Moldflow User Meeting
Moldflow Research and Development Update

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AUTODESK

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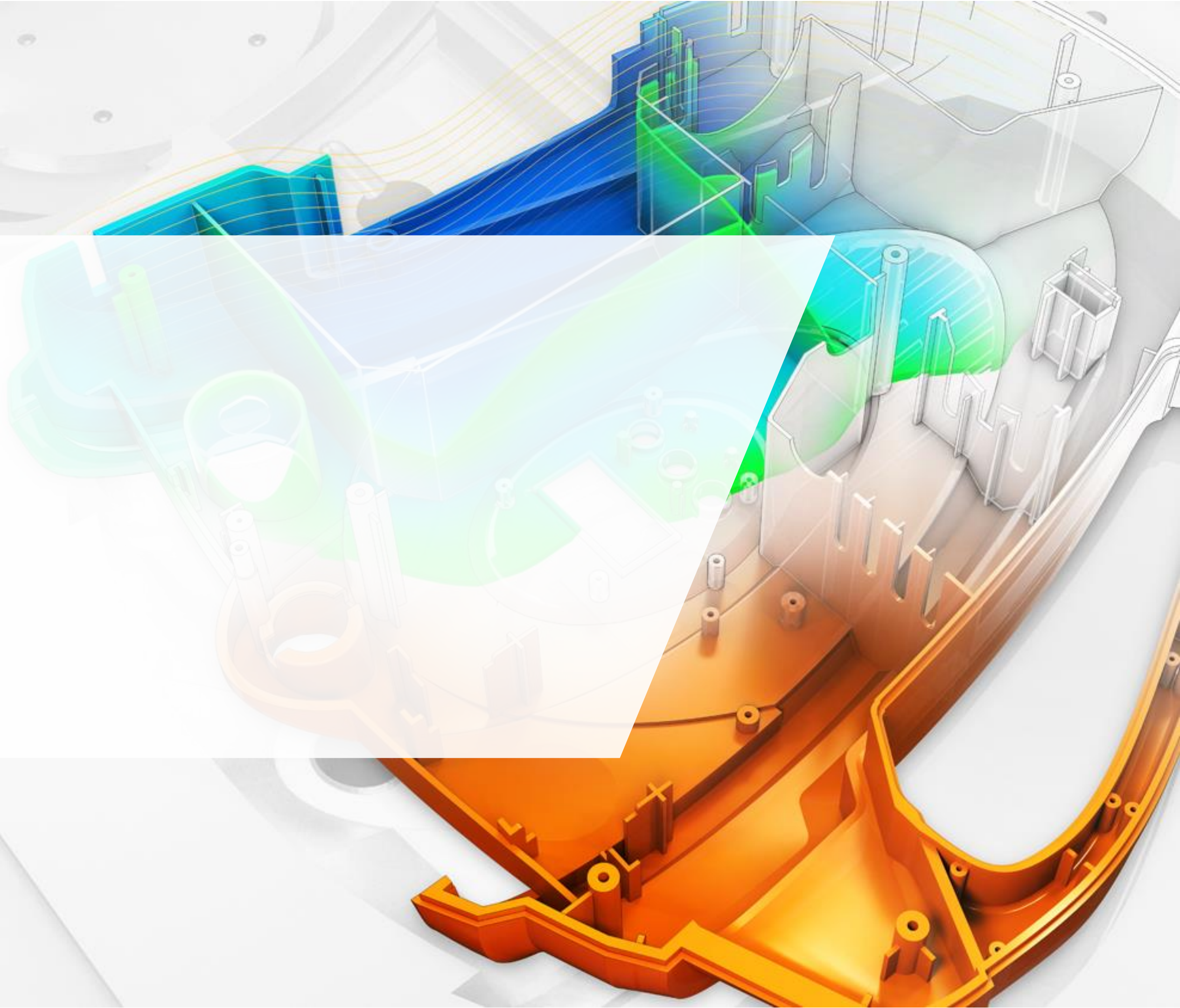
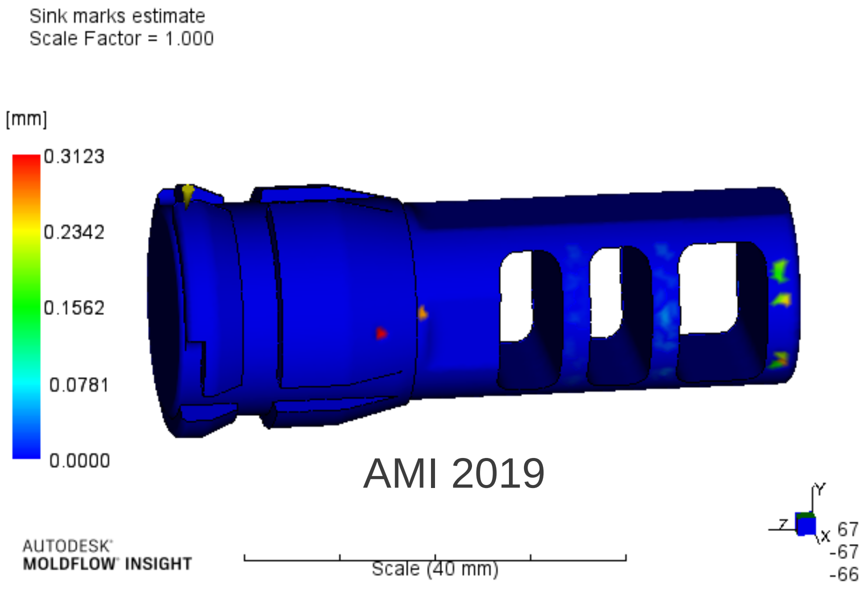
Sink Marks

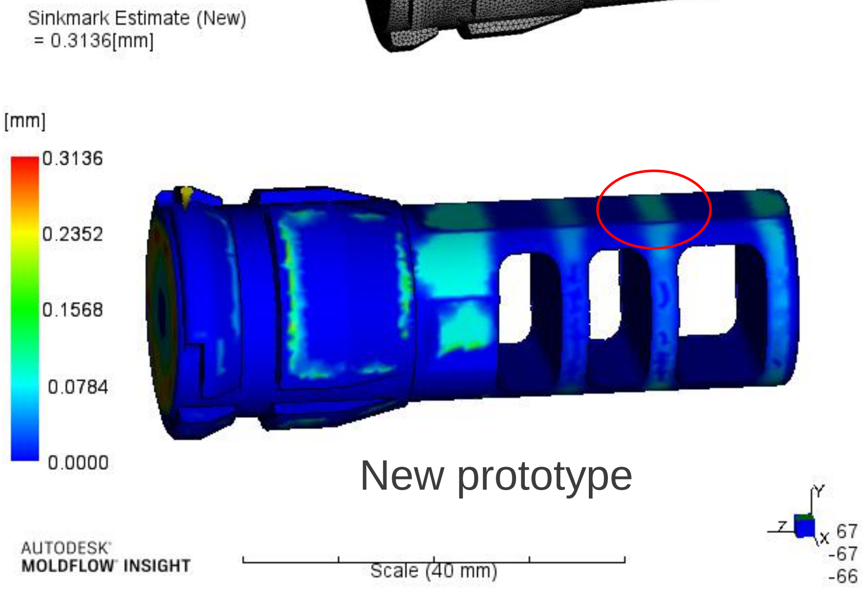


Sink Mark Predictions for General 3D Geometry

- Current method is limited to clearly defined ribs
- New method considers all geometry



AMI 2019



New prototype

Sink Mark Predictions for General 3D Geometry

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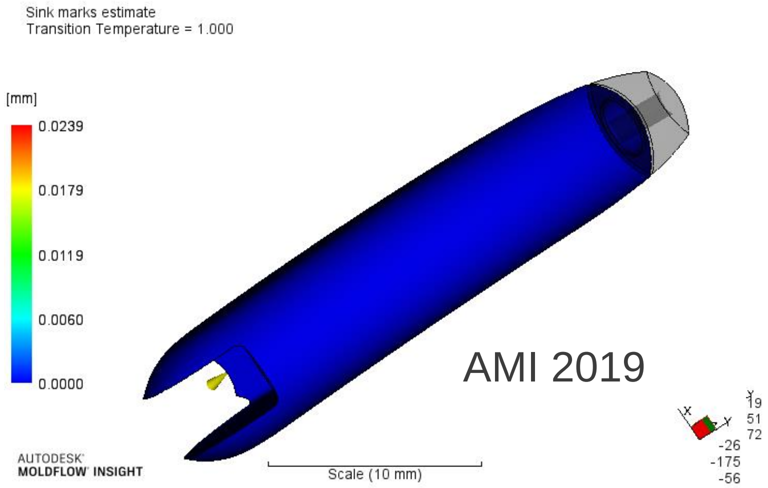
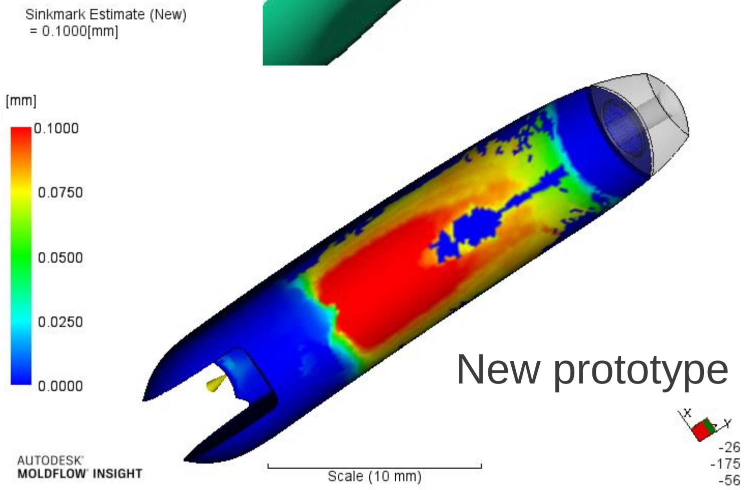
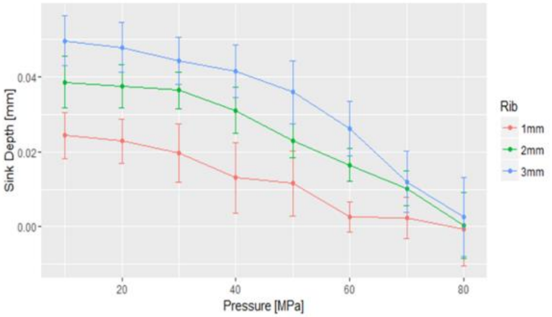
- New method considers all geometry

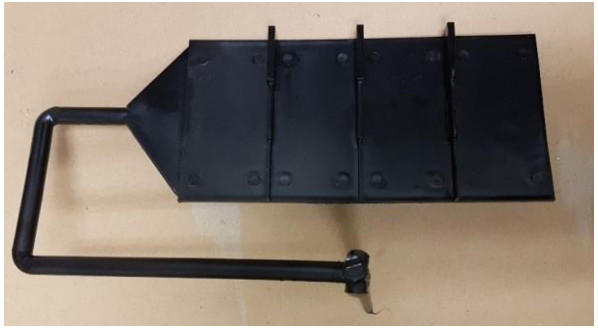


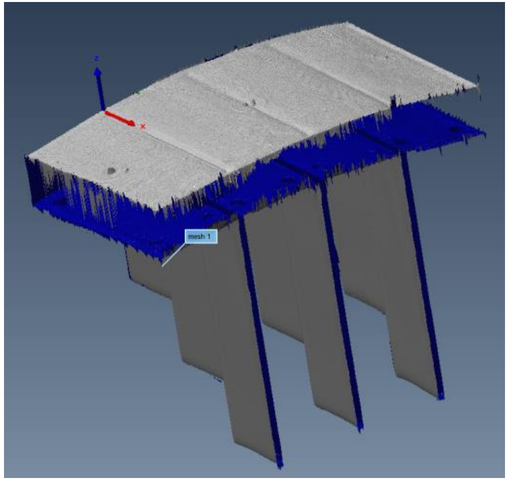


Sink Mark Validation

- Test Plaque with 1, 2 & 3mm thick ribs molded with different materials at various packing pressures
  - Example shown: ASA material
- Sink Mark Depth measured using laser scanner (exaggerated scan shown)
- Validation data:
  - Sink mark depth - pack pressure influence opposite each rib
  - Part cavity weight and volume measurements for solver validation

