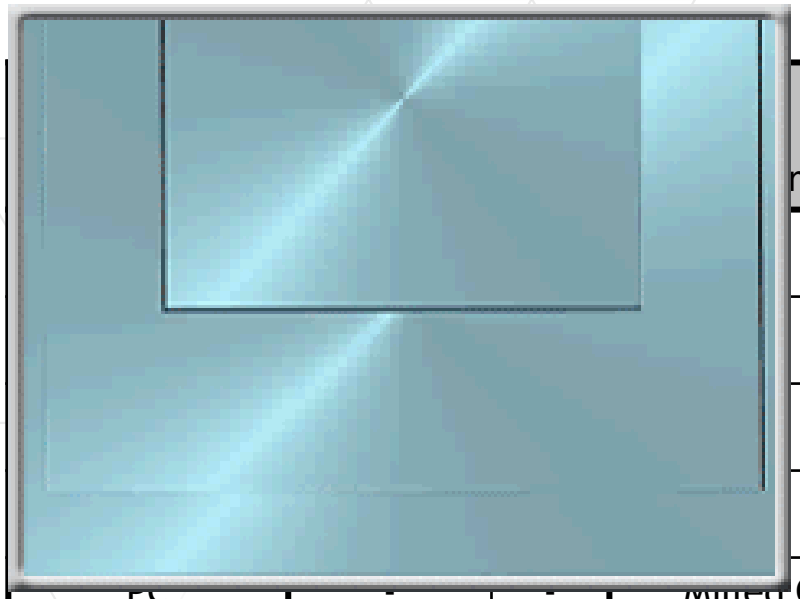

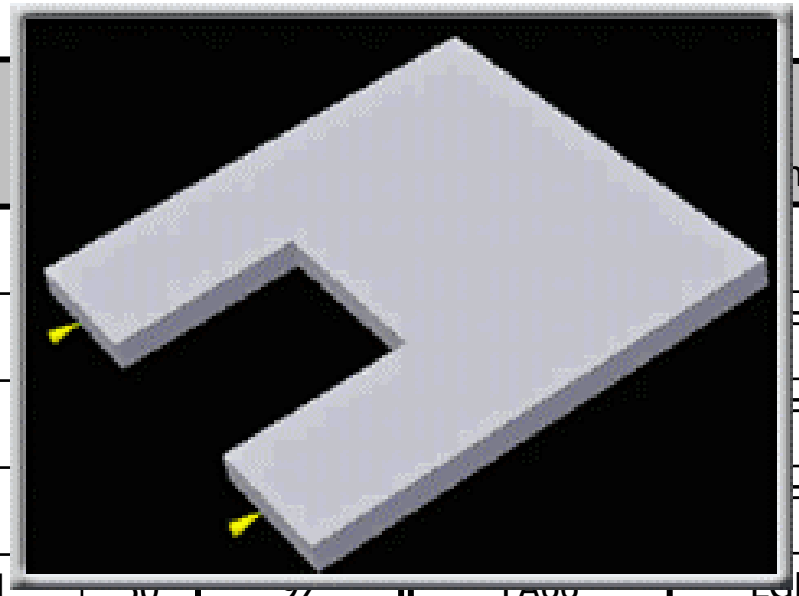

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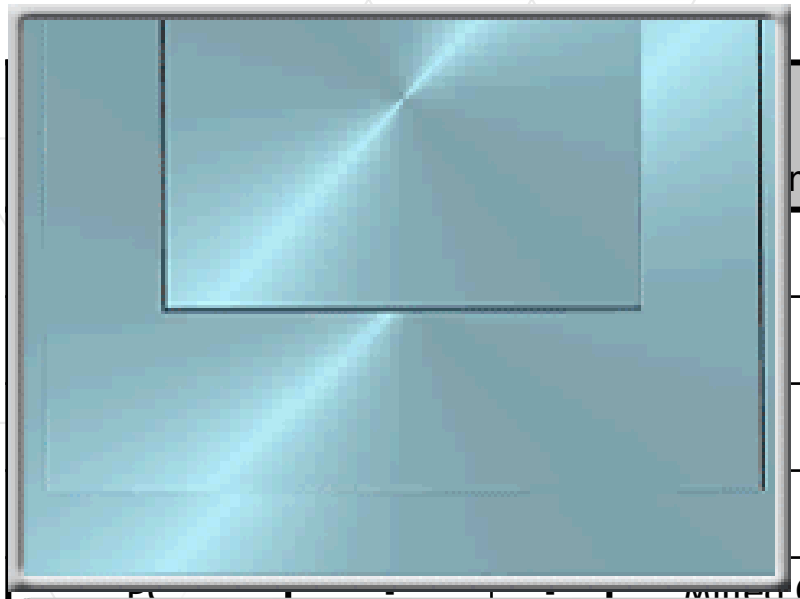

