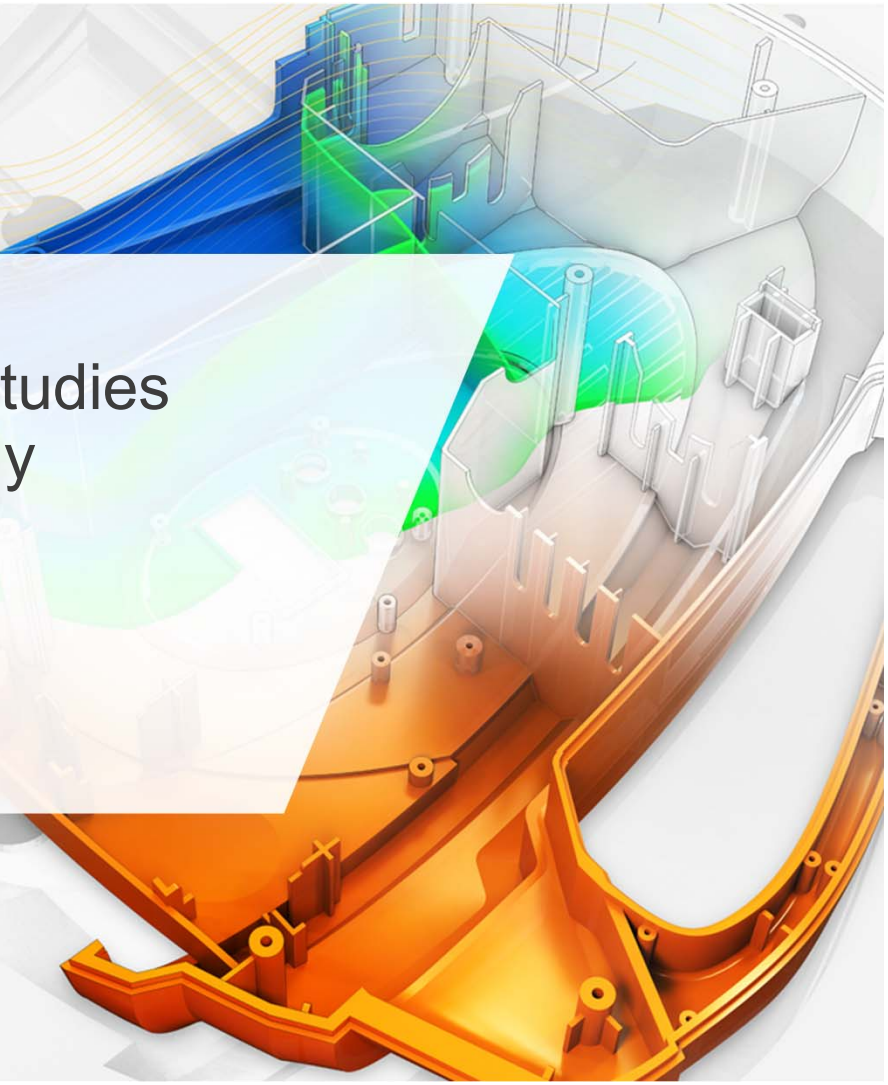
Moldflow Summit 2019
General Motors Moldflow Case Studies
The Good, The Bad, and The Ugly

Aaron Leonard (General Motors)

Sr. Manufacturing Engineer | aaron.leonard@gm.com

AUTODESK.



GENERAL MOTORS

INTRO

GLOBAL STANDARDS

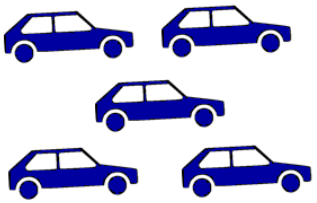
INTRO – GM VALUES

OUR VISION

ZERO CRASHES
ZERO EMISSIONS
ZERO CONGESTION

ZERO Crashes
Autonomous
1.25M Annual Deaths
90% Human Error

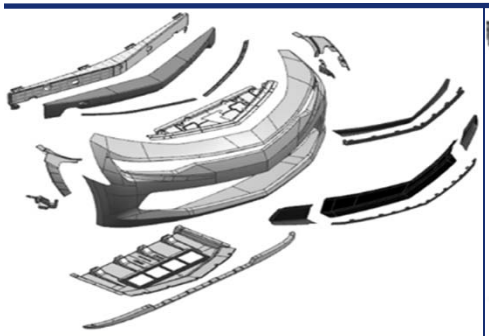
ZERO Emissions
Committed to EV
238 Miles (Bolt)