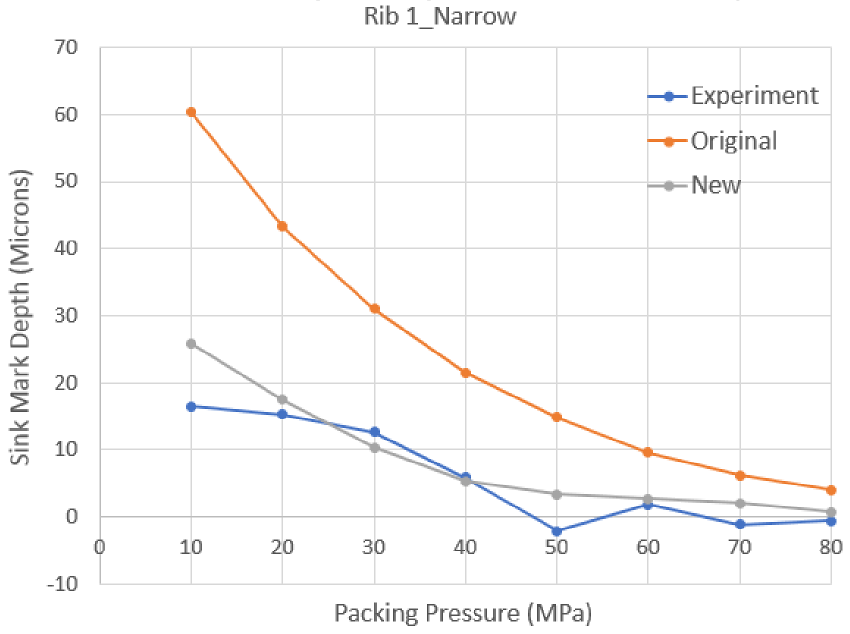




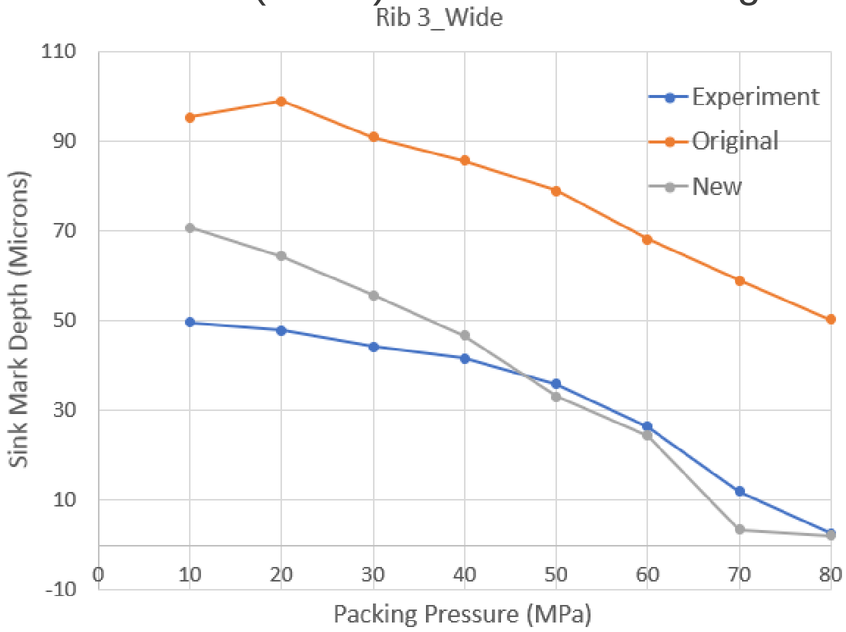


Sink Mark Validation Comparison

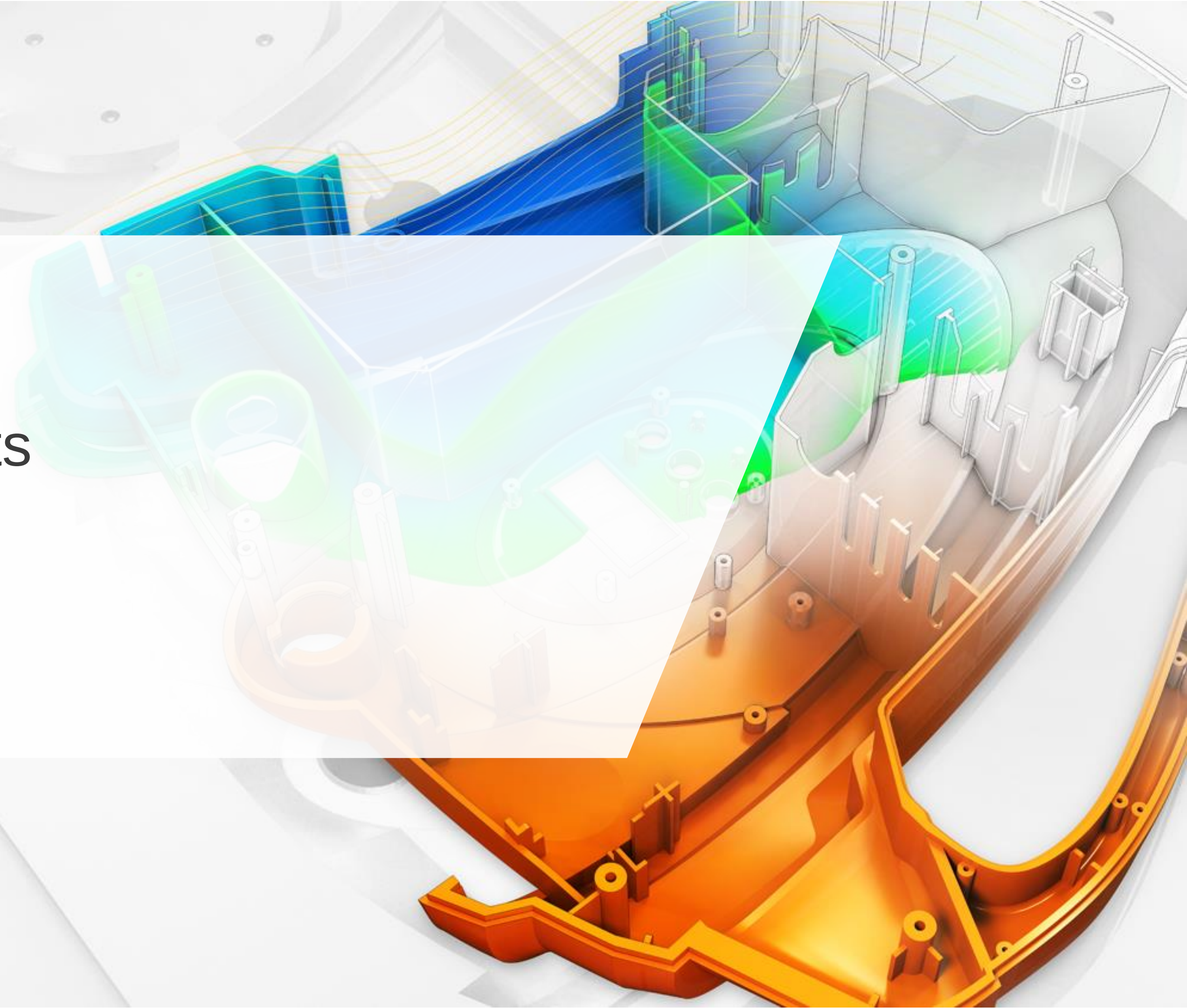
Narrow Rib (1 mm) Closest to the gate



Wide Rib (3 mm) Furthest from the gate

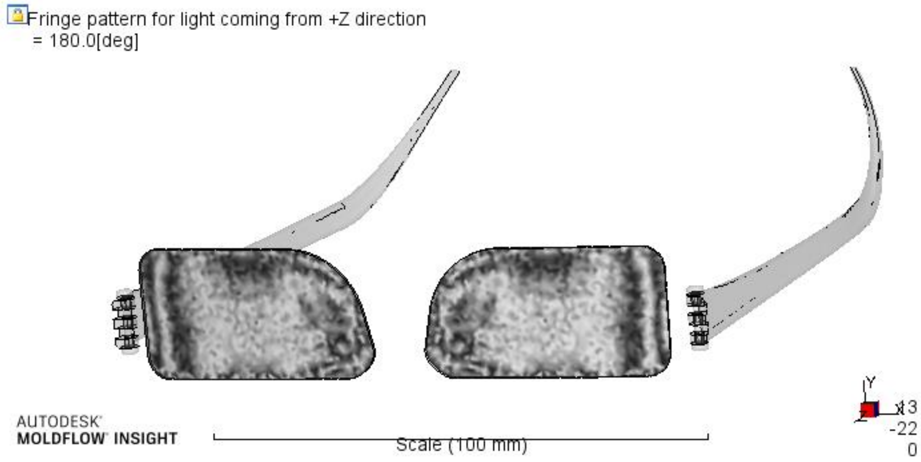


Other Visual Defects

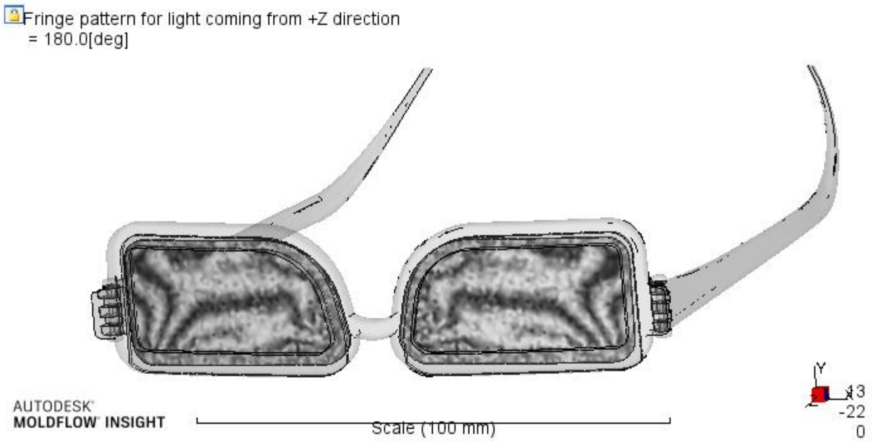


Birefringence Fringe Plot

- New post-processing option to interpret birefringence results
  - Case-study shows the influence of overmolding stresses from the frame which changes the fringe (stress) pattern



Single shot (no overmolding)



With Overmolded Frame

Prototype Tiger Stripes Prediction

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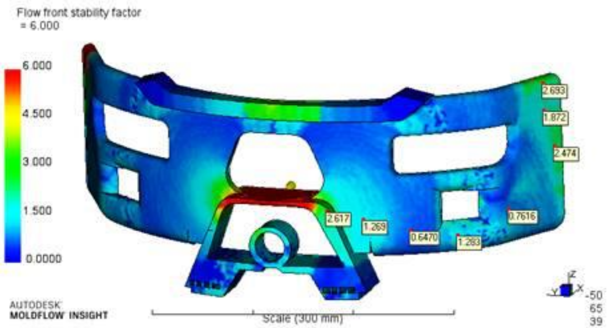
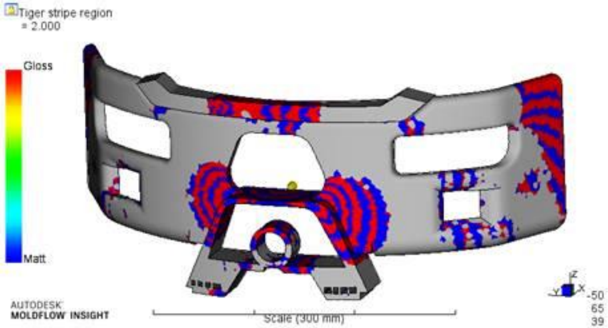
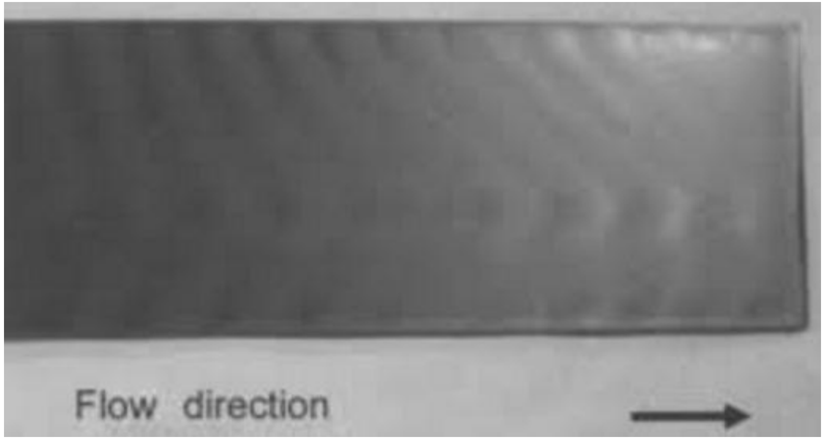
Tech Preview

