Autodesk Moldflow

Moldflow Research & Development

Dr Shishir Ray

Research Manager: Geometry, Mesh, & Solver

AUTODESK

Research & Development

Research In-house

- 24 PhD employees in Moldflow development
- A Lab with state-of-the-art equipment
  - Four modern injection molding machines for test & validation
  - Establishing a network of third-party Labs

Academic Research Collaboration

- Six Universities with seven PhD students

Industrial Research Partnerships

- Over 20 companies and institutions

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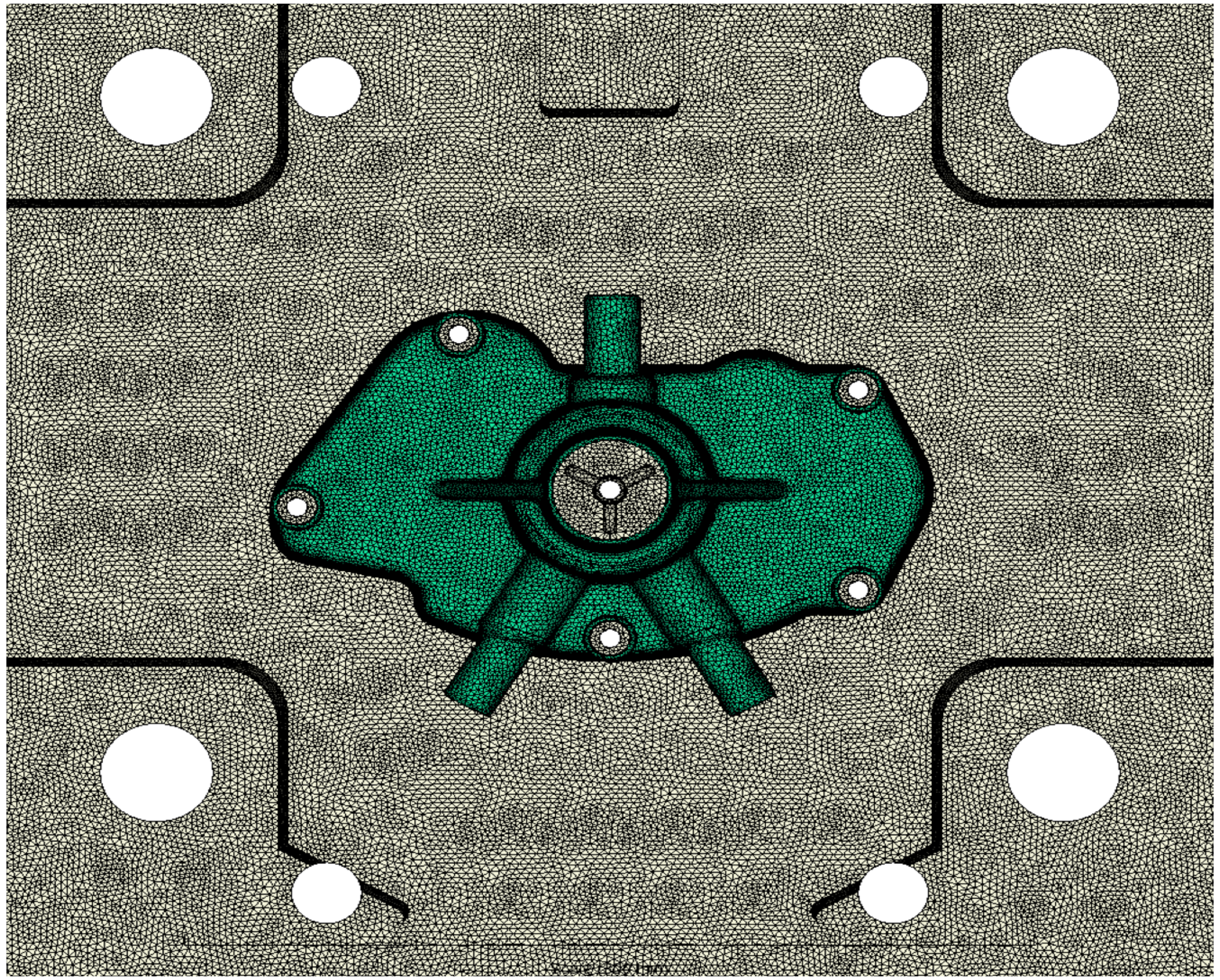
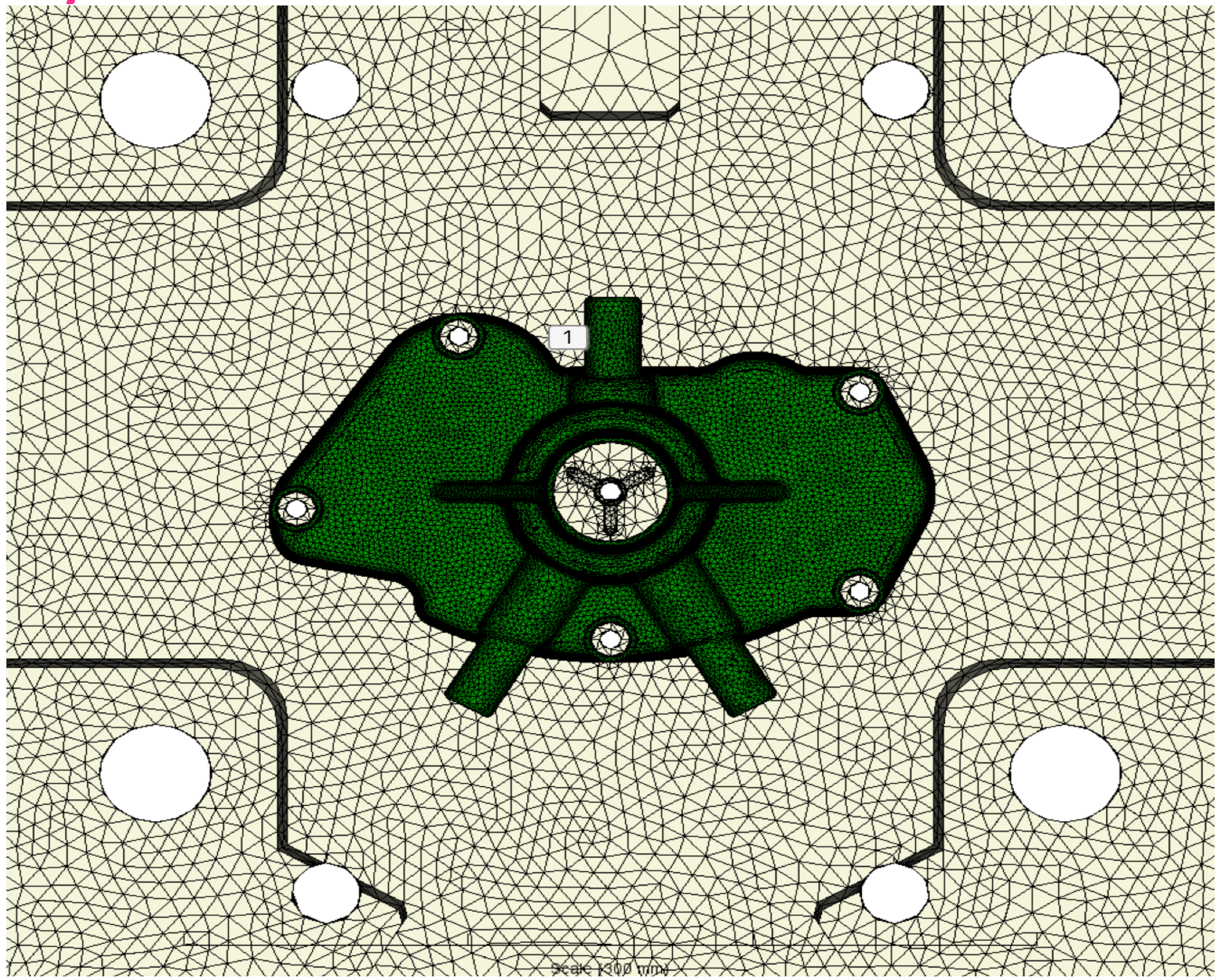
Auto Sizing for CAD

2017.3

AMI 2017: One global edge length, no chord angle.
10 M Tets.



New: Separate global edge length for each body.
Chord angle on selected faces.
1.7 M Tets.
7 days to 4min.



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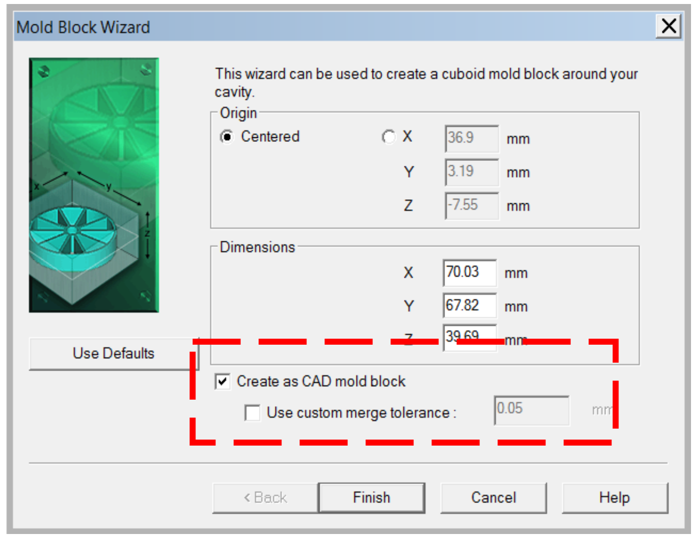
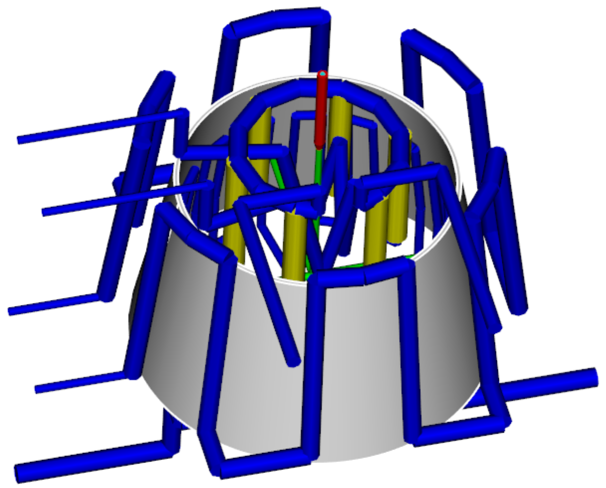
Create CAD Bodies for Mold Blocks

2017.3

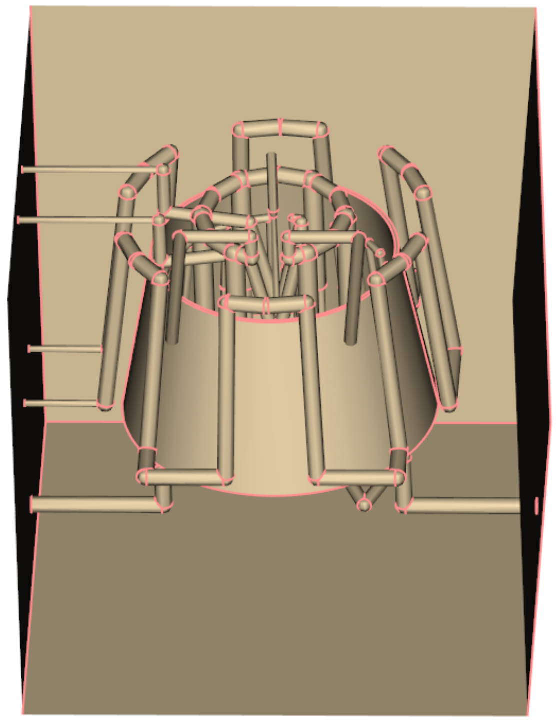
Previously, mold blocks are represented by regions.
Users need to stitch contact interfaces to form mold internal boundary

Now we can create CAD bodies for mold blocks.
Users do NOT need to stitch contact interfaces manually

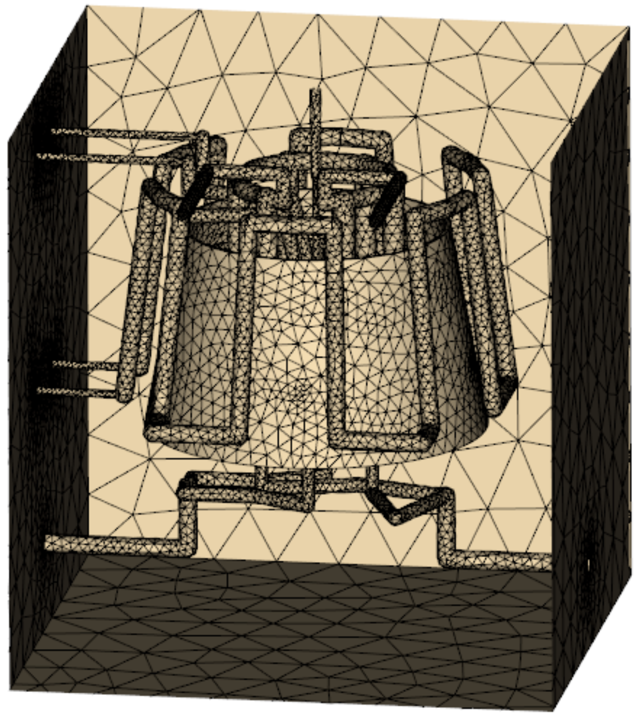




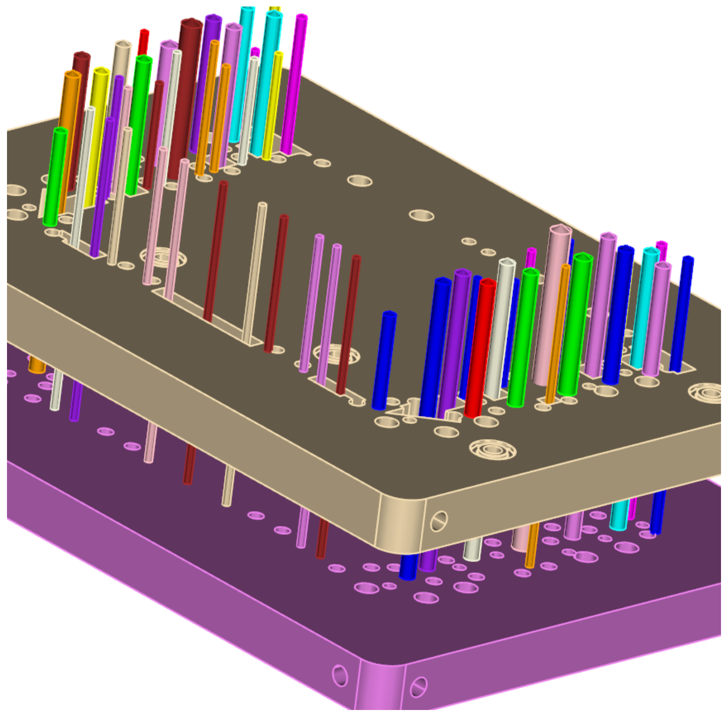
Internal components



CAD body for mold block



Surface mesh for mold block



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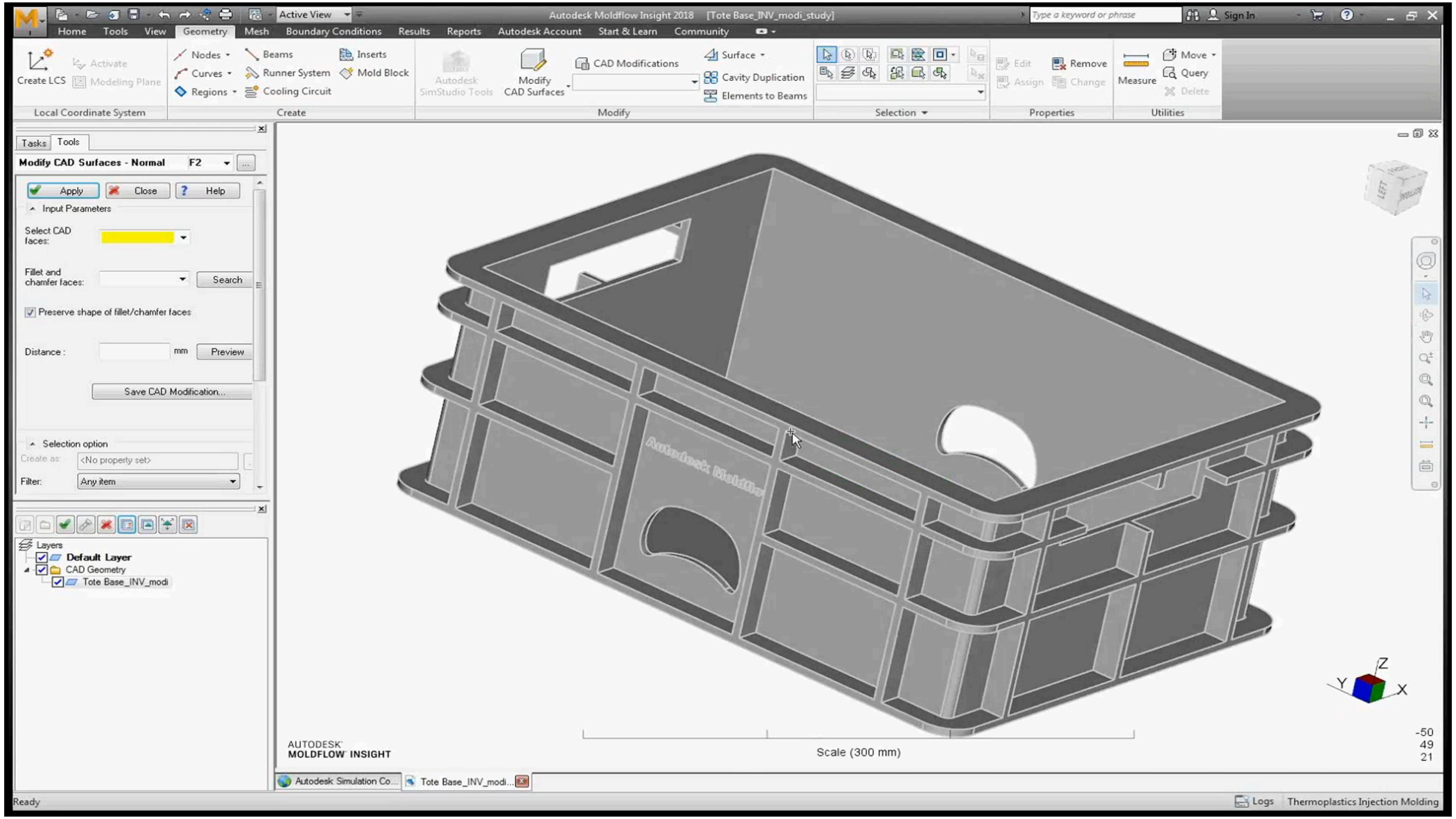
Define Your Own Feature - DYOF

2018.0

Modify CAD shape by changing parameters

Identify a collection of faces (features), & Move them using a vector or a normal



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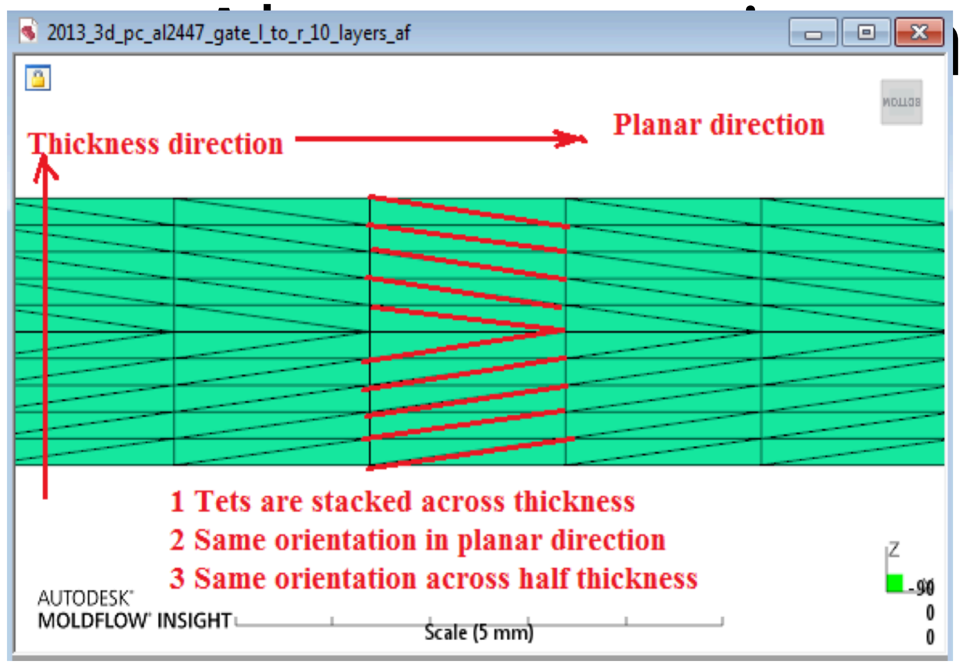
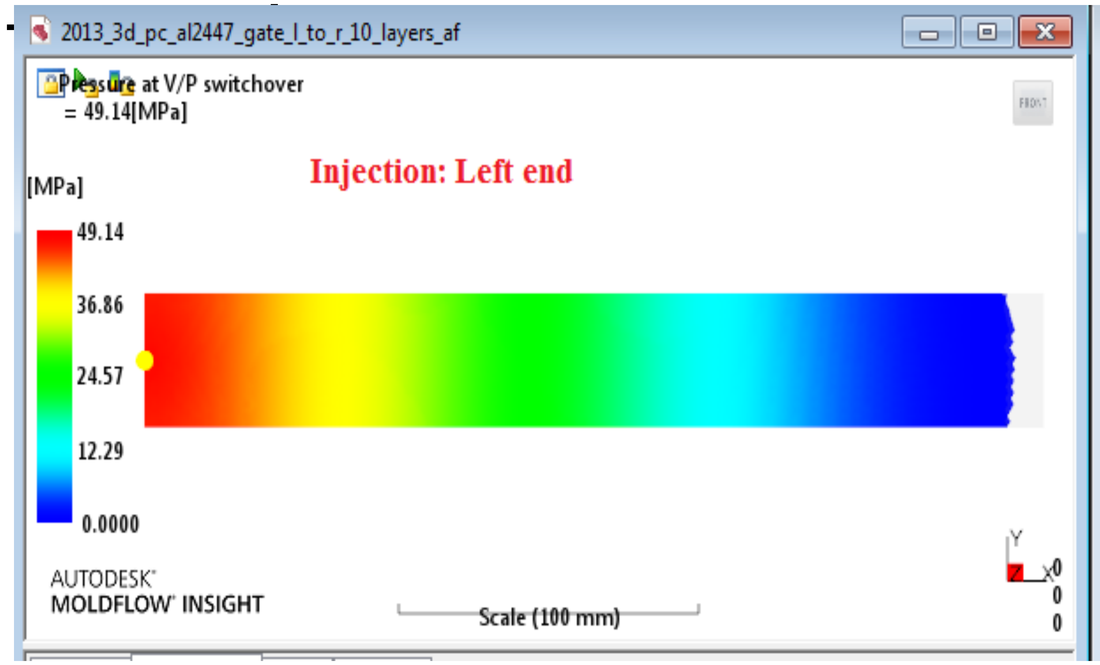
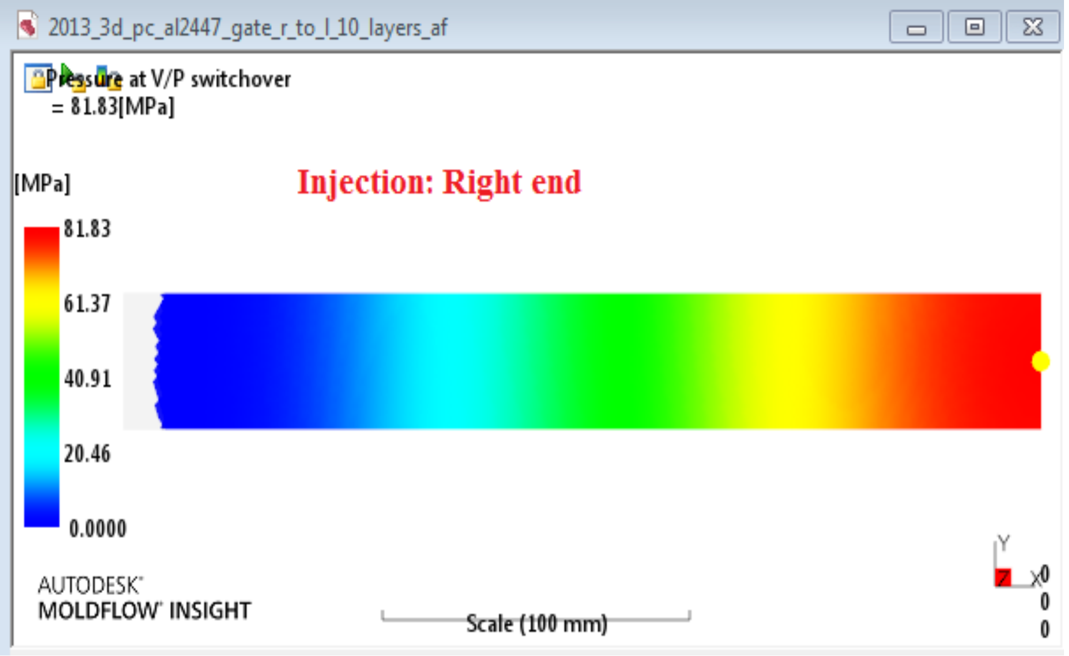
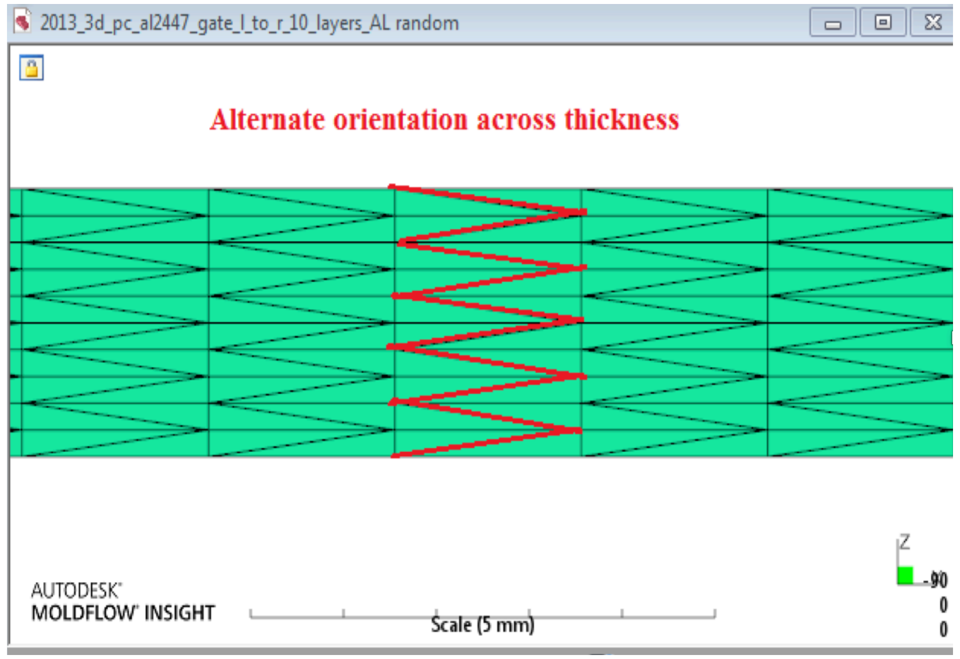
Mesh Improvements