ZERO Congestion
168 Hours Idle
Sharing (Maven/Lyft)
Cruise Program

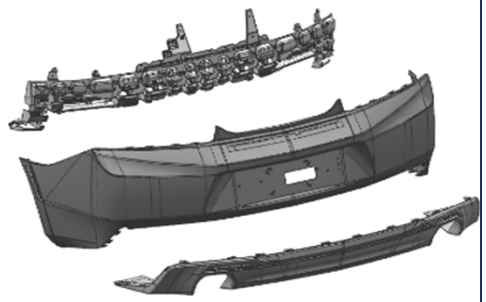
INTRO – APPENDIX E8 COMPONENTS

Exterior

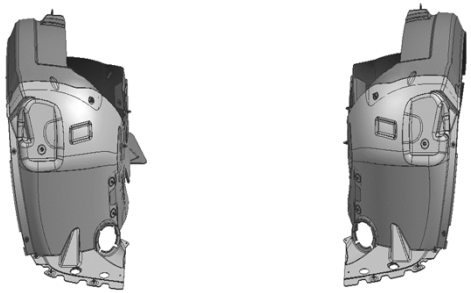


Front Bumper

Lighting

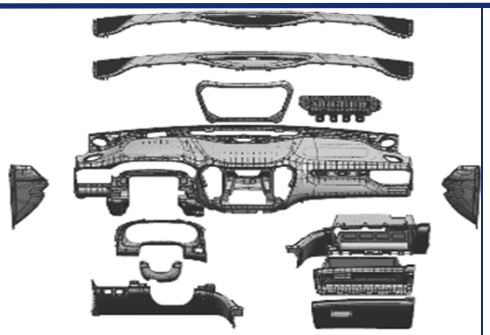


Rear Bumper

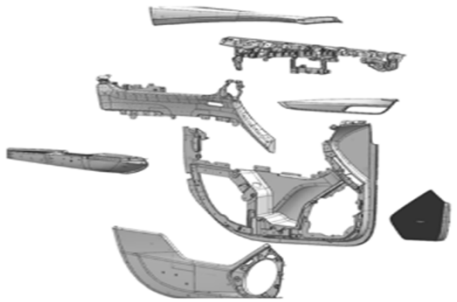


Wheel Liner

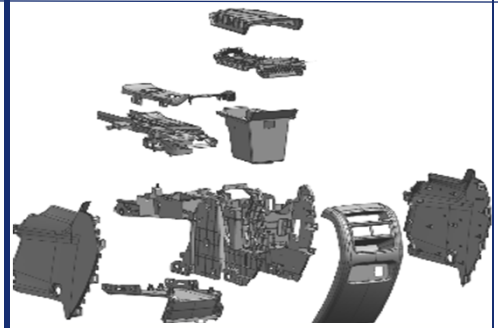
Interior



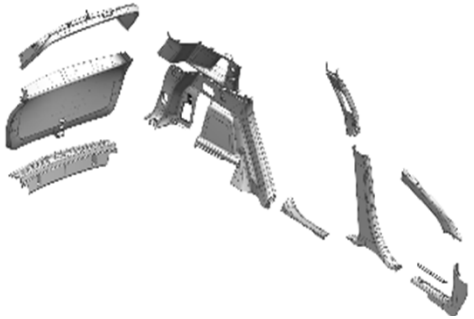
Instrument Panel



Door Trim



Floor Console



Hard Trim

INTRO – GMW STANDARDS

Five Global Engineering Standards Documents

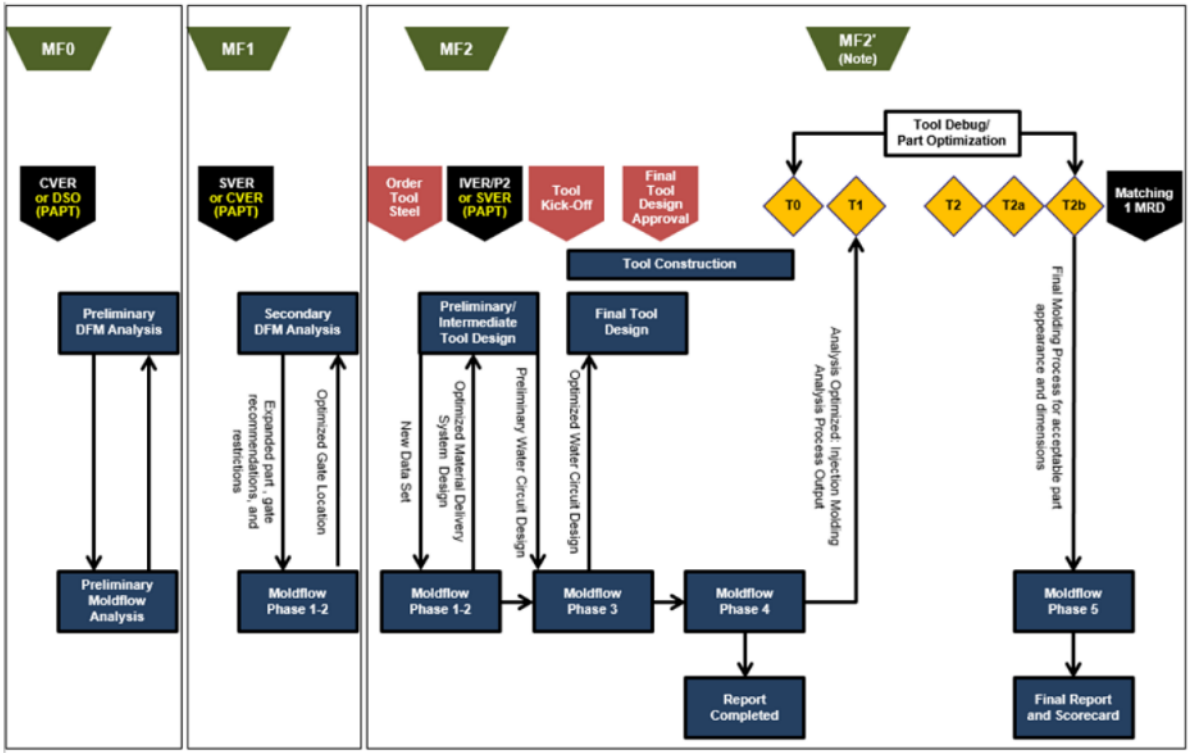
GMW15850	Mold Design & Construction
GMW16355	Injection Molding Analysis
GMW16365	T1 Tryout Protocol
GMW16375	Injection Mold Maintenance
GMW18157	Tool Steel for Injection Molds

New May, 2019

Available to Download on IHS Website (www.ihs.com)

Standards Enable Kaizen Improvements

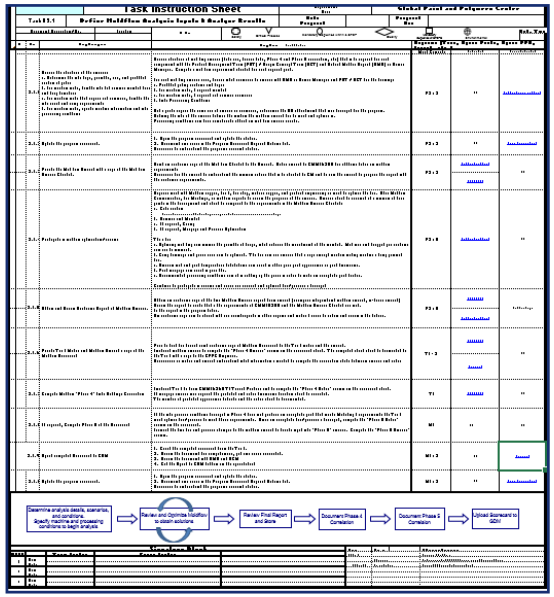
INTRO – MOLDFLOW FLOW CHART



Note: DFM = Design for Manufacturing, MRD = Material Required Date.
Note: MF2' may be required after IVER for PAPT. If MF2' required, Moldflow Phases 1 thru 4 will be required again, excluding full report and Moldflow scorecard.