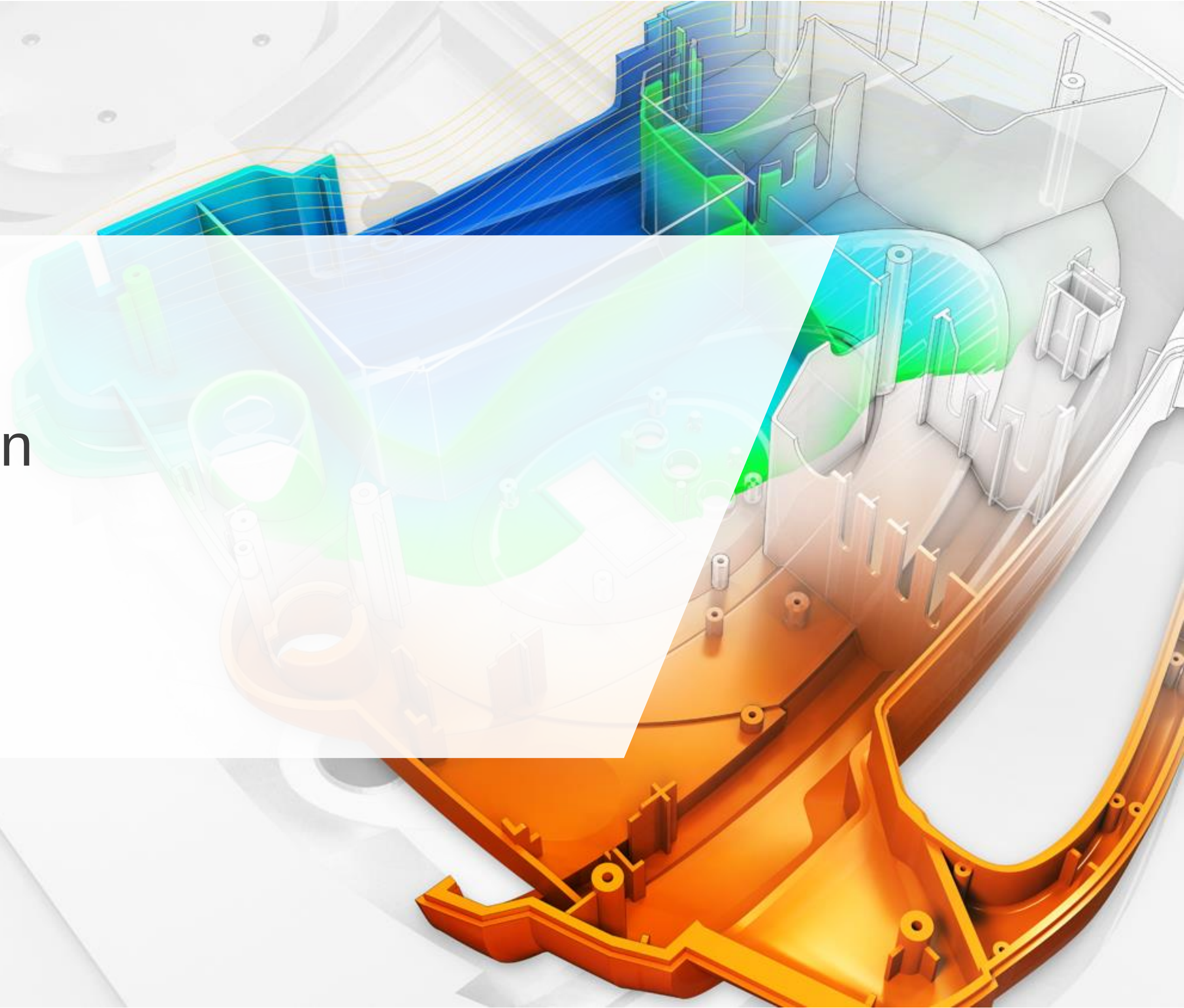
3D; Collaborating on Validation Studies







Shrinkage Prediction



Shrinkage Calibrated Coefficient of Thermal Expansion

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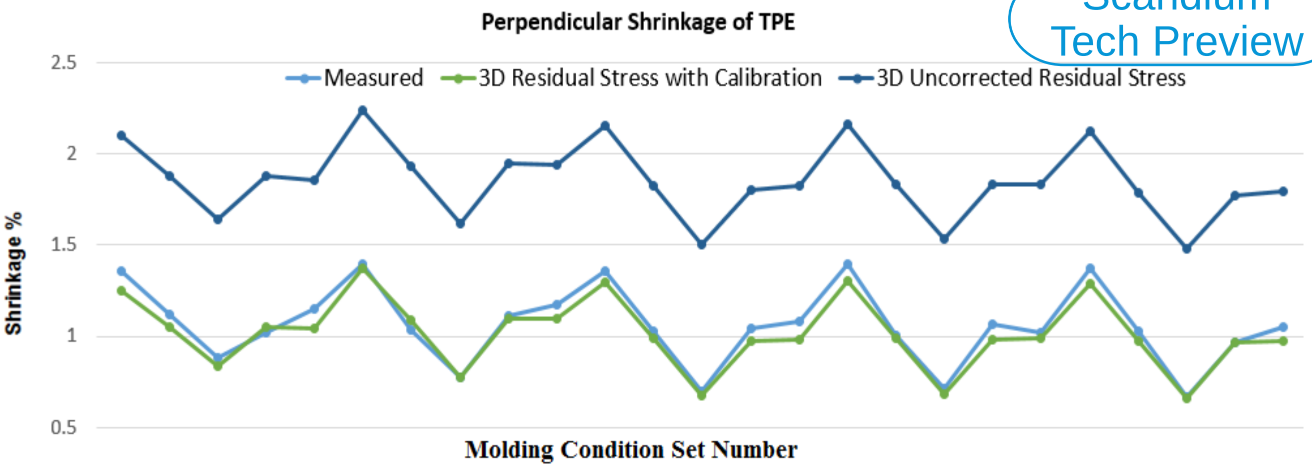
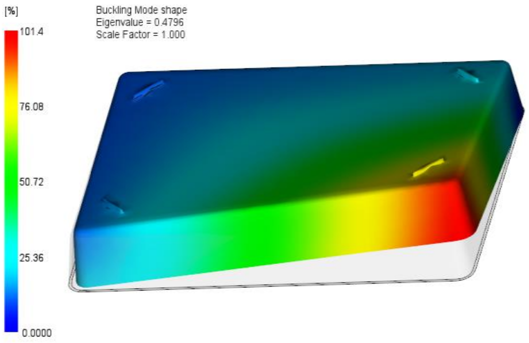
Tech Preview

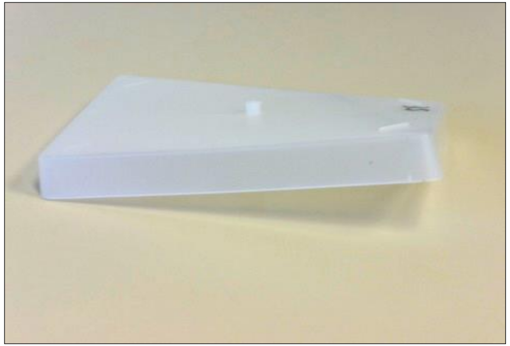
Moldflow's Shrinkage moldings



<u>3D. For unfilled semi-crystalline materials with measured shrinkage data</u>

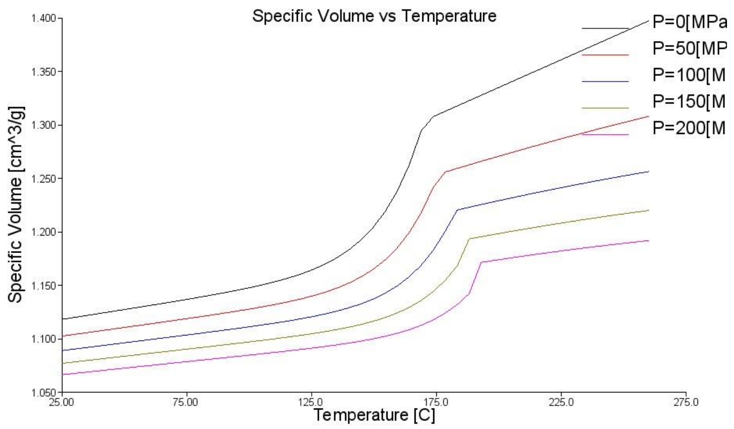
Warp Validation Molding





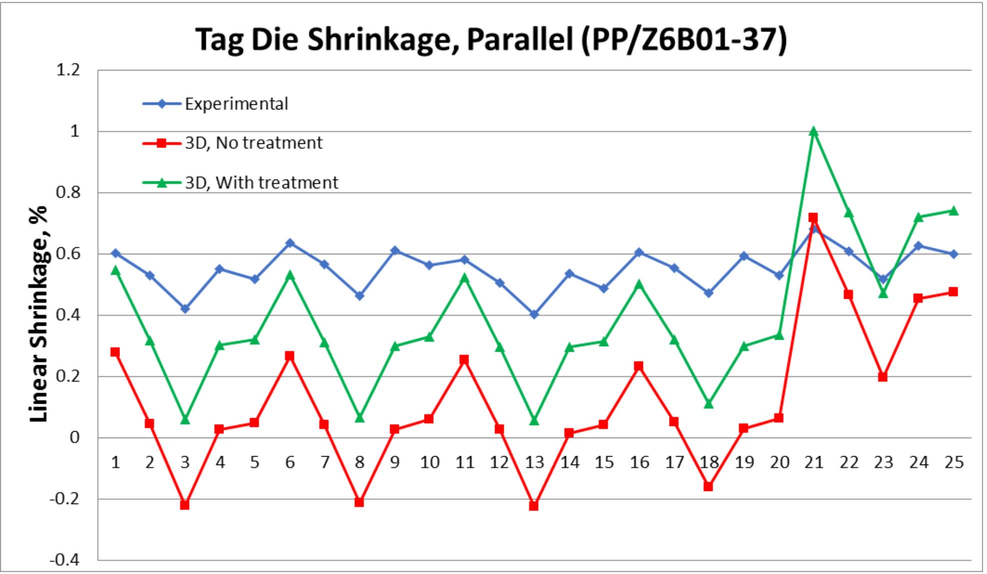
Consider Crystallization Effects on (3D) Shrinkage

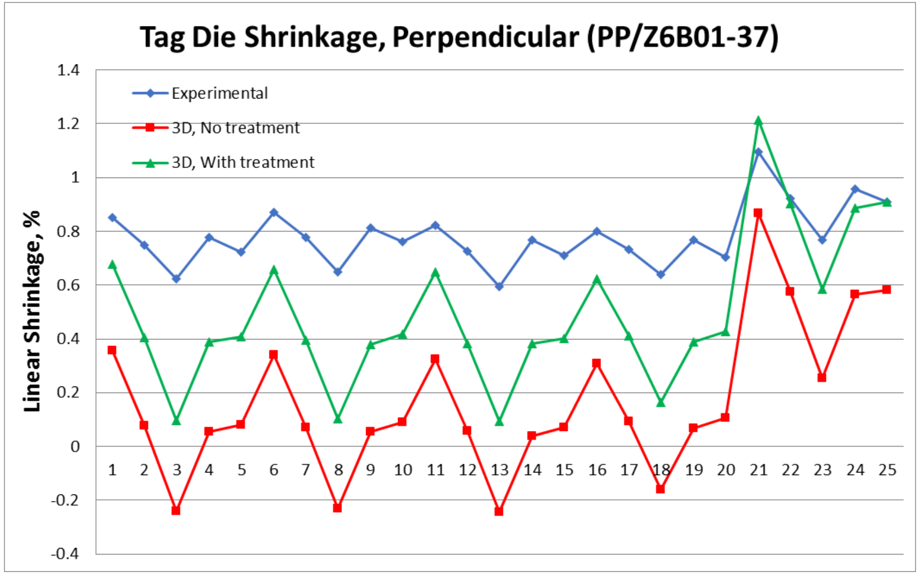
- Sharp drop in specific volume when a semi-crystalline material undergoes crystallization
- Proprietary treatment developed and implemented in Midplane and Dual Domain (DD) solvers in the past
- Same treatment has recently been implemented in 3D solvers
- Expected benefits:
  - More accurate shrinkage & warpage predictions from 3D solutions
  - Better consistency in shrinkage predictions between Midplane/DD and 3D solutions



Consider Crystallization Effects on (3D) Shrinkage

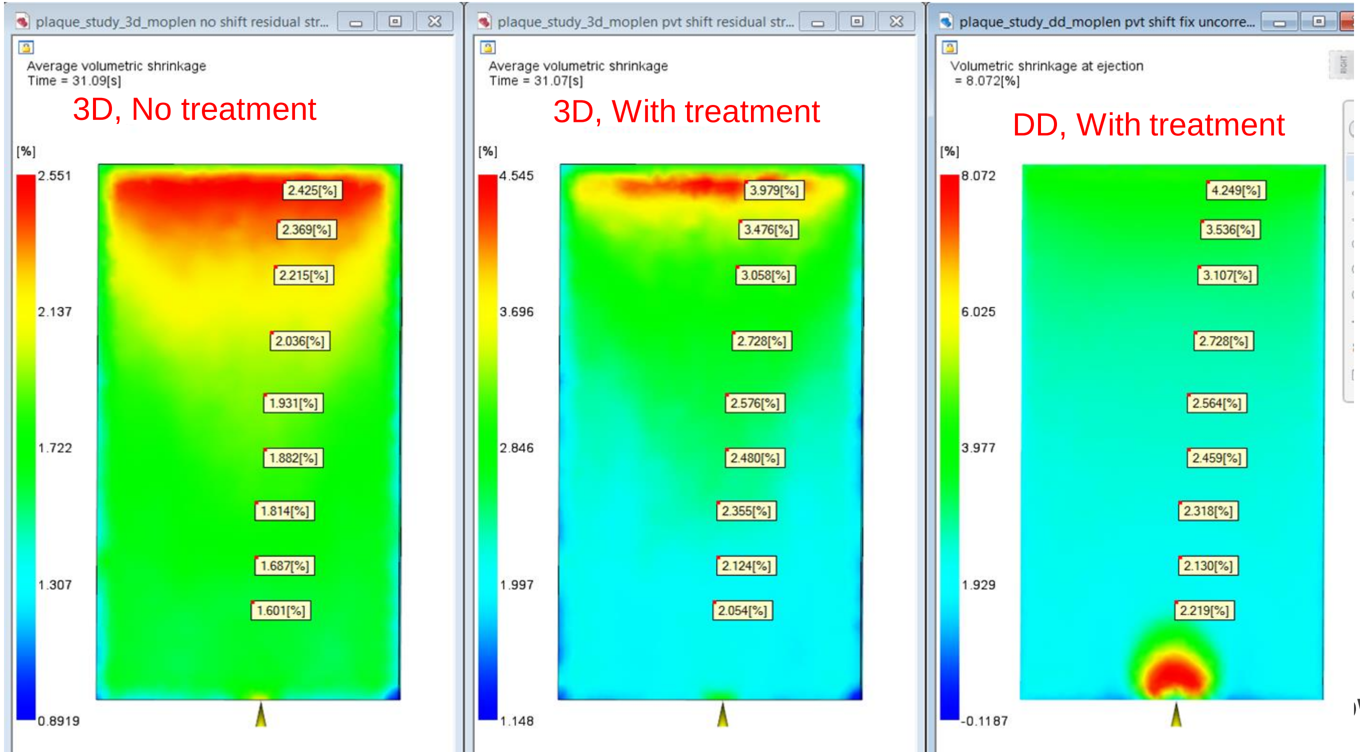
- 3D Flow analyses for Shrinakge Tag Die / 25 processing conditions / uncorrected residual stress model)
- Comparison of linear shrinkage in parallel and perpendicular directions
- Level of predicted linear shrinkage improved after the treatment





Consider Crystallization Effects on (3D) Shrinkage

- More consistent volumetric shrinkage predictions between DD and 3D solvers with the treatment

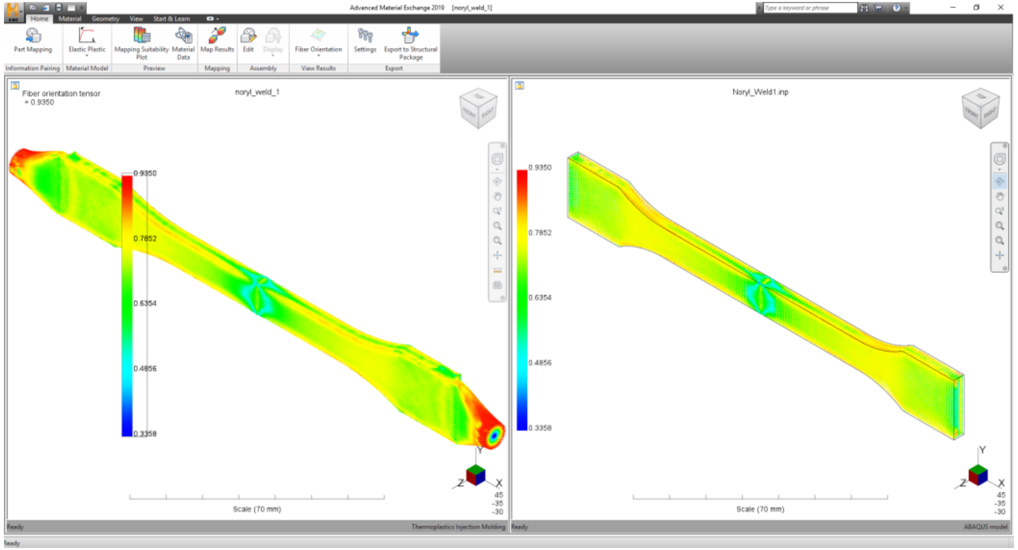


Autodesk Material Exchange / Helius

Extend FEA Support for AME/Helius

FEA Support

FEA Platform for Helius (future)	Version
Abaqus	2018, 2019
ANSYS	19.x, 2019 R1
Autodesk Nastran/Nastran In-CAD	2019, 2020