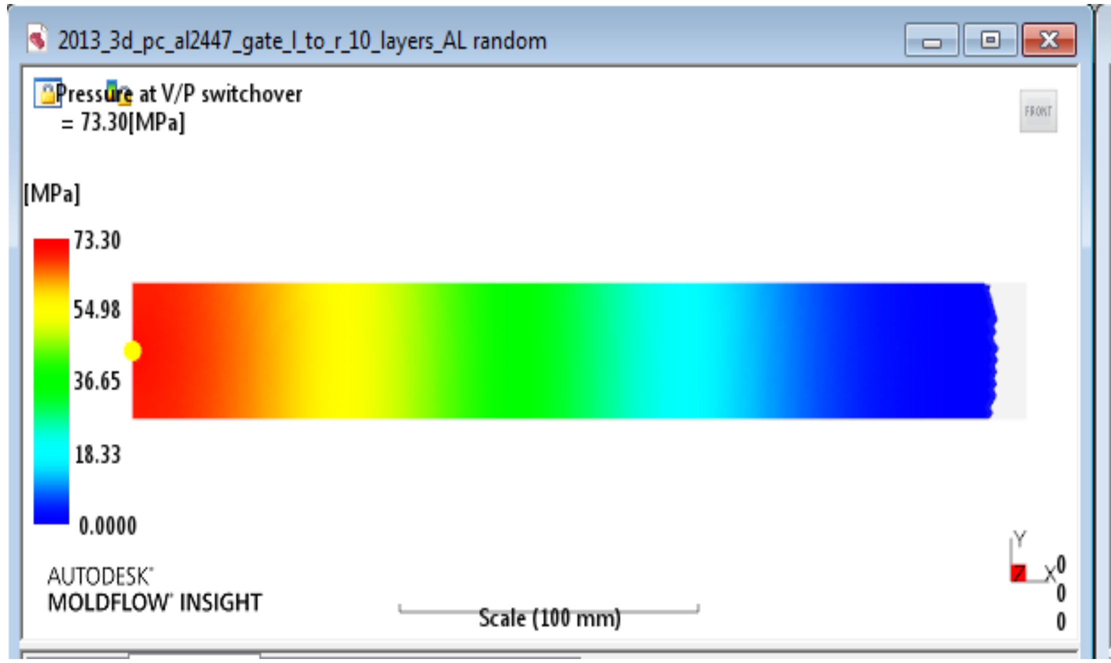
2017.0

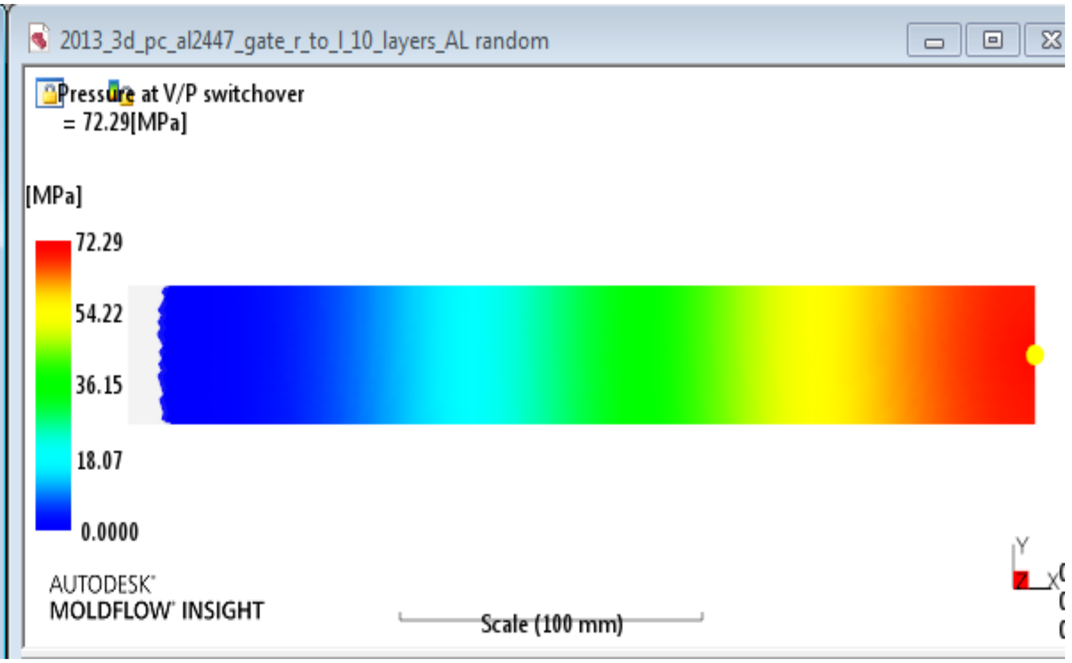












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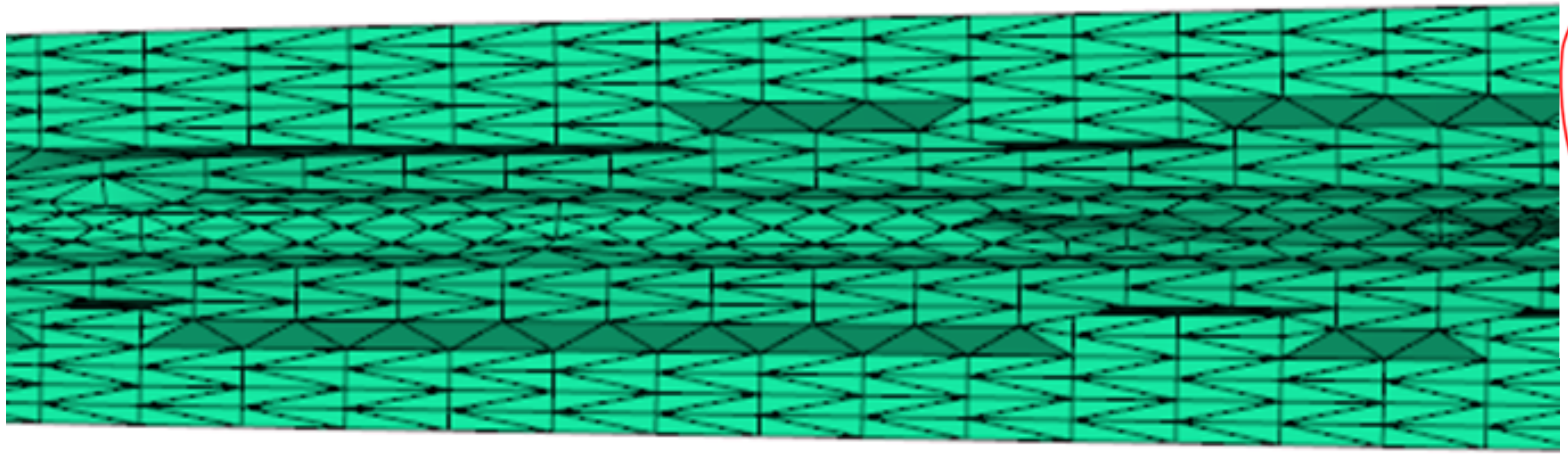
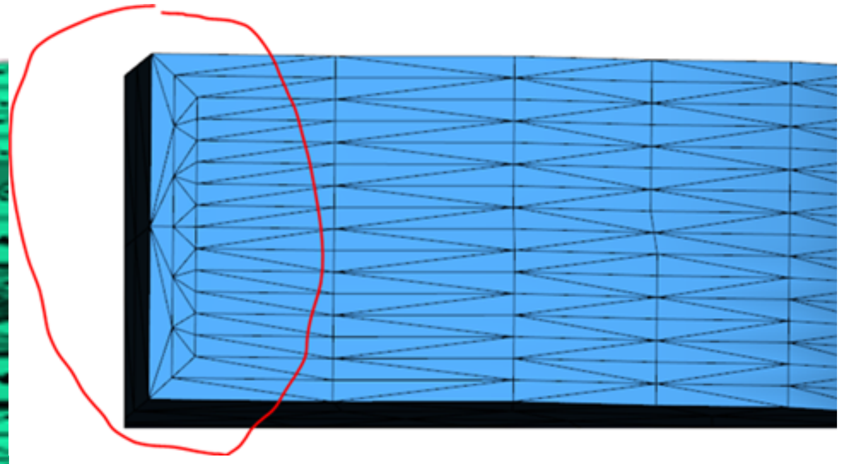
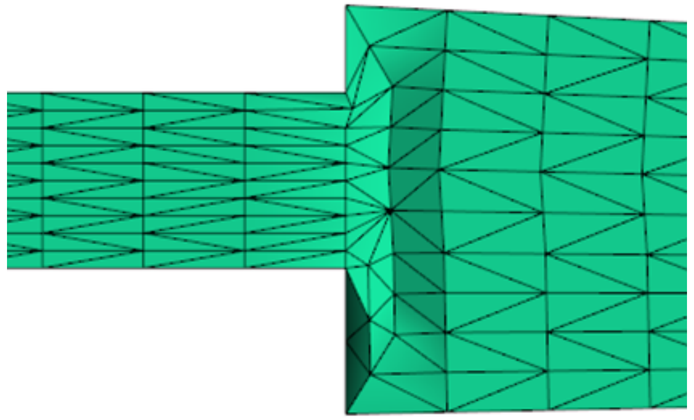
New 3D Mesher

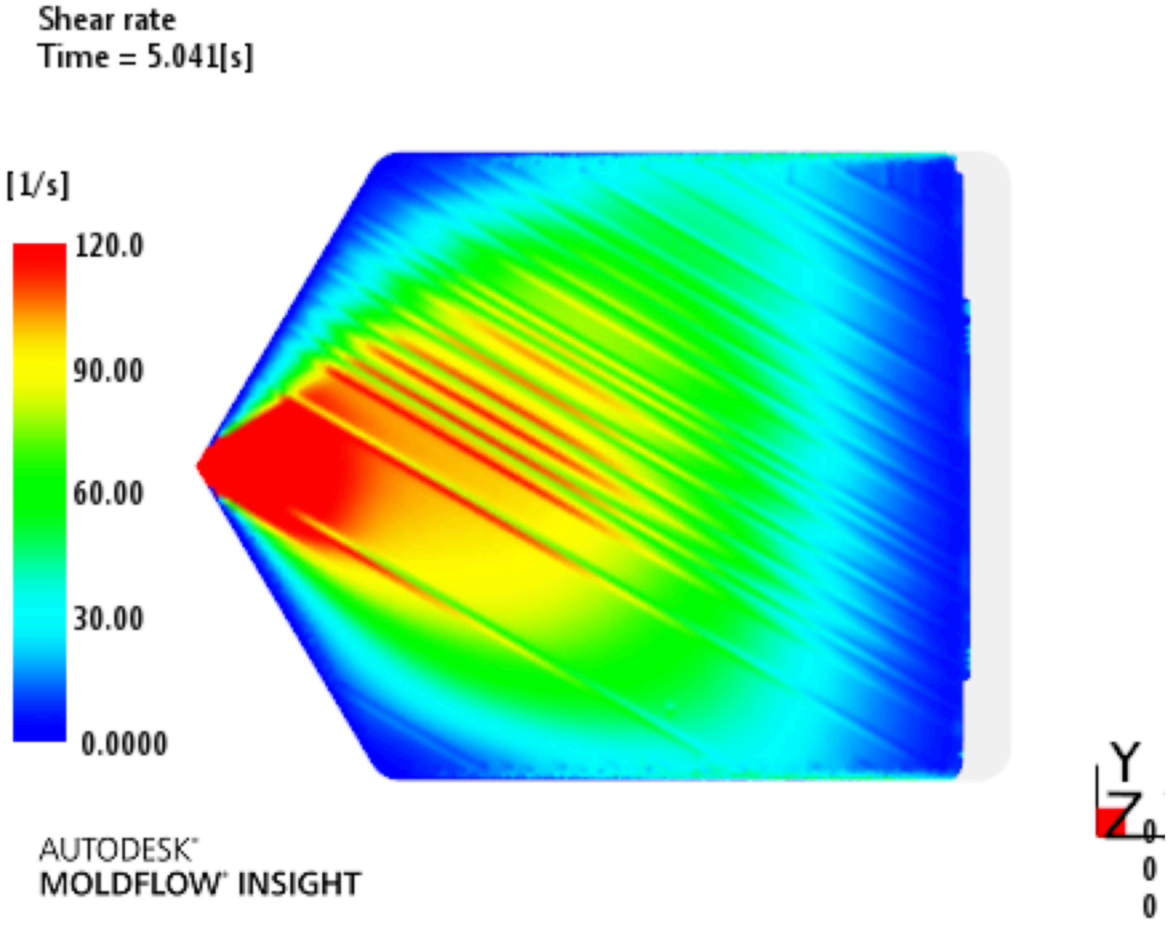
2017.0

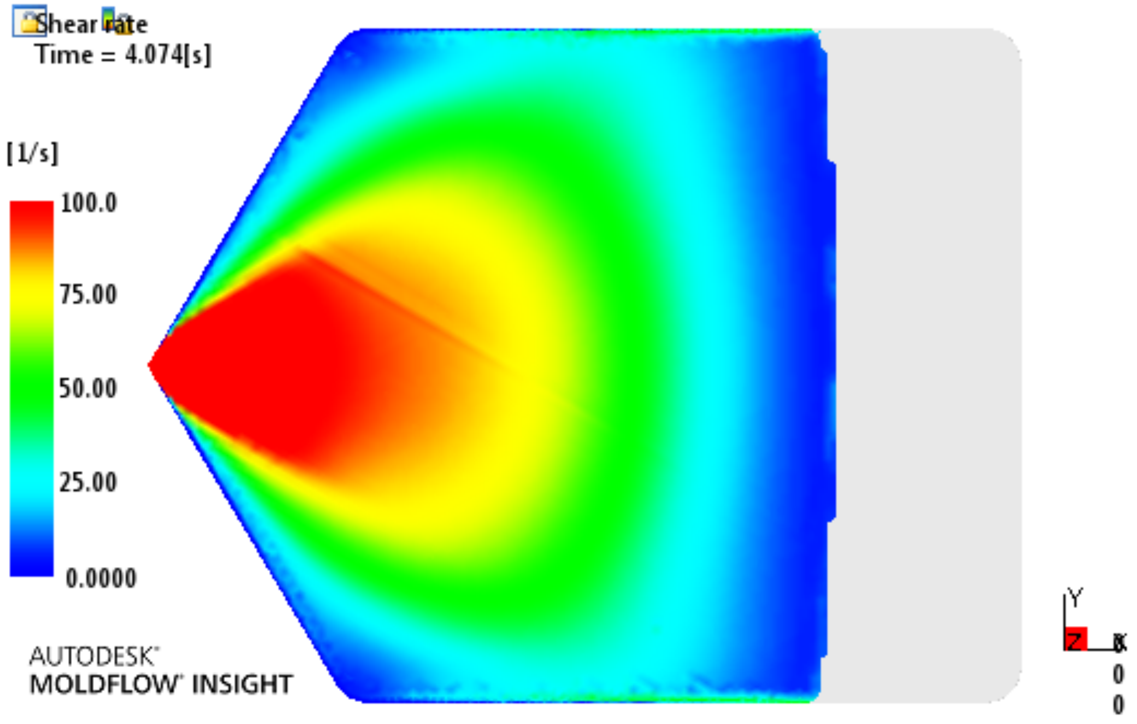
More smooth near edges and corners











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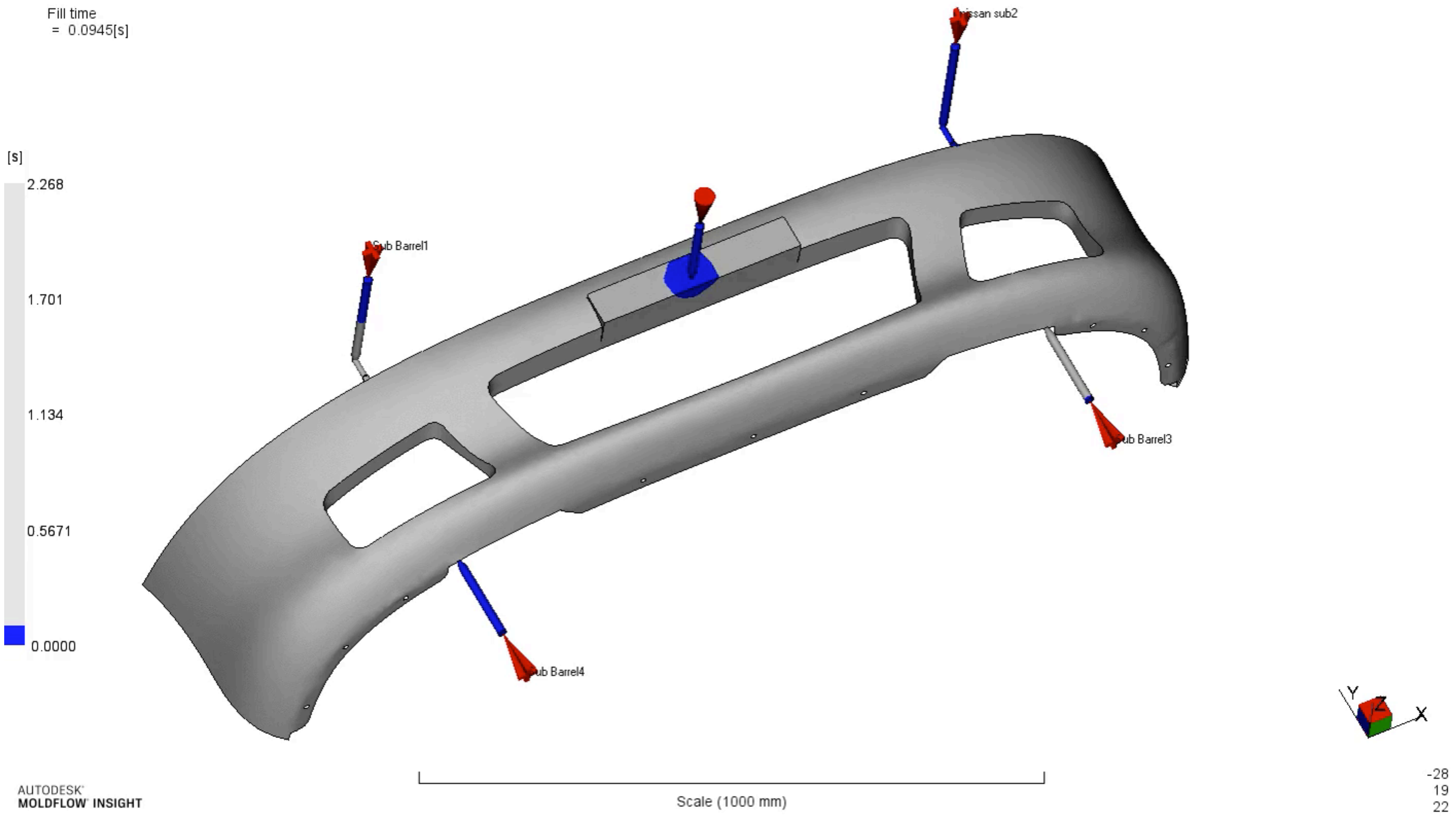
Multi-barrel Injection Molding Simulation

2018.0

Master Barrel with 4 sub-barrel

Delay time 0.25 s and 0.5 s for sub3 and sub 4, respectively



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RTM and SRIM in 3D

2017.2

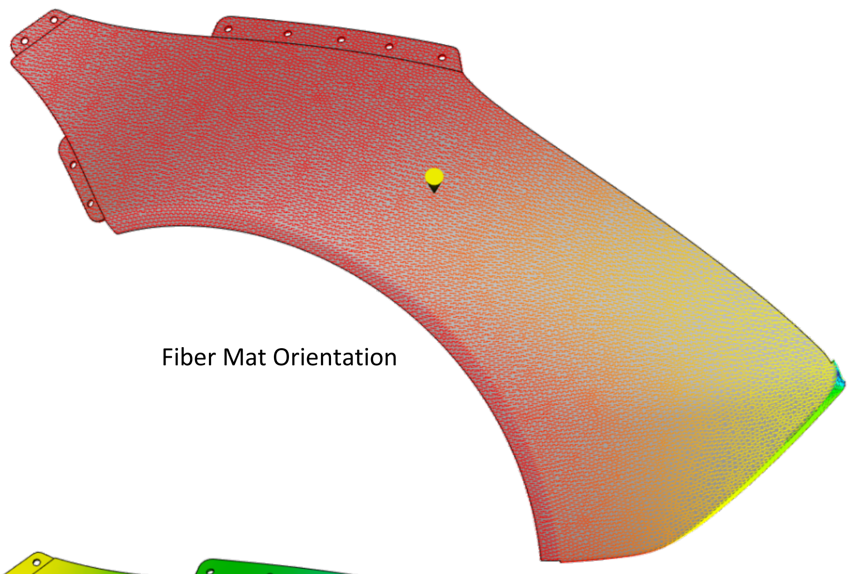
Features

Apply a dry fiber mat properties where needed.

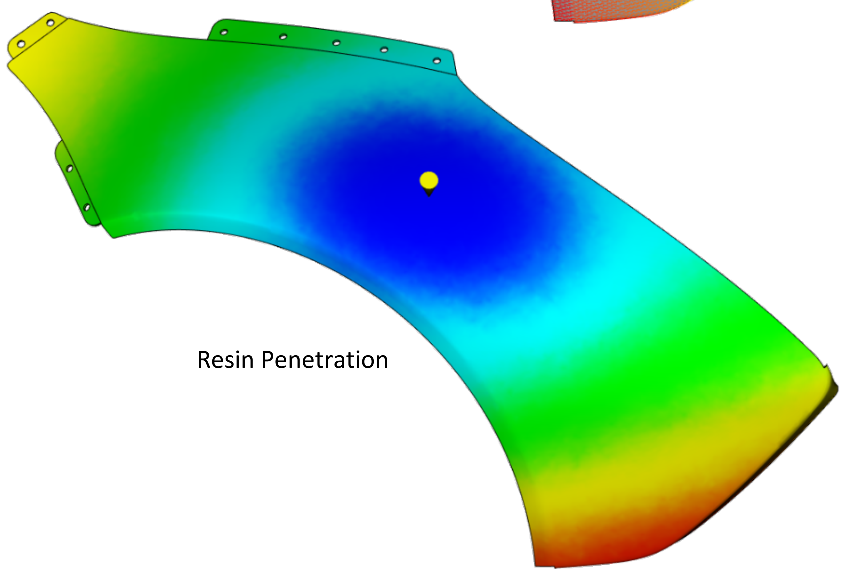
Anisotropic permeability follow the shape of the product.

Detect areas where resin cannot penetrate.

Include Vacuum pressure & Gravity.



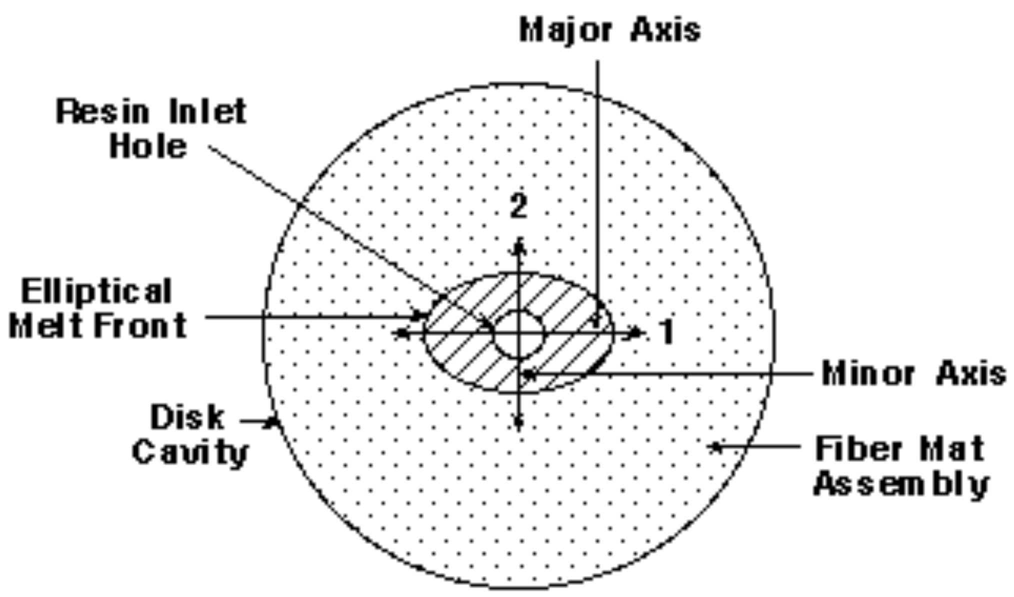
Fiber Mat Orientation

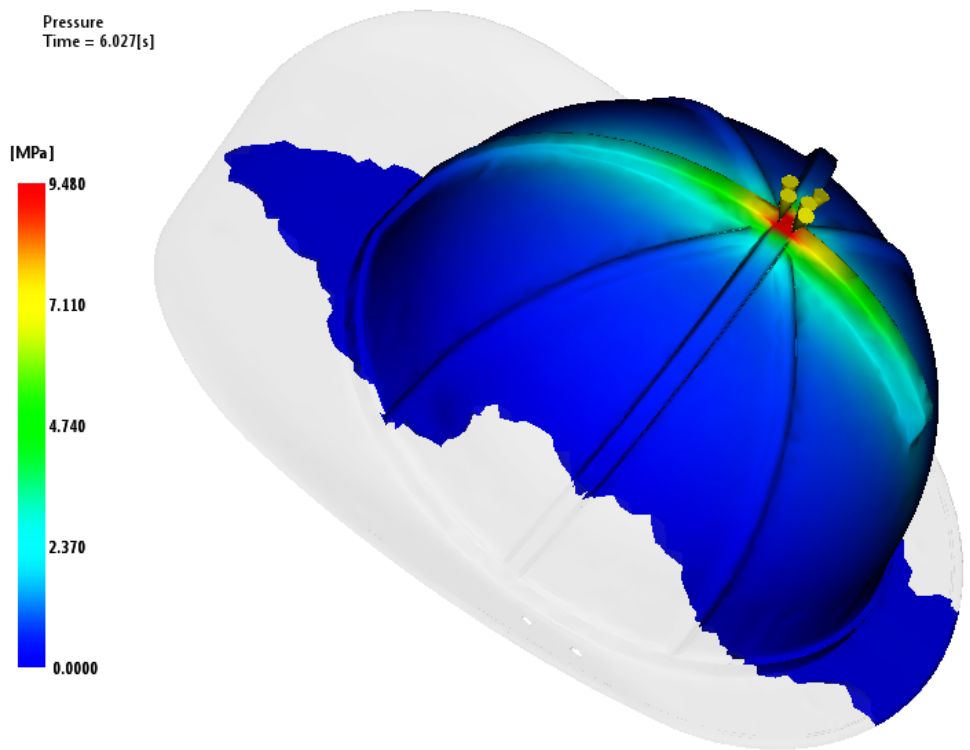


Resin Penetration

Results

Degree of Cure, Volumetric shrinkage, Mat orientation, etc.





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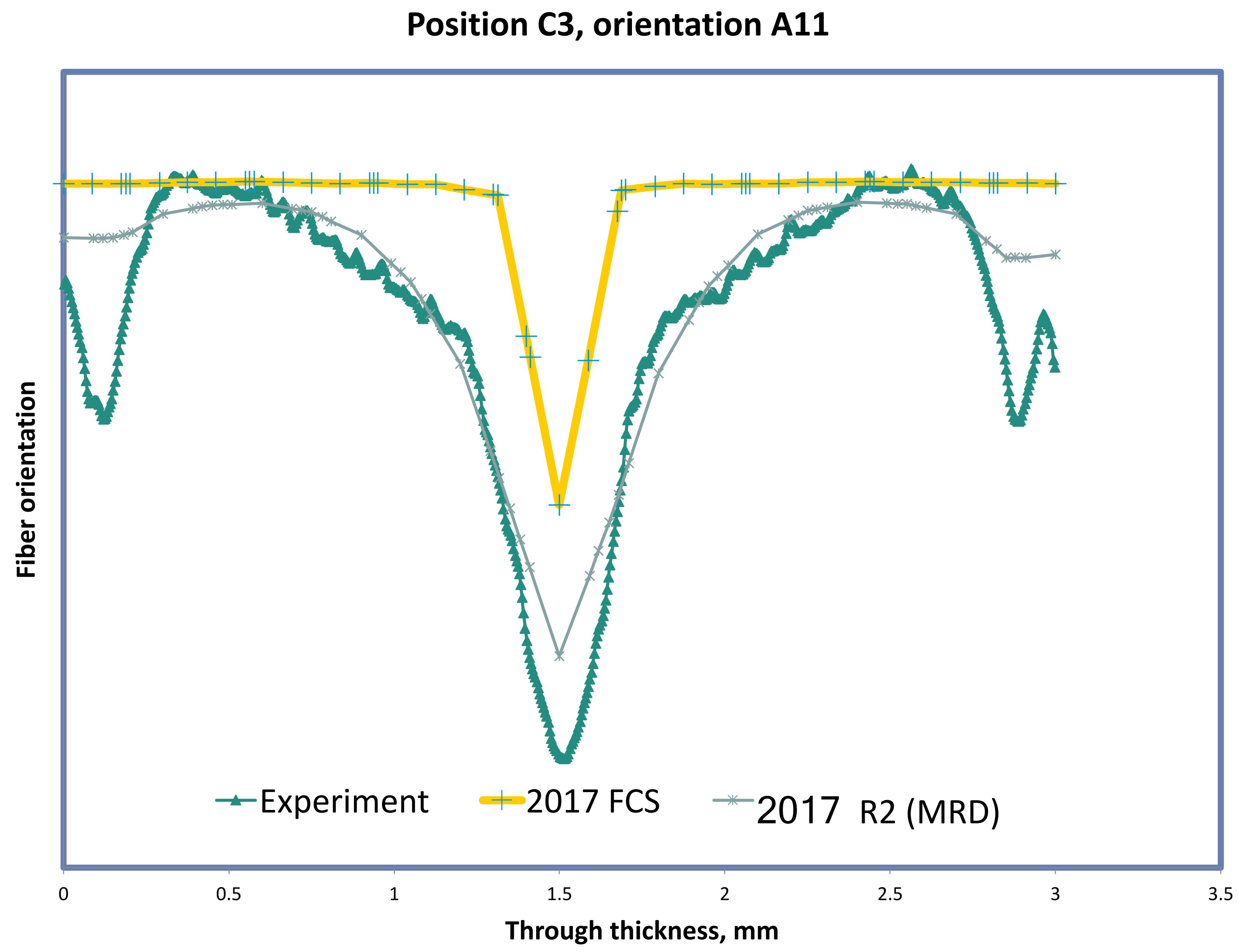
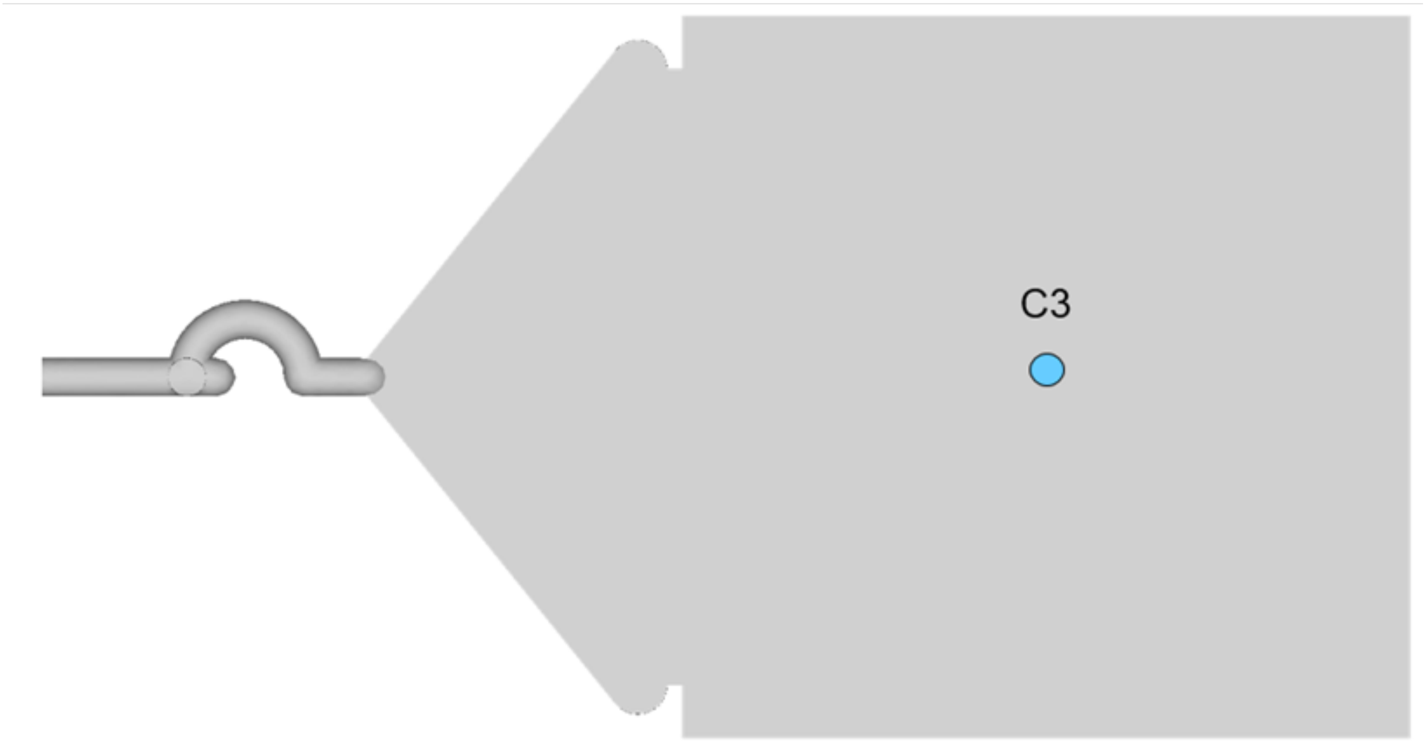
Improved 3D Fiber Orientation

2017.2



Implementation of a New Model

MRD (Moldflow Rotational Diffusion)



Measured data provided by BASF

BASF PA 30%GF

BASF We create chemistry

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Validation

2017.2

Average error of predictions for different releases and constitutive models.
Results for the default models are in **bold**

AMI release	Constitutive model	BASF	Bradford	Delphi	DSM	EMS	Mechanical Plaque
Number of cases		1	2	23	1	1	1
Number of locations for each case		9	3	3	6	1	1
2017FCS	**F-T**	**0.16**	**0.20**	**0.14**	**0.11**	**0.23**	**0.17**
	RSC	0.11	0.12	0.11	0.089	0.16	0.14
2017 R2	F-T	0.091	0.16	0.11	0.079	0.16	0.13
	RSC	0.076	0.11	0.10	0.077	0.14	0.10
	MRD	**0.071**	**0.11**	**0.08**	**0.054**	**0.12**	**0.085**