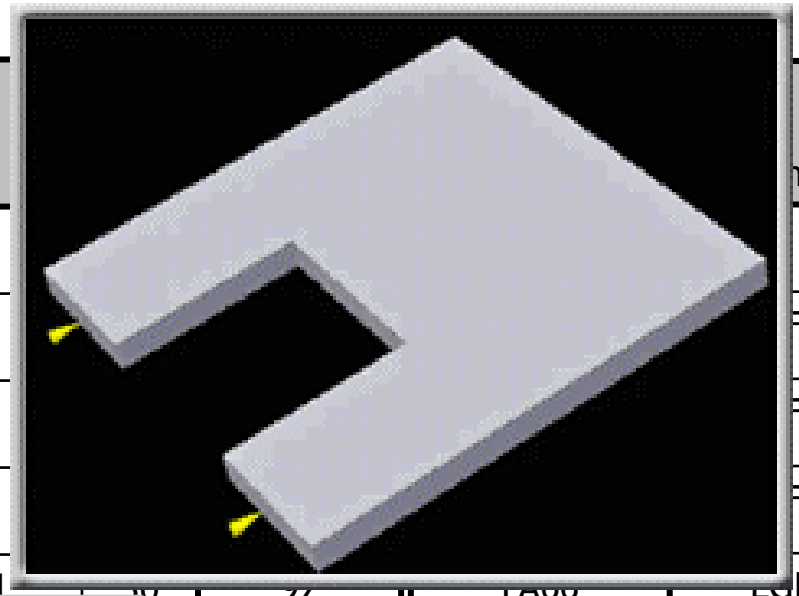

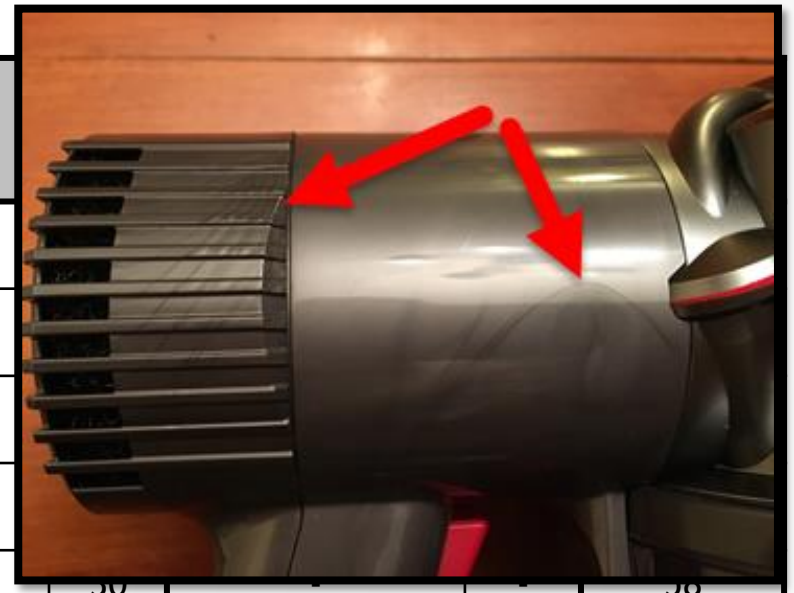

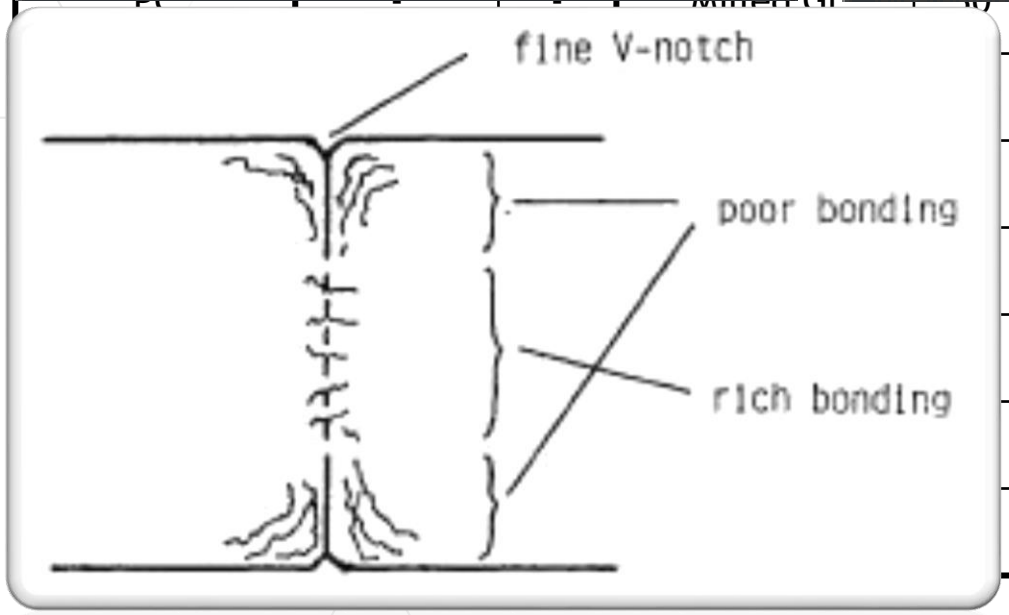

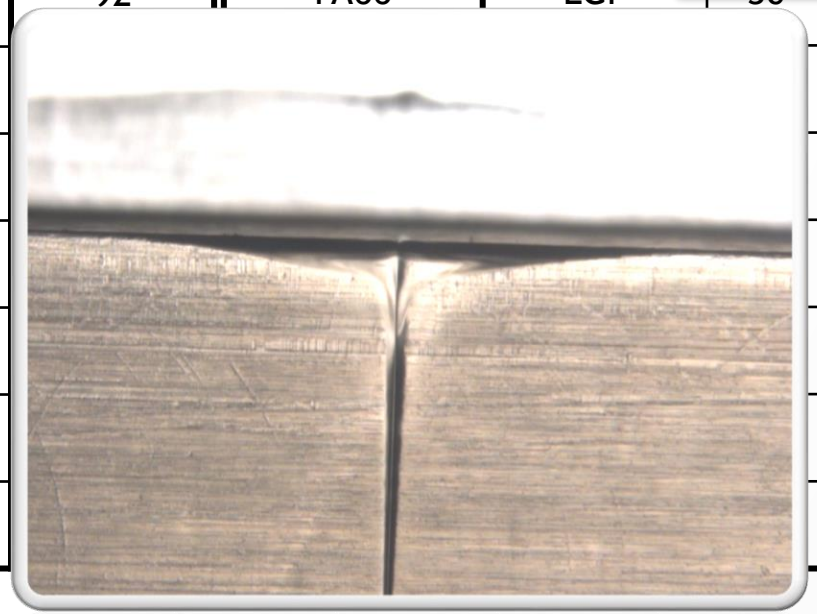

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As-manufactured Simulation

As-Manufactured Simulation Workflow Overview

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Process Simulation

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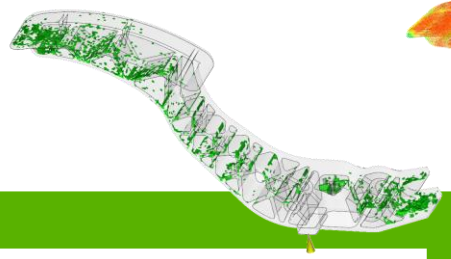
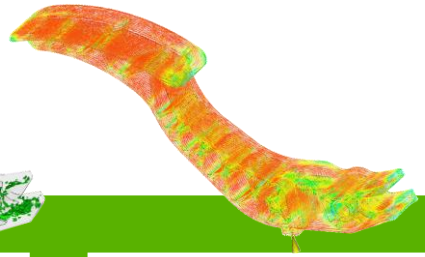