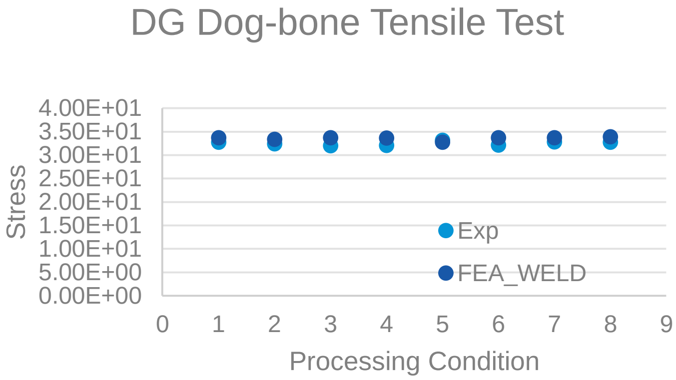
Robust Weld Strength Failure Model in Helius

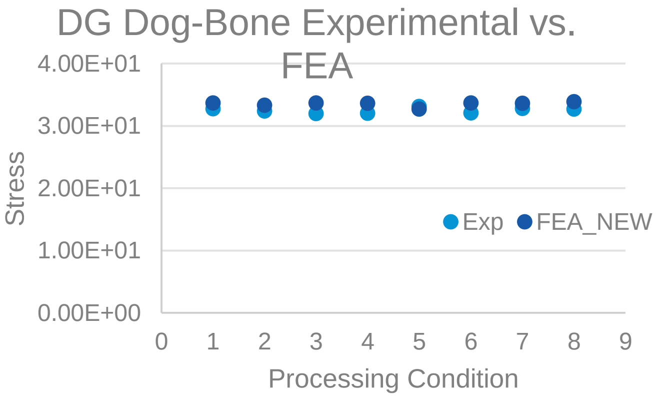
Helius / AME

- Maximum Distortion Energy Criterion i.e. Von Mises Stress measure.

$$\sqrt{\frac{(\tau_{11}-\tau_{22})^2+(\tau_{22}-\tau_{33})^2+(\tau_{33}-\tau_{11})^2+6(\tau_{12}^2+\tau_{23}^2+\tau_{13}^2)}{2}}=S_y$$

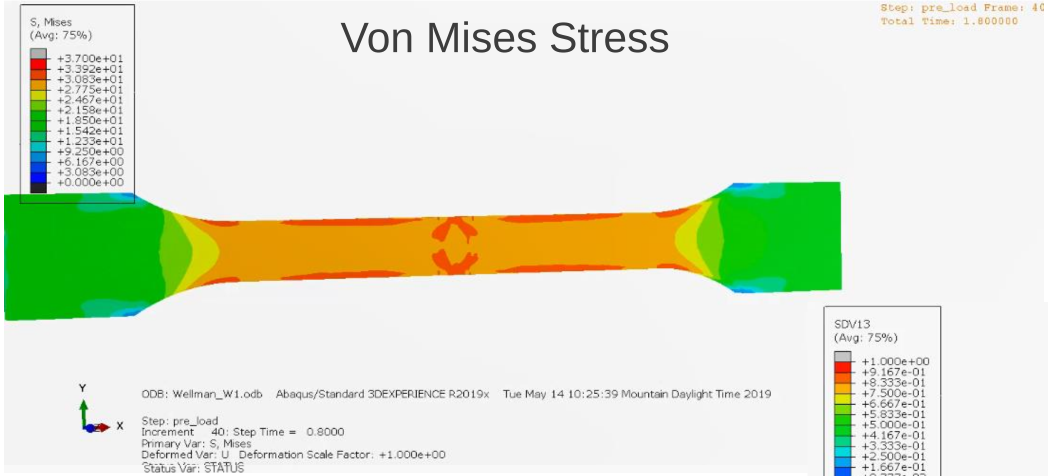
- Requires only one Double-gated tensile test to calibrate.

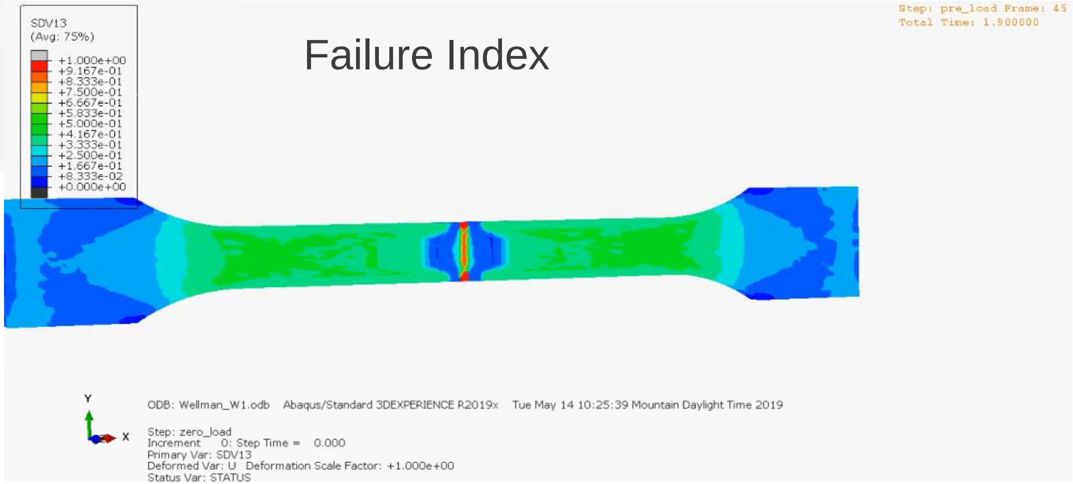




Robust Weld Strength Failure Model in Helius

Helius / AME

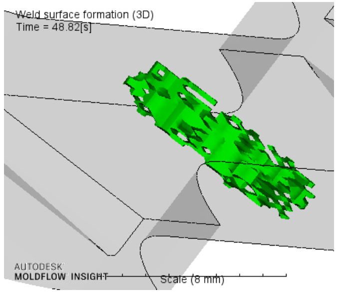




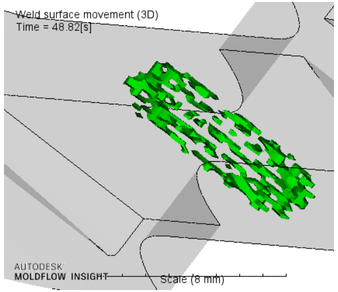
Weld Surface Prediction

- Broken weld surfaces predicted in Moldflow 2019:
  - Difficulty in weld surface strength characterization
  - Less accurate in structural FEA

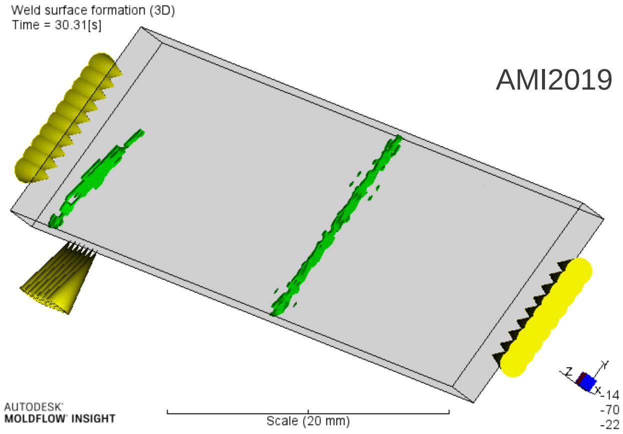
Initial Weld Surface position

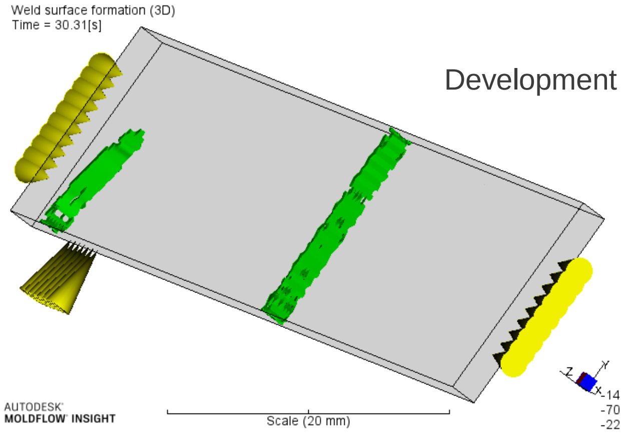


Weld position after packing flow



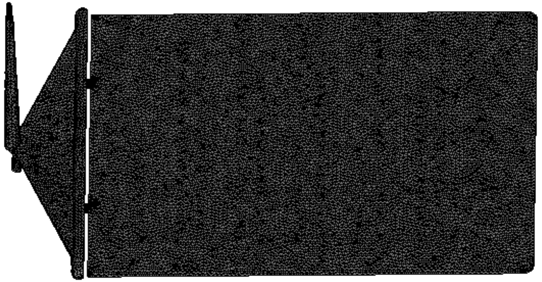
- Improvement to obtain more continuous weld surface



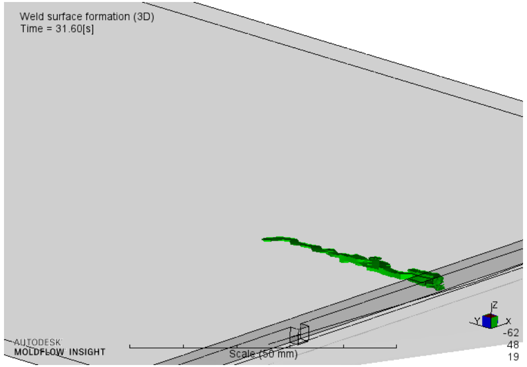


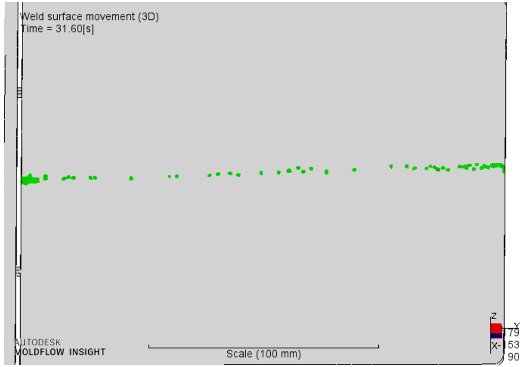
Weld Surface Movement

Two tab gate plaque

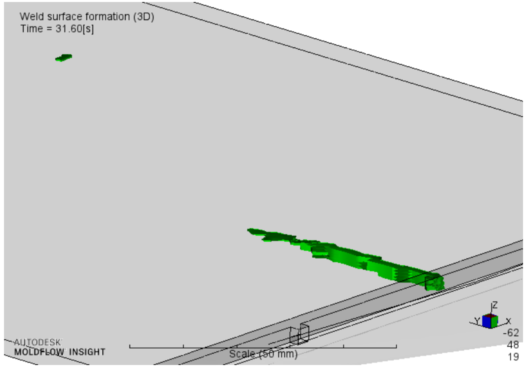


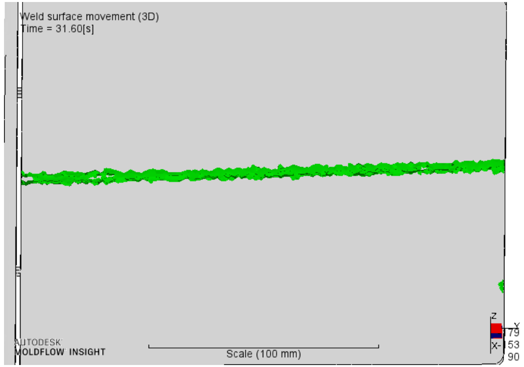
AMI2019





Development





Mechanical Properties

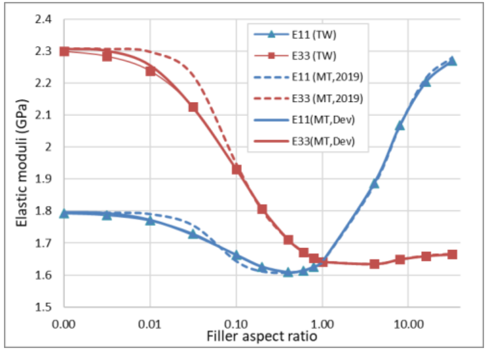
Improvement and Bugfix in Property Calculation

Moldflow: Midplane, Dual-Domain & 3D

- Issue: non-physical composite properties predicted for some certain grades with *isotropic matrix*
  - Cause: wrong formula for one minor Poisson's ratio of composite in Tandon-Weng solution
  - Fix: re-derived and implemented the correct formula
  - Change: decomposed matrix properties and calculated composite properties
    - Changes are expected to be small for most grades, but might be large in decomposed matrix for some grades

- Issue: poor accuracy in Mori-Tanaka solution for some ranges of aspect ratio for *anisotropic matrix* (e.g. LCP)
  - Cause: poor accuracy in numerical integration for Mori-Tanaka solution
  - Fix: increased the accuracy and efficient of numerical solution
  - Change: Significant for disk-like fillers, not significant for fibers

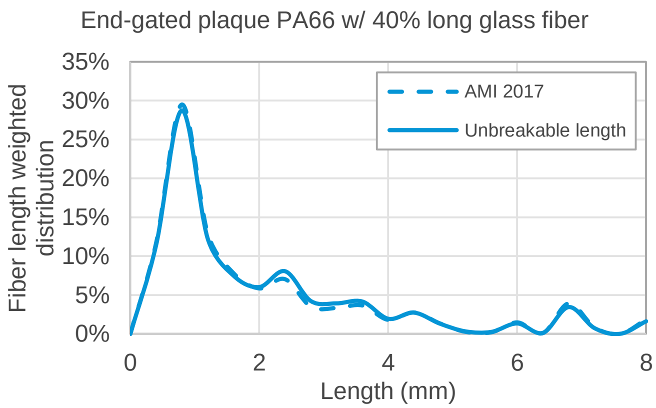
Verification for uni-directional composite with isotropic matrix (TW and MT should be identical)