INTRO – STANDARDIZED WORK

Moldflow Workflow


Task Instruction Sheet

Global Panel and Polymers Center

Task 13.1 Define Moldflow Analysis Inputs & Analyze Results

Determine analysis assets, scenarios, and conditions. Specify machine and processing conditions to begin analysis

Review and Optimize Moldflow to obtain solutions

Review Final Report and Store

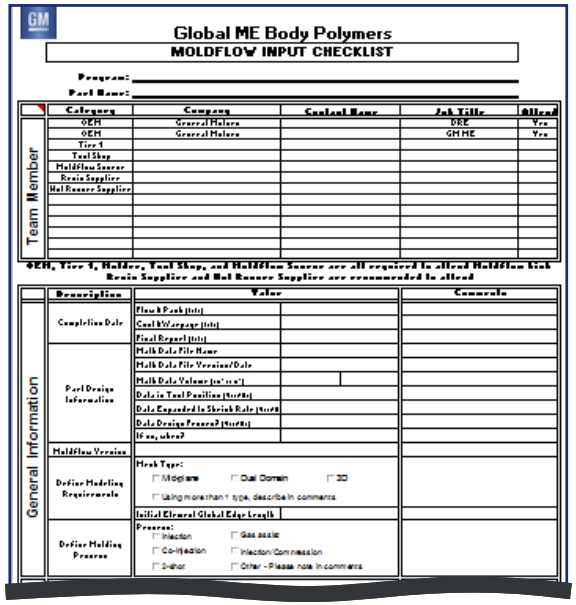
Document Phase 2 Correlation

Document Phase 2 Correlation

Upload Scorecard to GDX

Lessons Learned

Moldflow Inputs


Global ME Body Polymers

MOLDFLOW INPUT CHECKLIST

Program:

Part Name:

Team Member

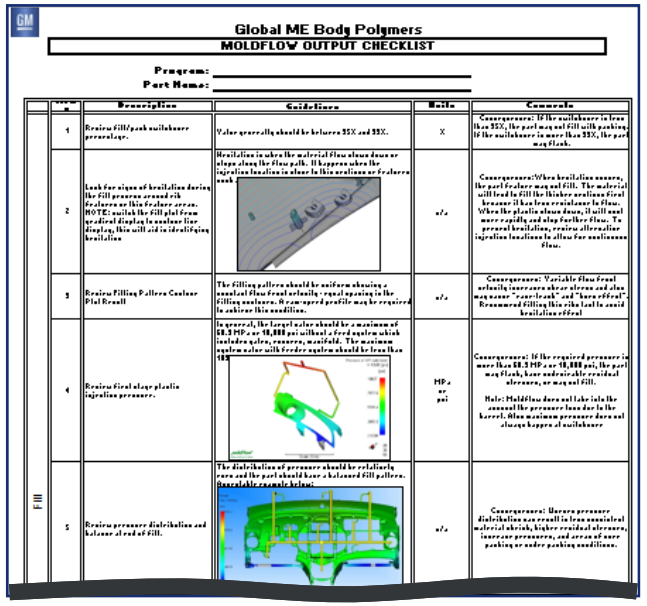
Category	Company	Contact Name	Job Title	Attend
OEM	General Motors		PRE	Yes
OEM	General Motors		GM ME	Yes
Tier 1				
Tool Shop				
Moldflow Source				
Resin Supplier				
Mat Reuse Supplier				

OEM, Tier 1, Moldor, Tool Shop, and Moldflow Source are all required to attend Moldflow link
Resin Supplier and Mat Reuse Supplier are recommended to attend

General Information

Description	Value		Comments
Completion Date	Flow & Pack [date]		
	Cool & Warpage [date]		
	Final Report [date]		
Part Design Information	Moldflow Data File Name		
	Moldflow Data File Version/Date		
	Moldflow Data Volume [cm³ or in³]		
	Data in Tool Position [Yes/No]		
	Data Expanded to Shrink Rate [Yes/No]		
	Data Design Frozen? [Yes/No]		
	If no, when?		
Moldflow Version			
Define Modeling Requirements	Mesh Type: ☐ Midplane ☐ Dual Domain ☐ 3D ☐ Using more than 1 type, describe in comments		
	Initial Element Global Edge Length		
Define Molding Process	Process: ☐ Injection ☐ Gas assist ☐ Co-Injection ☐ Injection/Compression ☐ Other - Please note in comments		

Moldflow Outputs


Global ME Body Polymers

MOLDFLOW OUTPUT CHECKLIST

Program:

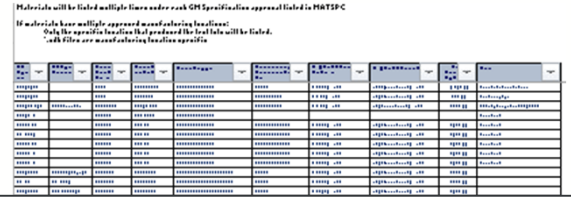
Part Name:

Fill

	Description	Guidelines	Units	Comments
1	Review Fill/pack moldshear percentage.	Value generally should be between 95% and 99%.	%	Consequence: If the moldshear is less than 95%, the part may not fill with packing. If the moldshear is more than 99%, the part may flash.
2	Look for signs of hesitation during the Fill process around rib features or thin feature areas. NOTE: switch the fill plot from an Axial display to another line display, this will aid in identifying hesitation	Hesitation is when the material flow slows down or stops along the flow path. It happens when the injection location is close to thin sections or features such as ribs.	n/a	Consequence: When hesitation occurs, the part feature may not fill. The material will tend to fill the thicker sections first because it is less resistance to flow. When the plastic slows down, it will cool more rapidly and stop further flow. To prevent hesitation, review alternative injection locations to allow for continuous flow.
3	Review Filling Pattern Contour Plot Result	The filling pattern should be uniform showing a constant flow front velocity - equal spacing in the filling contours. If a non-speed profile may be required to achieve this condition.	n/a	Consequence: Variable flow front velocity (non-even shear stress and also may cause "race-track" and "bare effect". Recommend filling this site tool to avoid hesitation effect
4	Review Final stage plastic injection pressure.	In general, the target value should be a maximum of 85% of 18,000 psi without a Feed system which includes gates, runners, manifold. The maximum system value with feeder system should be less than 18K	MPa or psi	Consequence: If the required pressure is more than 85% of 18,000 psi, the part may flash, have undesirable residual stresses, or may not fill. Note: Moldflow does not take into the account the pressure loss due to the barrel. Also maximum pressure does not always happen at moldshear
5	Review pressure distribution and balance at end of fill.	The distribution of pressure should be relatively even and the part should have a balanced fill pattern. Recreate example below:	n/a	Consequence: Uneven pressure distribution can result in less consistent material shrink, higher residual stresses, inaccurate pressures, and areas of over packing or under packing conditions.