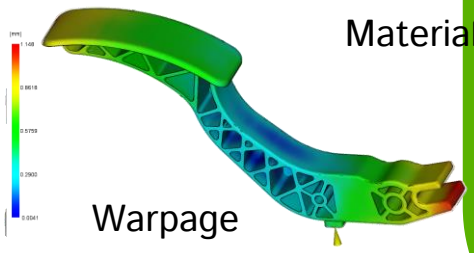


Weld Line Strength

Fiber Orientation

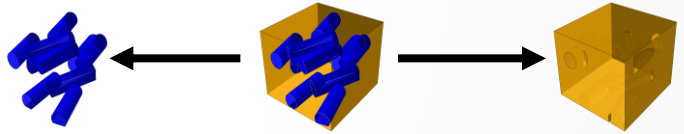
Material Properties

CAD



Warpage

AUTODESK® HELIUS PFA



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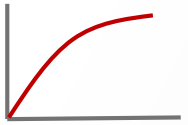
Structural Simulation

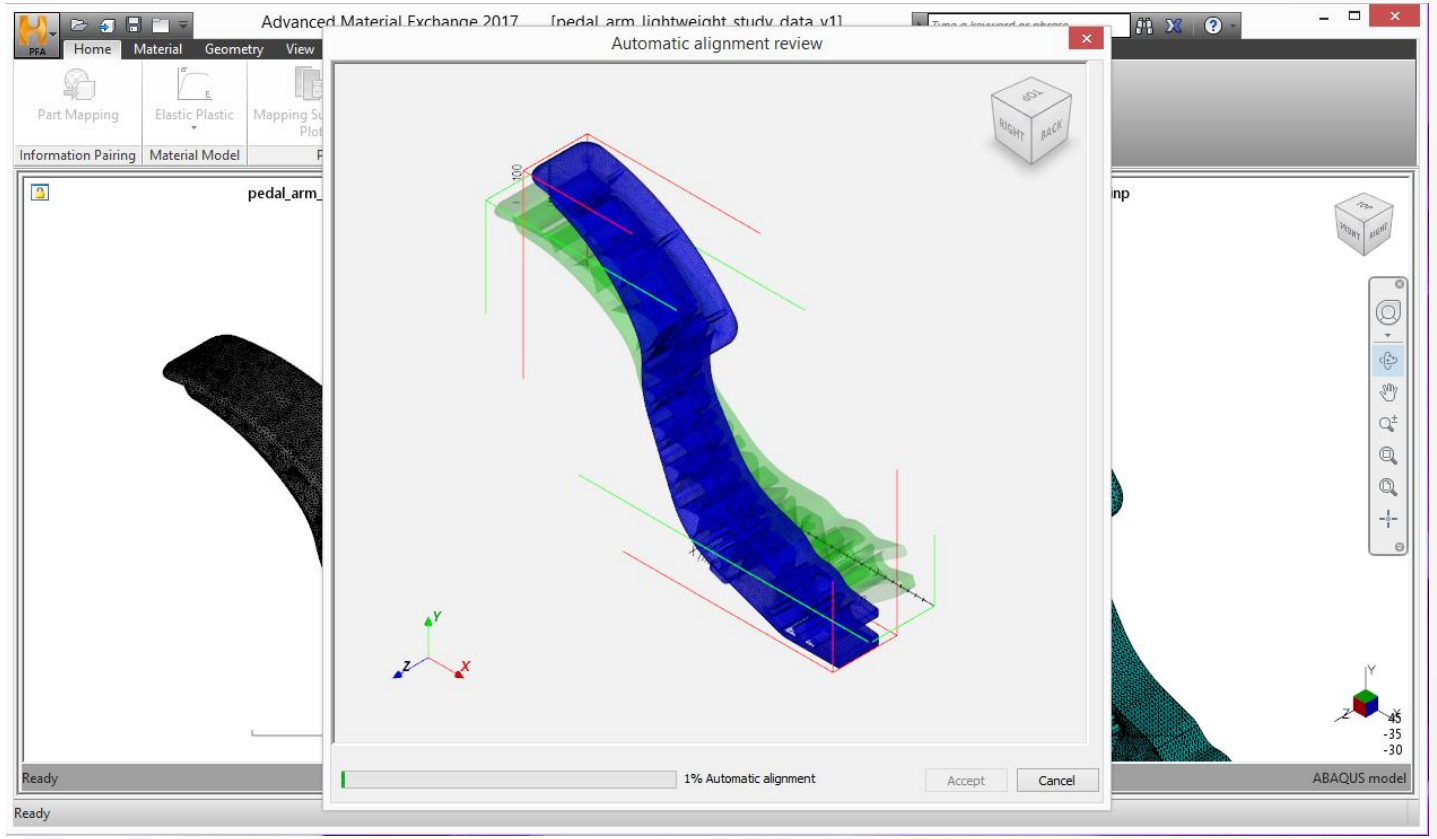
AUTODESK® HELIUS PFA



Anisotropic Plasticity Strength PFA

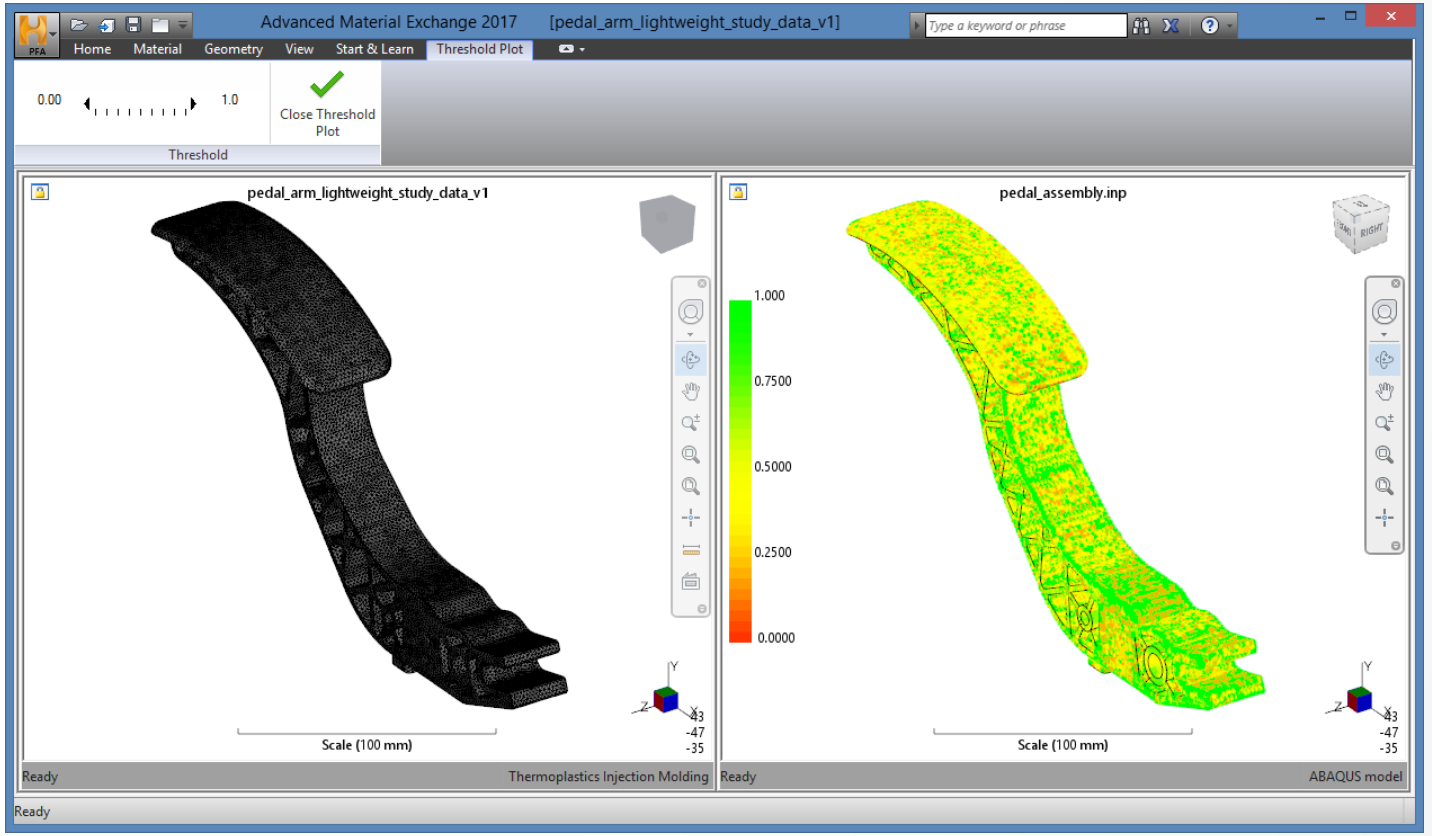
Helius PFA For Plastics Overview

- Dissimilar model support
  - Geometry
  - Mesh
  - Position