2017 R2 halves the average error of fiber orientation predictions

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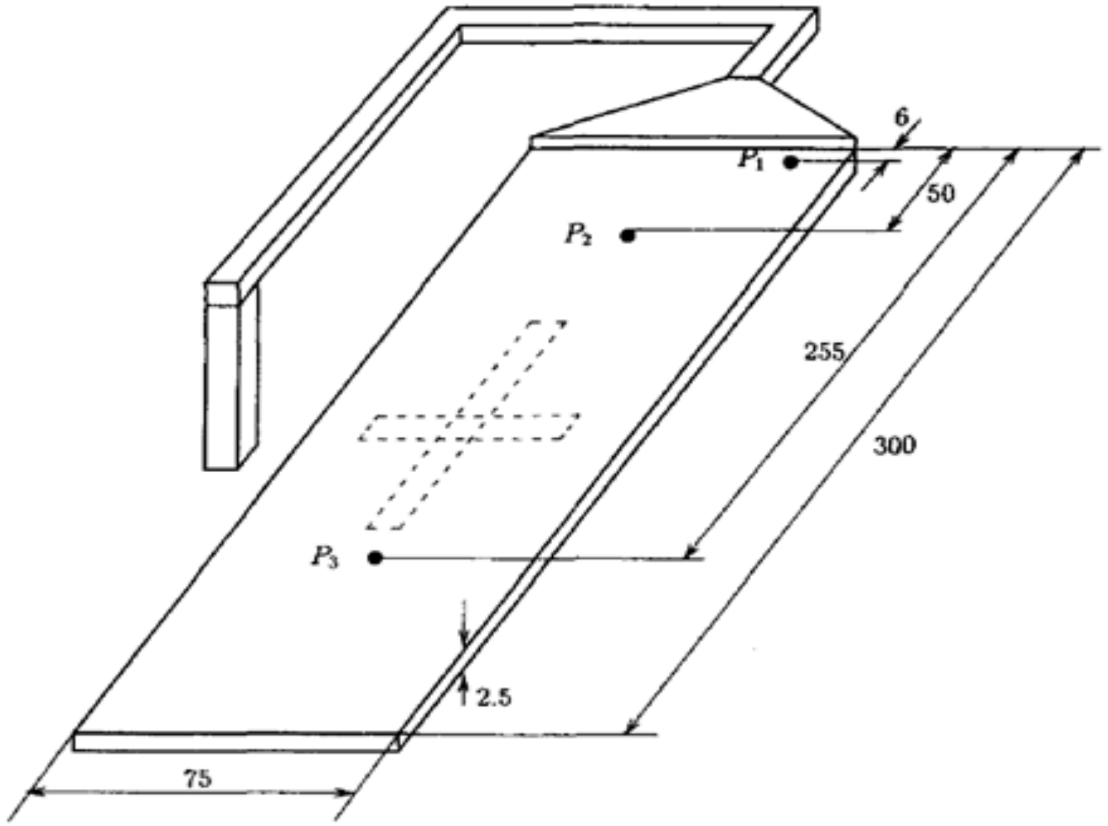
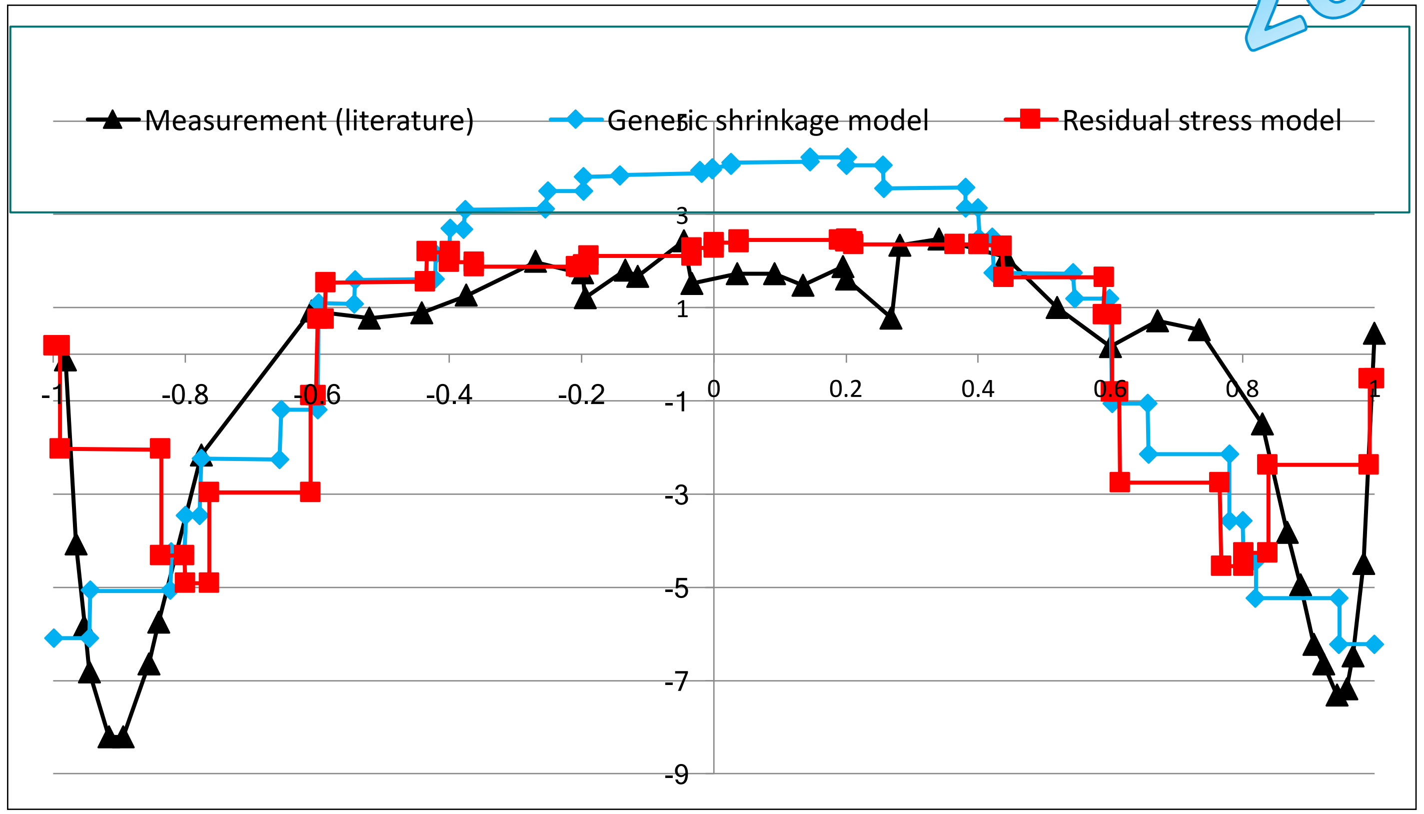
3D Residual Stress

2017.2

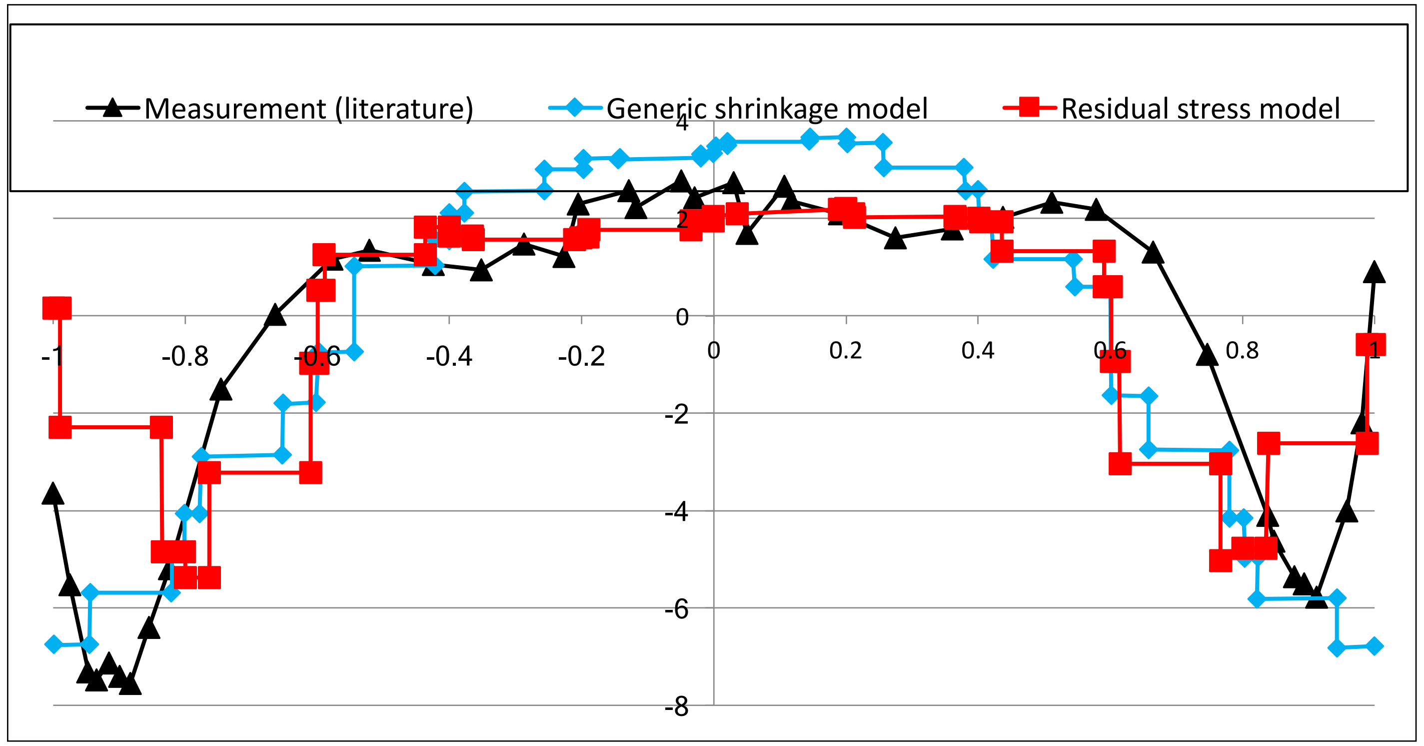
Molded-in residual stress prediction



Experimental data using layer removal method from W.F.Zoetelief, L.F.Douven, and A.J. Ingen Housz. Polymer Engineering and Science, 36(14), 1886-1896



$б_{xx}$



$б_{yy}$

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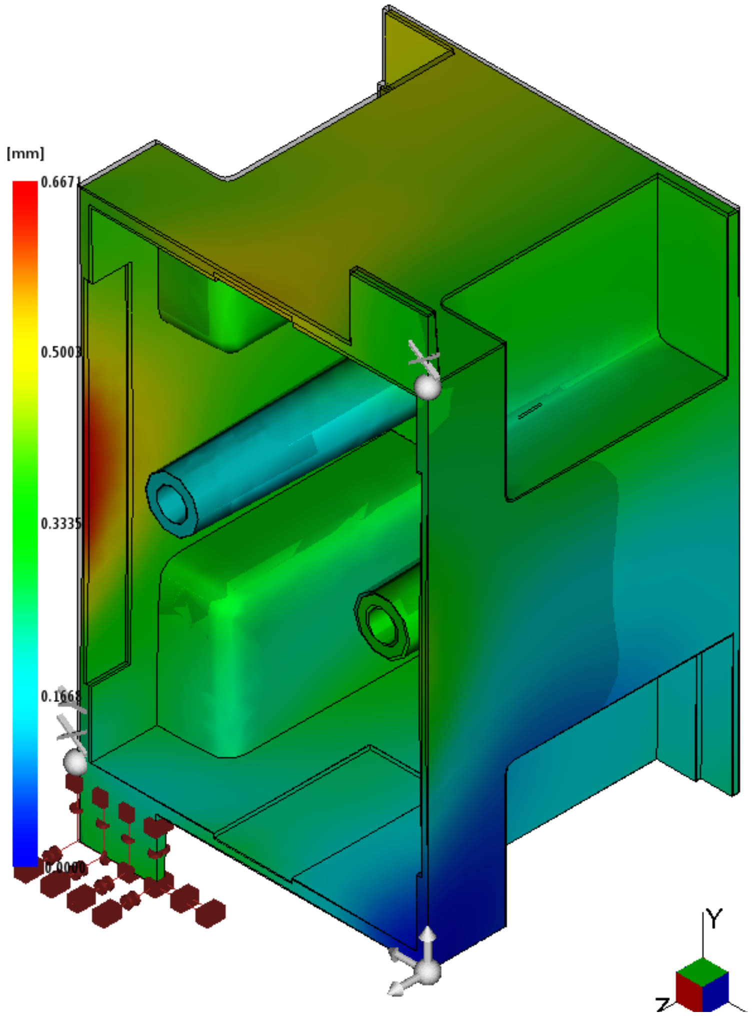
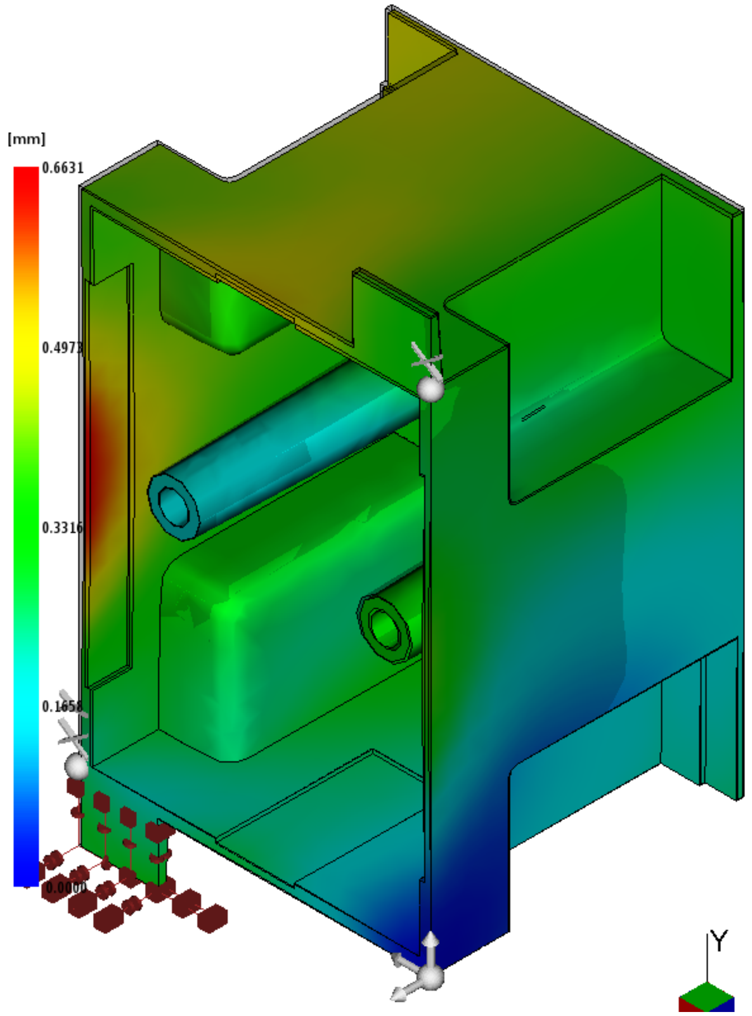
Mesh Aggregation for Isolating Cause of Warpage

2017.0

Combining the two helps users make product design decisions in a shorter time



No mesh aggregation



Mesh aggregation

	Total effect	Diff. cooling	Diff. shr.	Orient. eff.	Time (s)
No aggregation	0.6671	0.1993	0.5762	0.1967	1037
Aggregation	0.6631	0.1963	0.5787	0.1975	238

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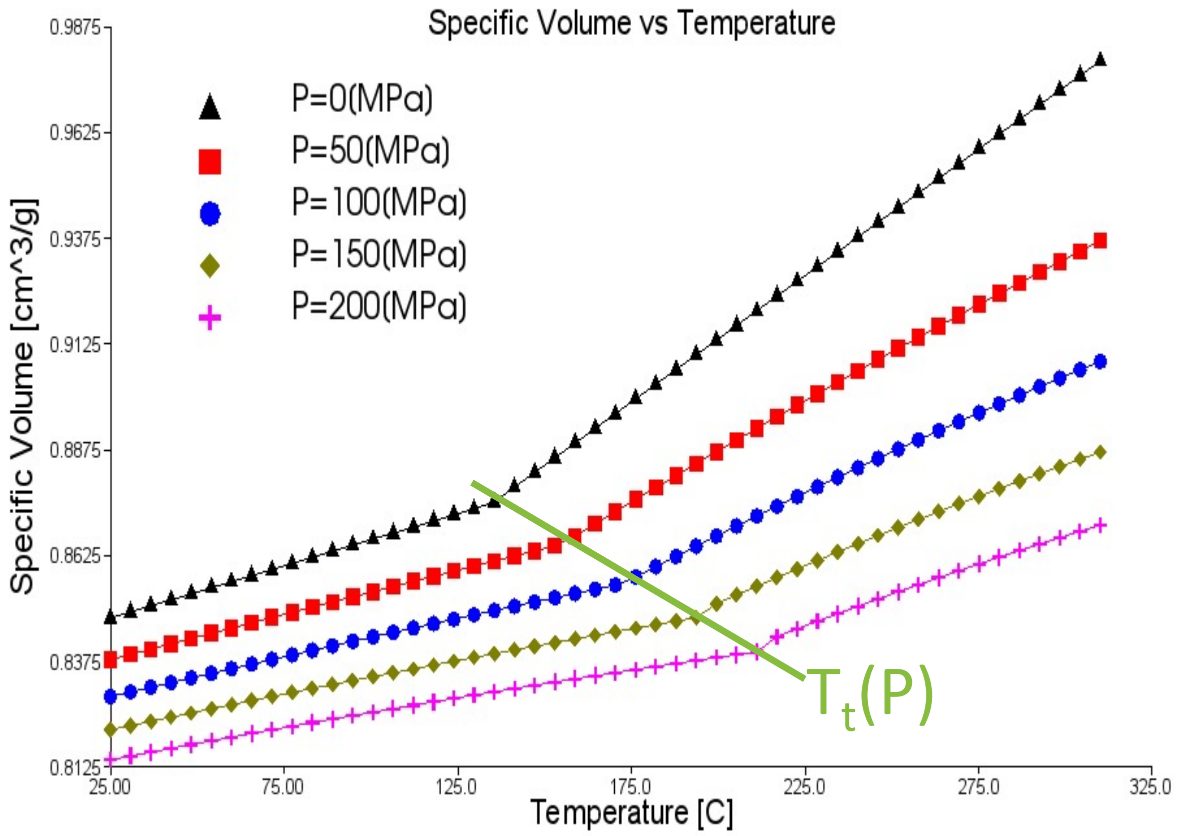
Solver API - Solidification

2018.0

You can now consider cooling rate and pressure effects on Solidification

Polycarbonate: Infino EH-1050; Cheil Industries



$$T_t(P) = b_5 + b_6 P$$

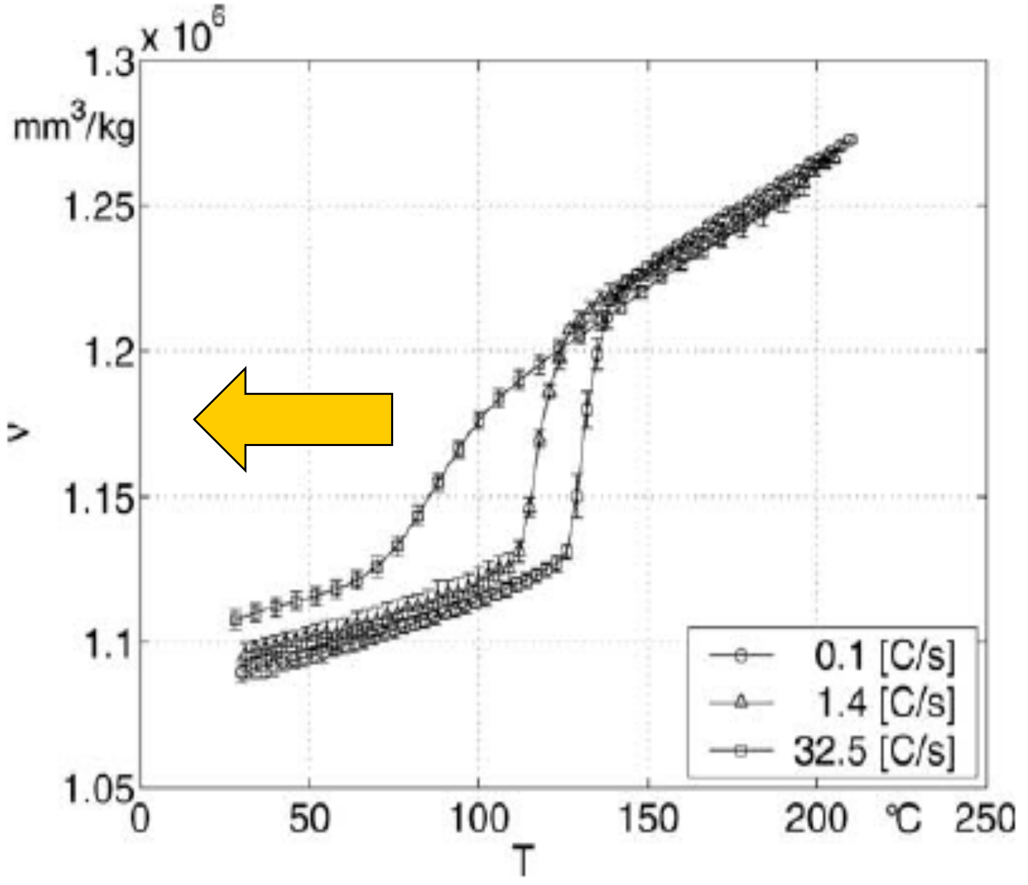


Fig. 9. Influence of cooling rate an the specific volume of i-PP at a pressure of 40 MPa. Average cooling rates during crystallization are given in the figure

van der Beek et. al. Inter. Polymer Processing, 20, 111-120, (2005).

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New Features for Recent Releases

Autodesk Moldflow Simulation 2017 R2

1. Wall Slip
2. Resin transfer molding
3. Thermocouple-controlled cooling
4. Heater wattage specification for heater element

Autodesk Moldflow Simulation 2017 R3

5. CAD meshing support for Linux
6. Synergy Support for Delete CAD bodies
7. Synergy Support for Copy of CAD bodies
8. Support the exporting of STEP files
9. Powder injection molding support

Autodesk Moldflow Simulation 2018.0

10. Multi-step large vector deformation support (modelling)
11. Multistage support for normal deformations (modelling)
12. User defined initial strain support for Anisotropic inserts (Warp)
13. Preconditioning analysis for reactive compression molding
14. Injection compression overmolding (3D)

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Research

Disclaimer

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 delivery of products, services or features but merely reflect our current plans, which may change. Purchasing decisions should not be made based upon reliance on these statements.

The Company assumes 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.

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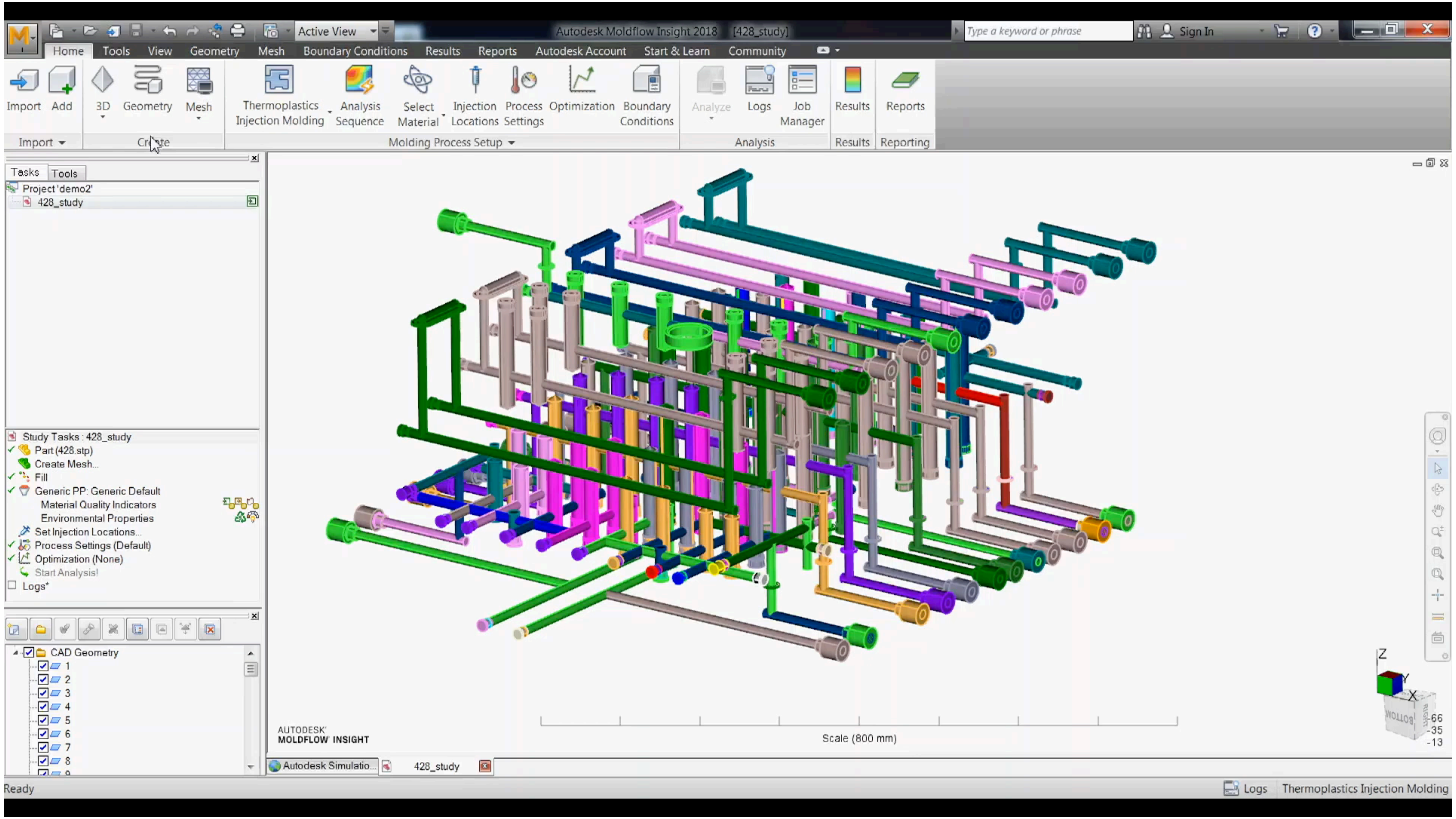
Centerline Extraction for CAD Cooling System

Extracting Center Lines of CAD Cooling System



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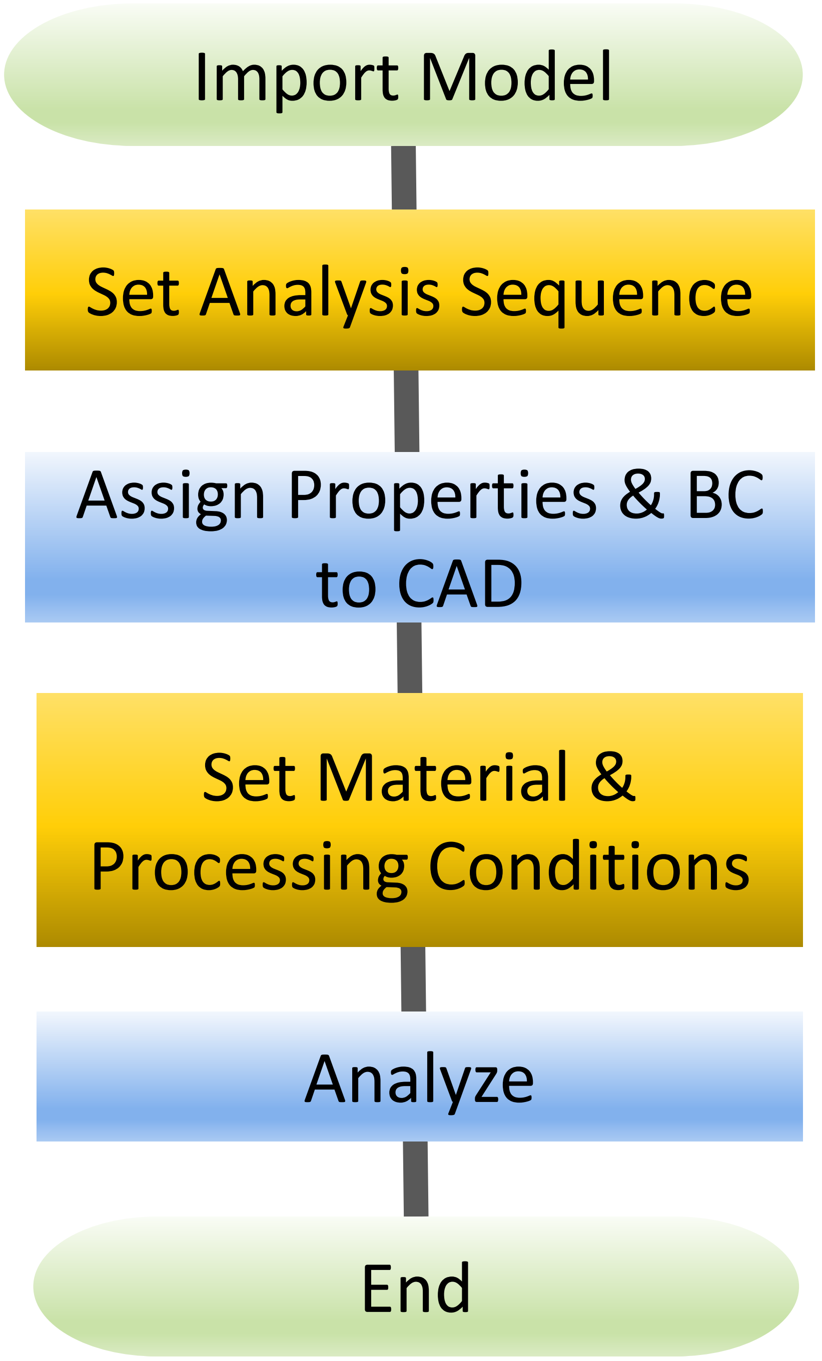
Invisible Meshing