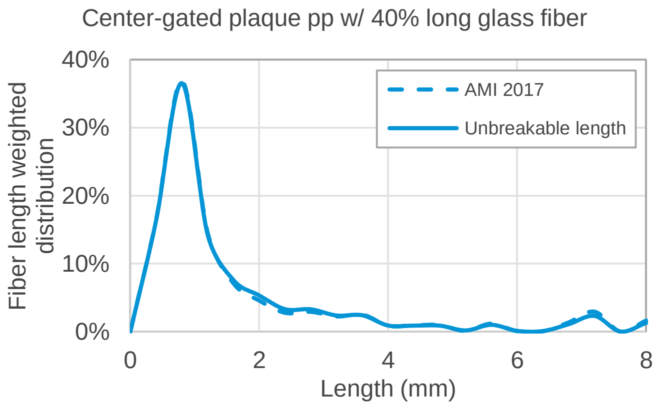


Fiber Breakage Model

Fiber Length Distribution

- Unbreakable length proposed by Phelps et al.*
  - More reasonable physical model
    - Already implemented in 3D in AMI 2017.3
    - To be implemented in Midplane and Dual Domain in next major AMI release
  - Very small change in length breakage is expected



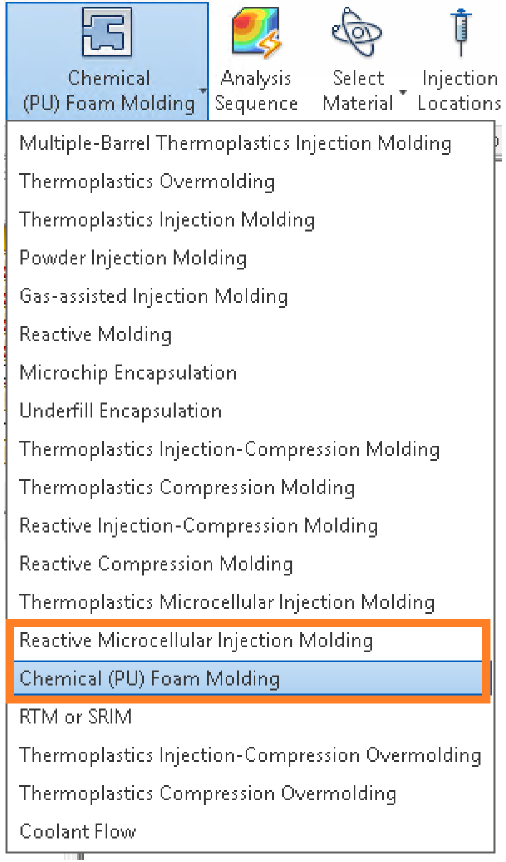


* Phelps, J. H., Abd El-Rahman, A. I., Kunc, V., & Tucker, C. L. (2013). A model for fiber length attrition in injection-molded long-fiber composites. *Composites Part A: Applied Science and Manufacturing*, *51*, 11–21. https://doi.org/10.1016/j.compositesa.2013.04.002

Foam Injection Molding

Reactive Microcellular Injection Molding & Chemical (PU) Foam Molding

Scandium Tech Preview

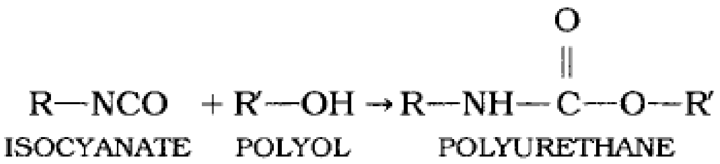


Two New Processes:

- Reactive Microcellular Injection Molding
  - Similar to “Thermoplastics Microcellular Injection Molding” process except that it is for thermoset materials
- Chemical (PU) Foam Molding
  - PU Foaming or General Chemical Blowing Agent Reaction
  - Foaming gas is generated during molding, so the reaction that generates a foaming gas is considered during the analysis
    - Still also have a separate reaction analysis for the curing of the resin

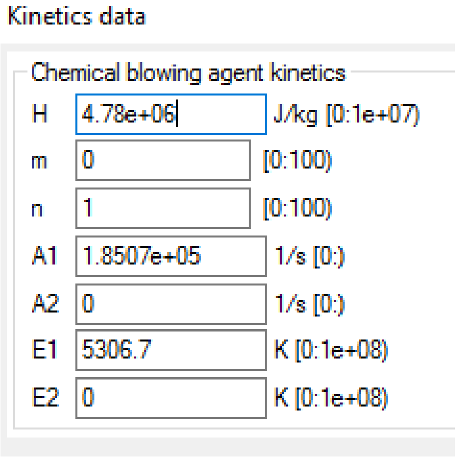
Chemical (PU) Foam Molding

- PU Foaming:
  - Considers gelling reaction and blowing reaction
  - Gelling reaction (thermoset curing)



  - Blowing reaction

$$\underset{\text{isocyanate}}{2R\text{–}NCO} + \underset{\text{water}}{H_2O} \rightarrow \underset{\text{urea}}{R\text{–}NH\text{–}CO\text{–}NH\text{–}R} + CO_2\uparrow$$

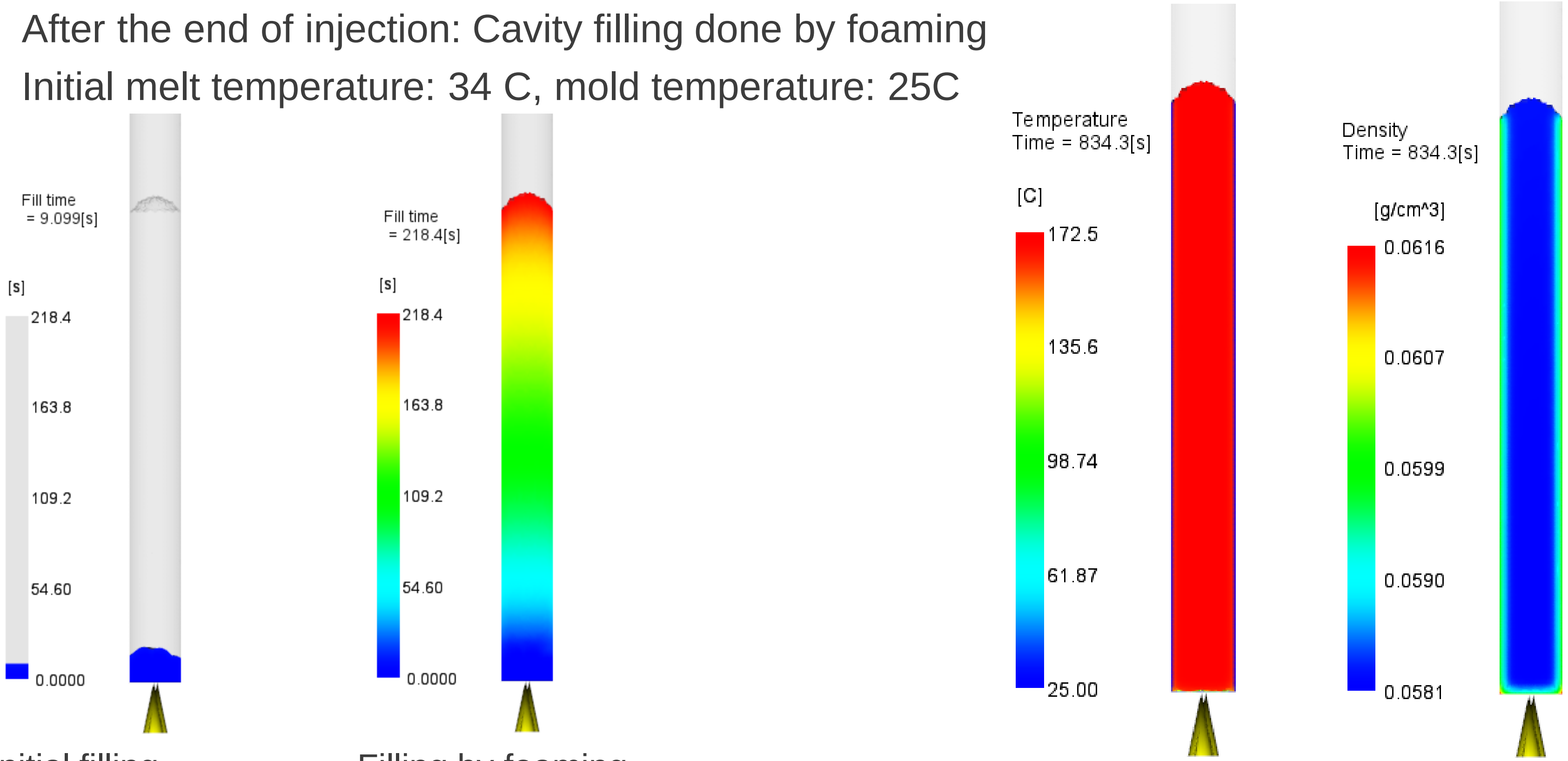


Chemical blowing agent kinetics

- General Chemical Blowing Agent Reaction
  - Blowing agent is generated by different chemical reaction from PU Foaming

Chemical (PU) Foam Molding: Example 1

- Initial cavity filling by injection: 2.5% of total cavity volume
- After the end of injection: Cavity filling done by foaming
- Initial melt temperature: 34 C, mold temperature: 25C

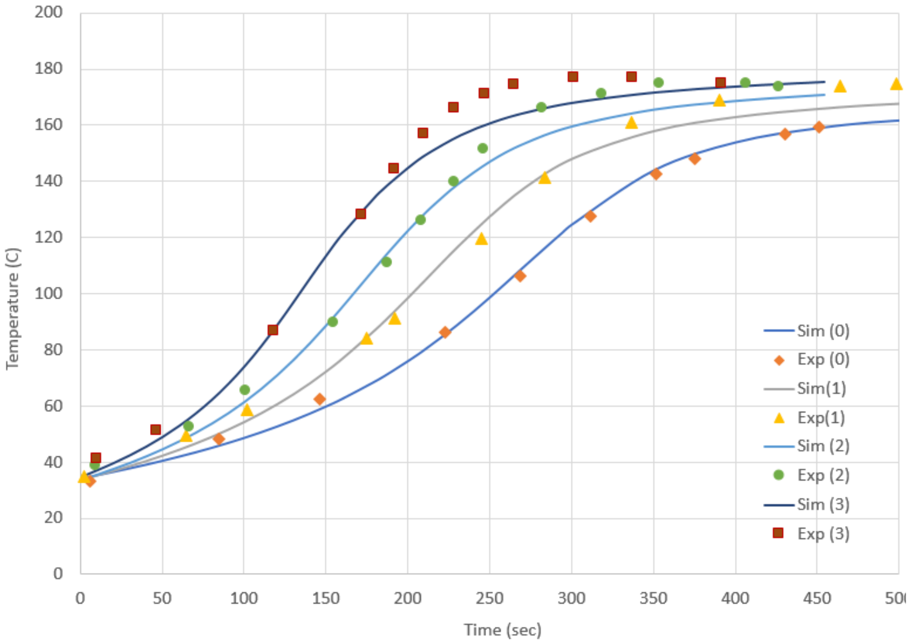


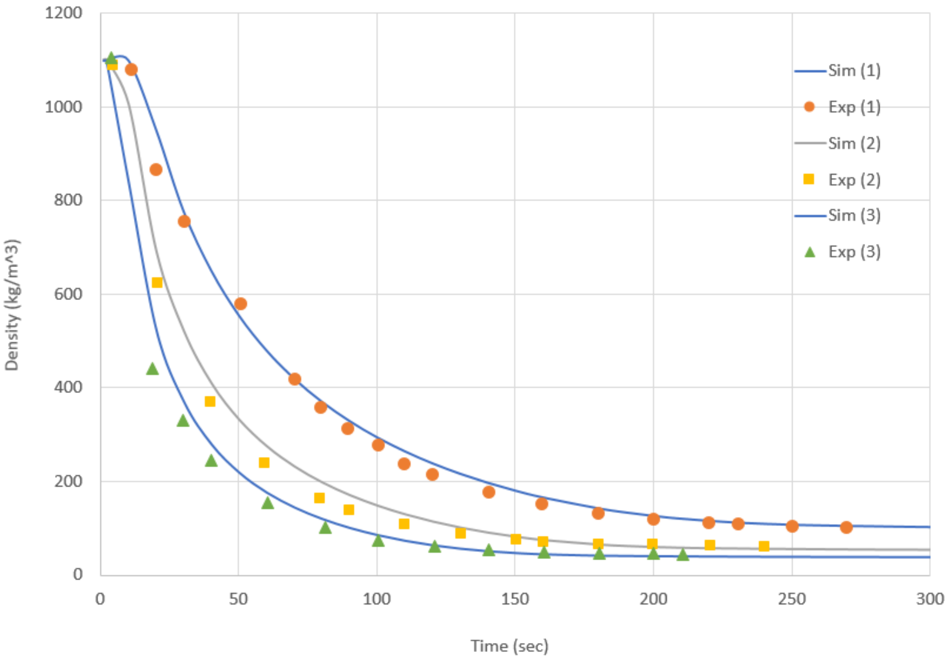
Initial filling

Filling by foaming

Chemical (PU) Foam Molding: Example 1

- Comparison of temperature and density history from experiment and simulation
- Water concentration: [0,] 1, 2, 3%