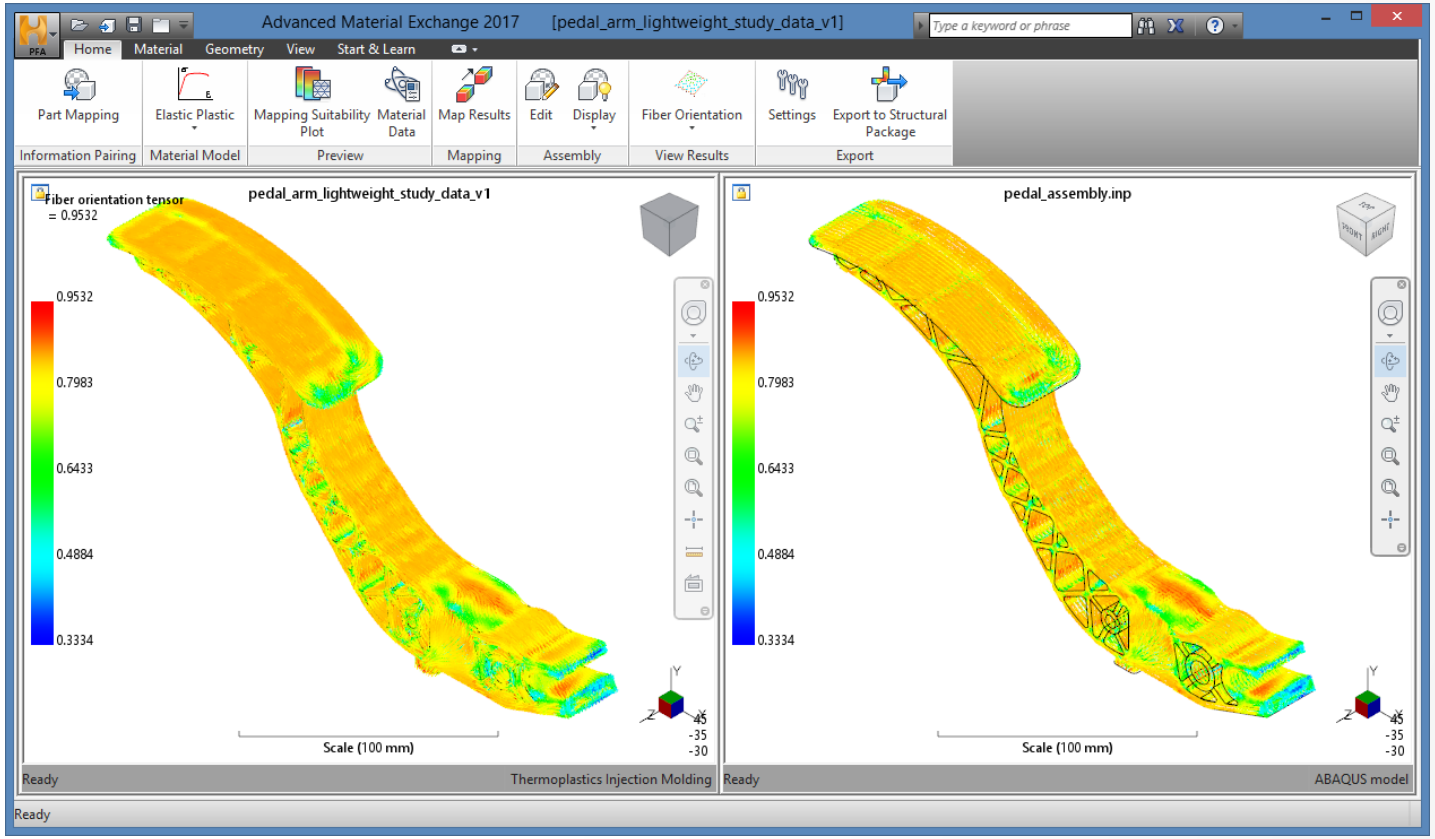
Helius PFA For Plastics Overview

- Dissimilar model support
  - Geometry
  - Mesh
  - Position
- Mapping
  - Solid to Solid
  - Shell to Shell
  - Mapping suitability
  - Assemblies



Helius PFA For Plastics Overview

- Dissimilar model support
  - Geometry
  - Mesh
  - Position
- Mapping
  - Solid to Solid
  - Shell to Shell
  - Mapping suitability
  - Assemblies
- Mapped data
  - Non-linear material properties
  - Fiber orientations
  - Strain (Warpage)
  - 3D weld surface strength