Mesh

- Remove all manual steps
- Optimize default settings
- Tolerate or fix defects

Solver

- Accommodate new mesh without loss of accuracy or speed

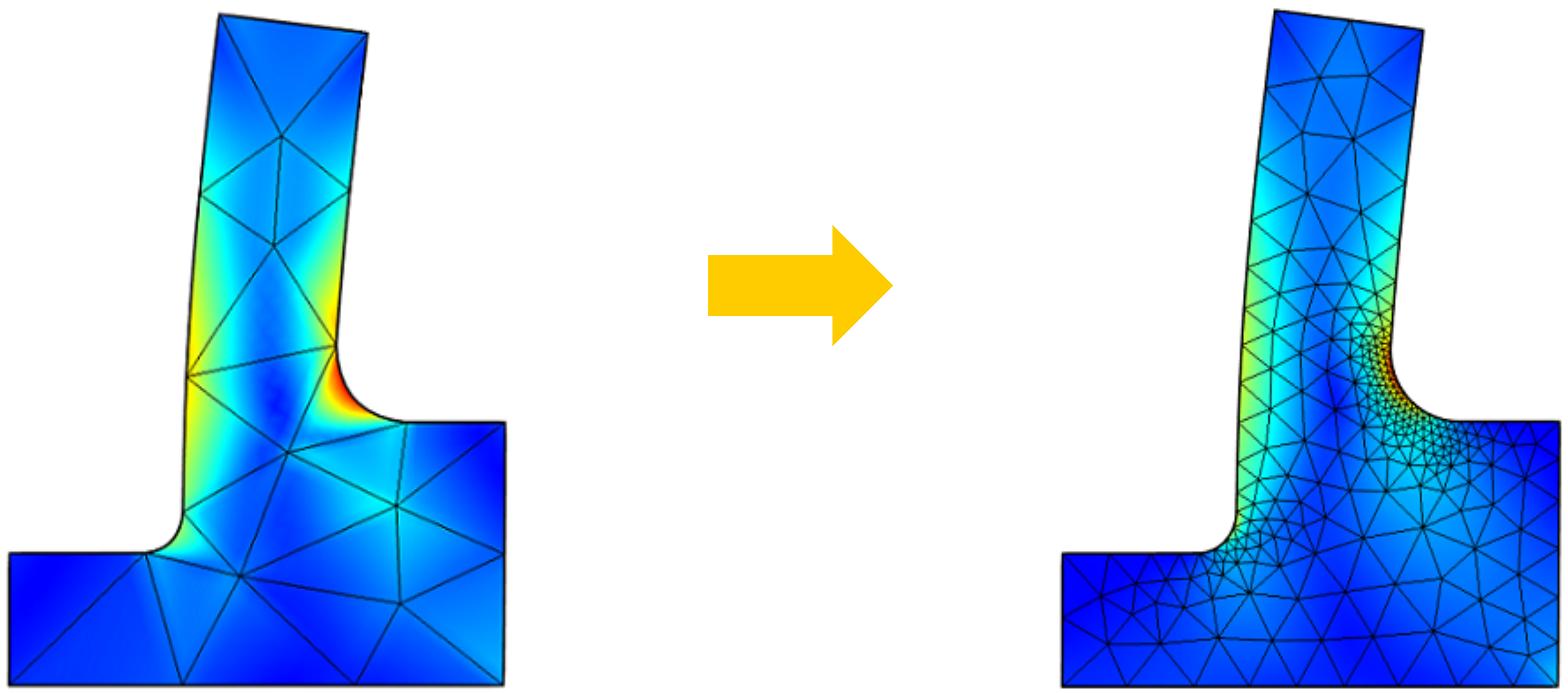


Adaptive Meshing

Start analyses with coarse meshes

Refine meshes based on analysis results

Re-run analysis with refined meshes



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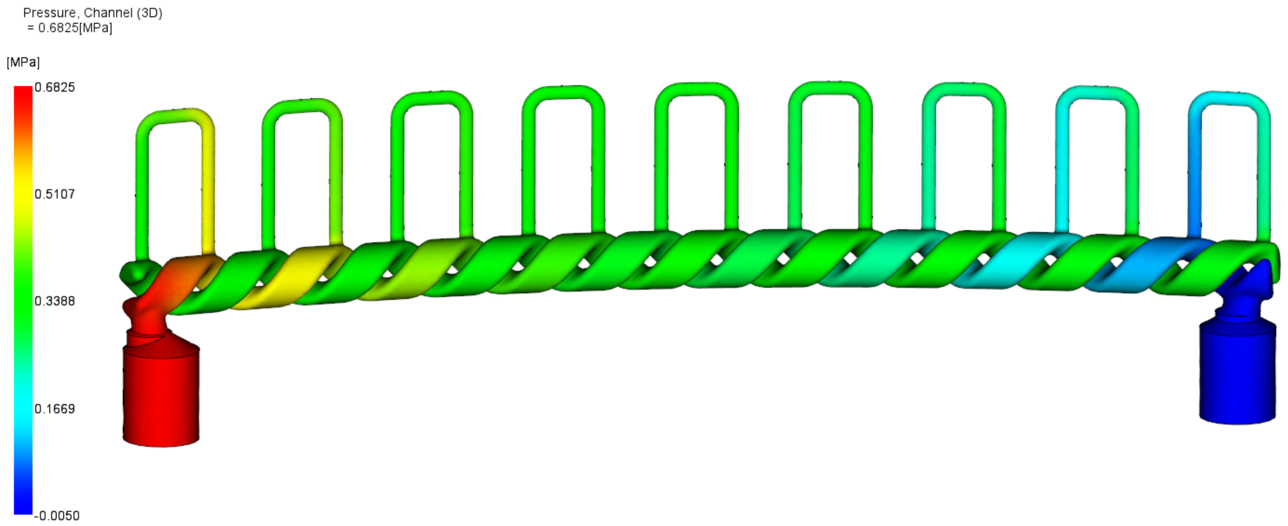
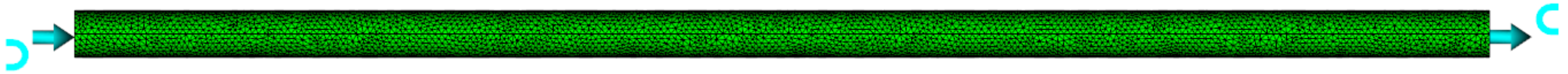
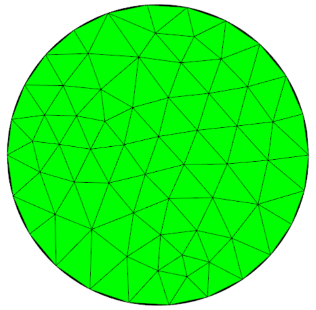
Faster Conformal Cooling Solver

Supports Linux, & Parallelization



Pressure





Cross section

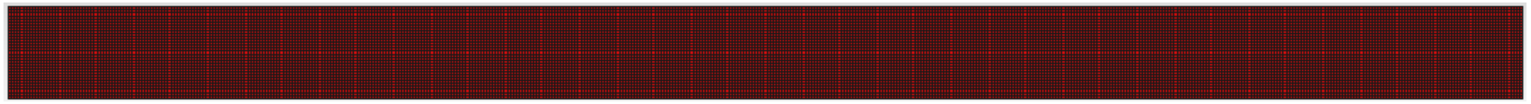
Moldflow 3D Channel mesh

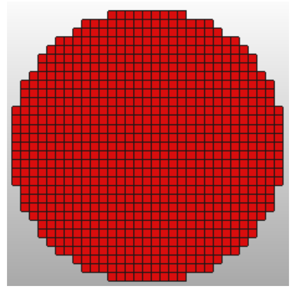
Moldflow results

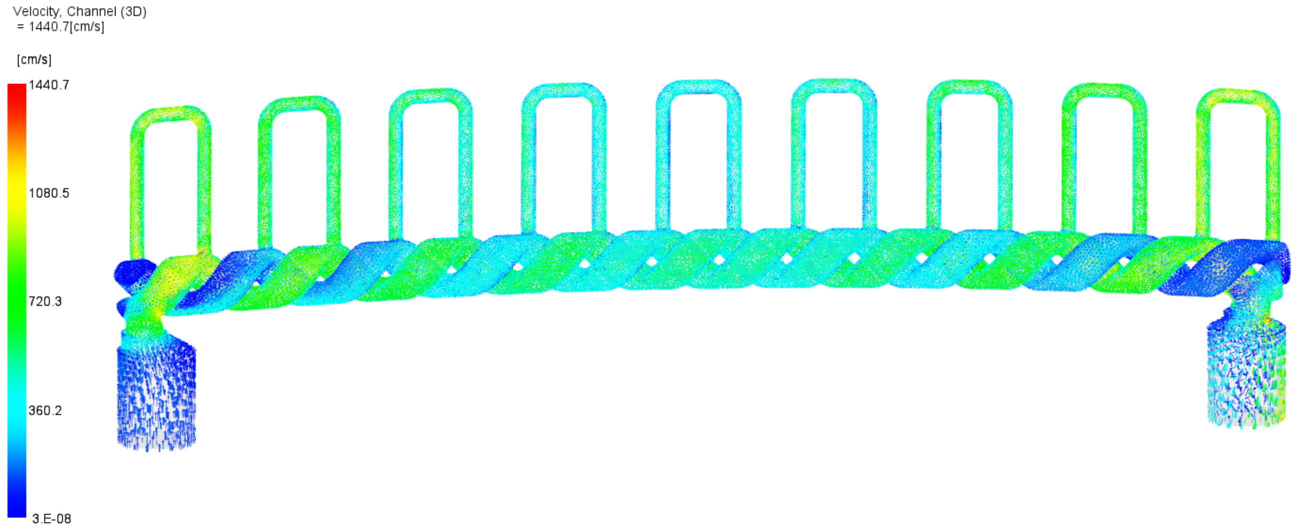
Voxel mesh

Voxel results

Voxel solve







Velocity

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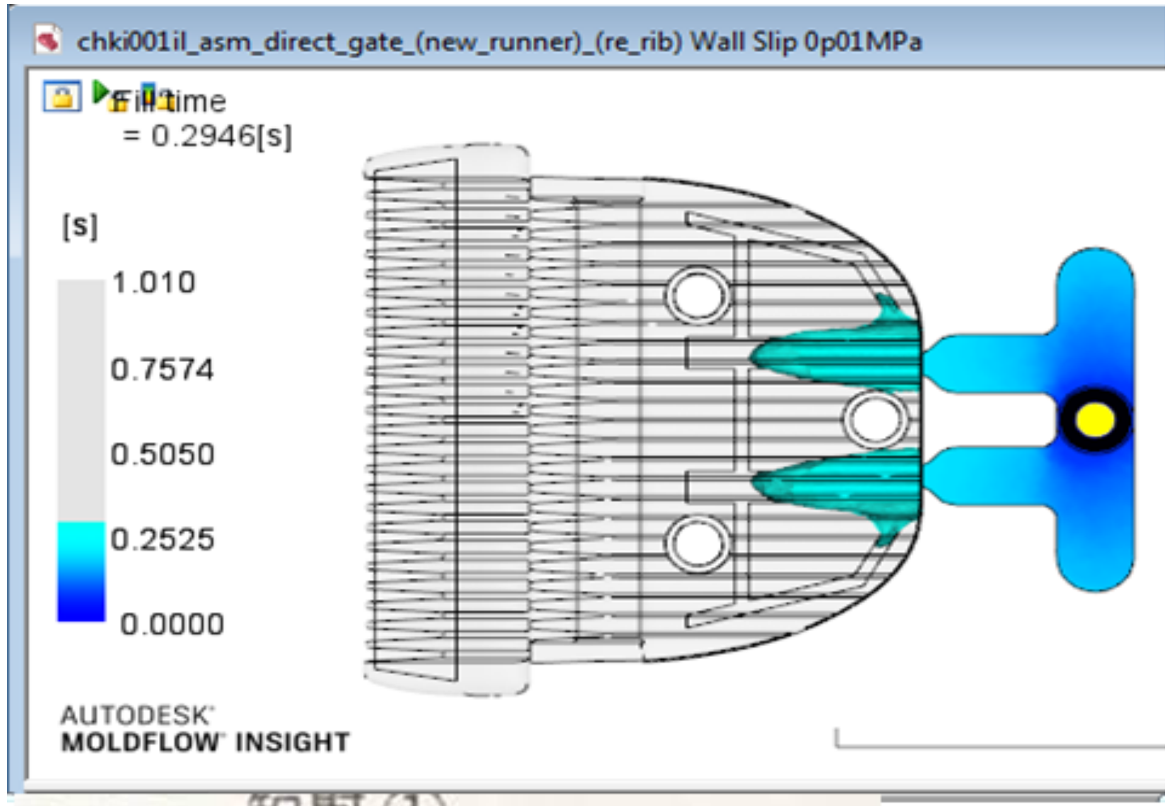
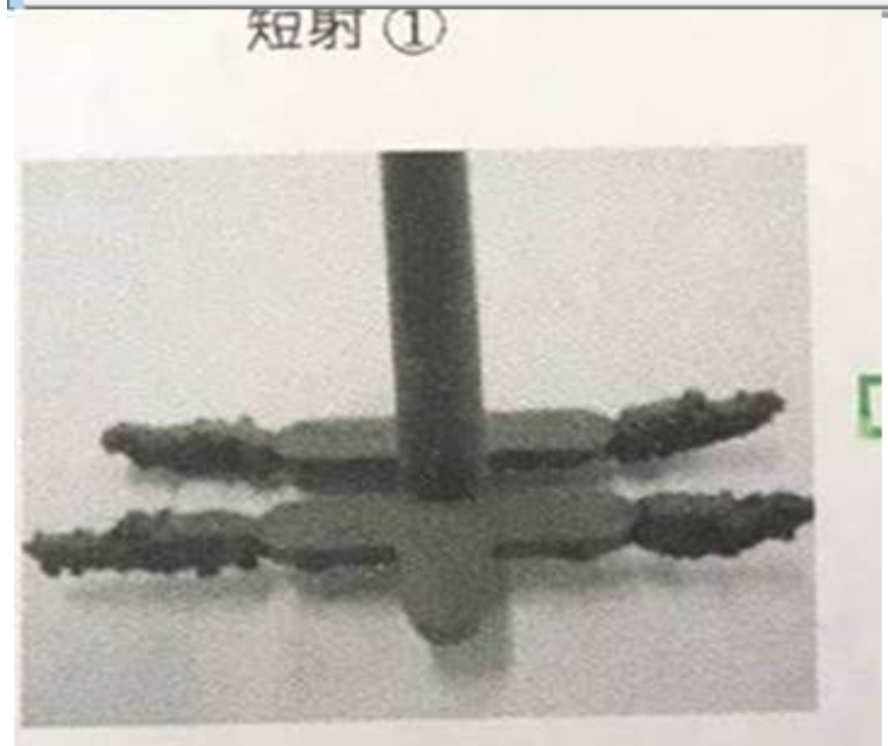
Including Wall Slip for PIM





τ_c	Critical shear stress	0.01 MPa
m	Slip exponent	1
a	Constant sip coefficient	1.0e-05
b	Temperature dependency	0
c	Pressure dependency	0

Failed to predict initial jetting without Wall Slip

With Wall Slip, predicted initial jetting in PIM simulation, which matched reality better

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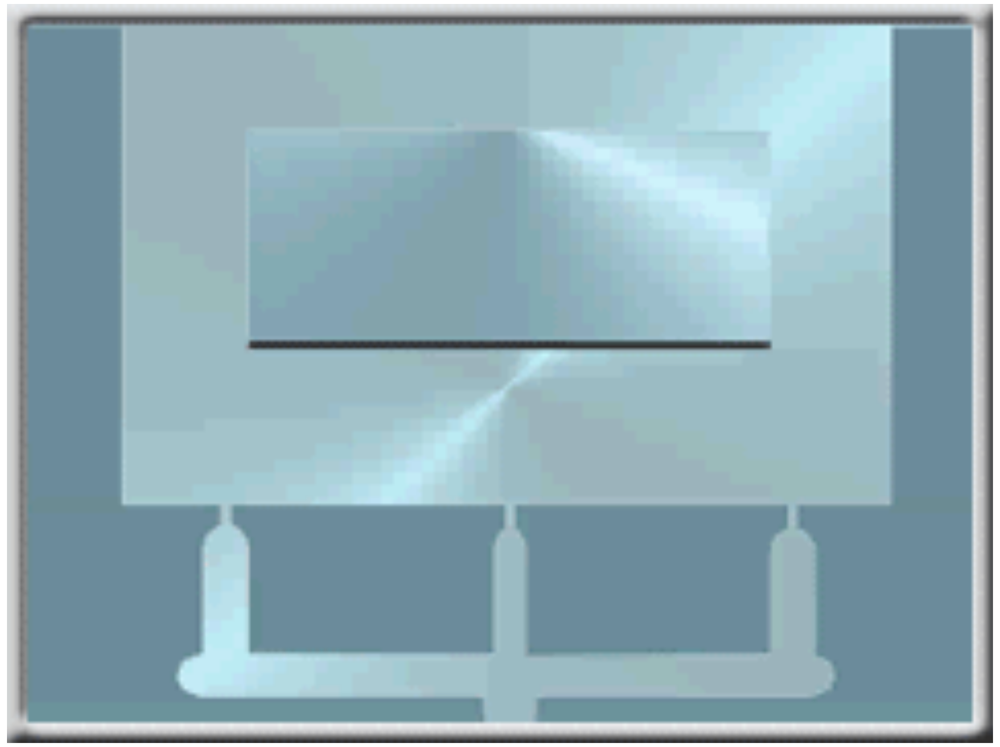
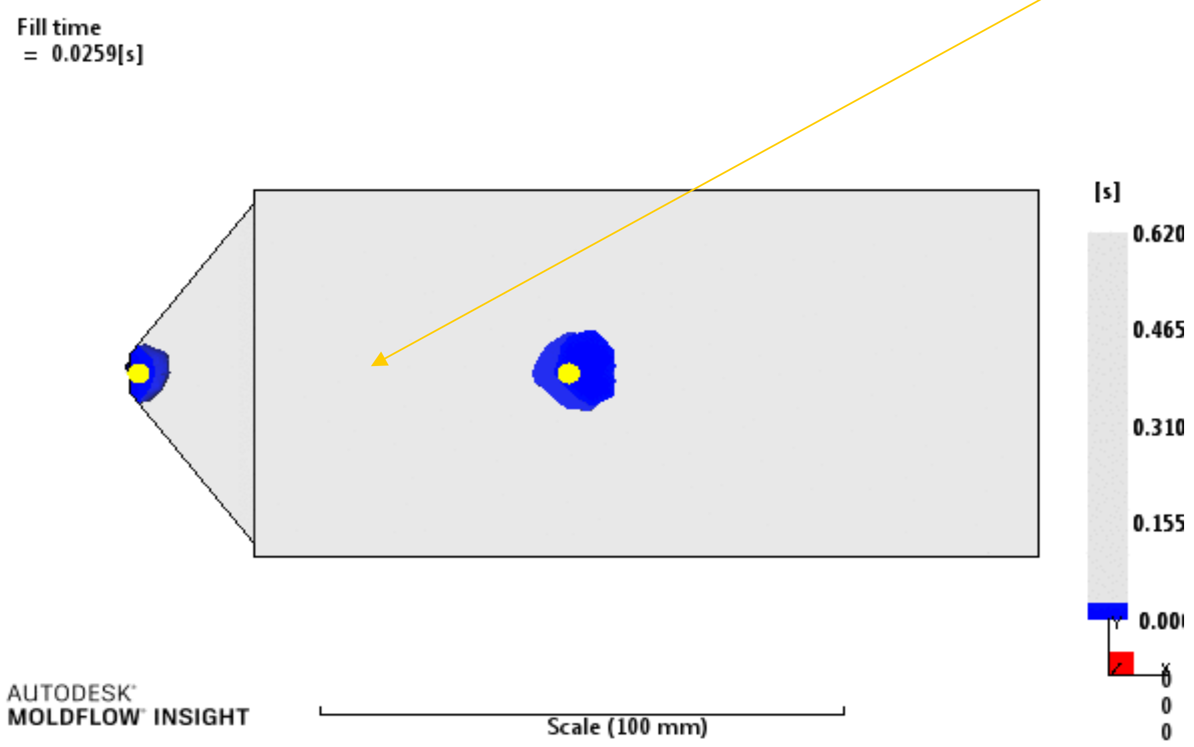
Underflow Diagnostic Plot

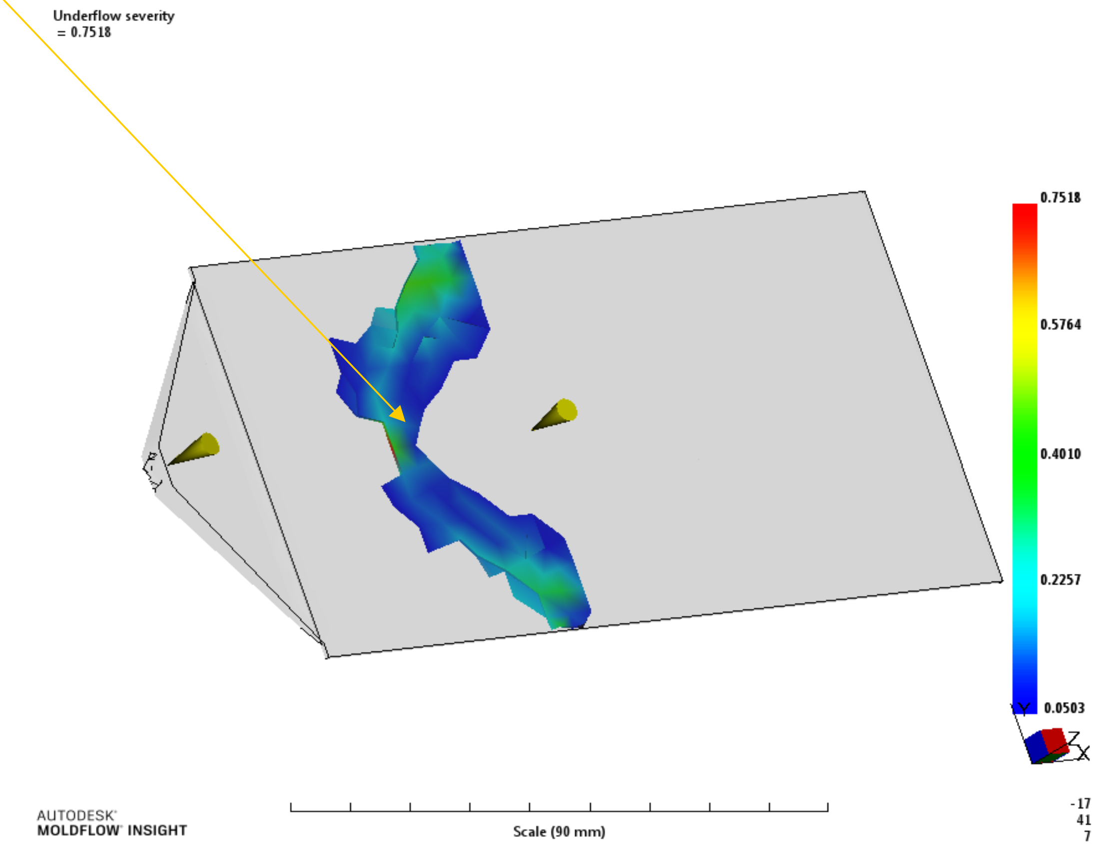
"Underflow severity" as a result



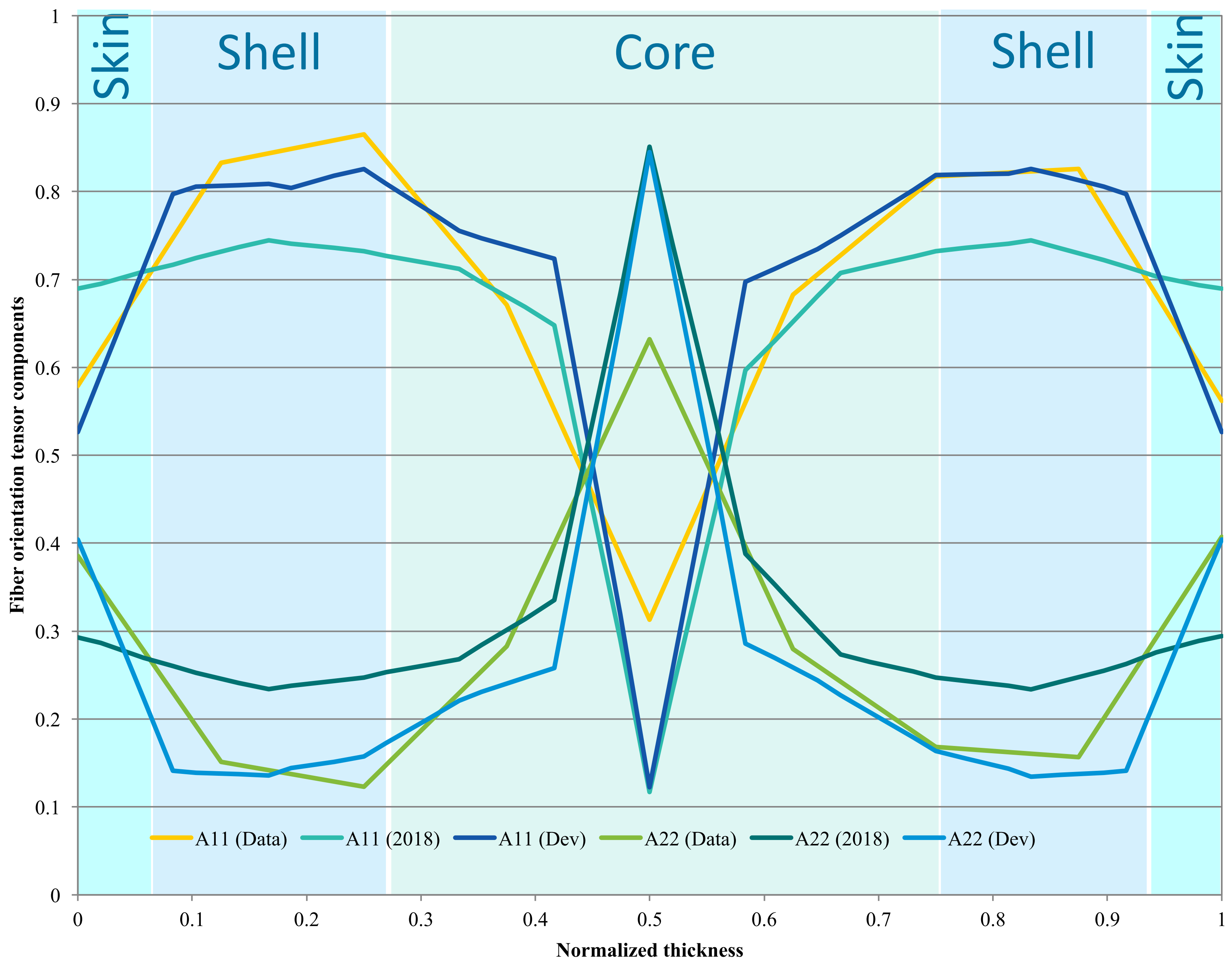
viewmold.com

Underflow region





Adaptive Fiber Model Orientation Prediction



Skin Orientation

Believed to be due to fountain flow

Shell Orientation

Strong alignment in flow direction

Alignment controlled by fiber interactions, C_I, ARD b_i, MRD D_i

Core Orientation

Transverse or random orientation dependent on flow near gate

Width Controlled RSC factor κ

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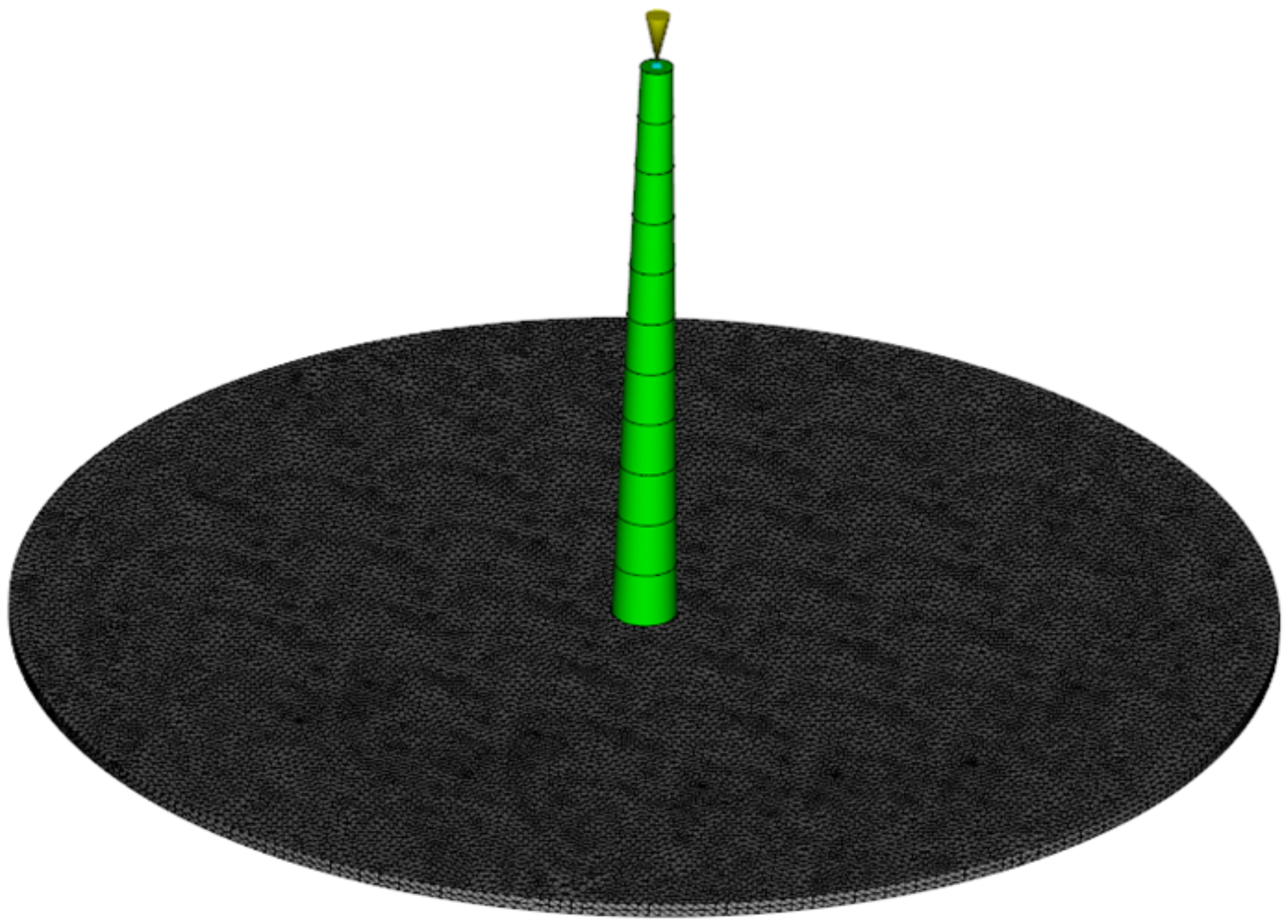
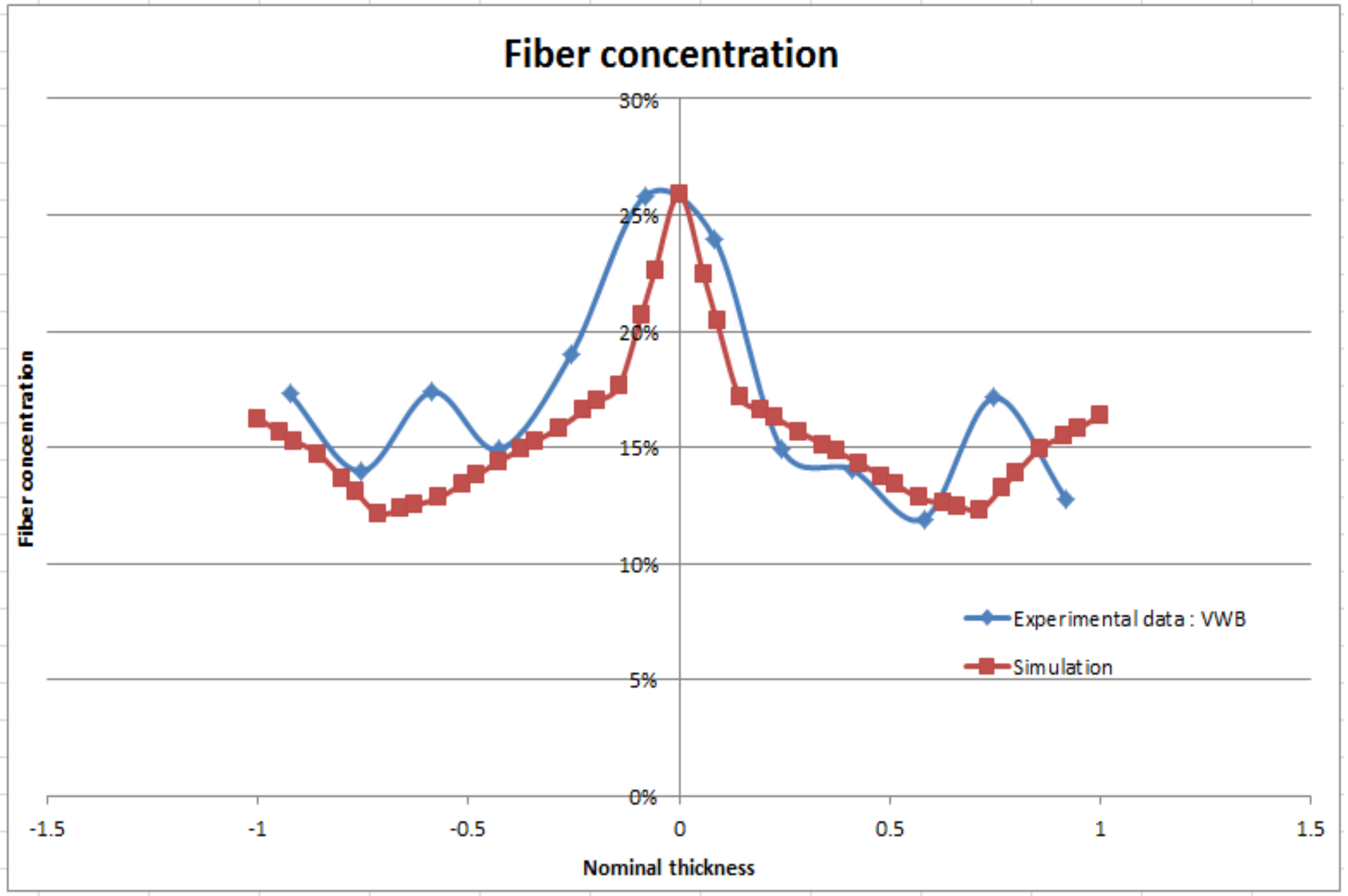
Fiber Concentration

Higher concentration at core while lower concentration at shear region.