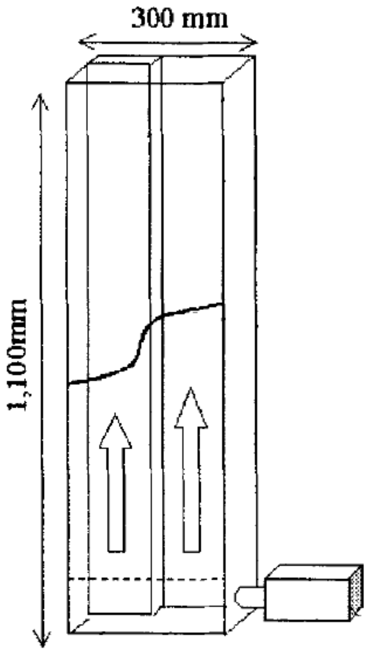




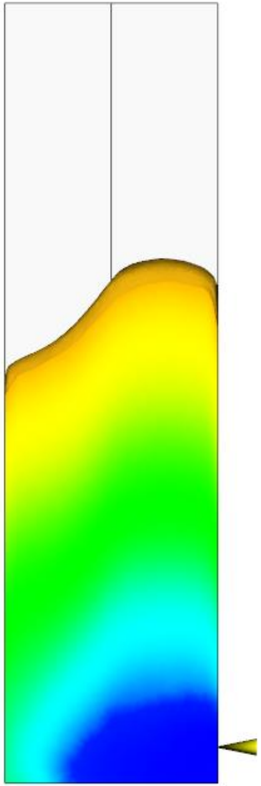
Experiment: Baser et al, 1994

Chemical (PU) Foam Molding: Example 2

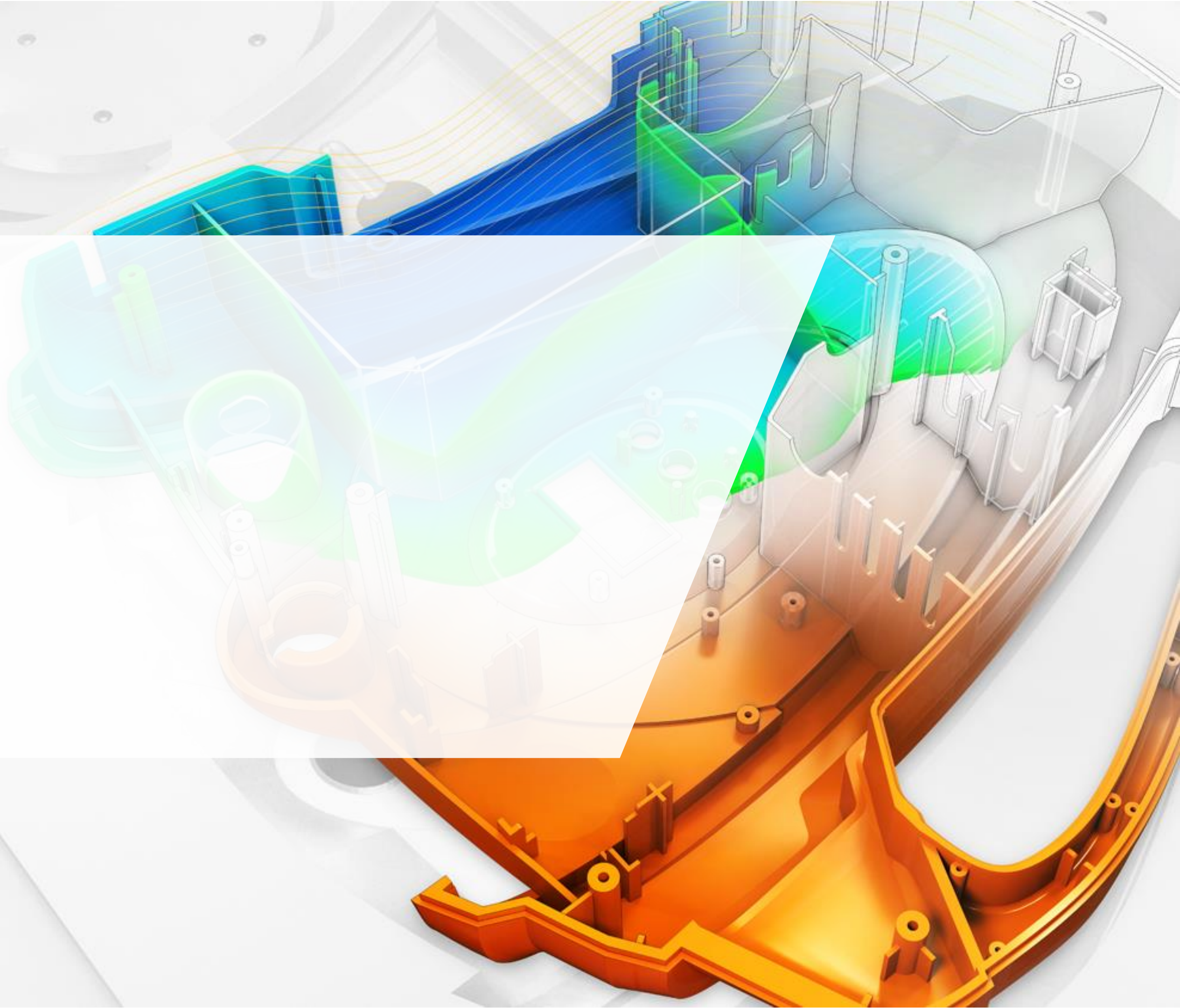
- Comparison of flow front advancement between experiment and simulation
- Variable cavity thickness (35 mm: left, 65 mm: right)



Experiment: Mitani et al, 2003



Optimization



Improve Strip Solver Accuracy

Used by Midplane, Dual-Domain & 3D

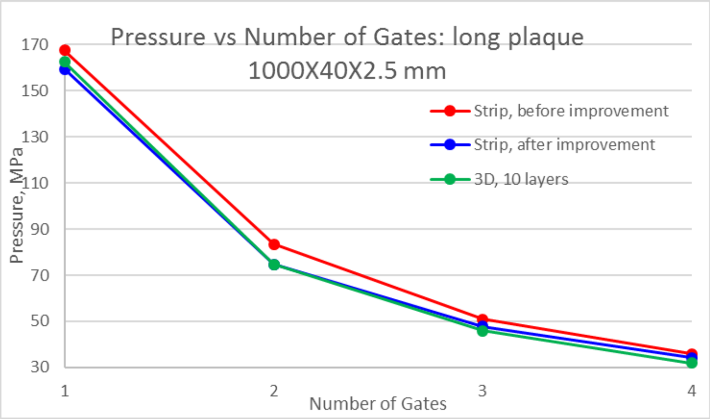
- Accuracy is important as Strip Solver is a building block for Moldflow products such as Auto Injection Time (AIT), Runner Balancing, Molding Window, etc.

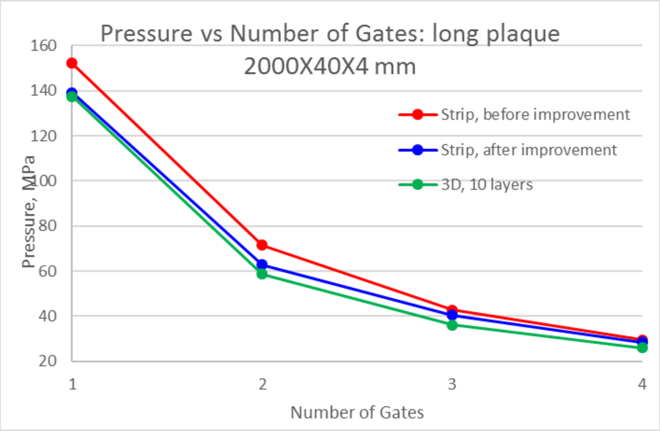
- Enhancements under implementation & testing
  - Include the effect of Mold-melt Heat Transfer Coefficient (HTC) – Consistent with the thermal boundary conditions used in other solvers (Midplane, DD, and 3D)

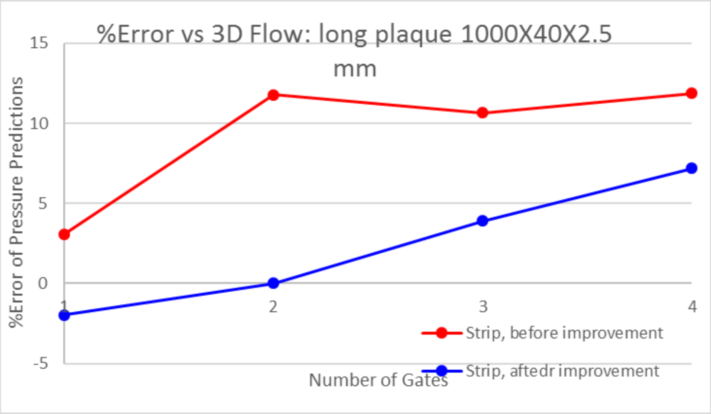
$$-k\frac{\partial T}{\partial n} = h[T - T_w]$$

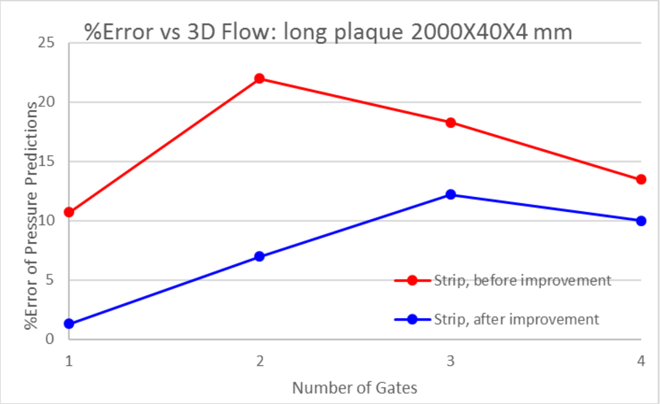
  - Improve pressure drop calculation within a strip segment by including shear heating effect into the calculation of current segment
  - Preliminary test on a long plaque with material Xantar C CF407 (PC+ABS blend) showed accuracy improvement in pressure predictions (compared with 10 layer 3D Flow solutions)

Improve Strip Solver Accuracy: Test on Long Plaque









Other Warp Enhancements / Prototypes

Molded Component Assembly--Mounting Analysis

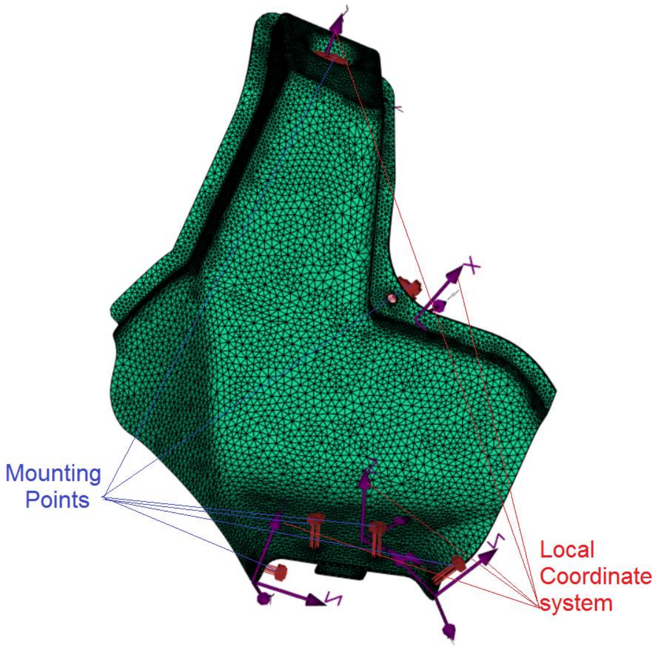
Scandium Tech Preview

- Predicting the deformation and stress of injection molded components after being mounted into designed position
- Check if the assembly outcome can meet the tolerance requirement of geometric dimensioning and tolerancing.
  - Analysis using mold dimensions
  - Adjusts assembly constraints according to mold shrinkage allowance
- Top requested issue in Users' Group Meeting India and Europe

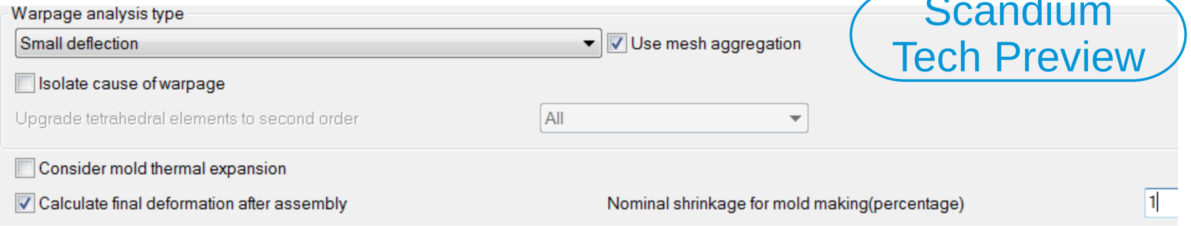
Courtesy of ChangAn Automotive

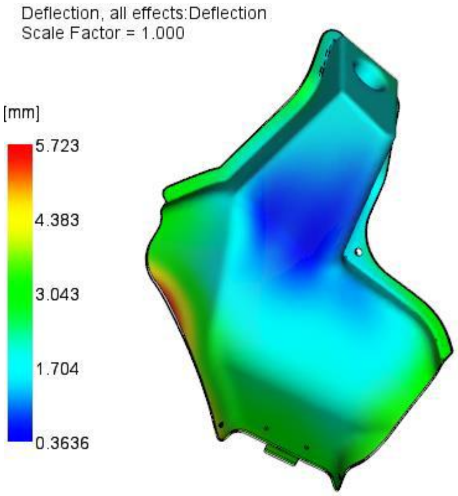
Molded Component Assembly--Mounting Analysis