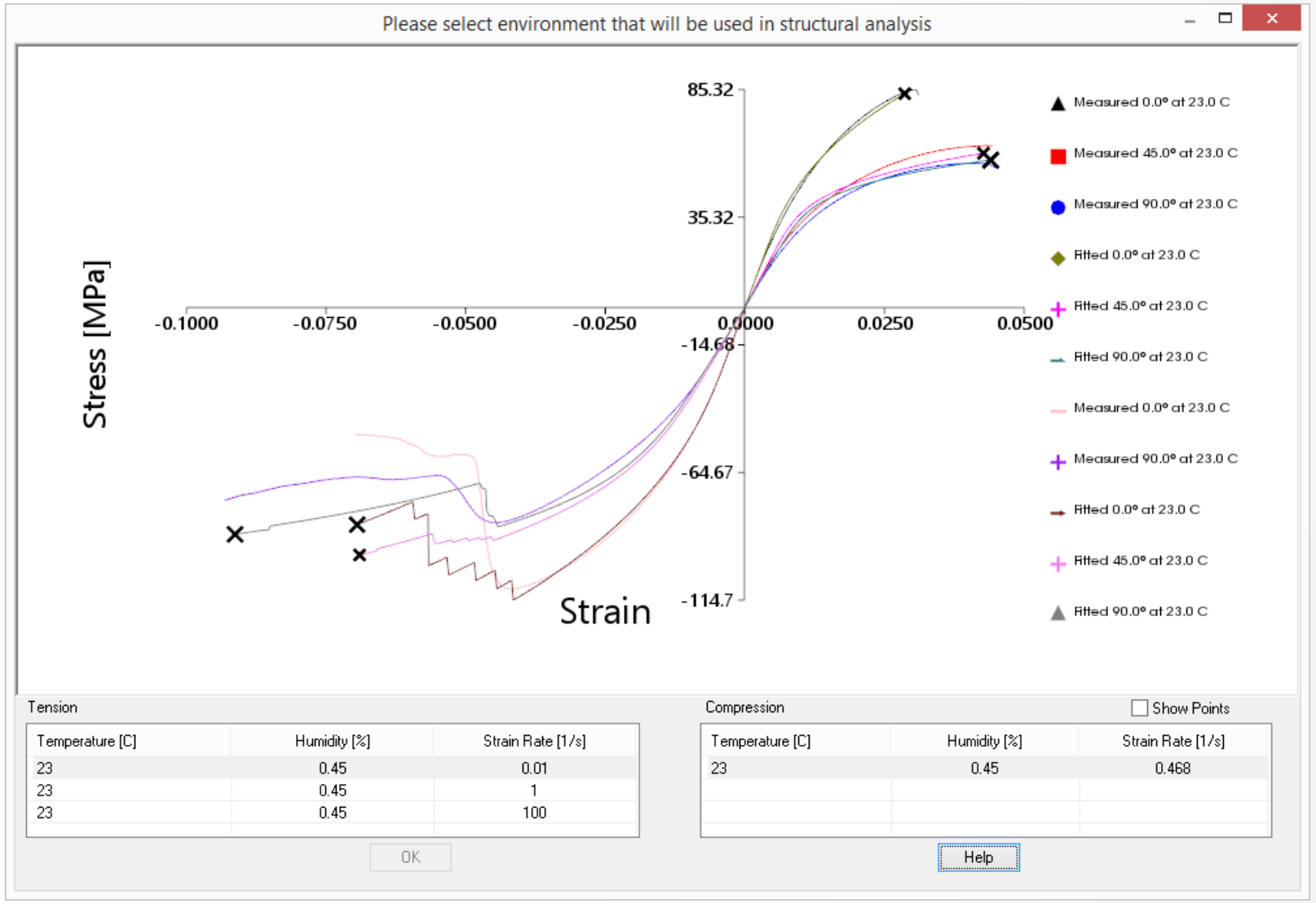


Moldflow **Structural**

Material Testing

Material Testing

- Testing offered through Autodesk Moldflow Labs
  - Parallel, perpendicular, 45^0 to flow direction
- Tension & compression data in MF database
- Many times compression data is not equivalent to inverse of tension