INTRO – PRIVATE GM DATABASES

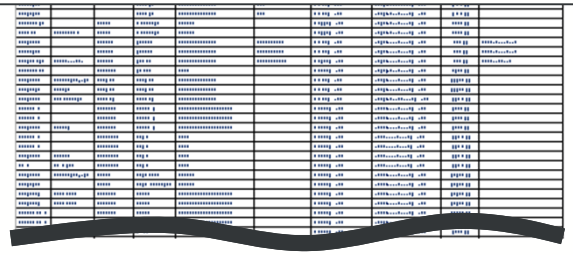
Private Material Database



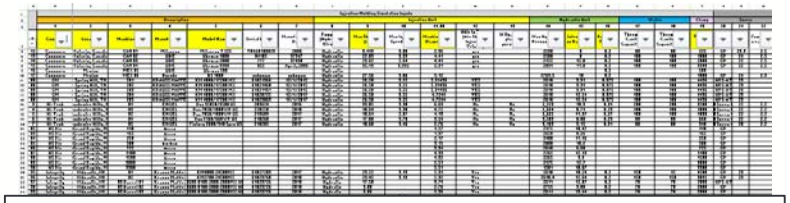
>50 Resins

Full MPL 150 Characterization

Available to All Approved Analysts



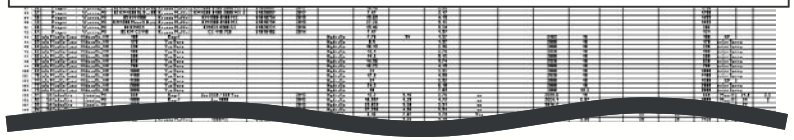
Private Machine Database



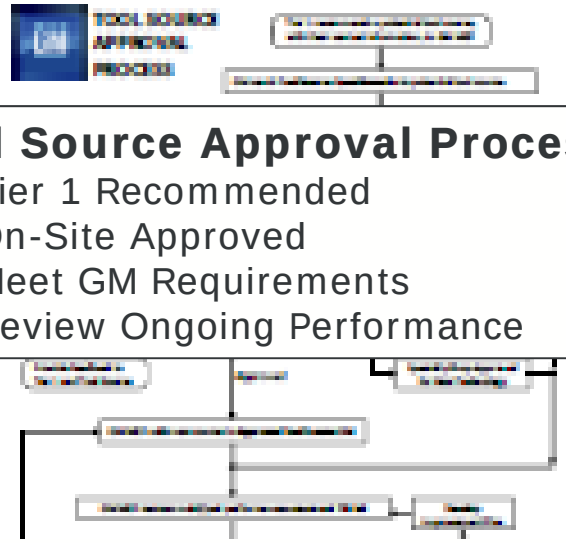
>110 Molding Machines

T1 Tryout Locations

Available to All Approved Analysts

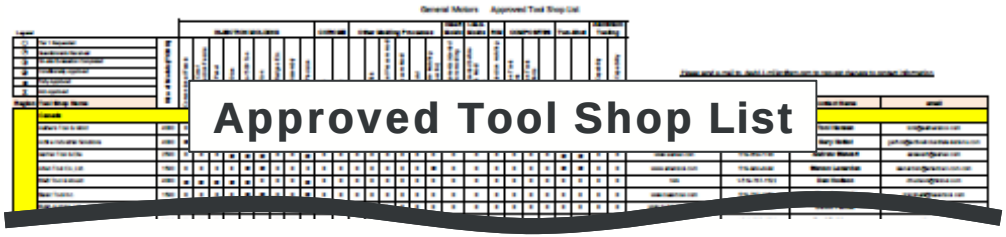


INTRO – APPROVED LIST & PROCESS

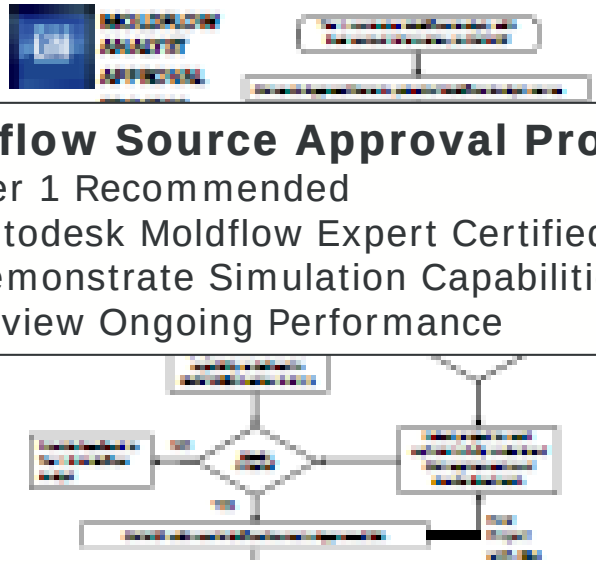


Tool Source Approval Process

1. Tier 1 Recommended
2. On-Site Approved
3. Meet GM Requirements
4. Review Ongoing Performance

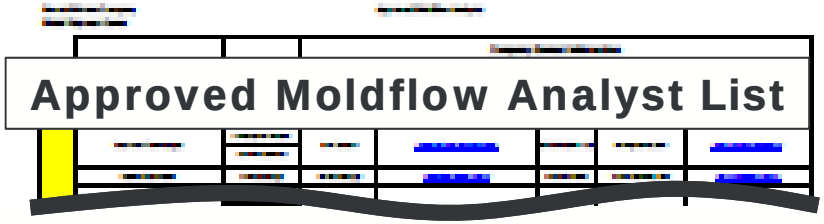


Approved Tool Shop List



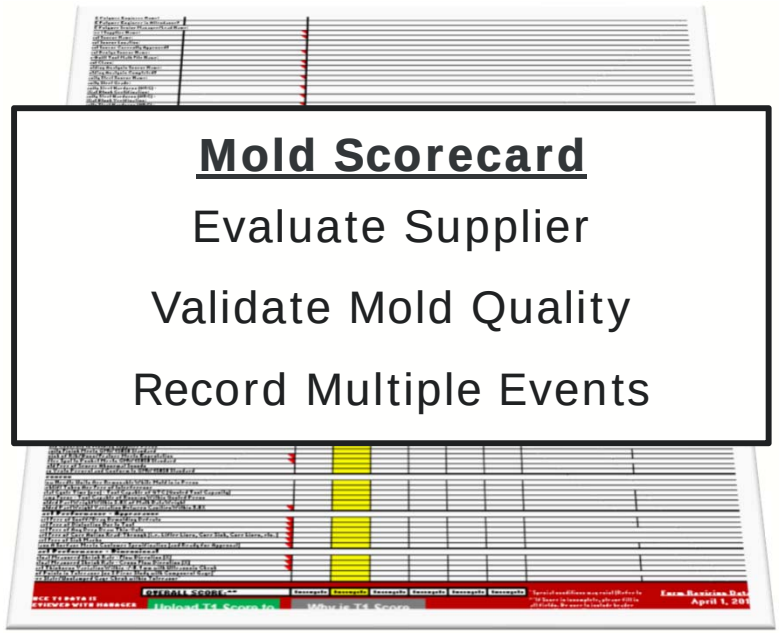
Moldflow Source Approval Process

1. Tier 1 Recommended
2. Autodesk Moldflow Expert Certified
3. Demonstrate Simulation Capabilities
4. Review Ongoing Performance



Approved Moldflow Analyst List

INTRO – CORRELATION

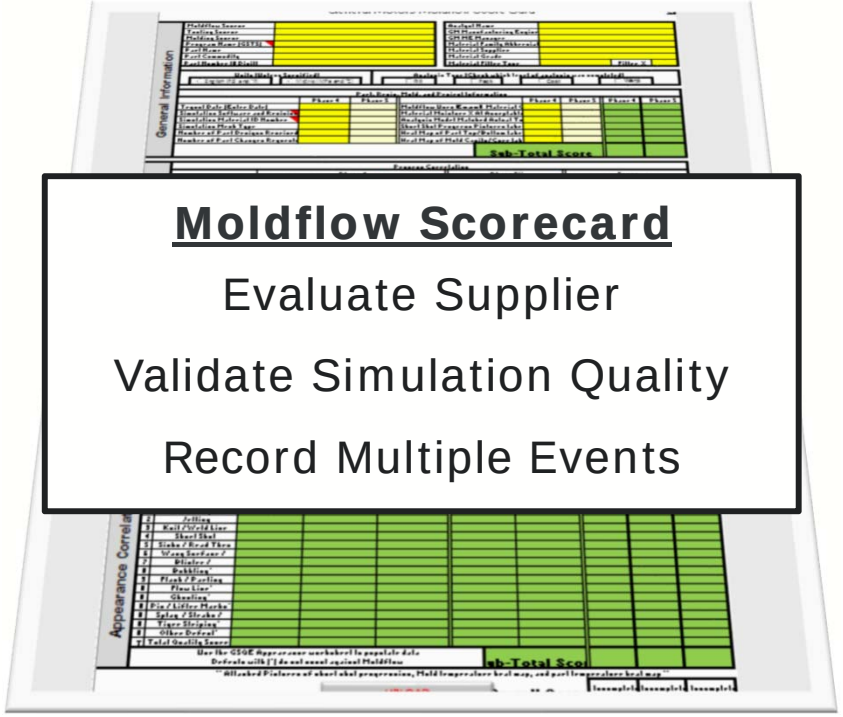


Mold Scorecard

Evaluate Supplier

Validate Mold Quality

Record Multiple Events



Moldflow Scorecard

Evaluate Supplier

Validate Simulation Quality

Record Multiple Events

INTRO – FORMAL KAIZEN ACTIVITIES

GM Pre-Summit

Advisory Board

INTRO – GMW16355 TRAINING

When: July 30-31 (Sold Out!)
October 2-3

Location: Novi, MI

Price: $600

https://aim.institute/moldflow/gmmoldflow/

THE GOOD

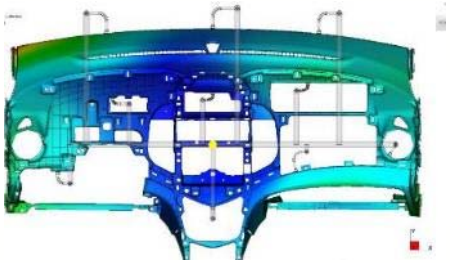
THE GOOD – DEFINITION

☑ Team Made Upfront Simulation-Driven Part Design, Process, and/or Mold Changes That Improved Part Quality