Fiber concentration, orientation, & breakage affect mechanical properties.





Measured data: G.M. Vélez-García, Compos. Part A-Appl. Vol 43: 104-113 (2012)

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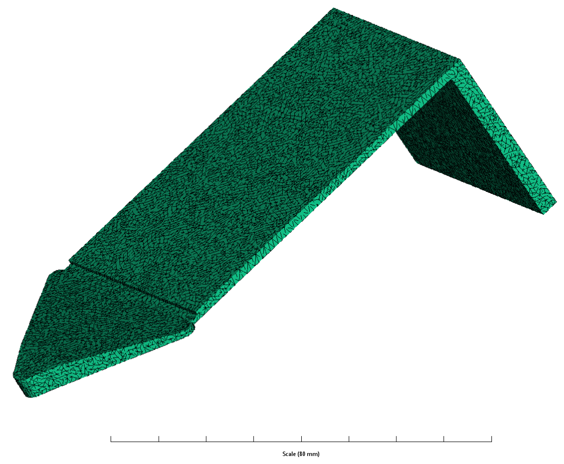
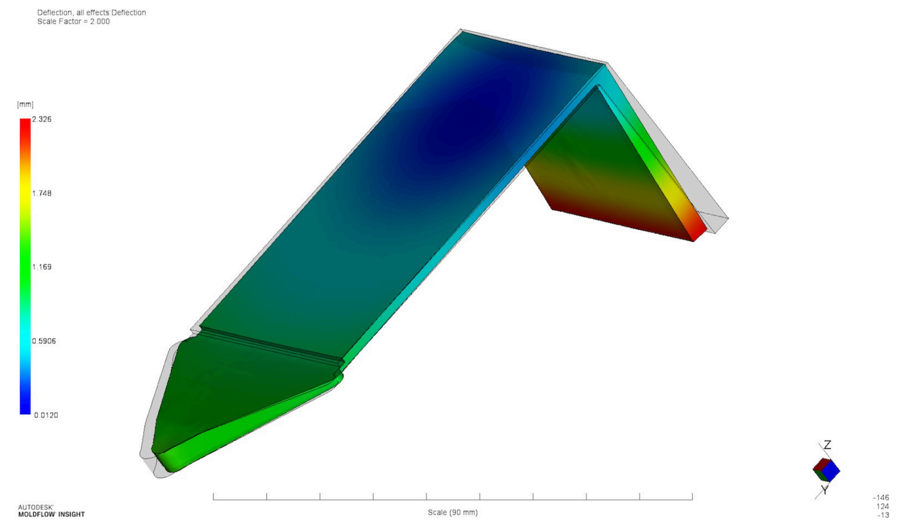
Warp Accuracy: Thickness Shrinkage for Warpage

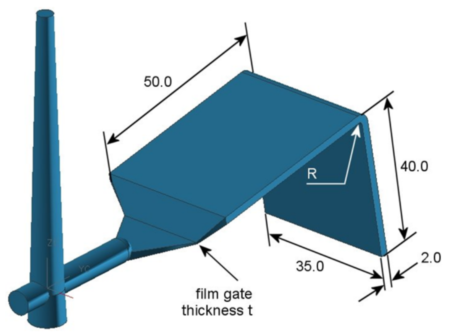
MF 2×4mm corner mold (MAT5322 PP)

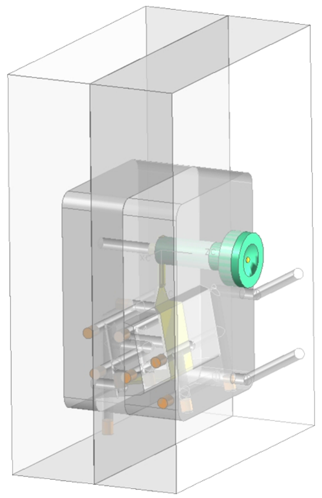


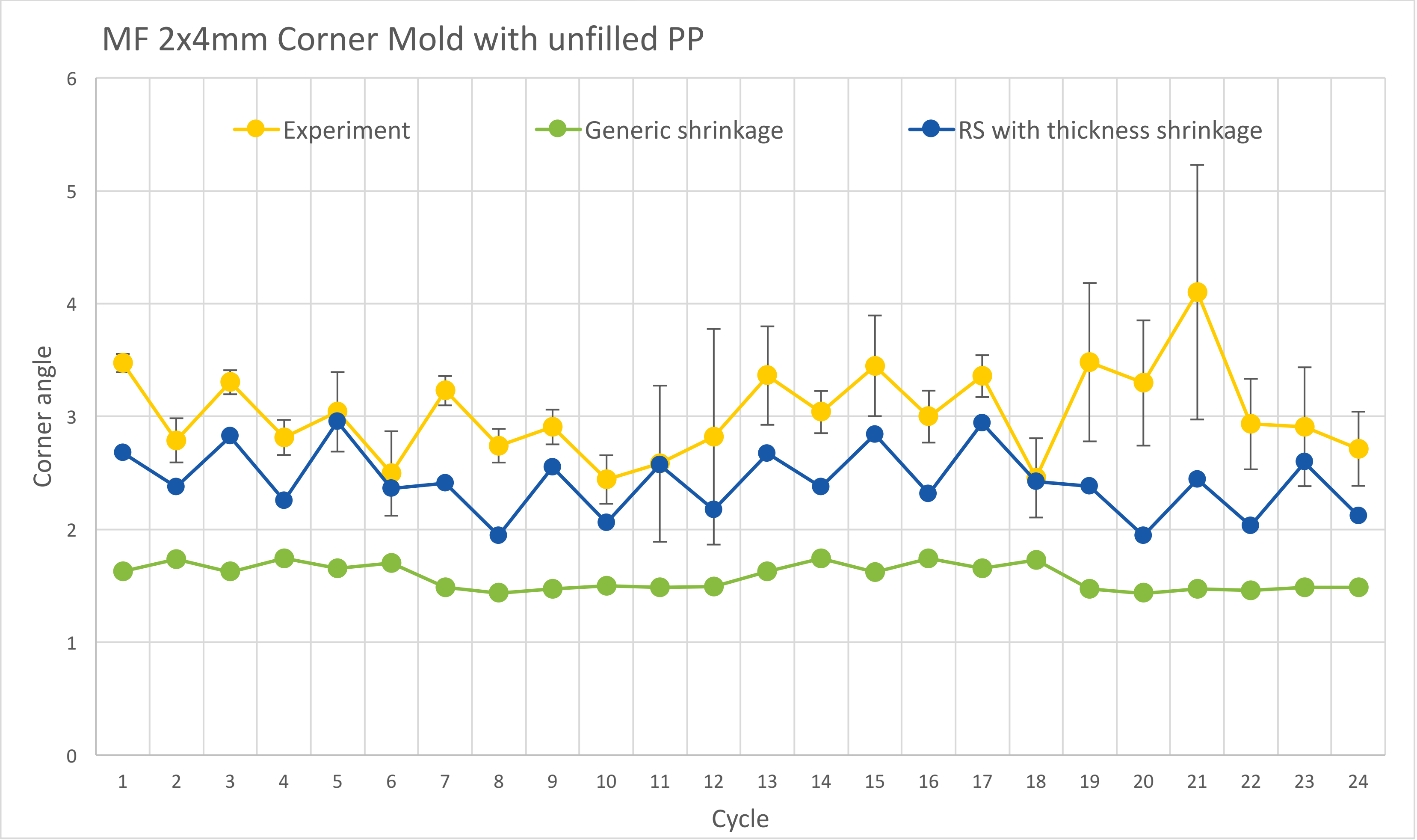


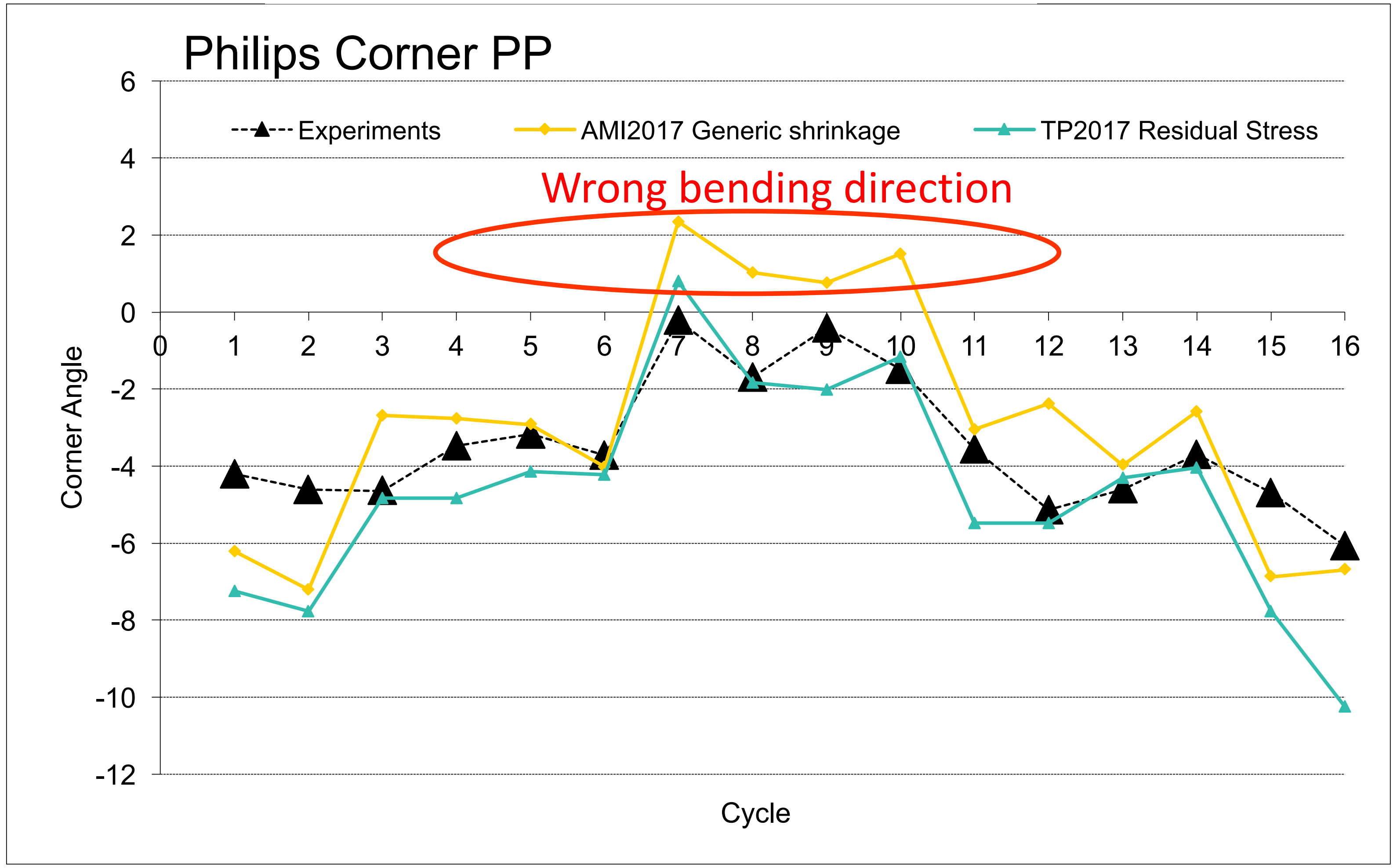
Philips corner mold (CM1160 PP)

- Corner piece test mold
- Local geometry options: R1 or R5
- Gate thicknesses: t = 0.6 or 0.9 [mm]









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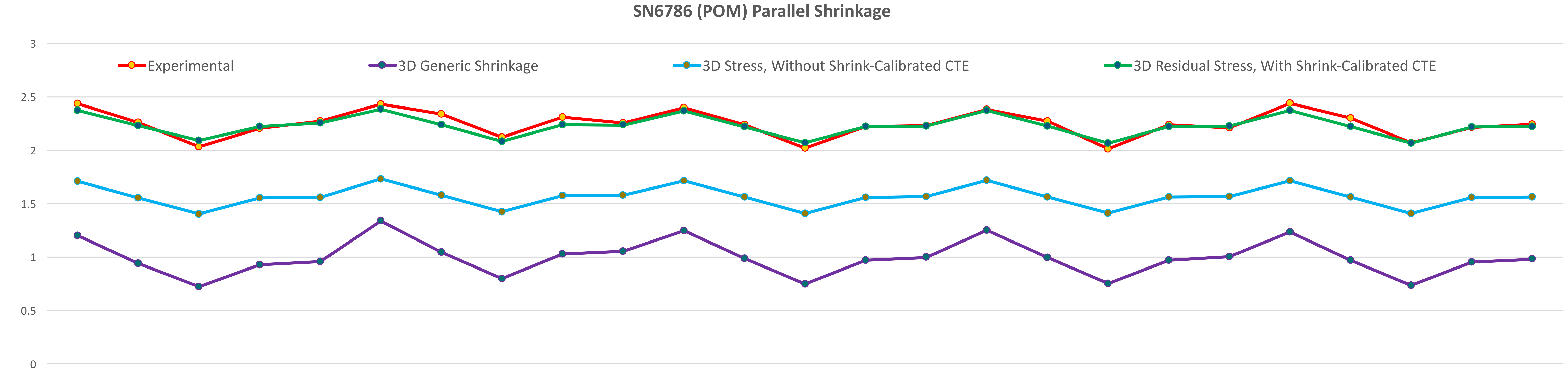
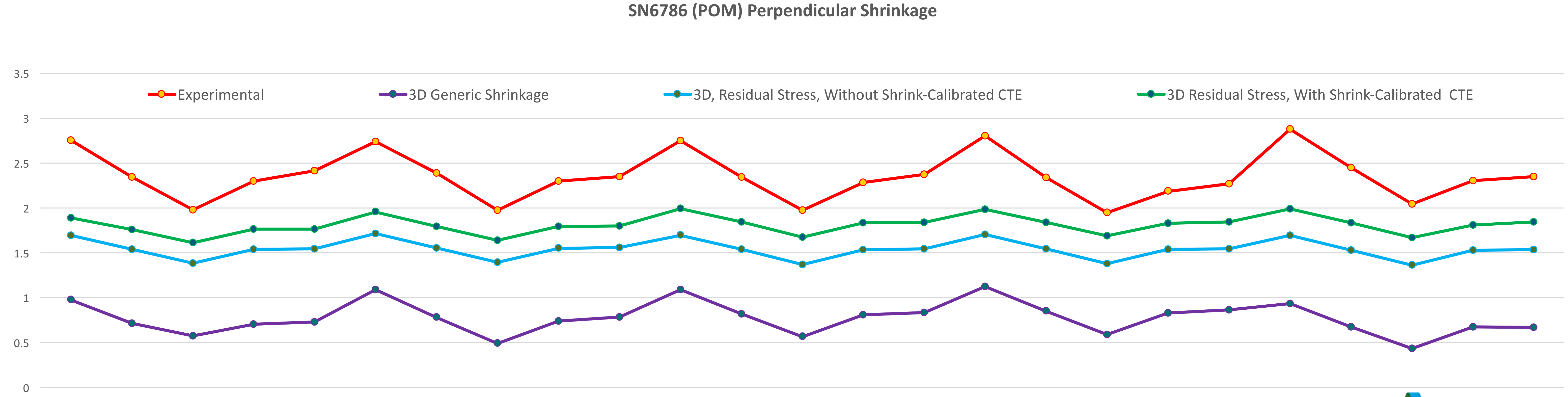
Warp Accuracy - Shrinkage Correlation





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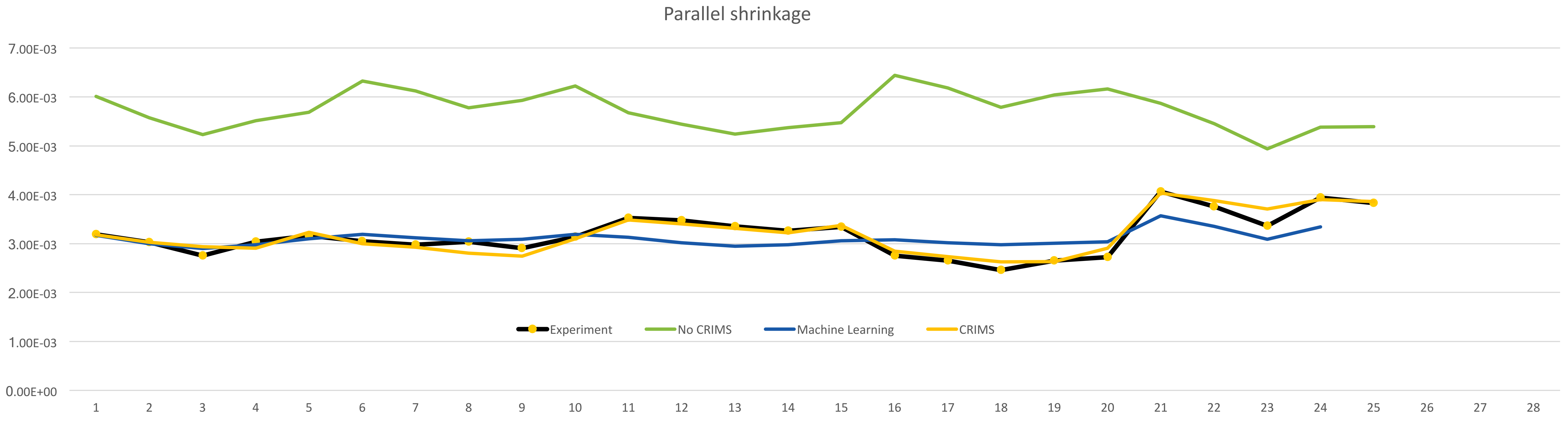
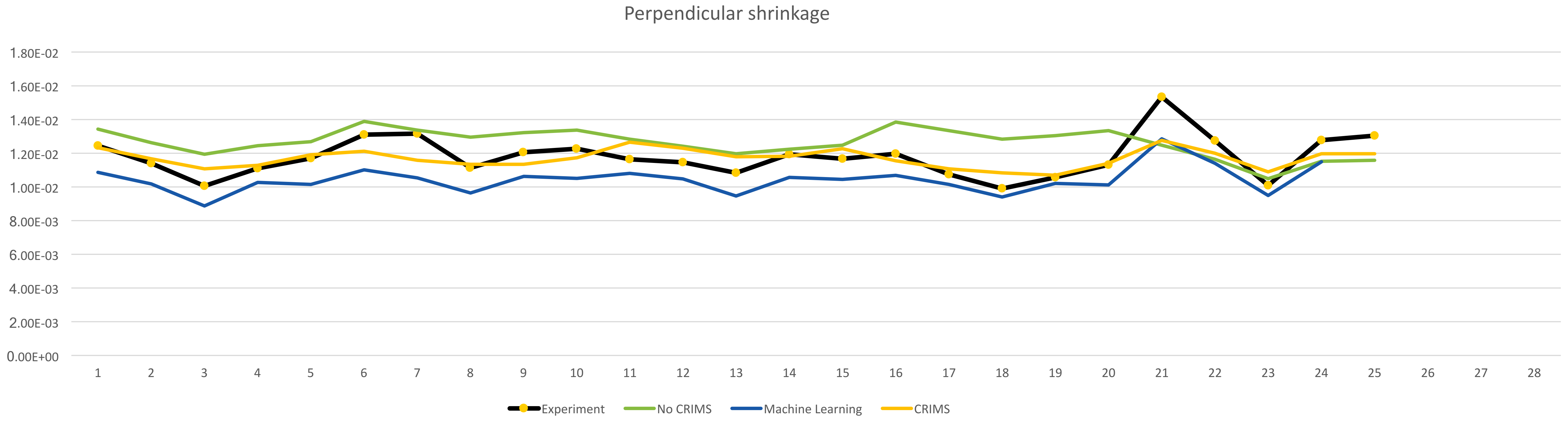
Warp Accuracy - Machine Learning (ML) for Shrinkage Correction





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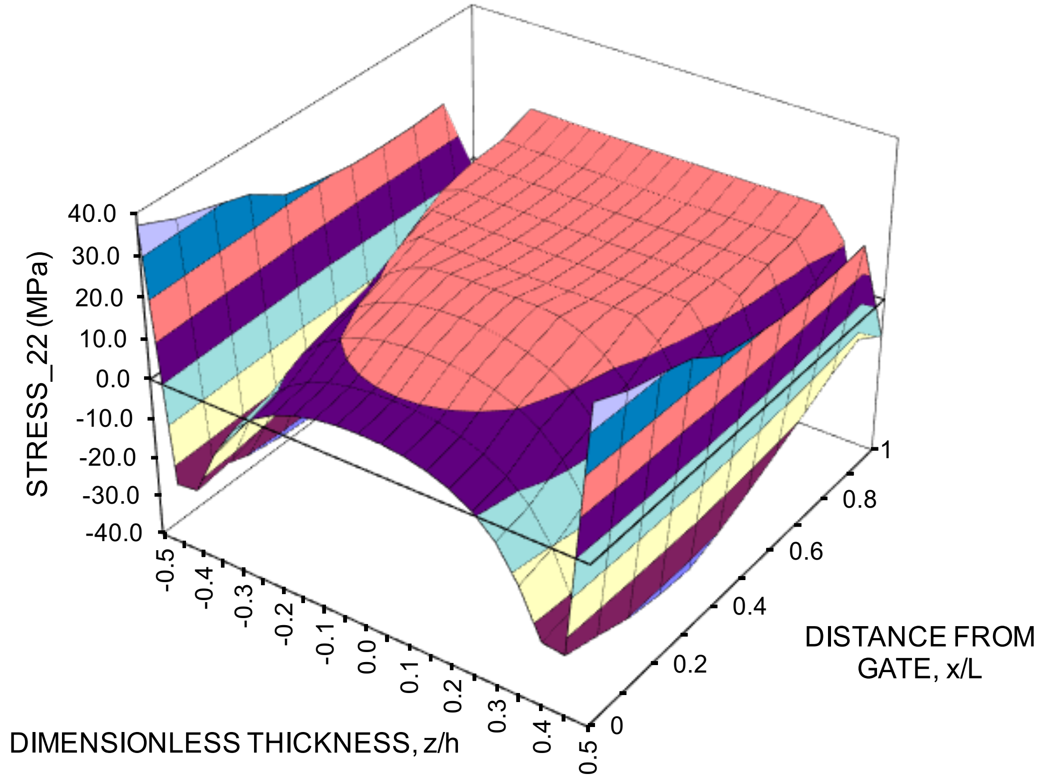
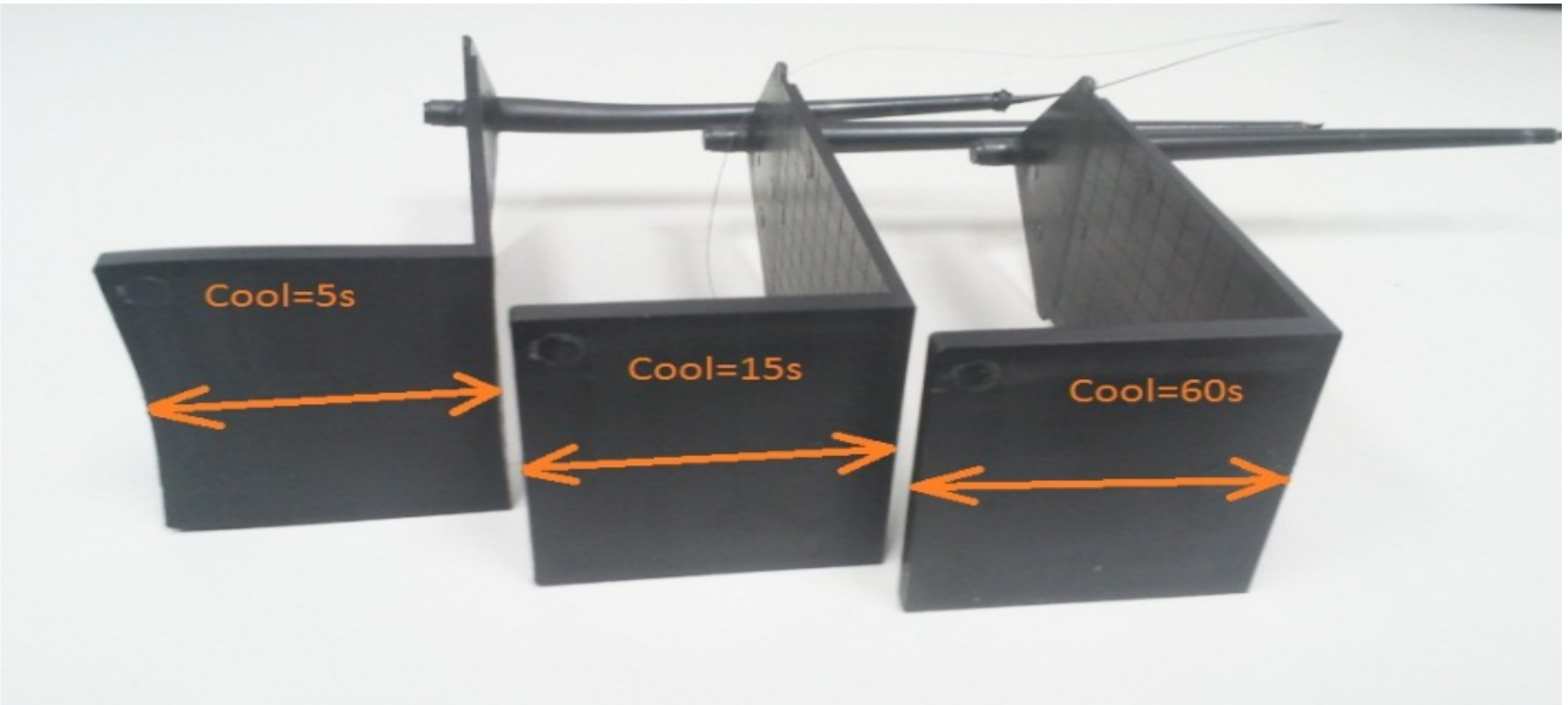
Warp Accuracy - Anisotropic Thermo-Viscoelastic Stress Model

Stress relaxation (viscoelastic)
Long cooling time effect
In-mold shrinkage
Liquid portion at ejection
Solidification sequence effect





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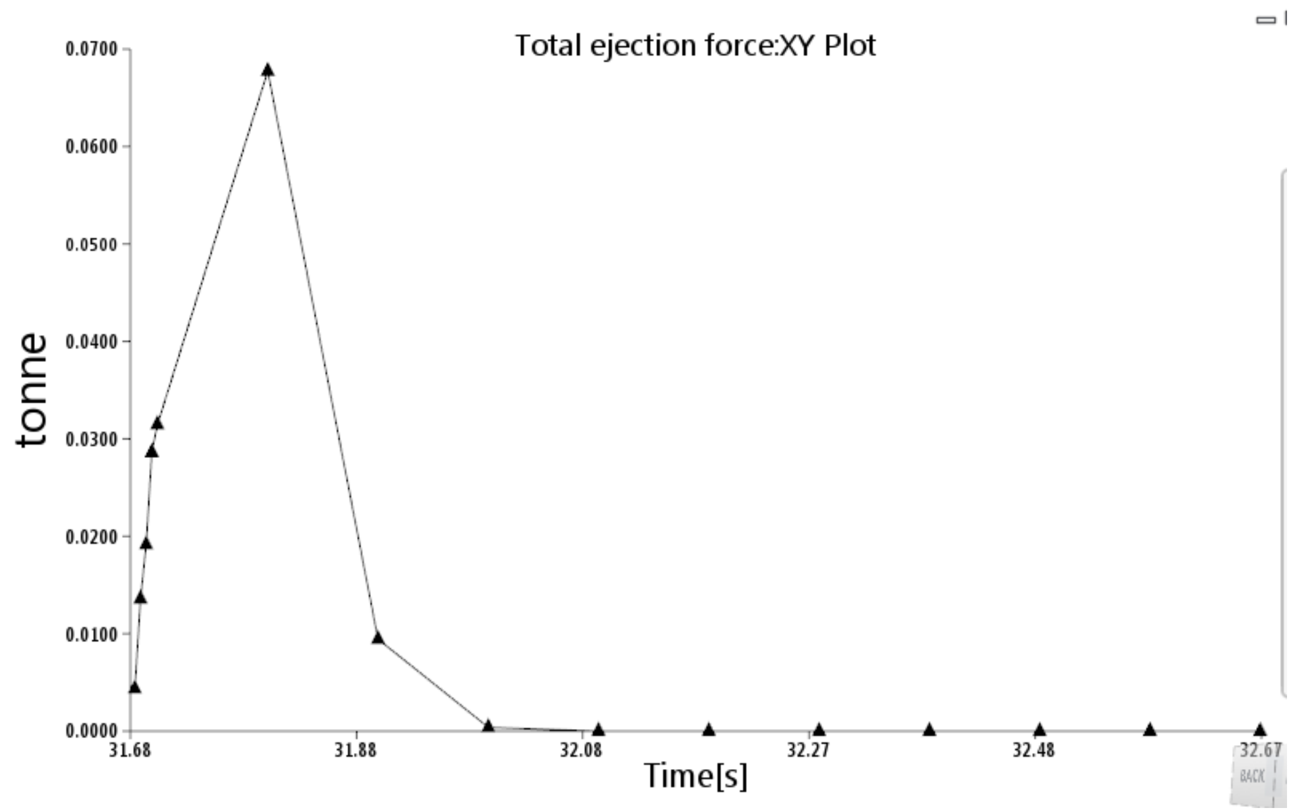
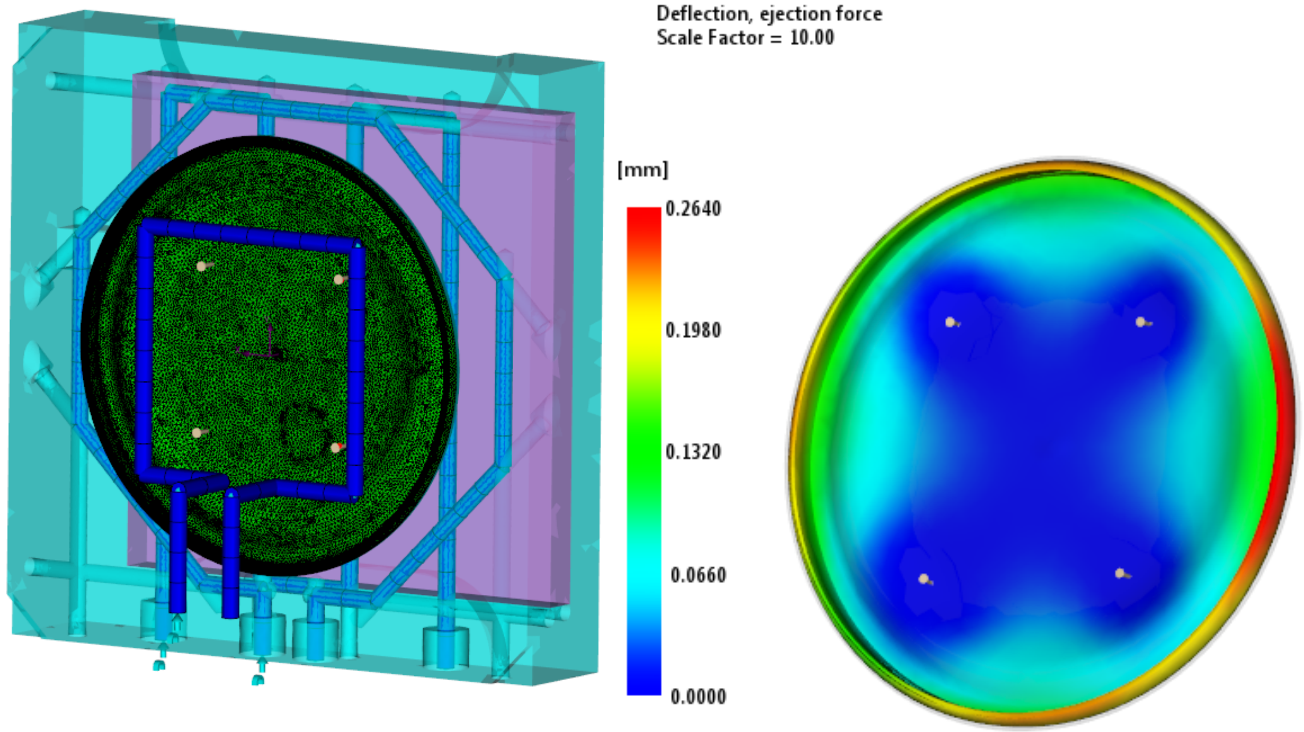
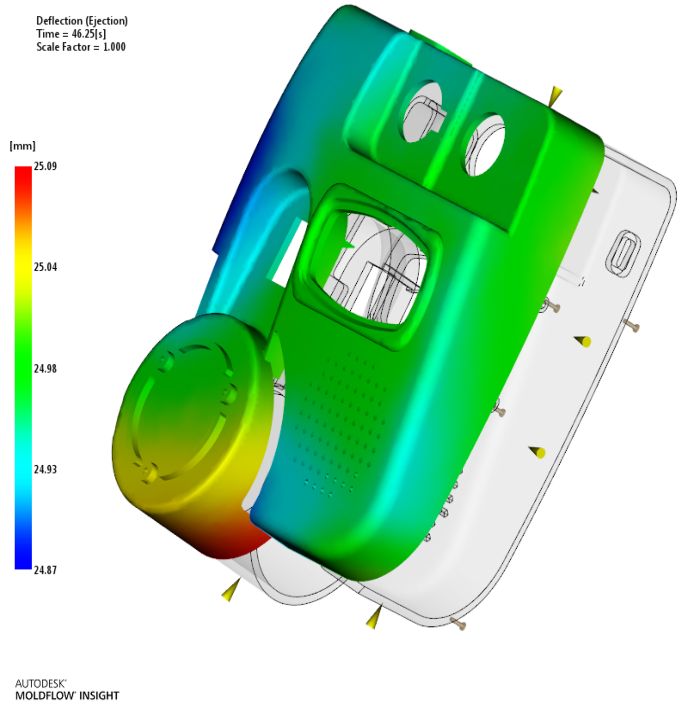
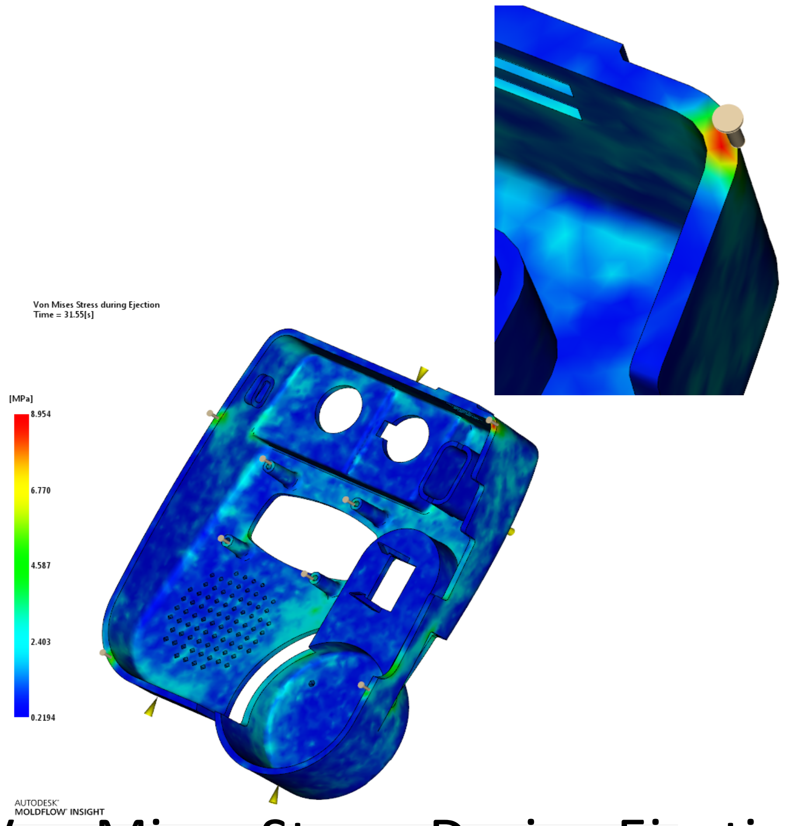
Ejection Force