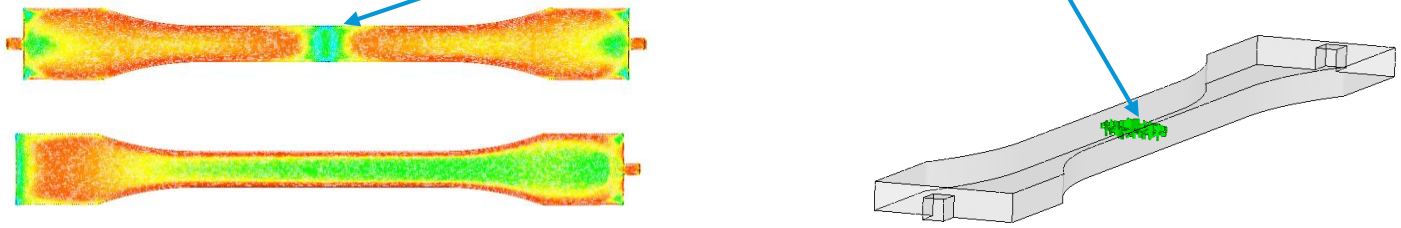


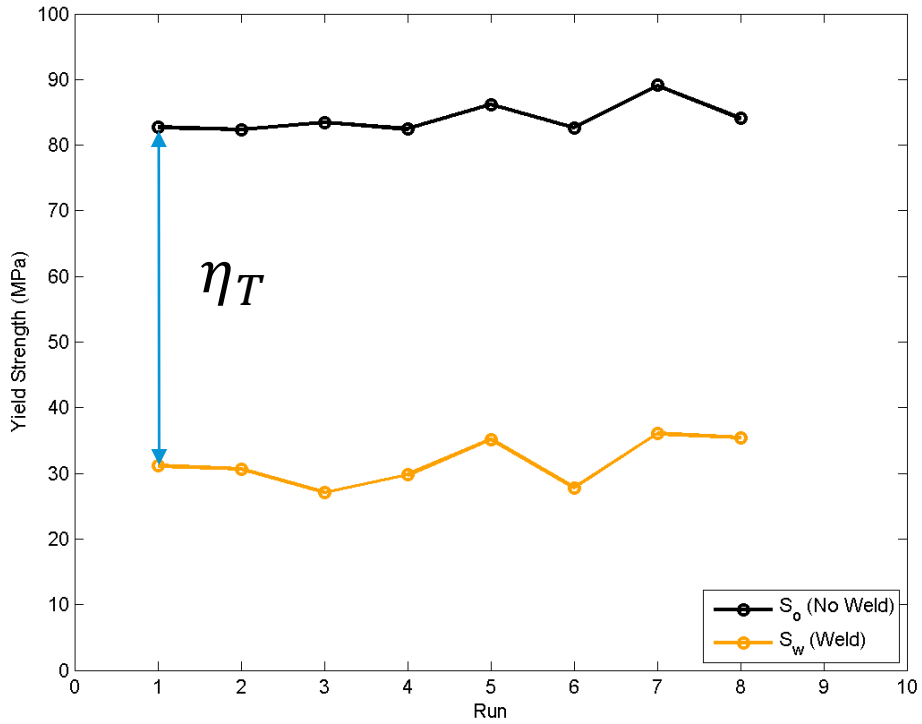
Weld Surface Strength Reduction

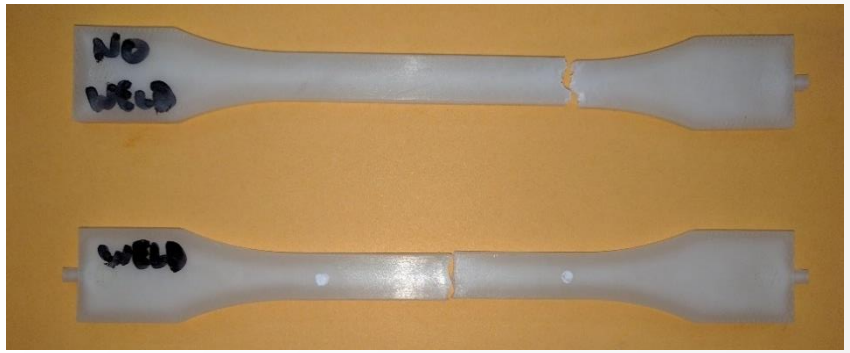
Weld Surface Strength Reduction Contributors

- Two contributors to strength reduction considered:
  - η_α – Fiber orientation
  - η_w – Weld surface

$$\eta_T = \frac{S_w}{S_o} = \eta_\alpha \eta_w$$







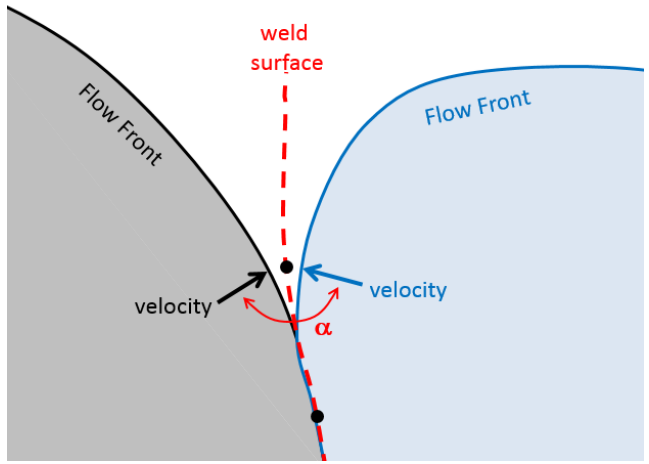
Weld Strength Reduction (Temperature & Pressure)

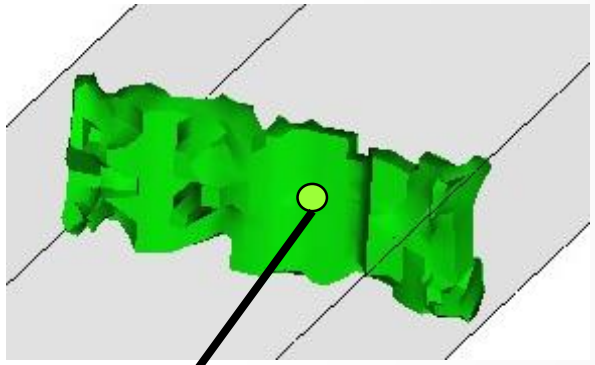
- Moldflow simulation yields detailed information for each point on the weld surface over time
  - Temperature and pressure history

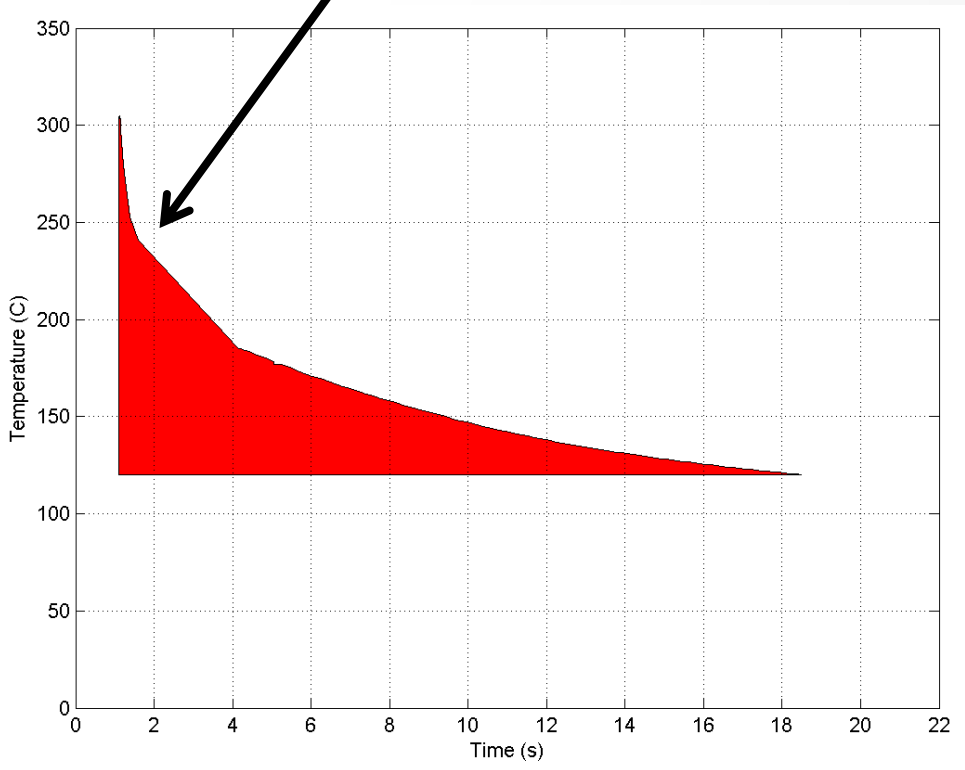
$$d\beta = \beta_{(t)}\left(c_T\left(T_{(t)} - T_g\right) + c_P P_{(t)}\right)dt$$

initial condition

$$\beta(0) = \left\langle \frac{\alpha_{crit} - \alpha}{\alpha_{crit}} \right\rangle$$