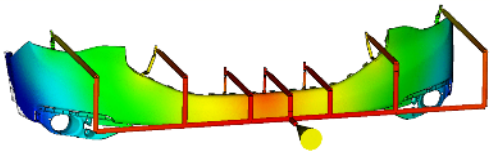
THE GOOD – EXAMPLE 1

Item:	**Controlling Flow Front by Gate Selection and Valve Gate**
Goal:	**Reduce Flow Length and Manage Weld Lines**

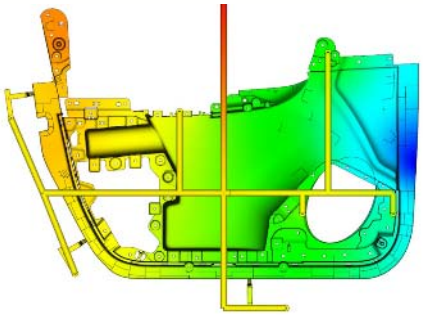
Instrument Panel



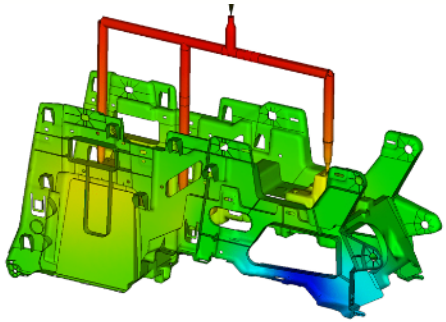
Fascia



Door Trim



Floor Console

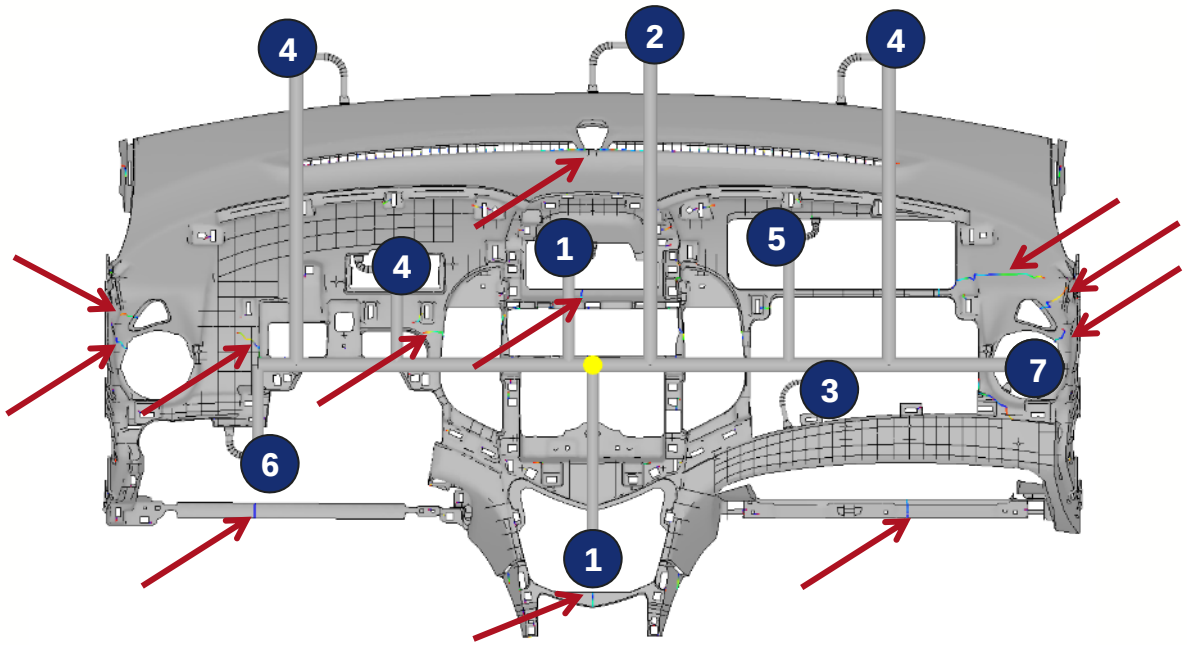


THE GOOD – EXAMPLE 1 (DETAILED)

Part: Instrument Panel Retainer

Result: Weld Lines Managed to Non-Visible Areas

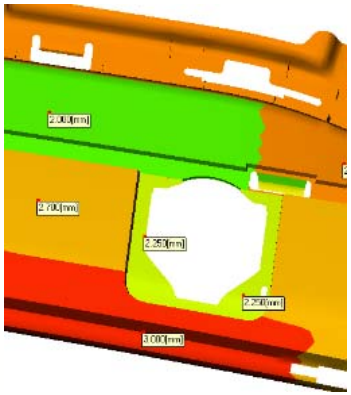
#	Time (sec)
1	0.00
1	0.00
2	0.55
3	1.97
4	2.42
4	2.42
4	2.42
5	2.62
6	3.47
7	3.93



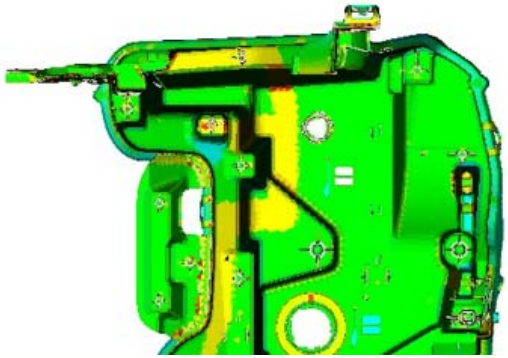
THE GOOD – EXAMPLE 2

Item:	**Controlling Flow Front by Part Thickness**
Goal:	**Manage Weld Lines / Air Traps and Improve Fill Balance**