Automatic Detecting based on ejectors movement direction → User check, add or remove surface elements manually → Final contact surface





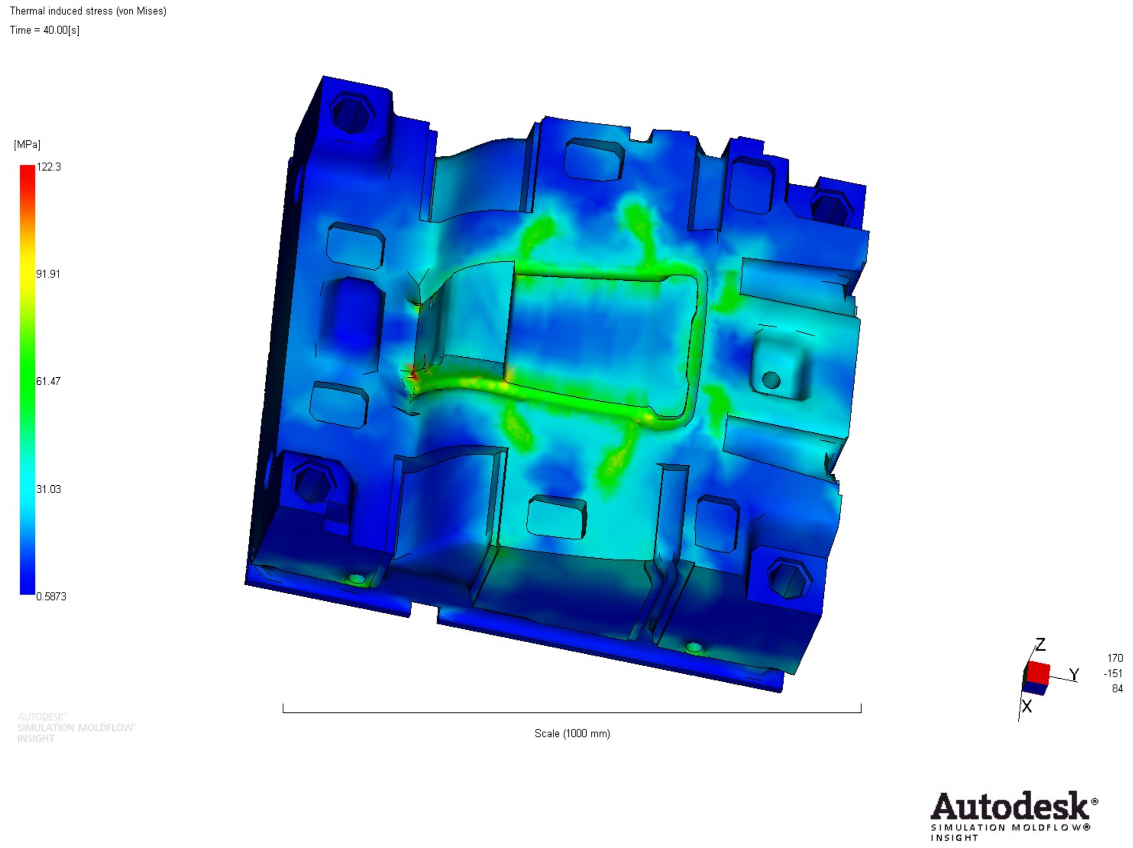


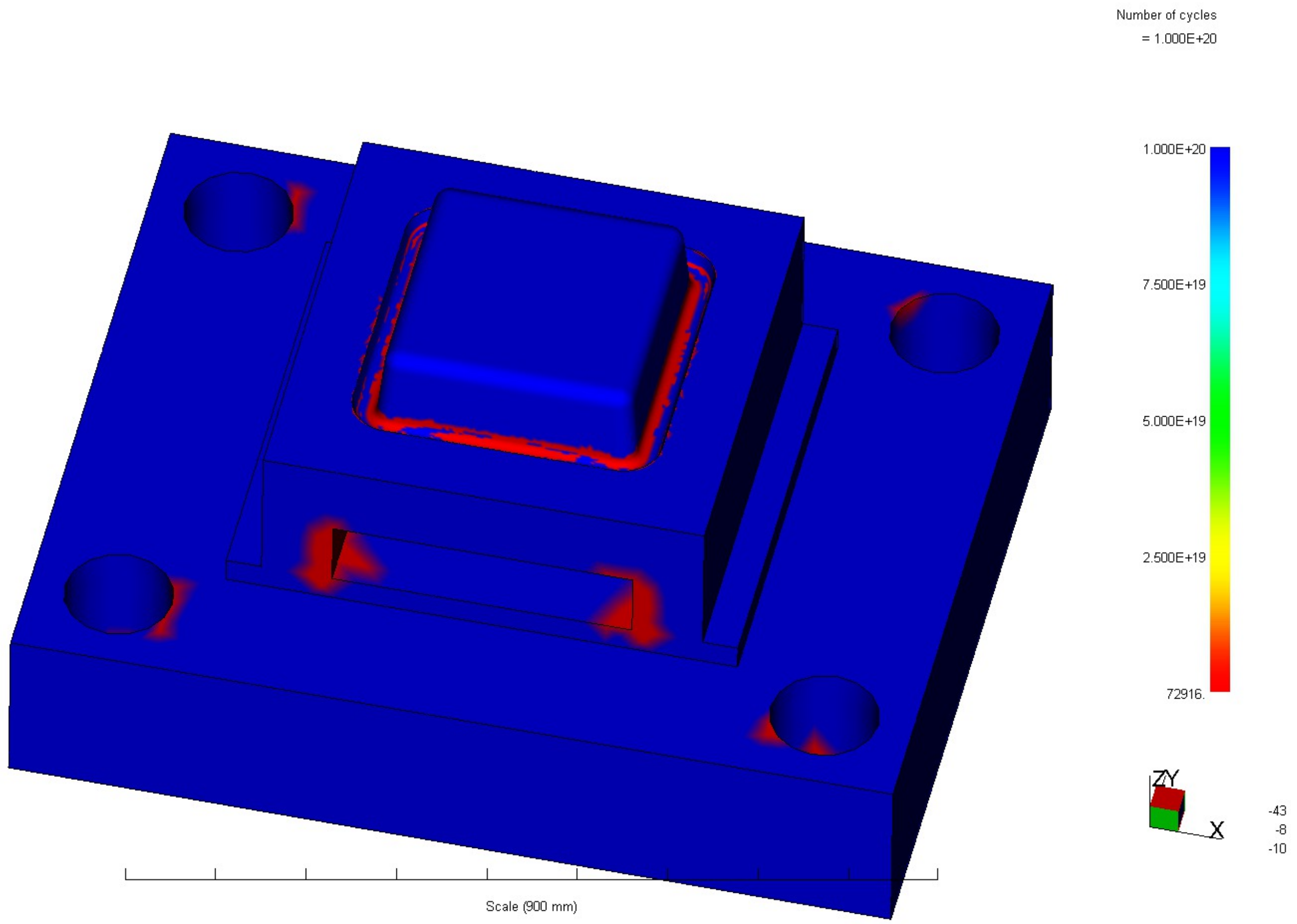


Von Mises Stress During Ejection

Mold Fatigue

Calculate the mold life and approximated range of cycles.





Thermal Stress

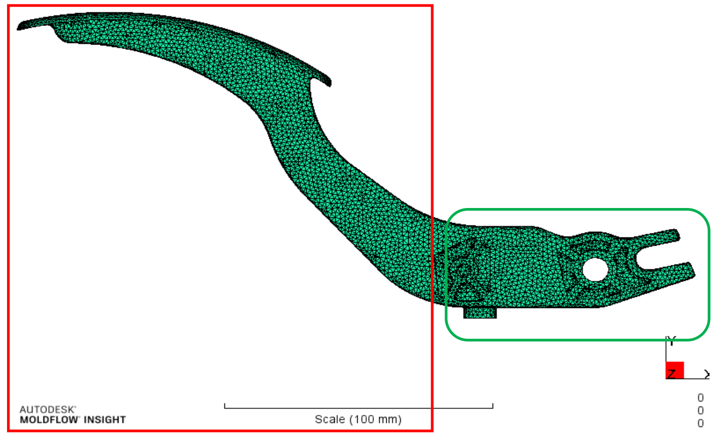
Pressure-induced Stress

Clamping-force-induced Stress

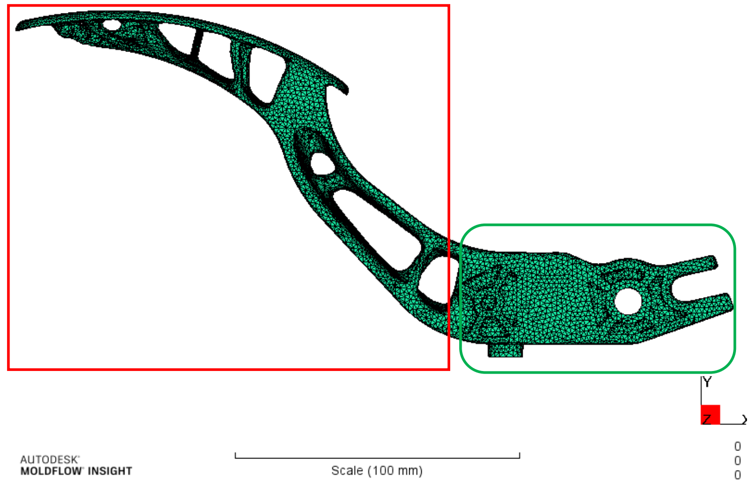
Mold Fatigue

Topology Optimization for Part Design – Joe Zuo

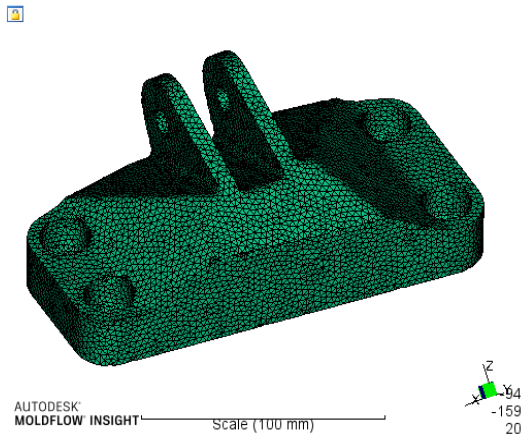
Improving existing design for structural performance, & light weighting



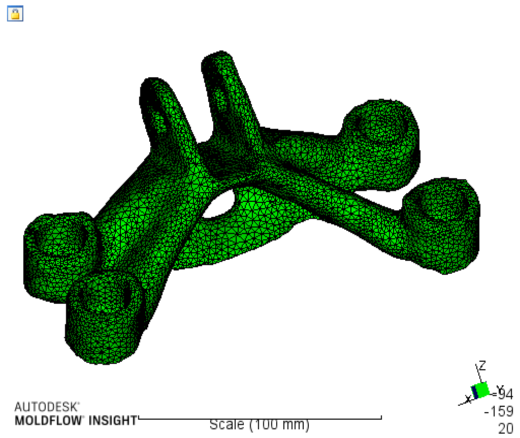
Initial design



Optimized design (removed 34% material)



Initial concept



Optimized concept (saved 70% material)

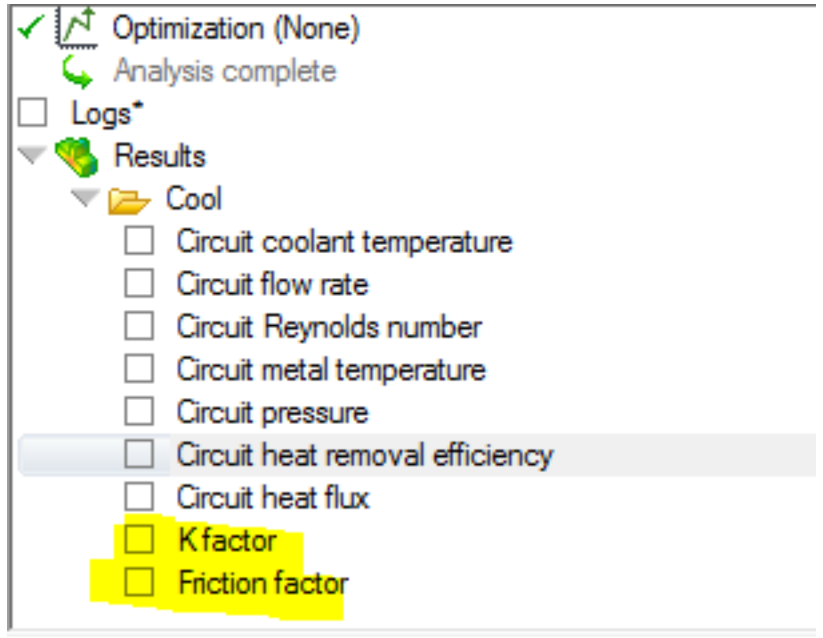
Optimized concept (saved 80% material)

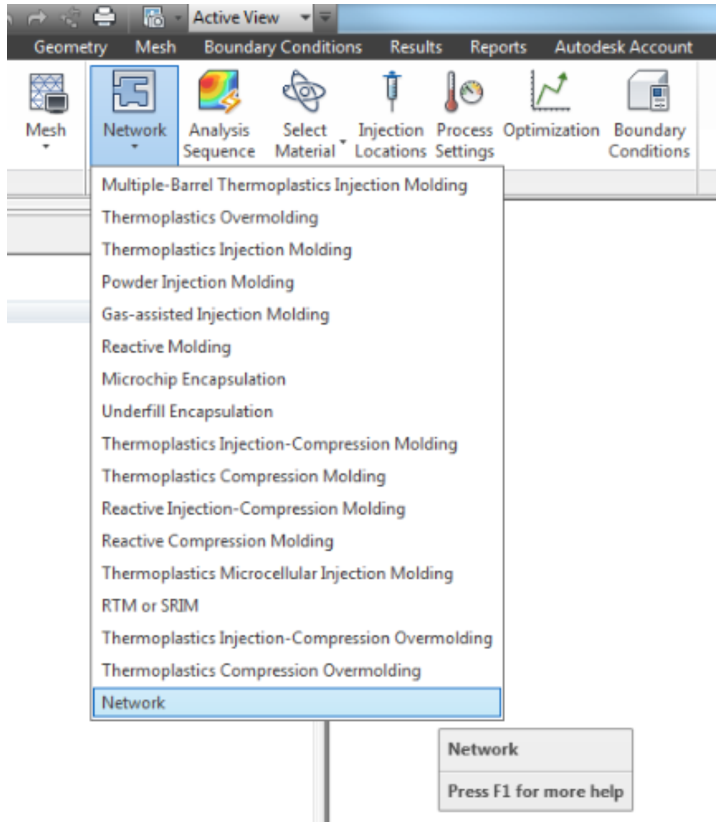
AUTODESK.

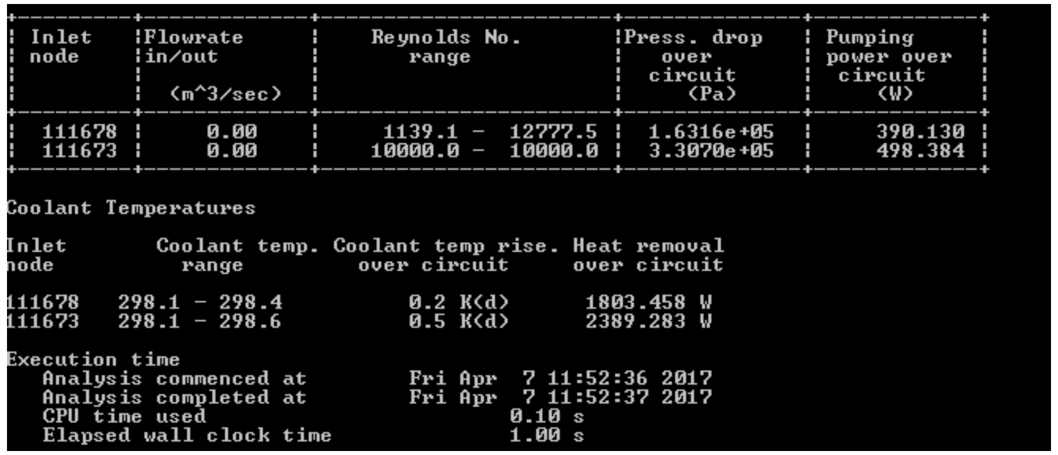
Network Only Analysis - Clinton Kietzmann

Features: Minor Loss, Friction formula, Simulate energy equation, & Simulate gravity

New results: K factor, & Friction factor

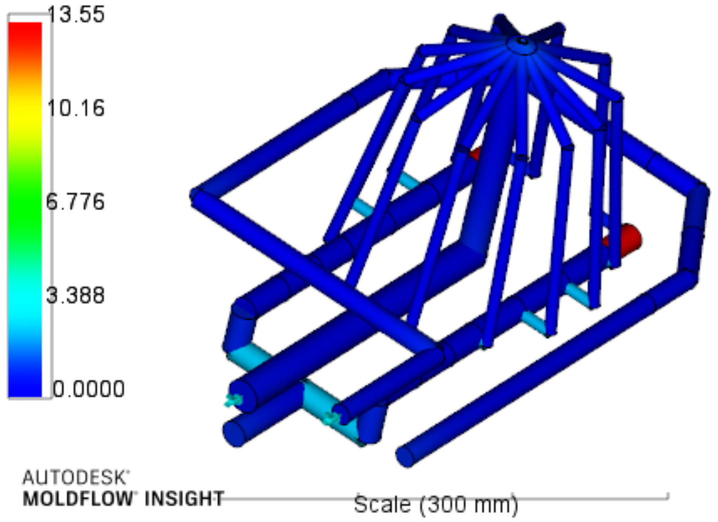




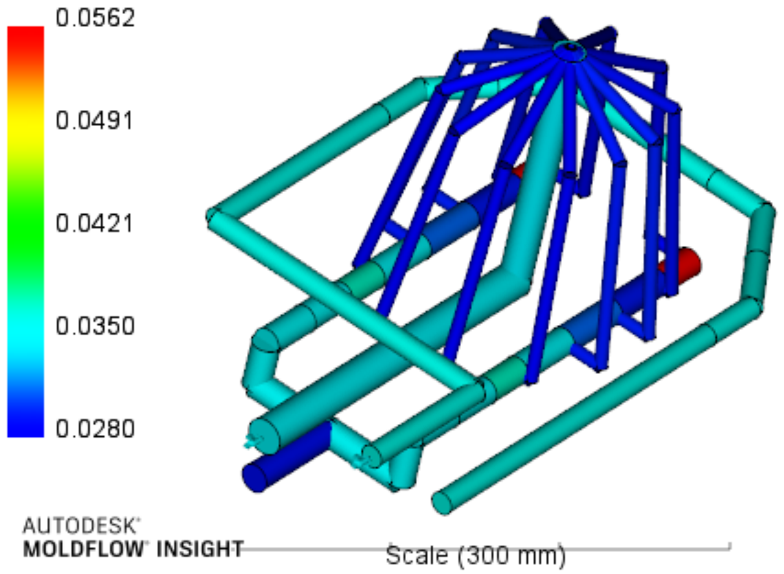


```
| Inlet  |Flowrate |     Reynolds No.      |Press. drop  | Pumping       |
| node   |in/out   |        range          | over        | power over    |
|        |         |                       | circuit     | circuit       |
|        | (m^3/sec)|                      |  (Pa)       |   (W)         |
| 111678 |  0.00   |   1139.1 -   12777.5  | 1.6316e+05  |   390.130     |
| 111673 |  0.00   |  10000.0 -   10000.0  | 3.3070e+05  |   498.384     |

Coolant Temperatures

Inlet        Coolant temp.  Coolant temp rise.  Heat removal
node           range          over circuit      over circuit

111678   298.1 - 298.4          0.2 K(d)        1803.458 W
111673   298.1 - 298.6          0.5 K(d)        2389.283 W

Execution time
    Analysis commenced at         Fri Apr  7 11:52:36 2017
    Analysis completed at         Fri Apr  7 11:52:37 2017
    CPU time used                           0.10 s
    Elapsed wall clock time                 1.00 s
```

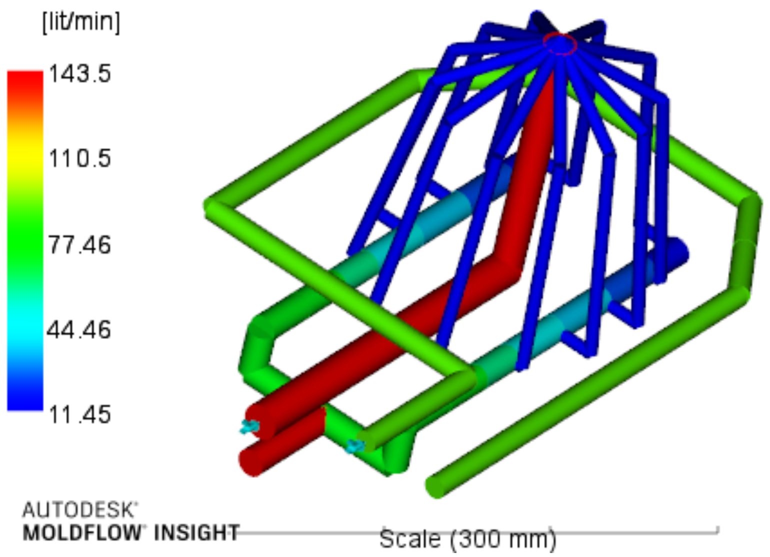
K factor
= 13.55



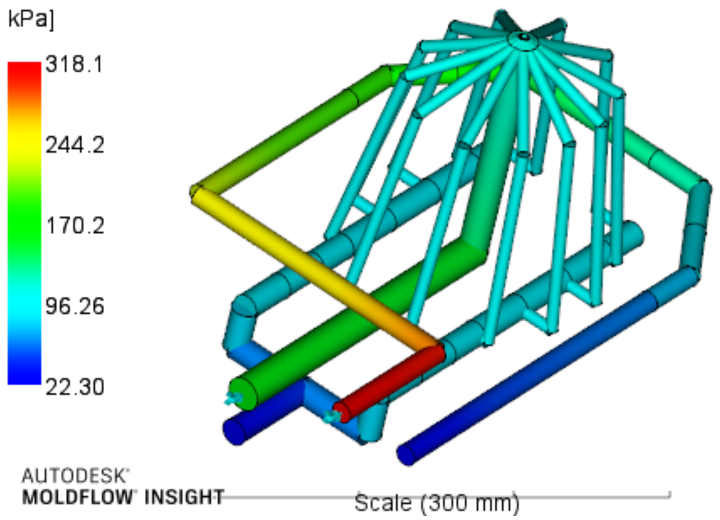
Friction factor
= 0.0562



Circuit flow rate
= 143.5[lit/min]



Circuit pressure
= 318.1[kPa]



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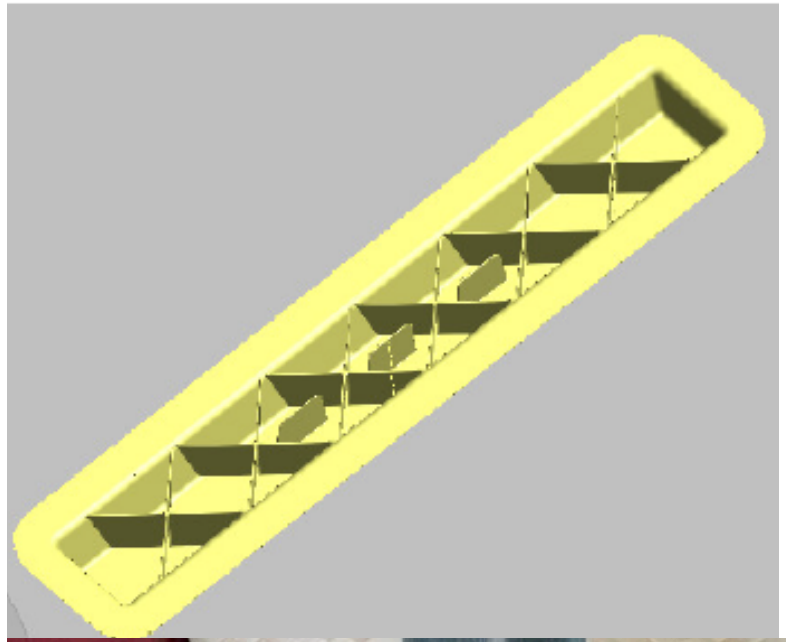
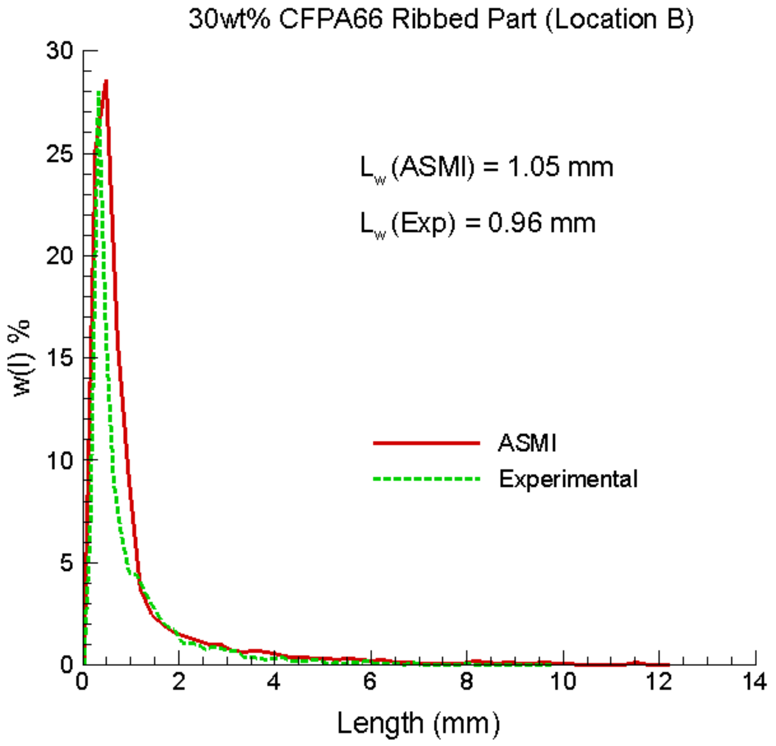
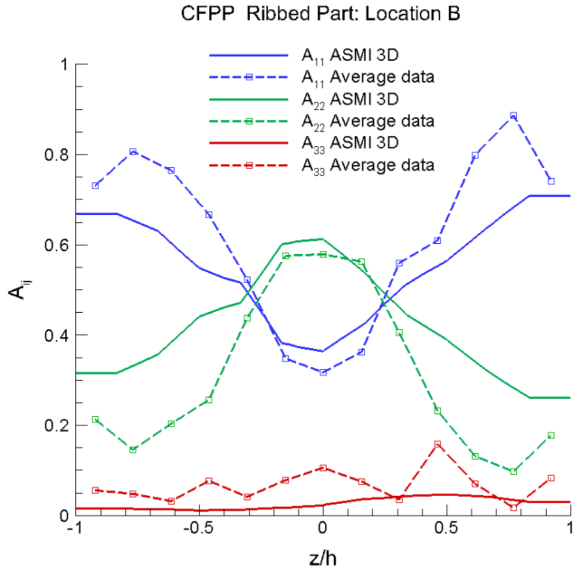
Long Carbon Fiber Thermoplastic: Fiber Length