Scandium Tech Preview

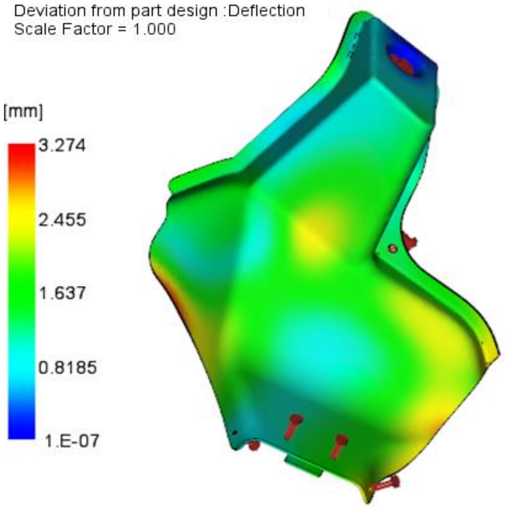


Mounting details





Warped shape without considering assembly



Final geometric deviation from designed shape and size after assembly

Considering Stress Relaxation

Scandium Tech Preview

3D Anisotropic Thermo-Viscoelastic Residual Stress Model

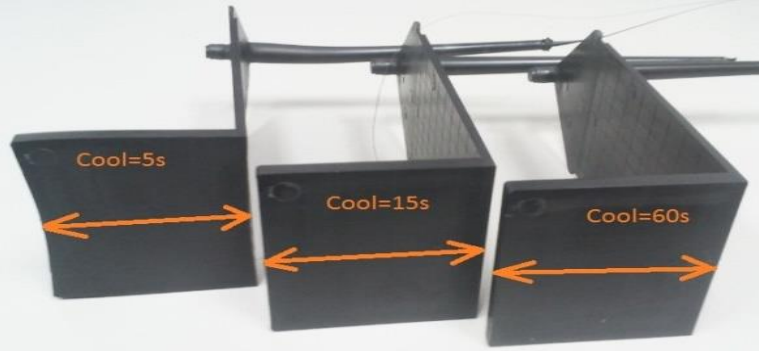
$$\sigma_{ij}(t) = \int_0^t C_{ijrs}\left(\xi_{(t)} - \xi_{(\tau)}\right)\left(\frac{\partial \varepsilon_{rs}}{\partial \tau} - \alpha_{rs}\frac{\partial T}{\partial \tau}\right)d\tau$$

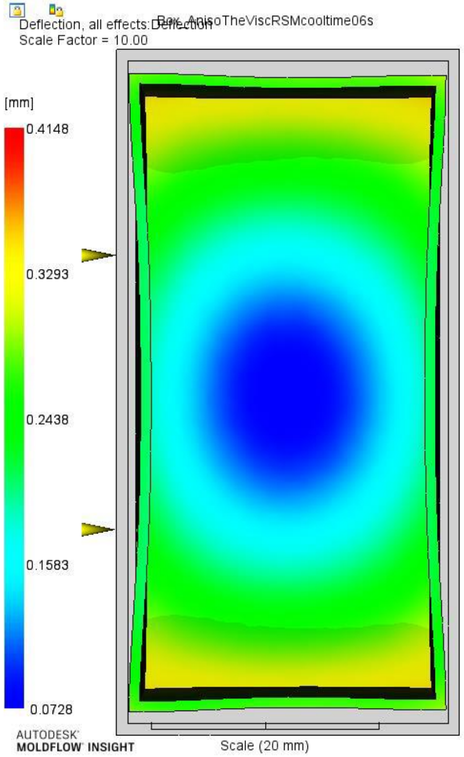
- Viscoelastic Material Modelling: Generalized Maxwell Model
  - $G(t) = G(0)\varphi(t) = G(0)[g_\infty + \sum_{k=1}^{N} g_k \exp(-\frac{t}{\tau_k})]$
- Shift factor for Time-temperature Superposition
  Tabulated shift Data, WLF equation, Arrhenius equation

Considering Stress Relaxation

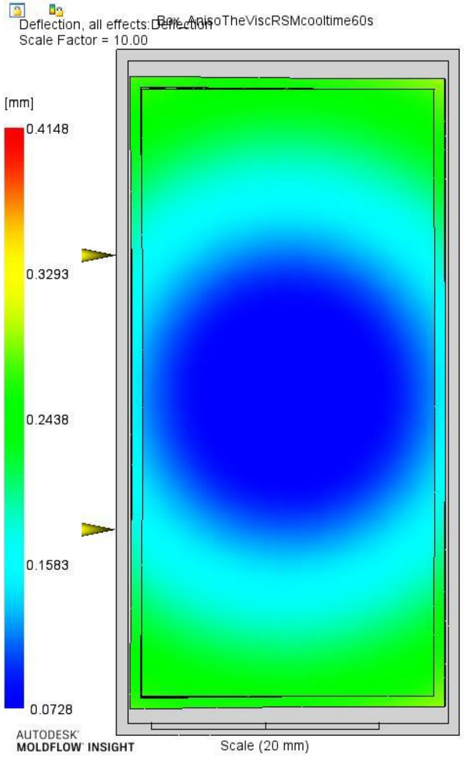
Scandium Tech Preview

- 3D Anisotropic Thermo-Viscoelastic Residual Stress Model
  - Stress relaxation (viscoelastic)
  - Long cooling time effect: 6 sec (left) and 60 sec (right)
  - Liquid portion at ejection
  - Solidification sequence effect





Cooling Time = 6 sec

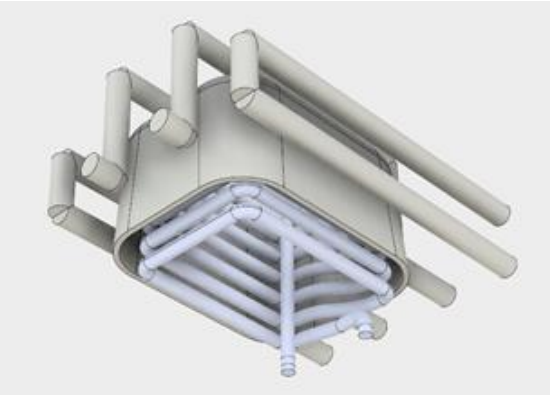


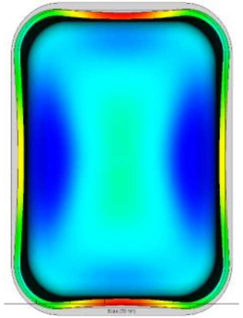
Cooling Time = 60 sec

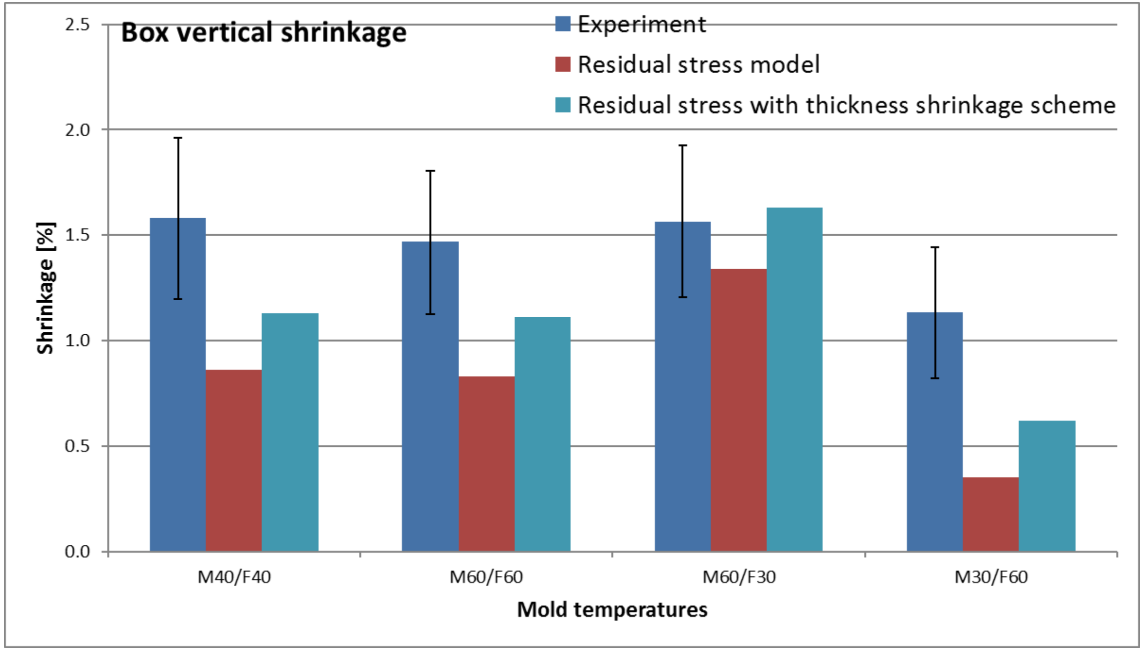
Thickness Shrinkage Scheme

Scandium
Tech Preview

- Consider that shrinkage in thickness direction is higher than in-plane directions due to mold restraint effects





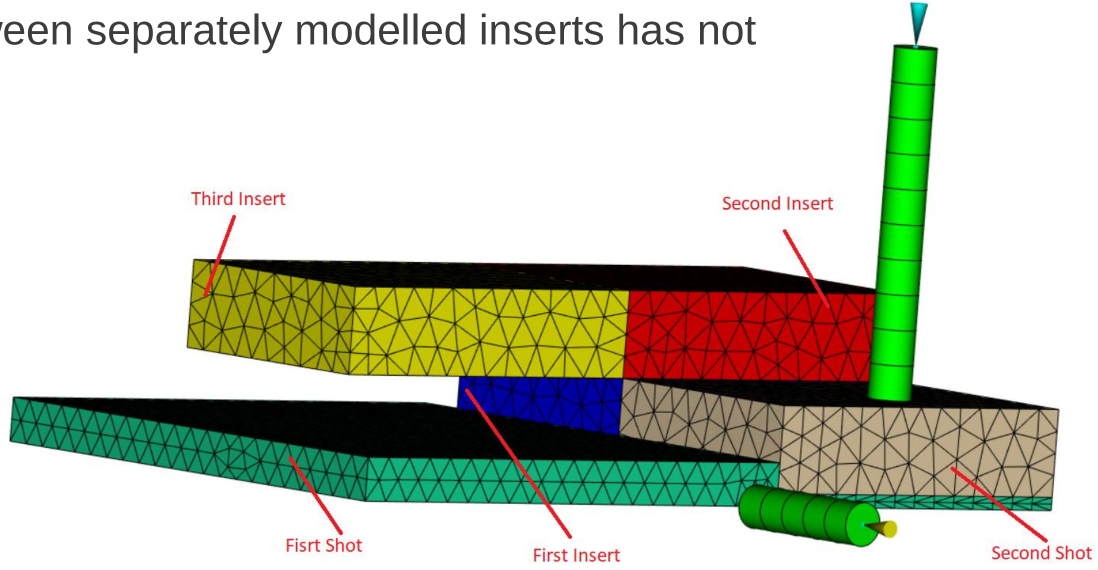


Handle Insert-insert Interface for Overmolded Parts

- AMI2019 warpage considers the bonded interface between
  - 1st Shot and Inserts
  - 2nd Shot and Inserts
  - 1st Shot and 2nd Shot

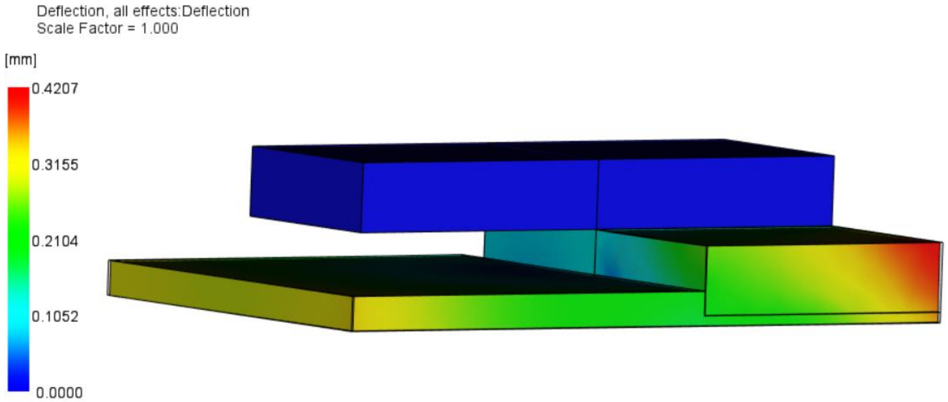
- Limitation: the bonded interface between separately modelled inserts has not been properly handled.

- The limitation has been eliminated!
  - Contact between all components is now handled