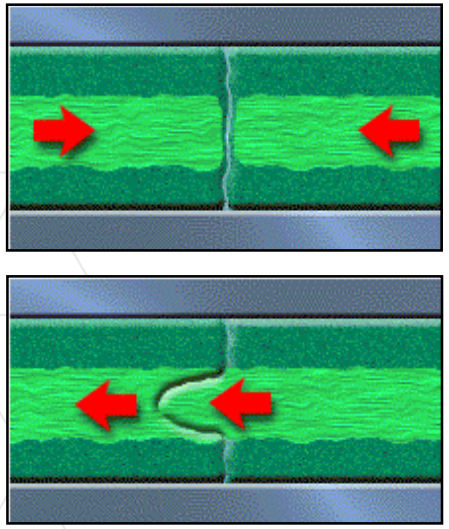


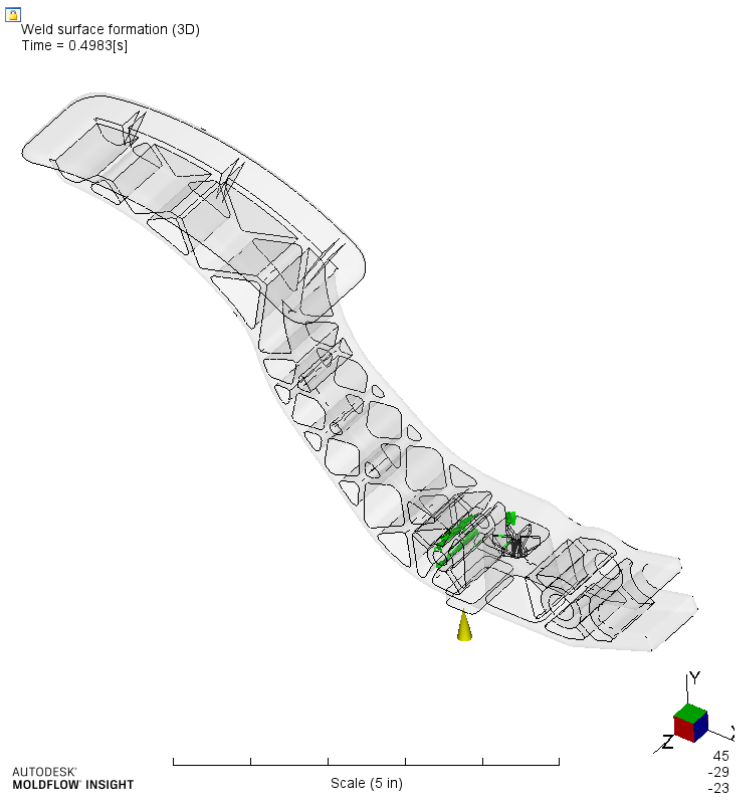


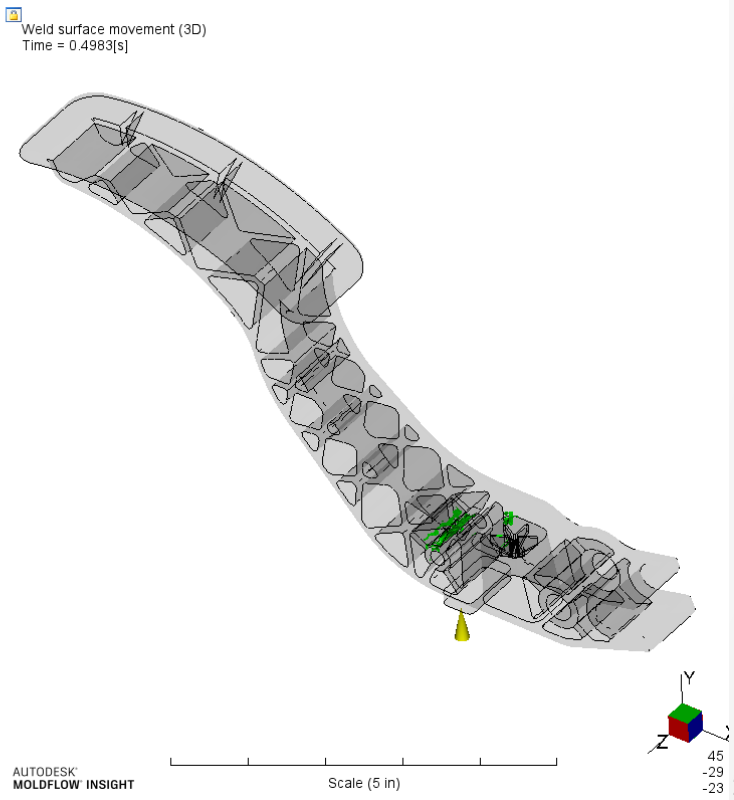


Weld Strength Reduction (Formation & Movement)