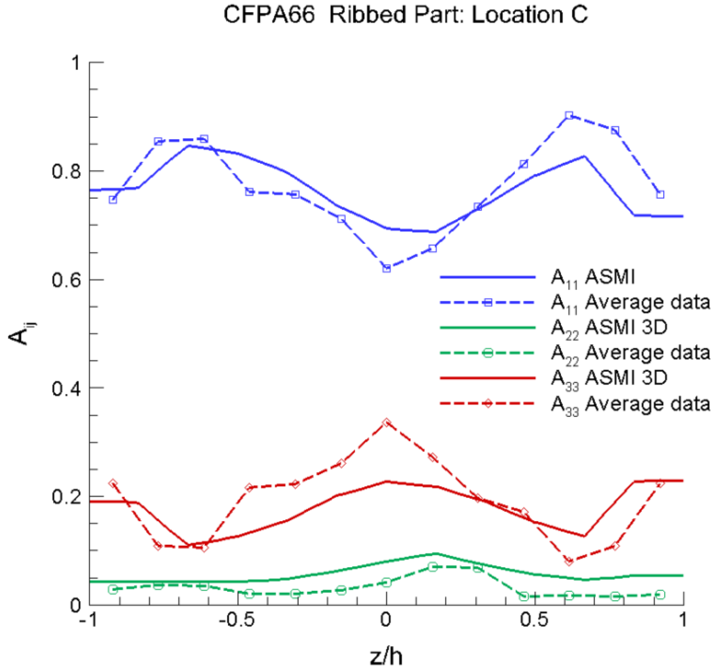
Prediction of fiber orientation and breakage during injection molding of “long” carbon fiber thermoplastics

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965







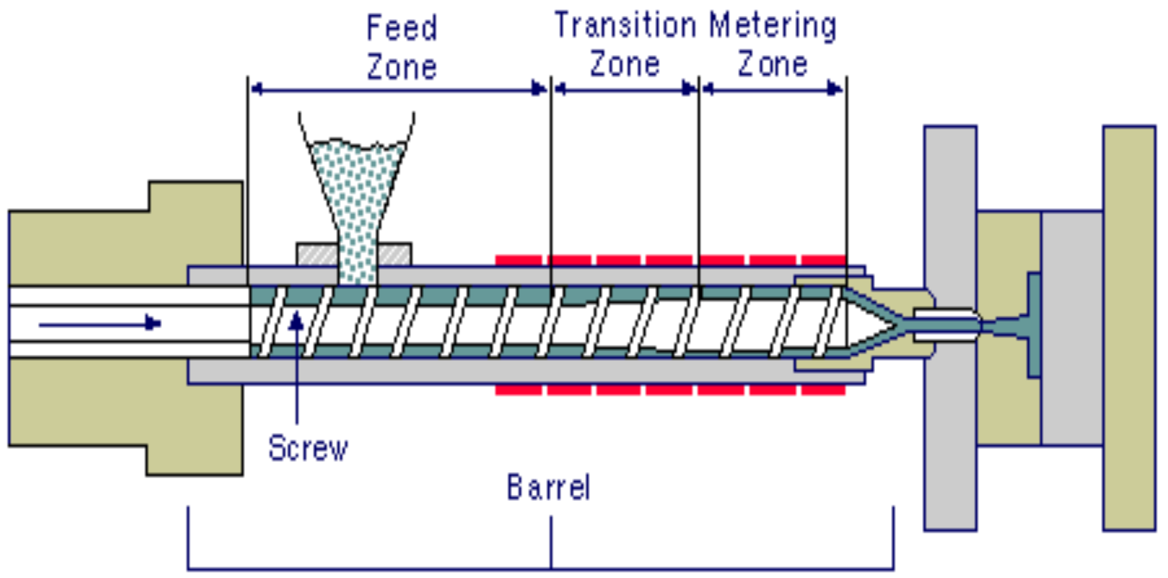


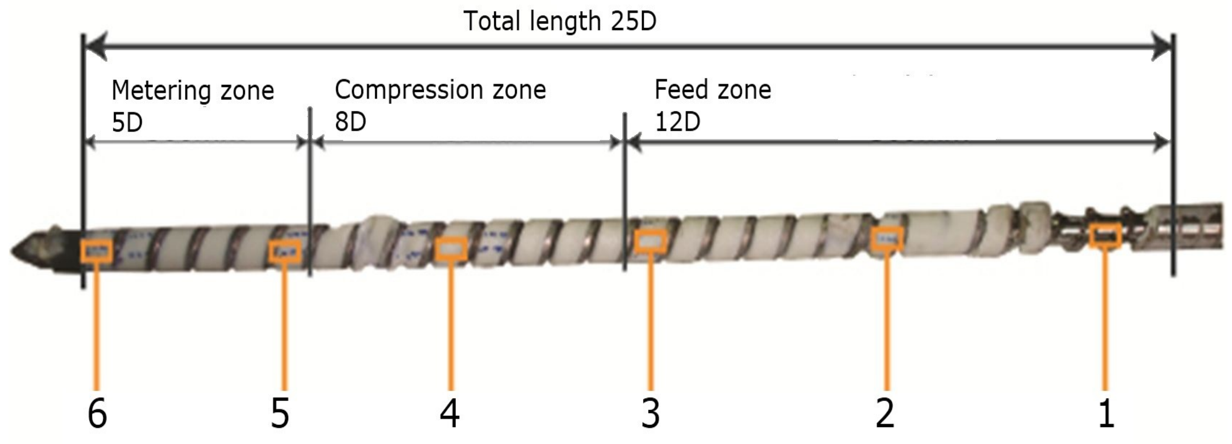
Comparison of measured and predicted fiber length distribution

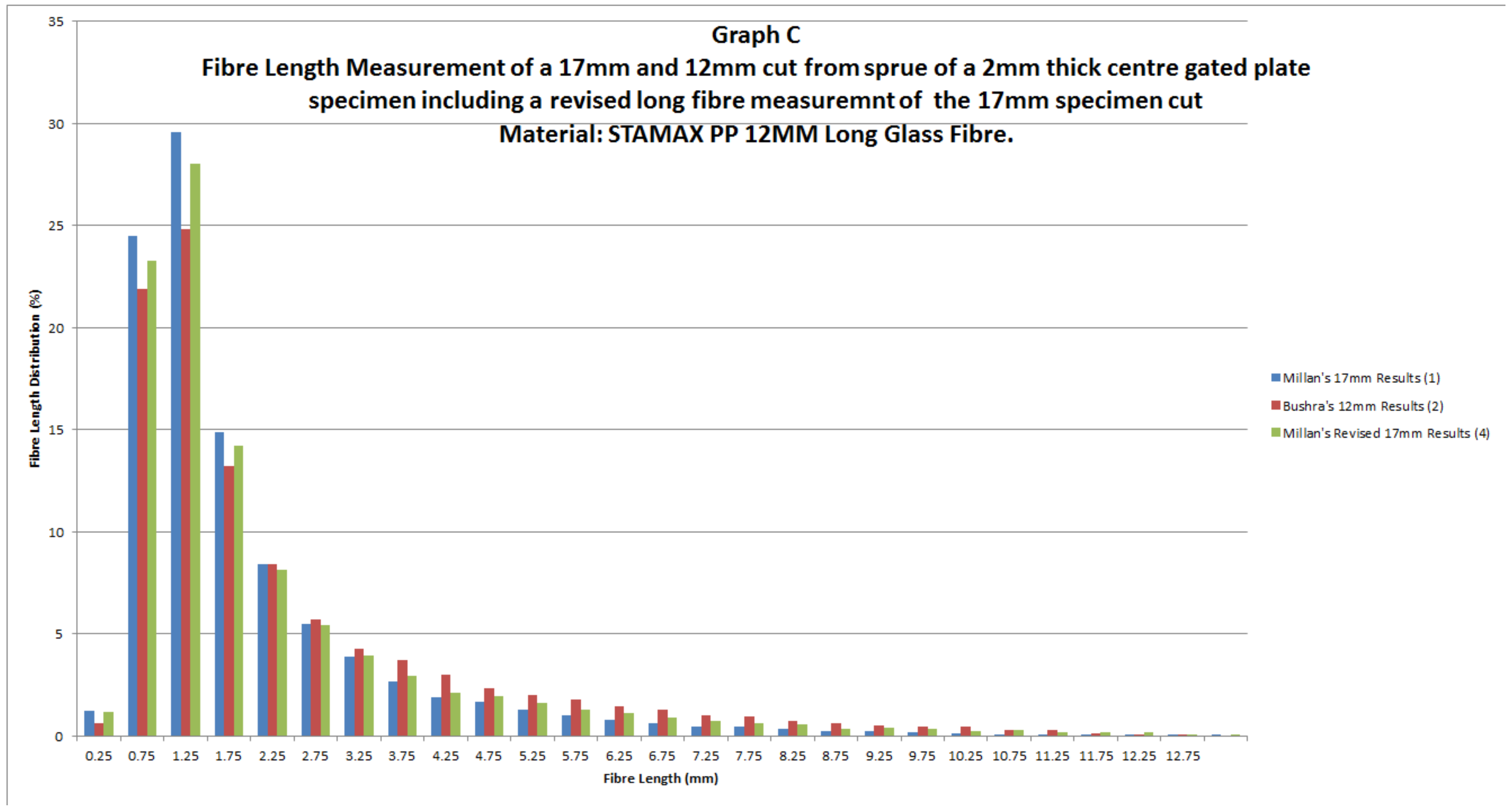
AUTODESK

Fiber Breakage in Barrel

Prediction of long fiber breakage during melting in injection barrel







Aim: Initial fiber length distribution for polymer at the sprue tip

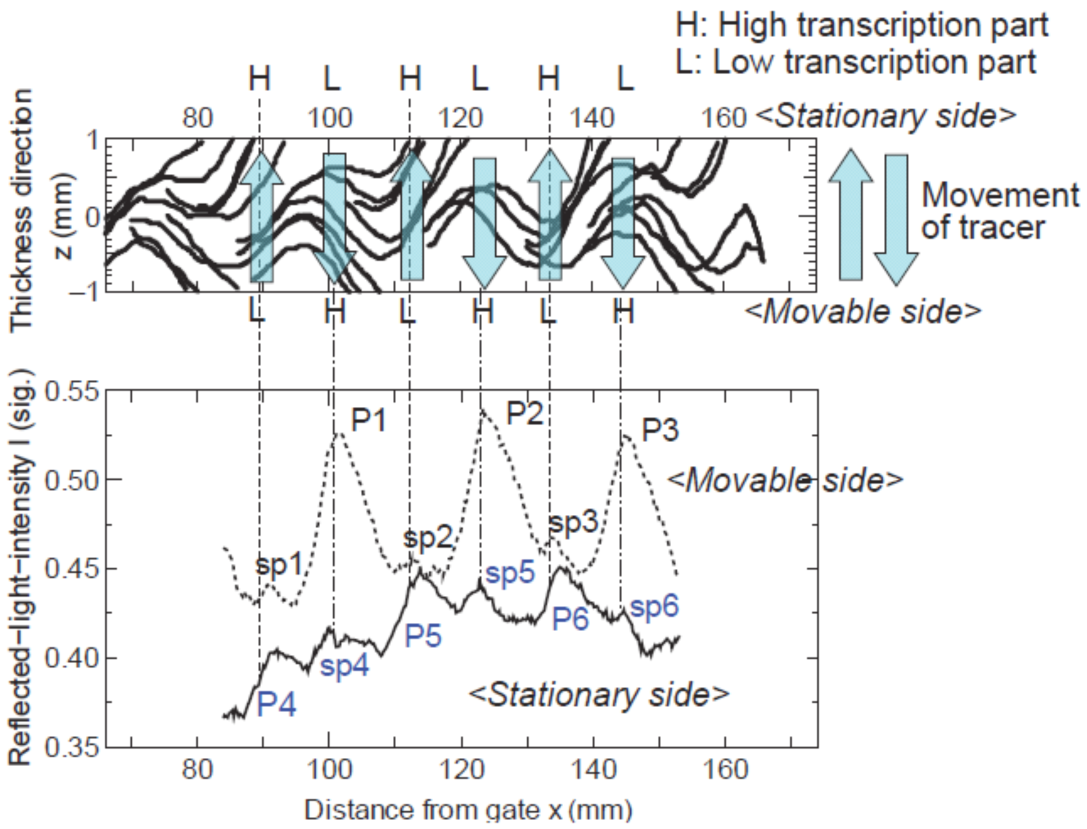
Yokoi Injection Molding Consortium

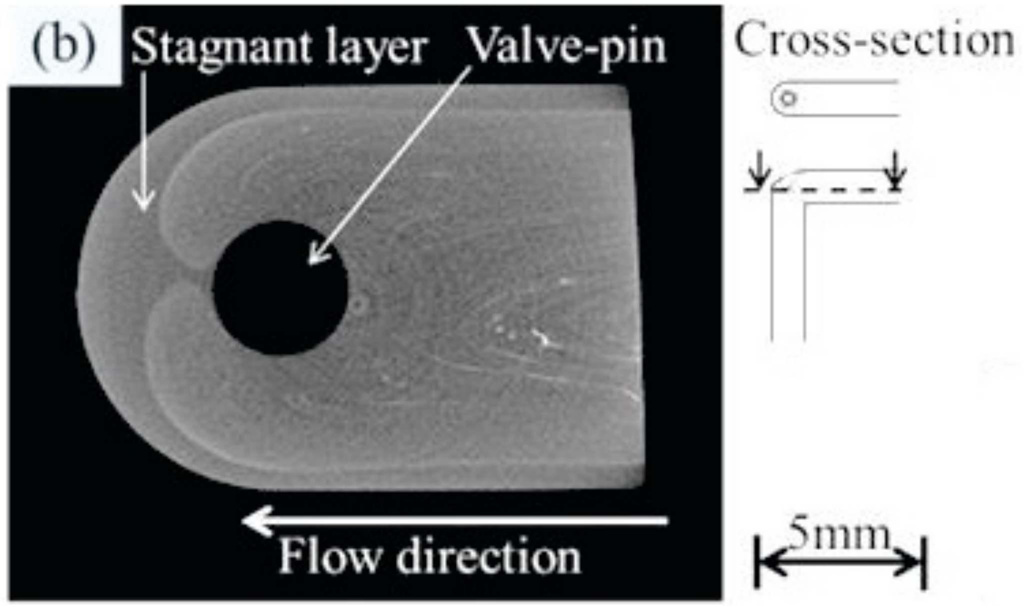
東京大学
THE UNIVERSITY OF TOKYO

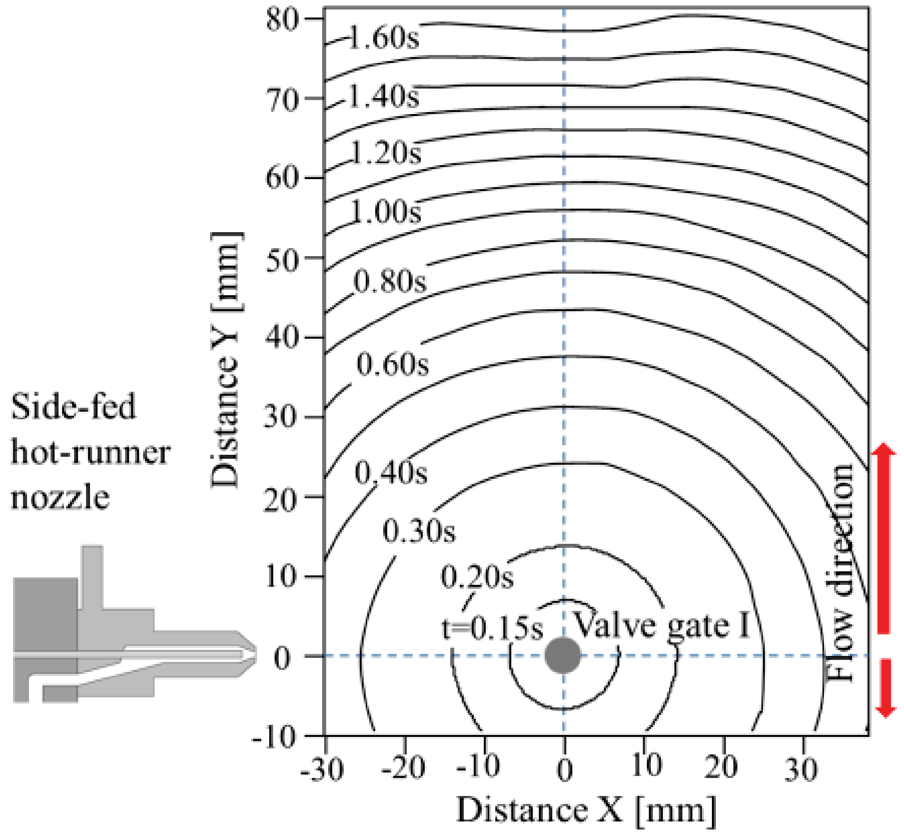
Fiber breakage in barrel

Observing Fountain Flow Oscillation (Tiger Stripe)

Flow Imbalance (Race-Track)







Yokoi et al. PPS-31, 144-148 & 350-354

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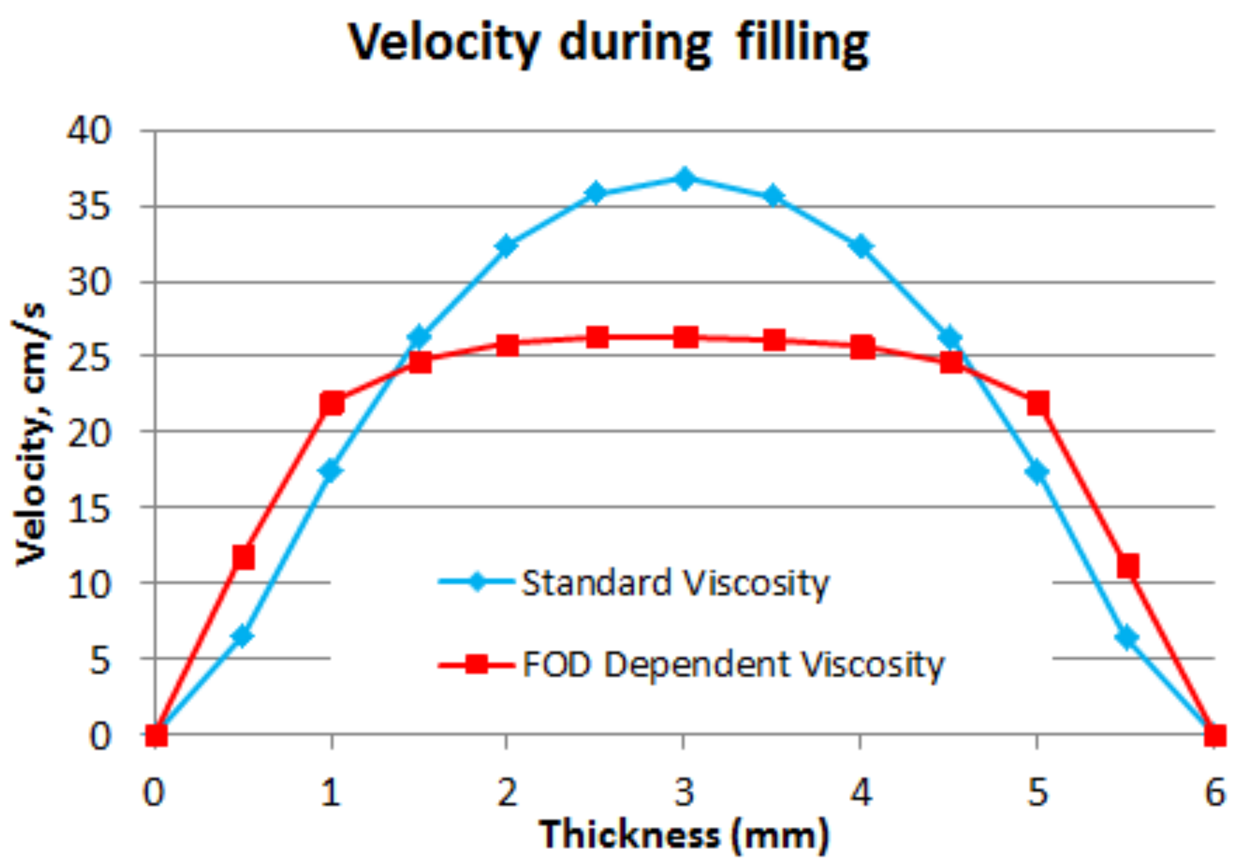
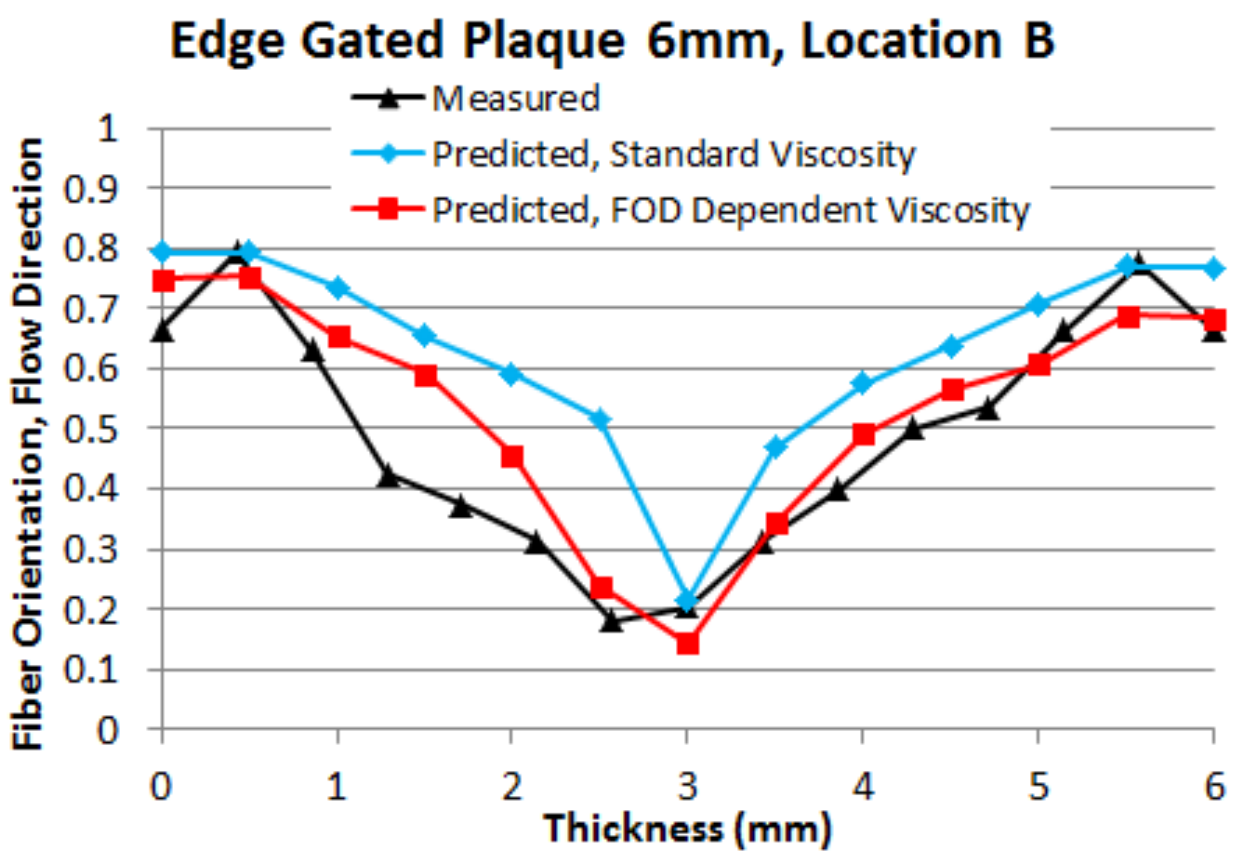
Filler Effect on Viscosity - RMIT

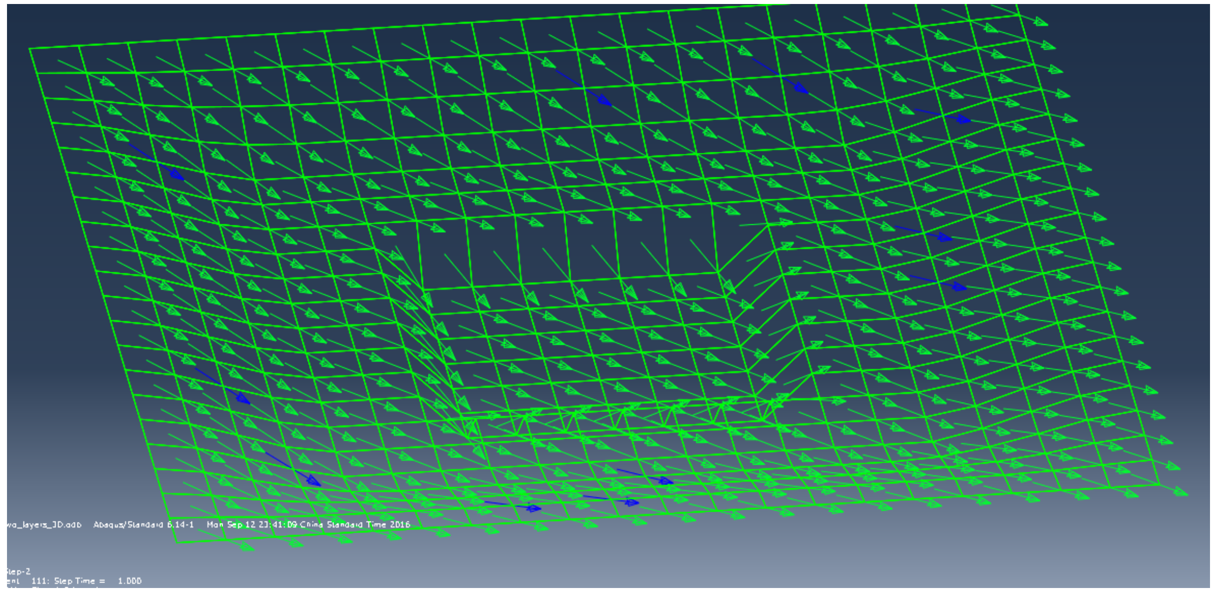
Model the change in viscosity due to filler migration, fiber orientation and fiber breakage

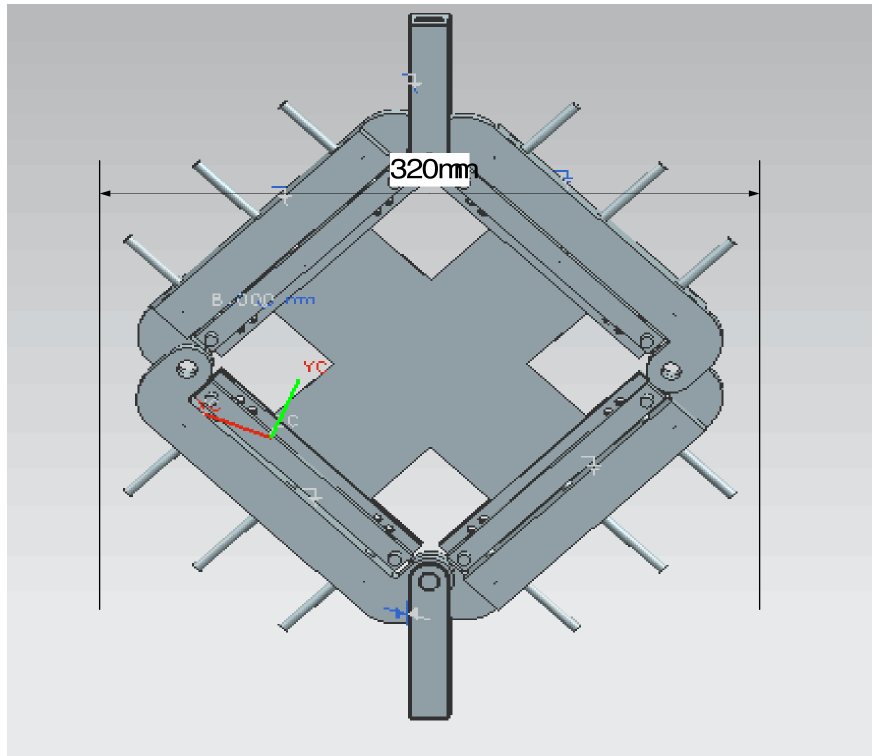


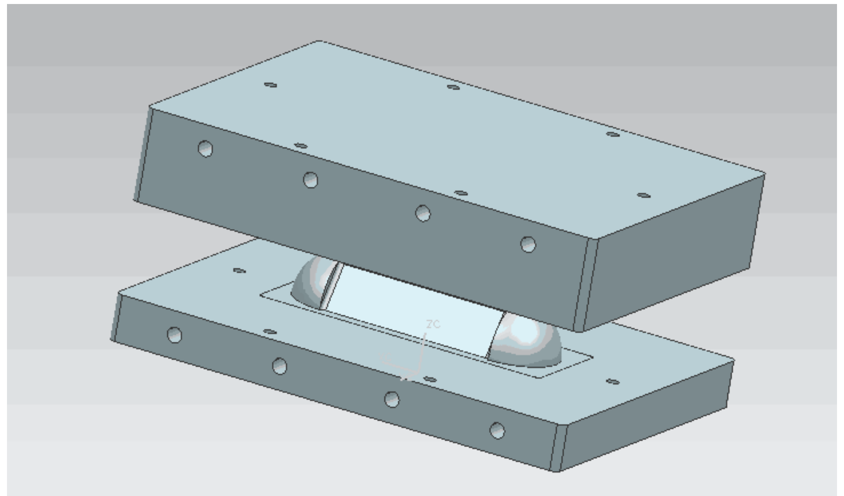


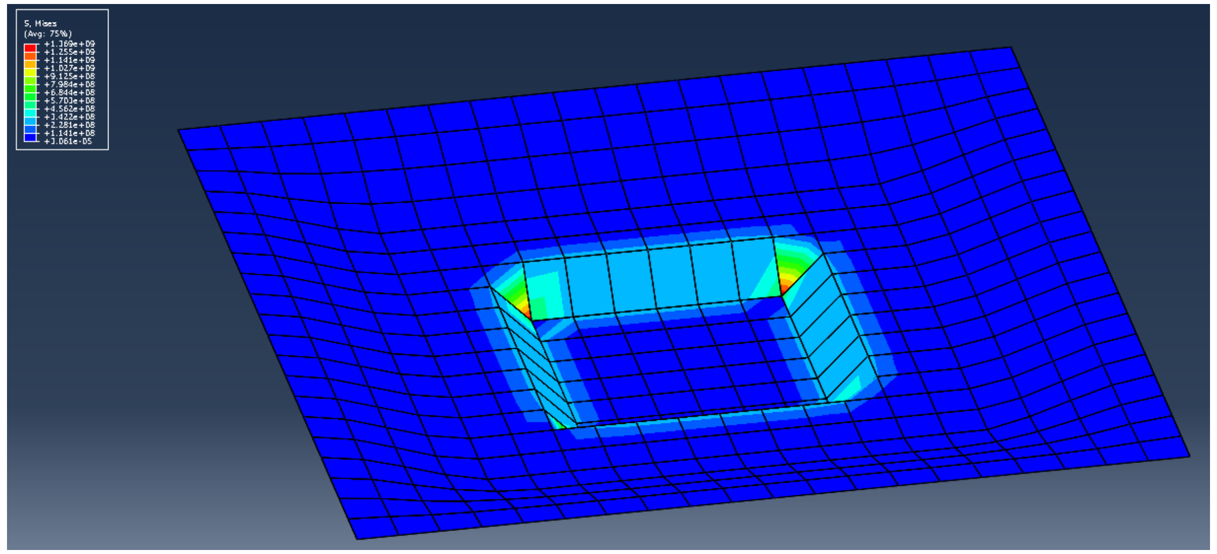
Composite Overmolding

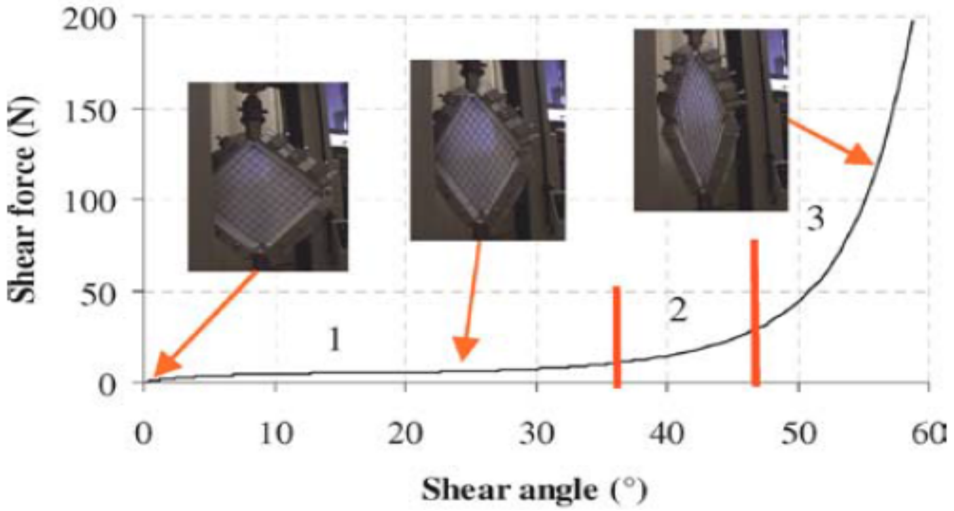
Model non-recoverable deformation and resistance of a continuous fiber composite (pre-preg) being compression overmolded