Fascia



Lighting Housing



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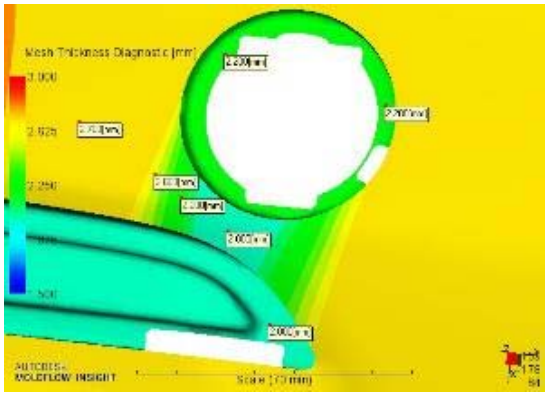

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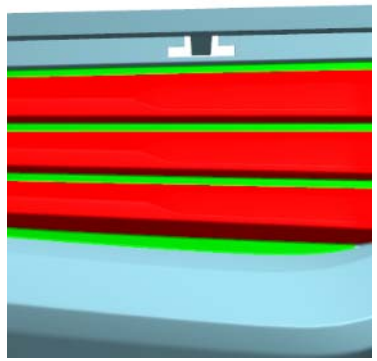
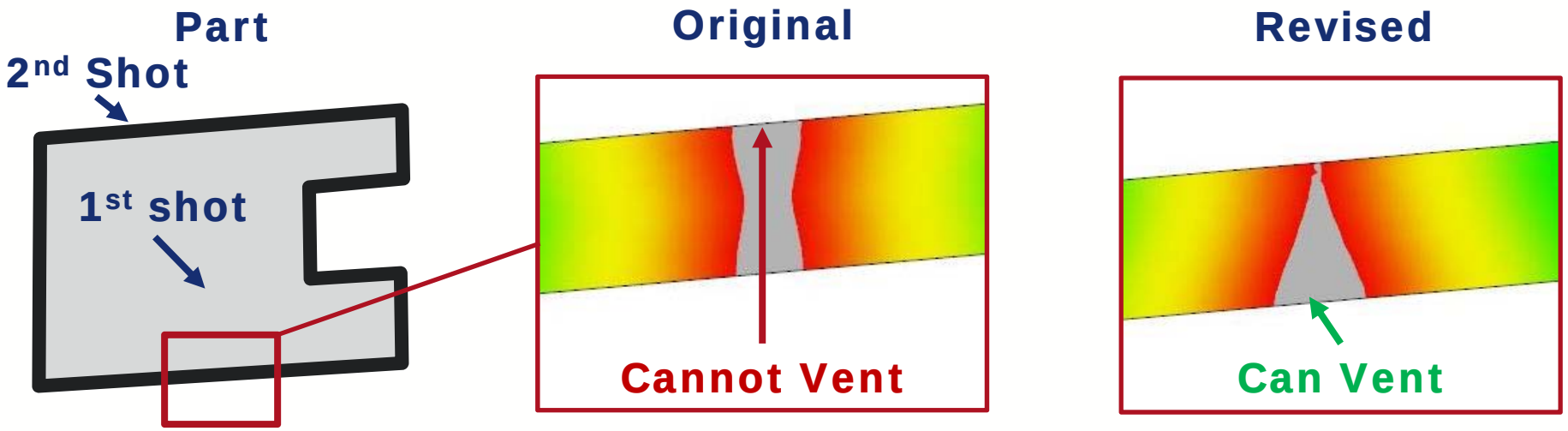


THE GOOD – EXAMPLE 2 (DETAILED)

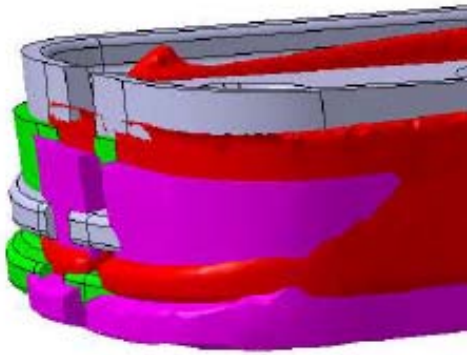
Part:	**2-Shot Headlamp Lens**
Result:	**Move Gas Trap to Area That Can Be Vented**



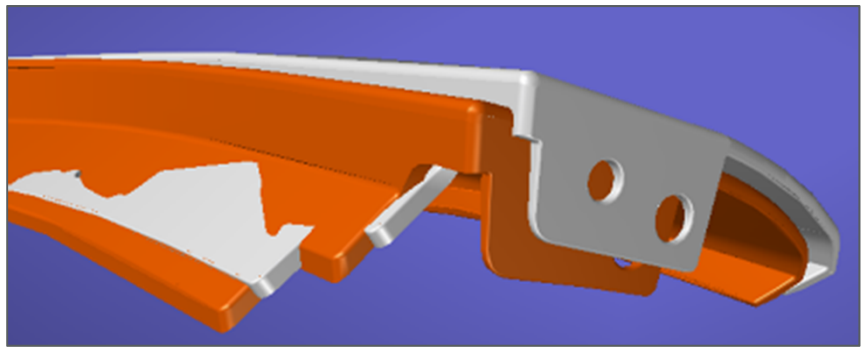
THE GOOD – EXAMPLE 3

Item:	**Applying Mold Compensation (Windage)**
Goal:	**Modify Mold Geometry to Counteract Predicted Warpage**