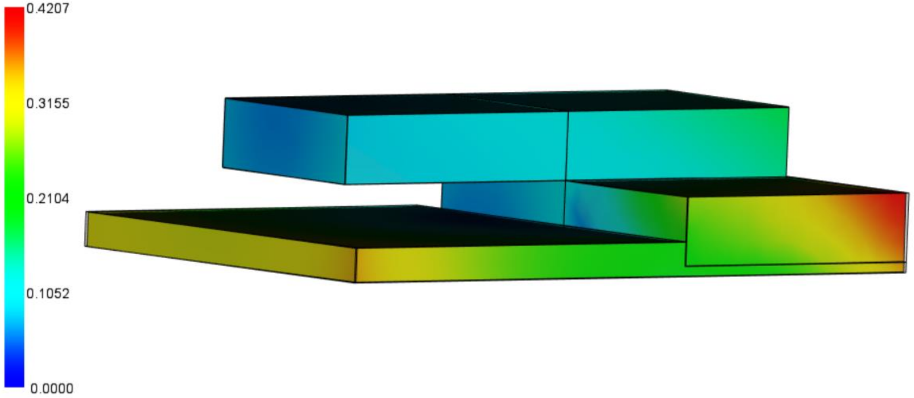


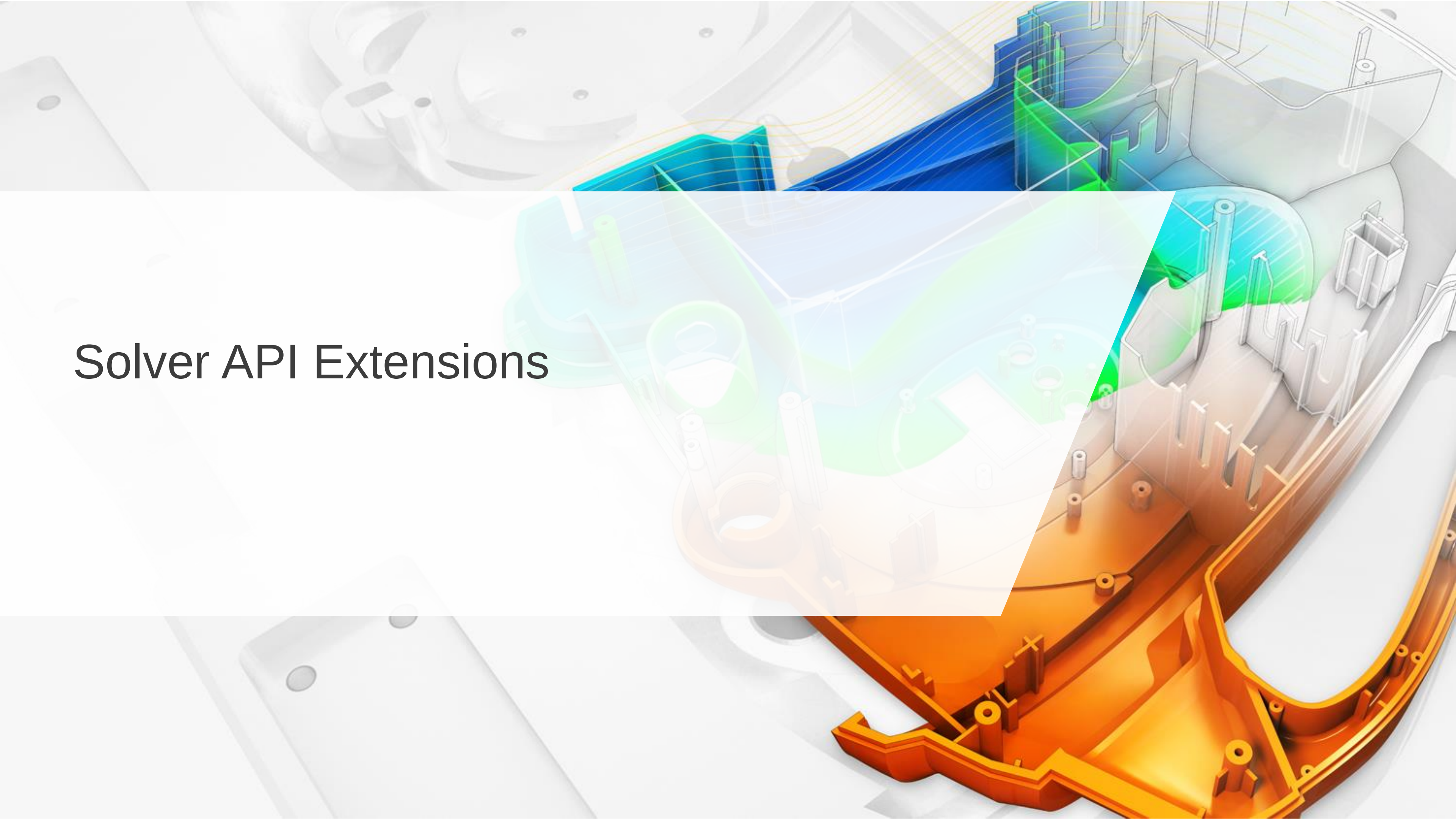
Handle Insert-insert Interface for Overmolded Parts

- AMI2019 Result:
  - 1st insert and 2nd insert are not involved in the warpage: no deformation at all



- After considering the bonded interface between inserts, 1st insert and 2nd insert are deformed together with other components!





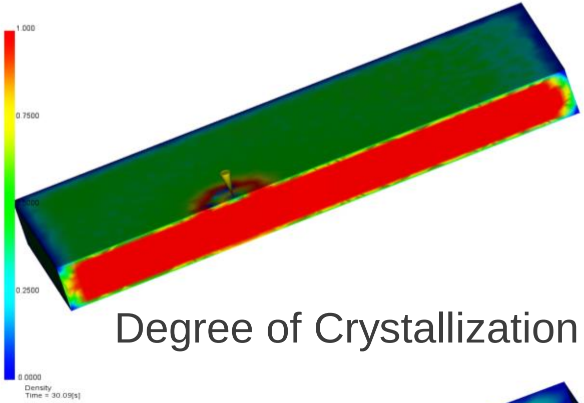
Solver API Extensions

Solver API Extensions

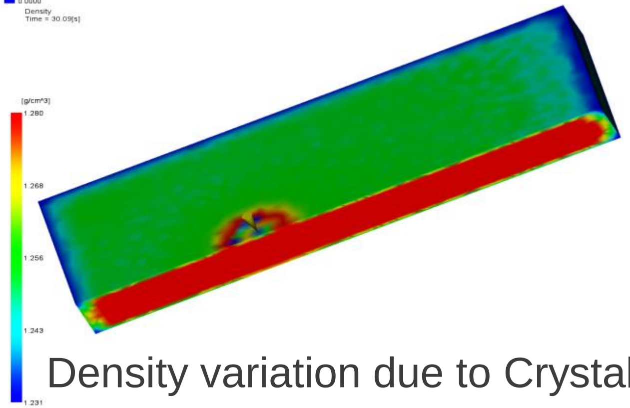
Example: Nakamura Crystallization model

Open Framework for external researchers

- Existing functions allow user coded viscosity, PVT, Solidification & Core-shift
- Next major release:
  - Provide general purpose convection of any user calculated quantity.
    - E.g. Degree of crystallization
  - User calculation of Fiber Orientation
    - Will be used by Warp and Mechanical Properties
  - Access powder concentration result at each node
  - Access average fiber length result at each node
  - Access material identifiers
  - Proposed: Control time-step and injection speed/pressure

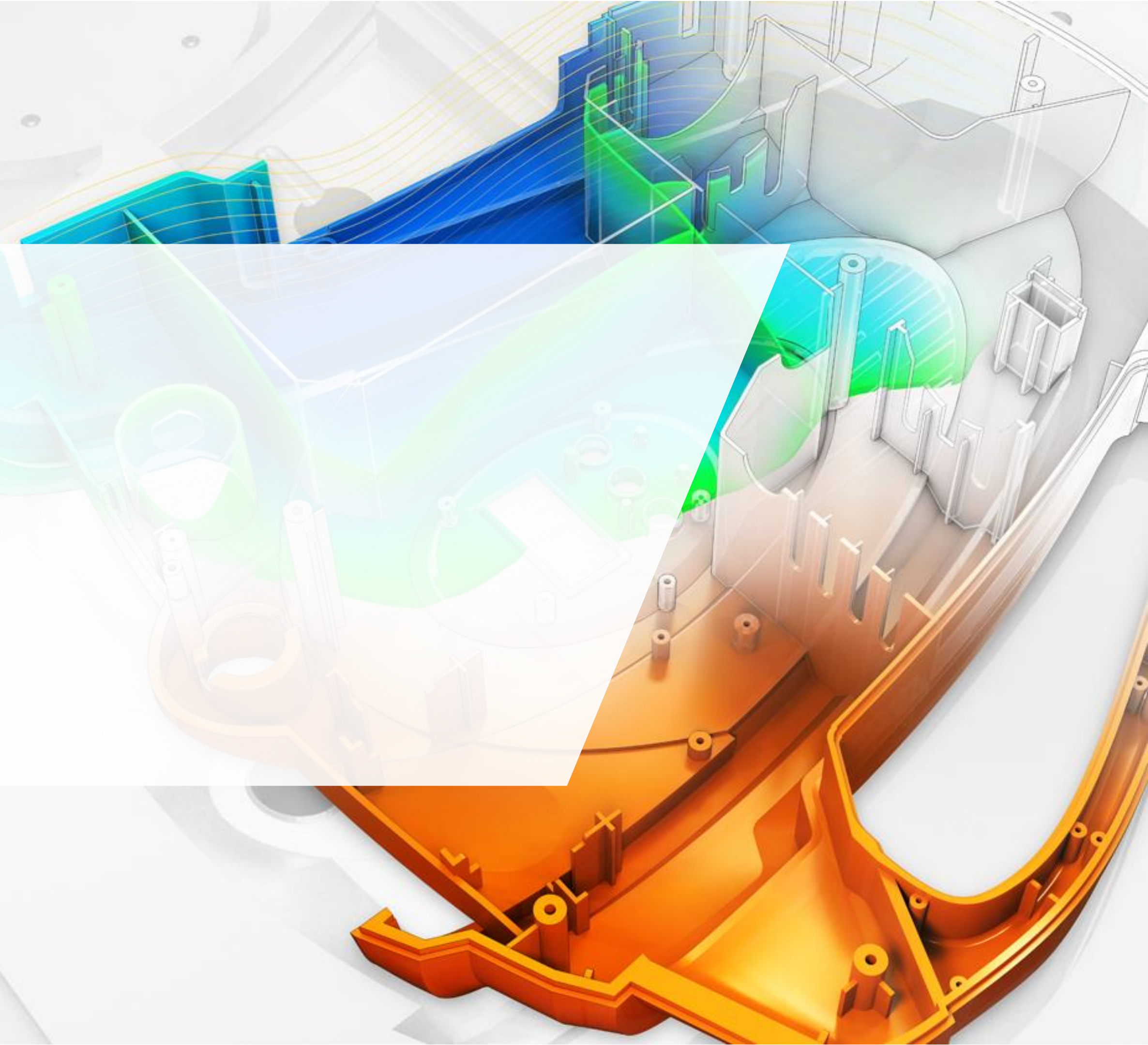


Degree of Crystallization



Density variation due to Crystallization

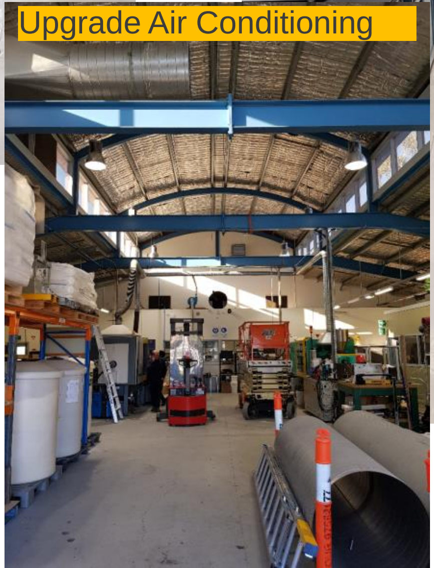
Autodesk Plastics Lab



Lab Refurbishment

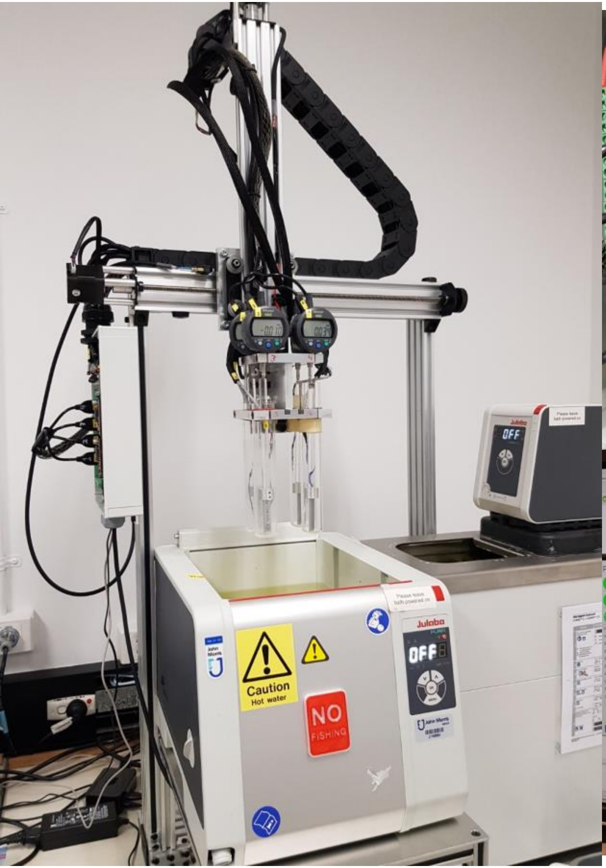

Arburg Electric IMM

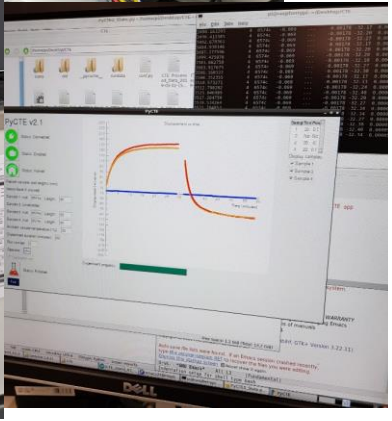

Repaint


Upgrade Air Conditioning


Materials Storage (300-400 bags)

New Device: Coefficient of Thermal Expansion





OBJECTIVE

- Increased capacity
- Up to 3 materials per day
- Flow & transverse (x4)

STATUS

- Mechatronics designed and built
- Software drafted
- Usability and performance testing in progress

Viscosity & PVT

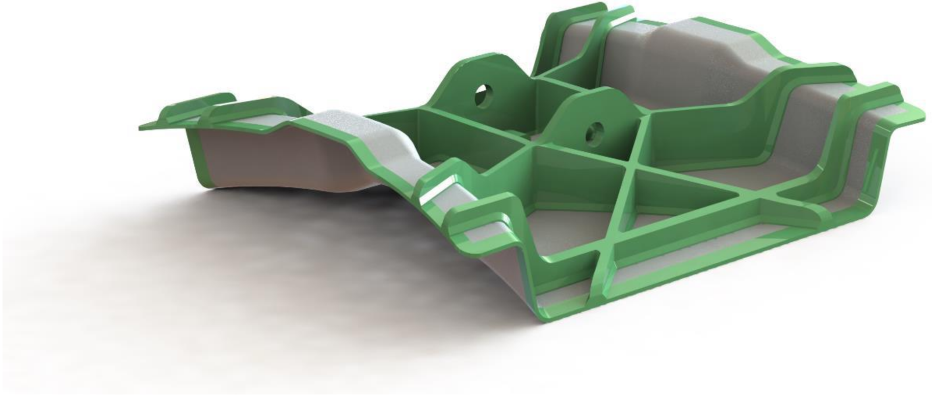
New Slit Die Injection Molding Rheometer

- New Slit Die Injection Molding Rheometer
  - Multiple pressure sensors for pressure dependency measurement
  - Suitable for long fiber material
- Building a 3rd PVT Device
  - Allow greater throughput of testing
  - Indirect dilatometry – Similar to existing Gnomix devices

External Research Collaborations

External Research Collaborations

- Composite Injection Overmolding (TPRC)
- Fiber breakage in Barrel (U of Bradford)
- Microcellular Foam Injection Molding (U of Toronto)
- Fiber Effect on Viscosity (RMIT, Australia)
- Microchip Panel Encapsulation (iNEMI)
- Wall Slip & Fiber breakage (U of Tokyo)



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