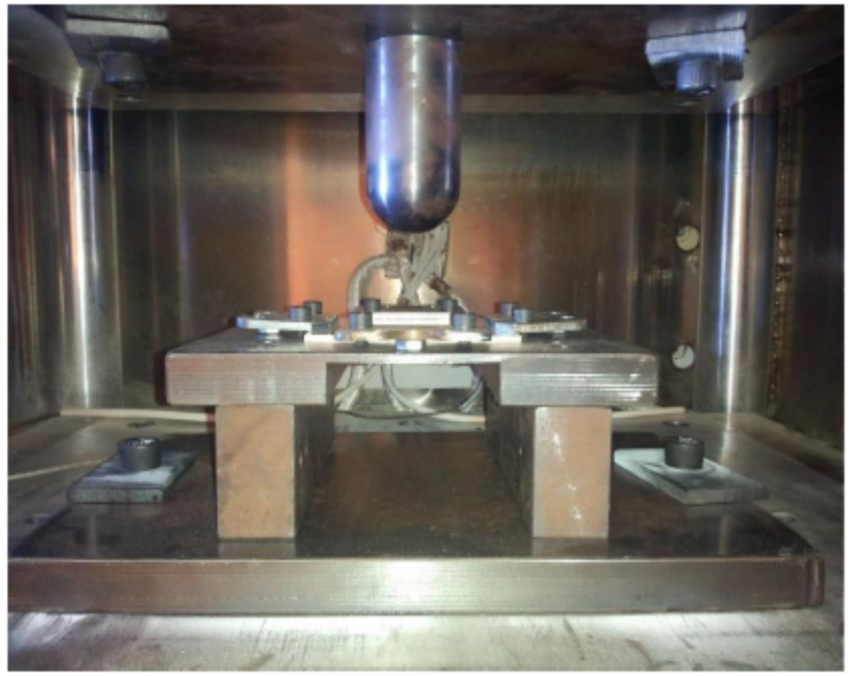












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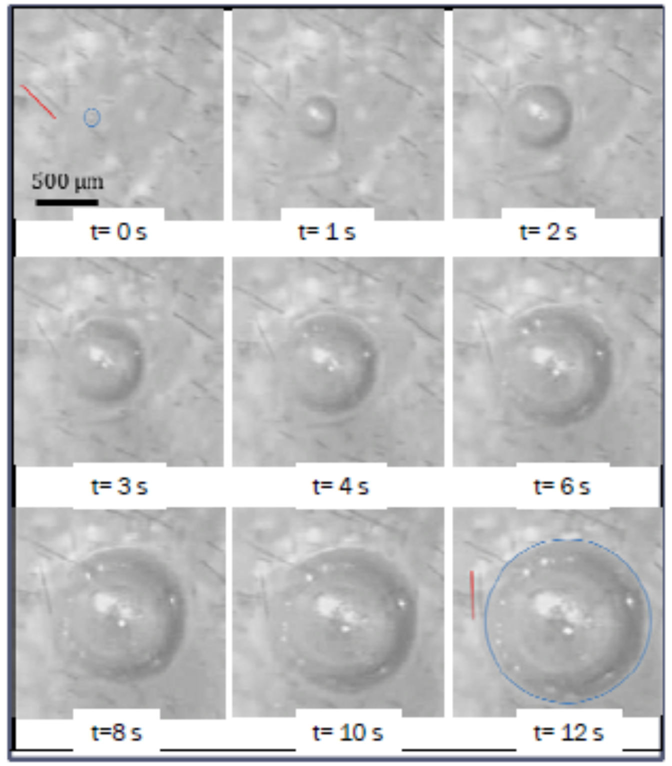
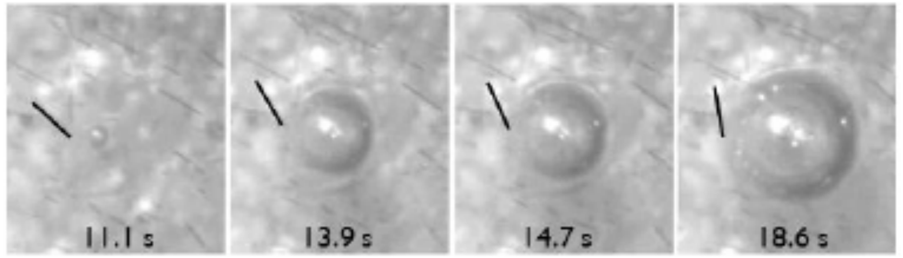
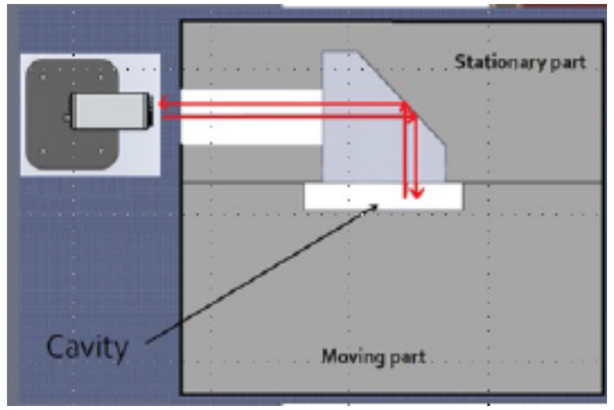
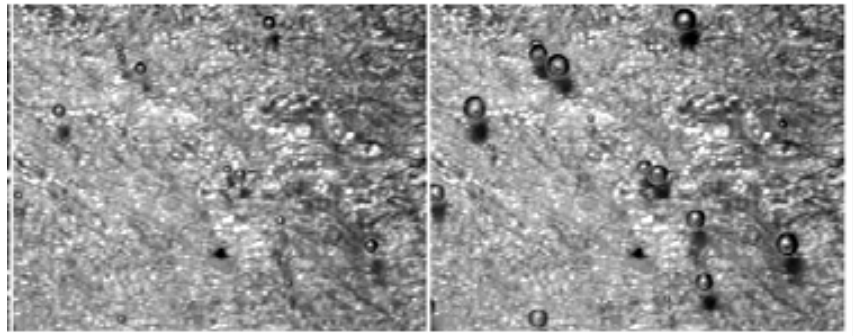
Microcellular Injection Molding



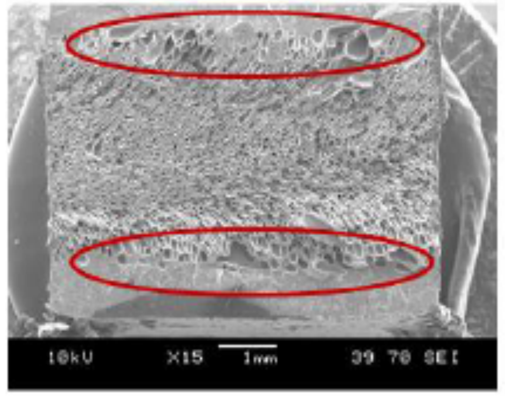


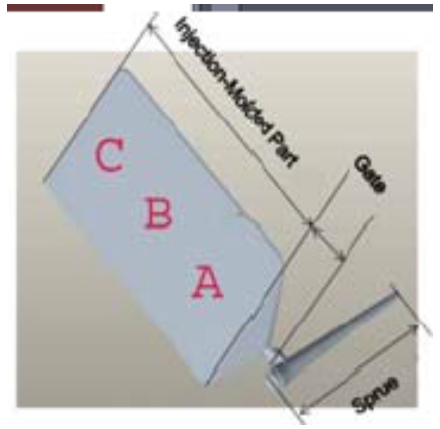
Bubble effects on fiber orientation

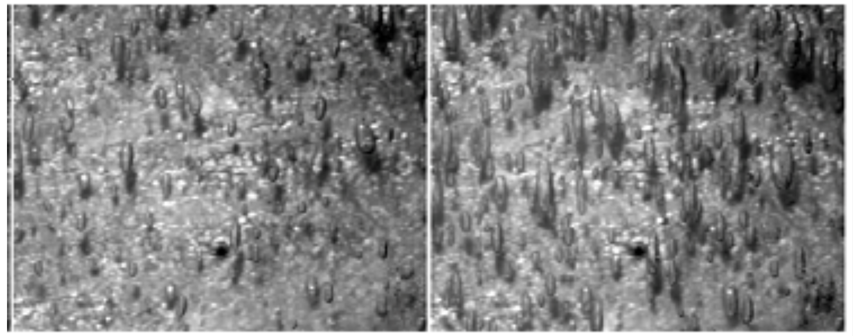




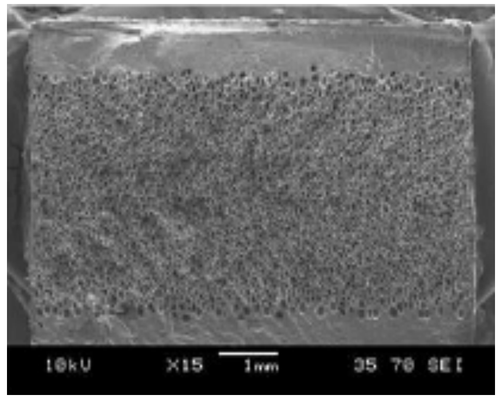
t= 20.1 s t= 25.9 s







t= 6.8 s t= 9.4 s



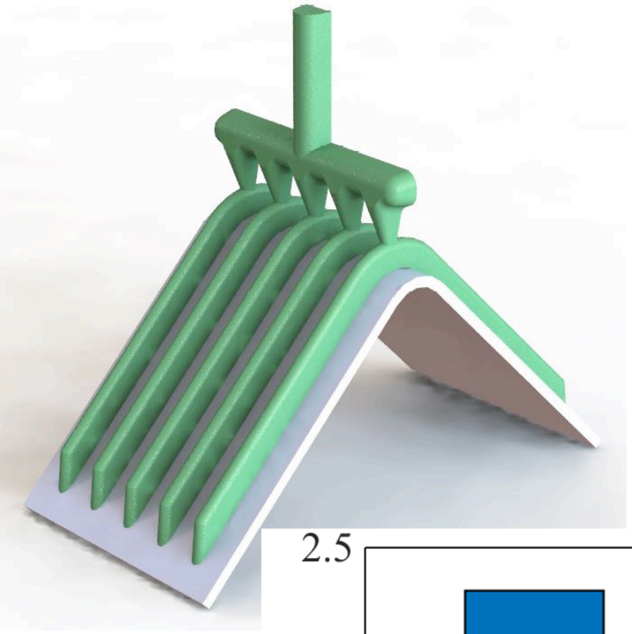
Bubble nucleation or growth and the final foam structure

(Microcellular Plastics Manufacturing Lab, Univ. Toronto)

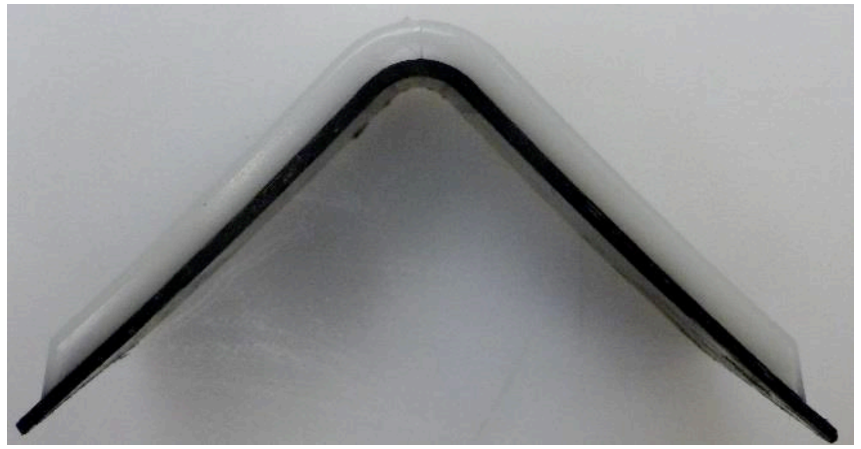
Injection Overmolding on Continuous Fibers Composites

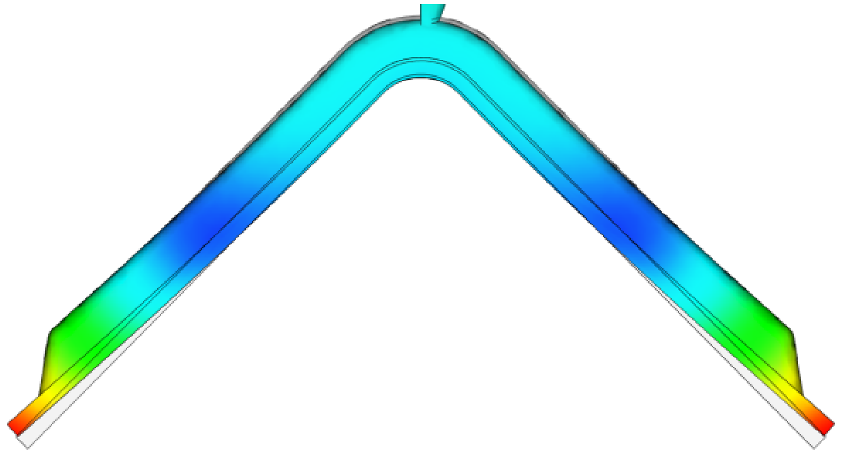
Interfaces AniForm draping solution to Moldflow Warp analysis of the combined structure

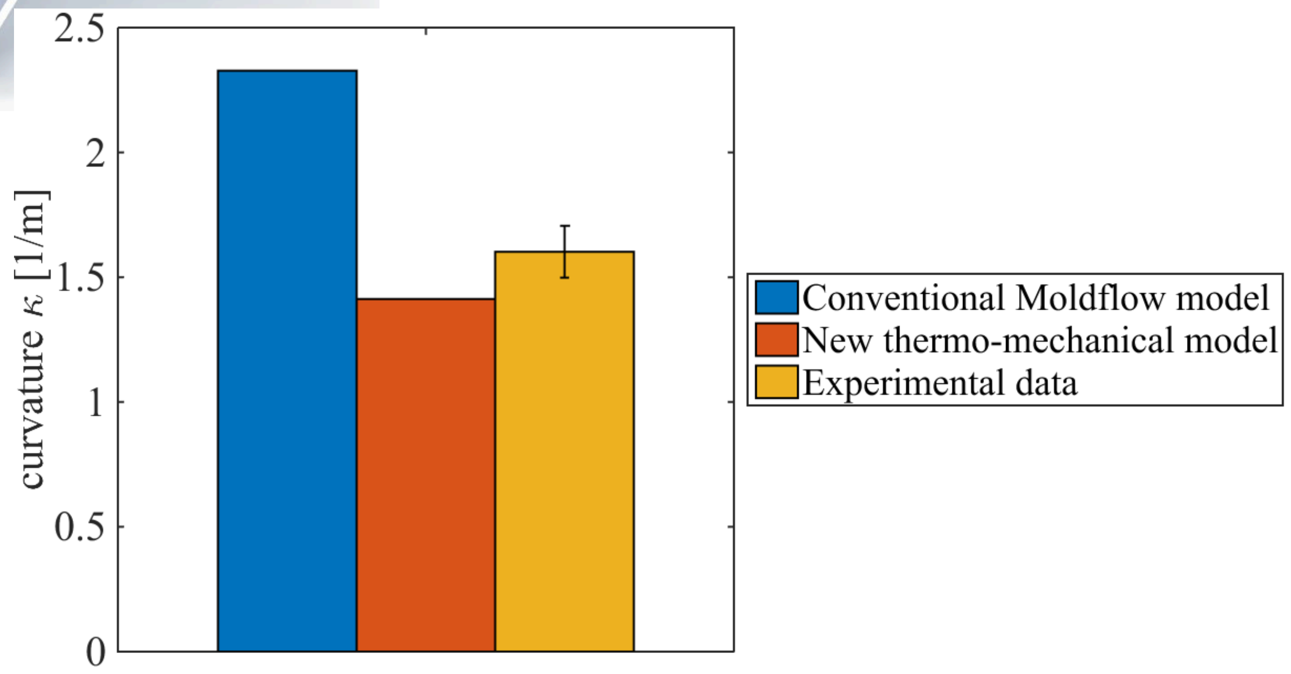
Models bond strength

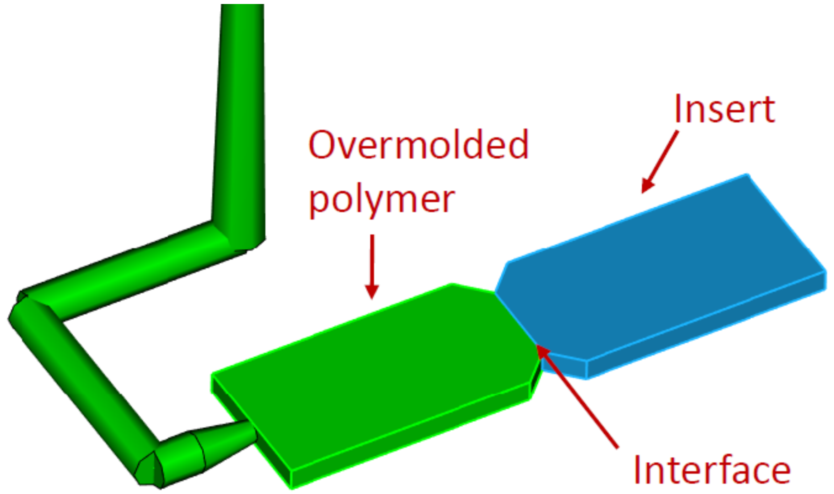


G/PA6 laminate + unfilled PA6







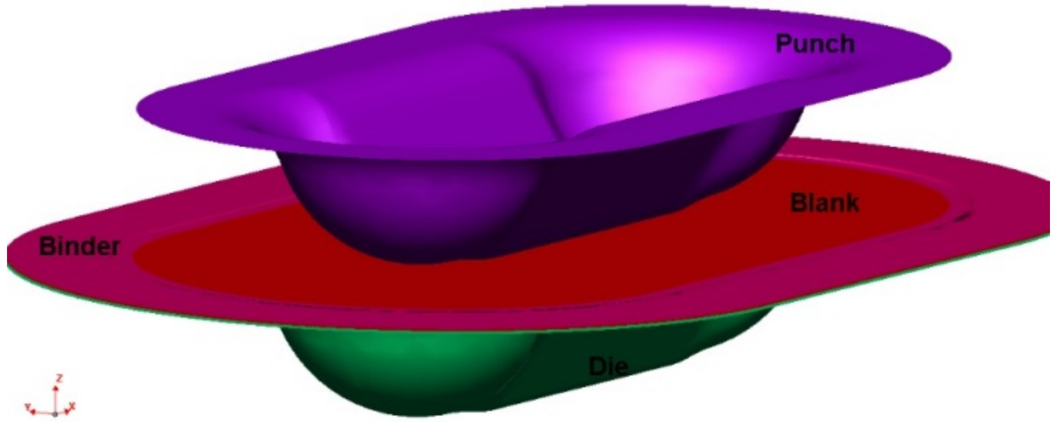


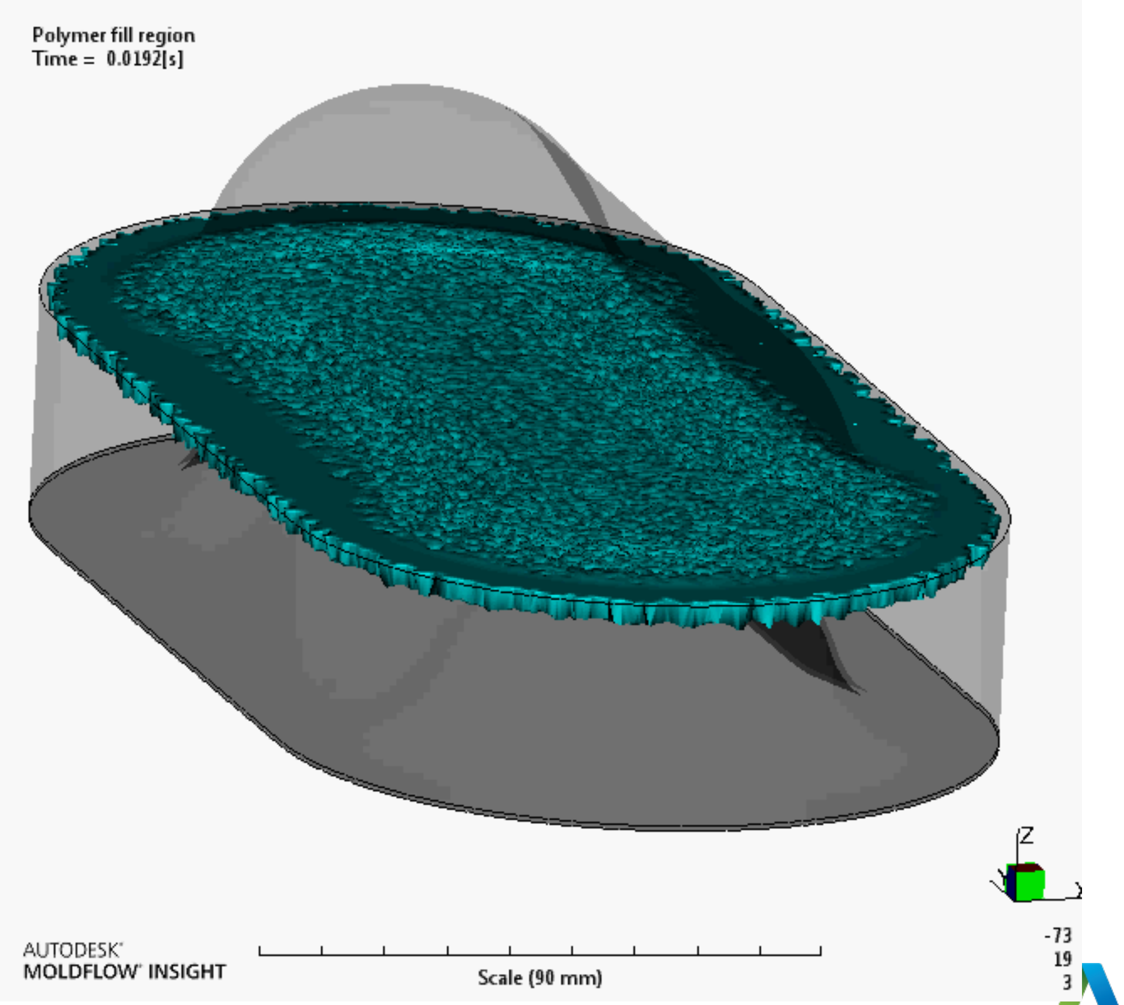
Chopped Carbon Fiber Compression

US DOE funding to develop ICME for carbon fiber draped and compression molded parts (Automotive)

Autodesk Moldflow was invited to provide process modeling of

Compression molding, Fiber Orientation, & Local fiber volume fraction

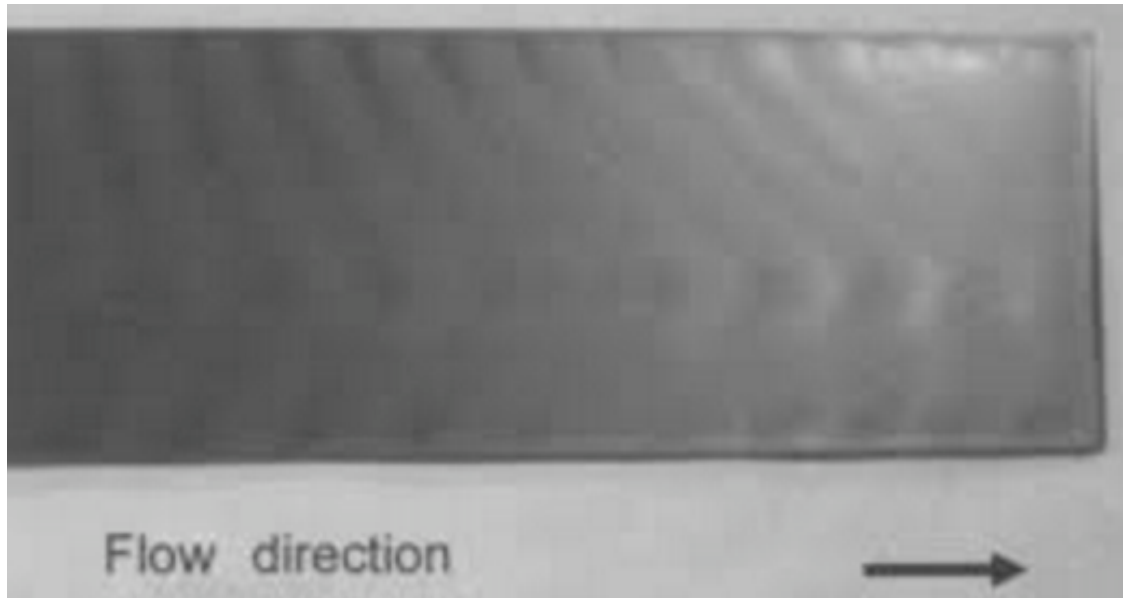




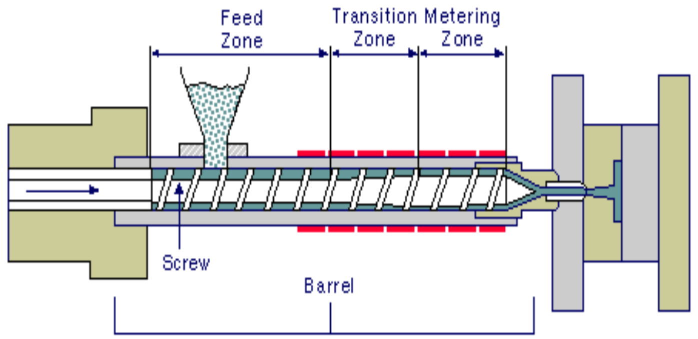
Surface Appearance (Tiger Stripes)

Flow instability mechanism understood.

Potential collaboration to study appearance factors (aimed at Automotive parts)



Academic Research Collaborations



University of Bradford (UK)

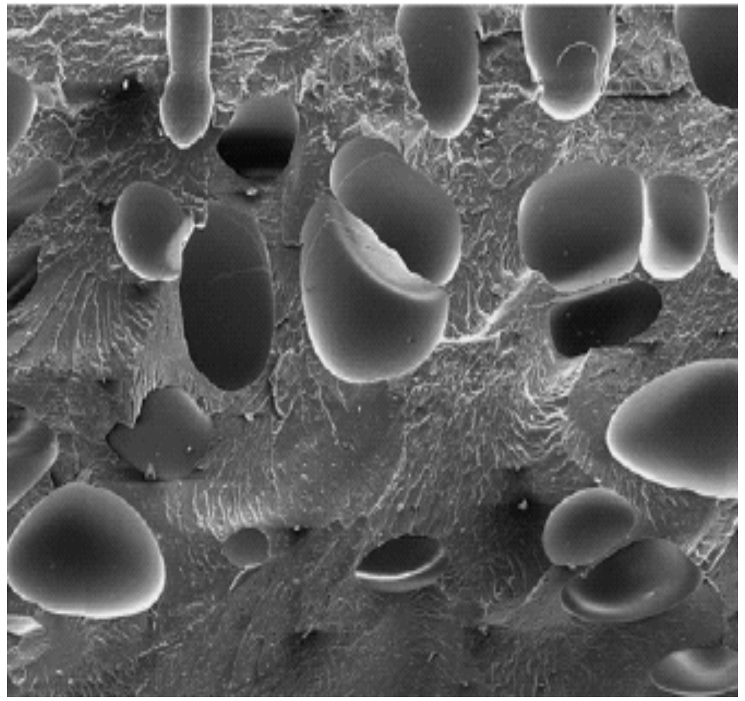
Long Fiber Orientations, & Fiber breakage in barrel

Tokyo University

Fiber breakage visualization, & Race track visualization

RMIT University (Australia)

Effect of fiber and filler migration to change viscosity, & Thermal stresses in SLM 3D Printed parts



Huazhong University of Science and Tech

Compression Overmolding of Continuous Fiber Composites

University of Toronto

Microcellular bubble formation

University of Wyoming

Progressive failure of composites

Industry Research Partnerships

Long Carbon Fiber Thermoplastics (Injection Molded)

Pacific Northwest National Labs, & GM

Chopped Carbon Fiber Thermoset (Compression Molded)

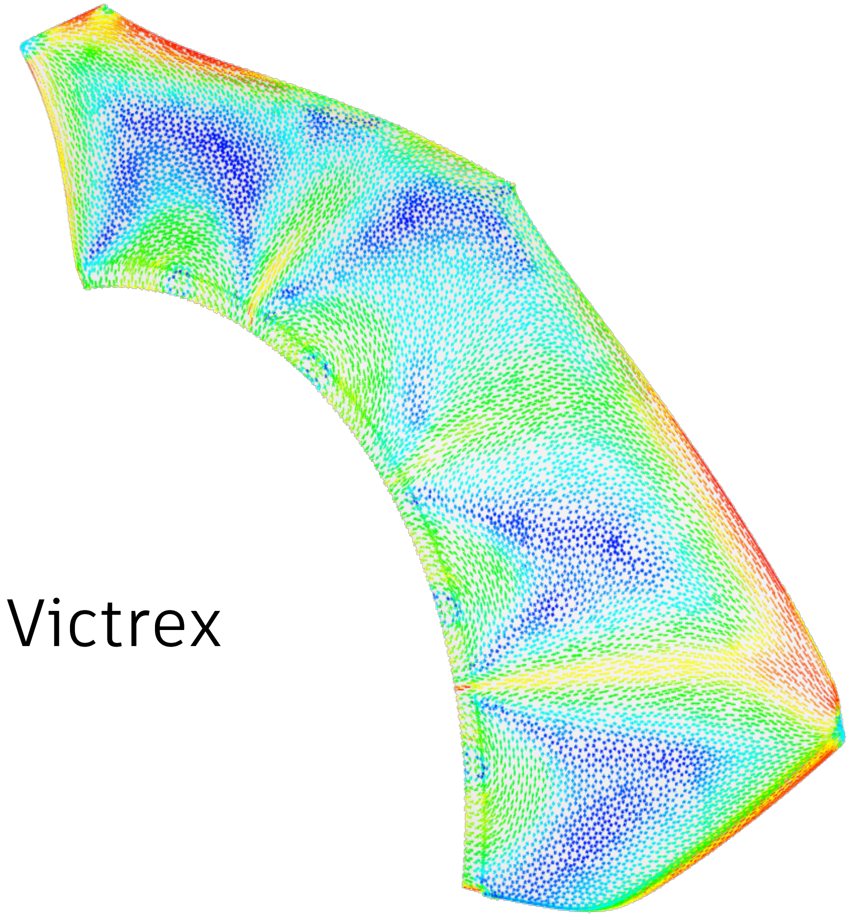
Ford, Dow, Northwestern University

Microcellular

Trexel, University of Toronto, & Ford

Thermoplastic Composite Overmolding

TPRC (The Netherlands), Boeing, Fokker, Johnson Controls, Victrex



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