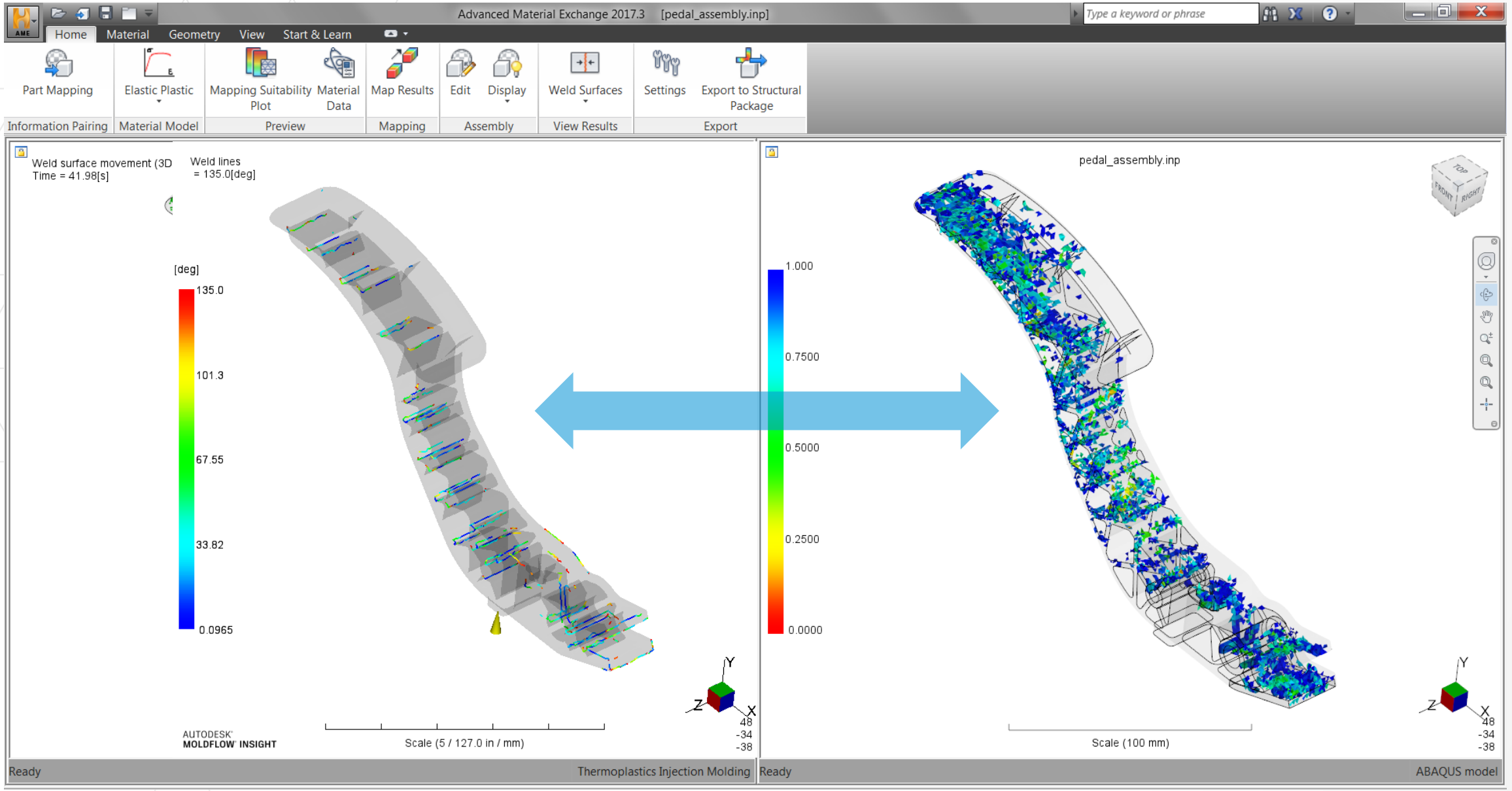
- Moldflow simulation yields detailed information for each point on the weld surface
  - Temperature and pressure history
  - Formation and movement







Weld Surface Strength Reduction In Helius PFA Example



Summary

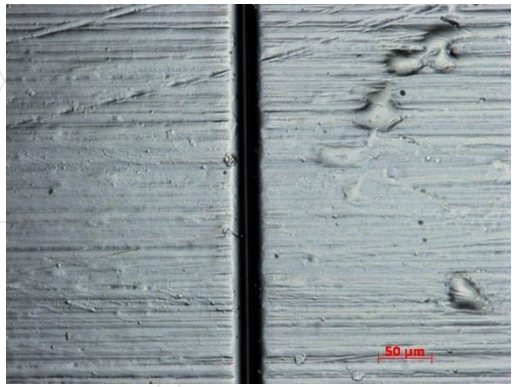
- Helius PFA for Plastics provides an integrated, simple approach to link the as-manufactured plastics simulation properties with structural simulation to increase FEA accuracy
  - Insight Ultimate 2018 Subscription customers have access to Helius PFA
  - Dissimilar mesh can be used (mapping suitability check)
  - Moldflow users can pass results to structural users
  - Simple interface for integration of both software packages
- Keys to increasing accuracy for structural simulation of plastics
  - Stiffness
    - Anisotropic
    - Nonlinear
  - Strength
    - Weld surface (meeting angle & movement, temp & pressure history)
    - Failure mode
    - Failure load

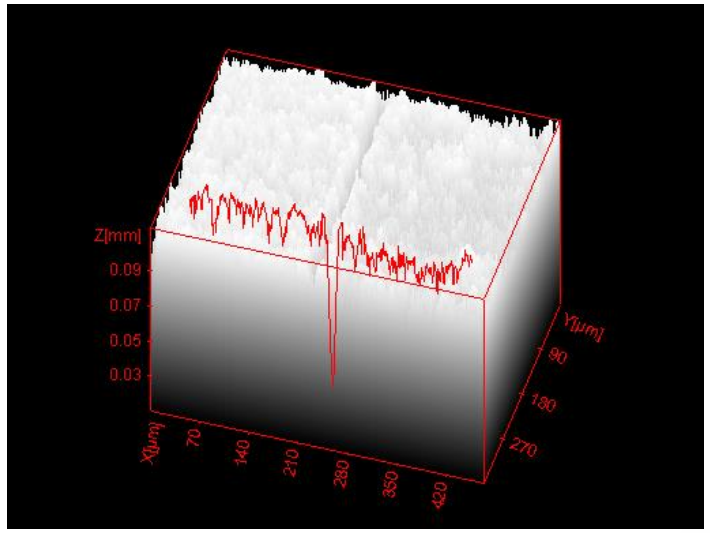
Future Work

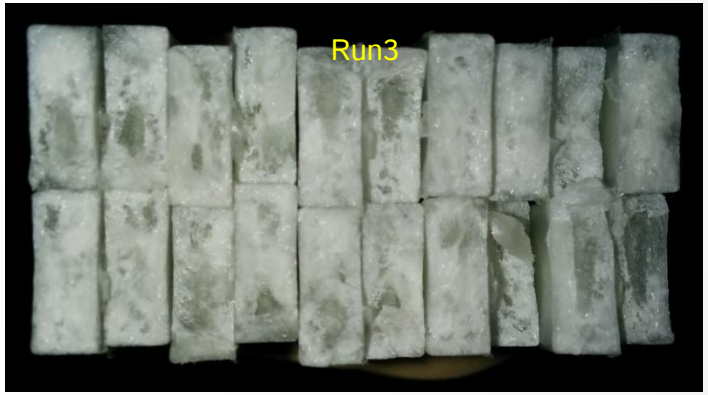
Future & Improvements

- Integrate venting analysis
  - Vnotch effects
  - Air traps
    - Specimens molded with high injection rate contained a large number of air traps

Run	Injection Rate (cm^3/s)	Air Traps
1	40	1
2	40	0
3	80	7
4	80	3
5	80	2
6	80	7
7	40	0
8	40	1







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Contact Information:

Jeff Higgins
Jeff.Higgins@autodesk.com