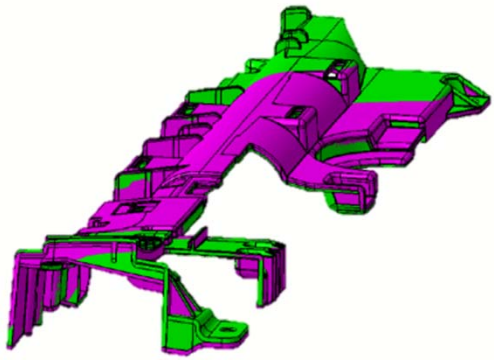
Lighting



Fascia



Structural

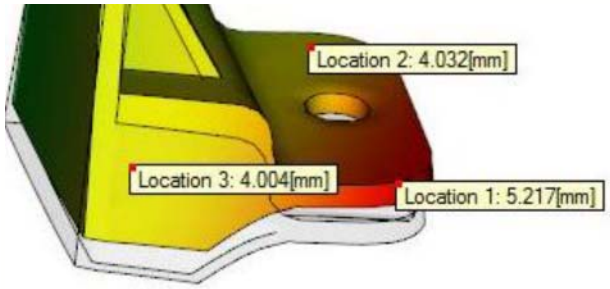


THE GOOD – EXAMPLE 3 (DETAILED)

Part: Interior Structural Part

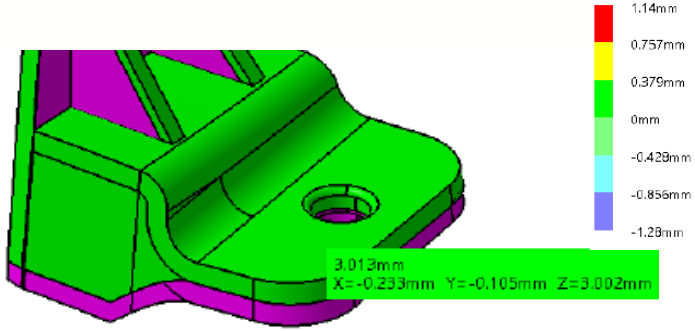
Result: Added Windage to Achieve Near Net Design Dimensions

Moldflow Warpage



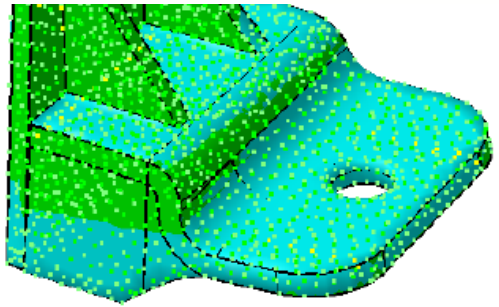
Warp Up (~4-5mm)

Add Windage



Windage Down (~3mm)

Final Warpage

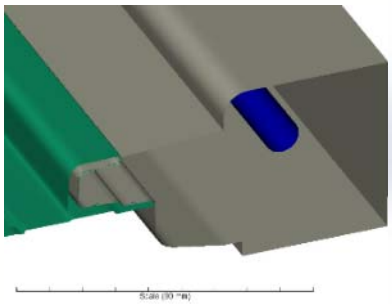


Final Results Near Net

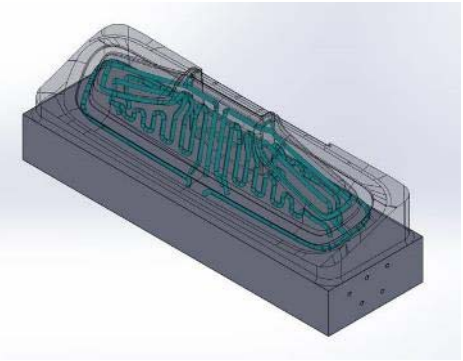
THE GOOD – EXAMPLE 4

Item:	**Optimizing Cooling by Various Techniques**
Goal:	**Improve Cooling Design and Efficiency**

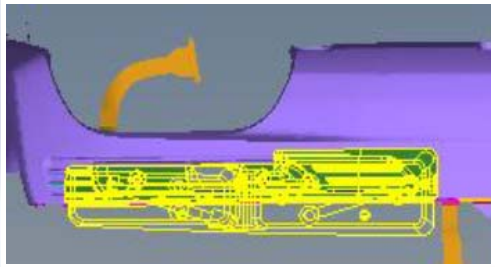
Thermal Insert



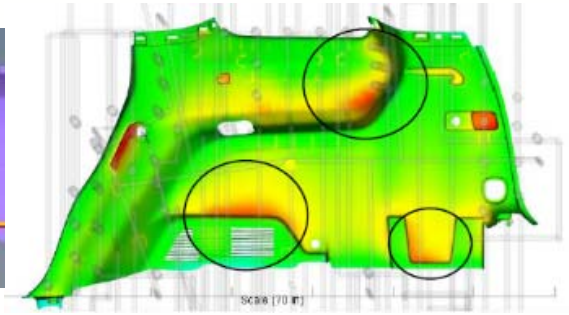
Conformal Cooling



Thermal Insert



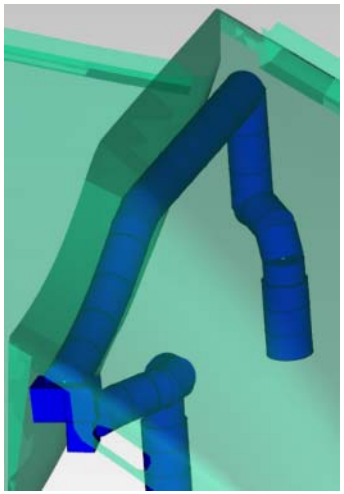
Cooling Optimization



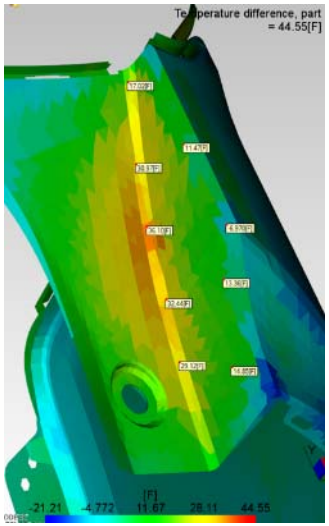
THE GOOD – EXAMPLE 4 (DETAILED)

Part:	**Rear Fascia**
Result:	**Improved Uniform Mold Temperatures by 30%**

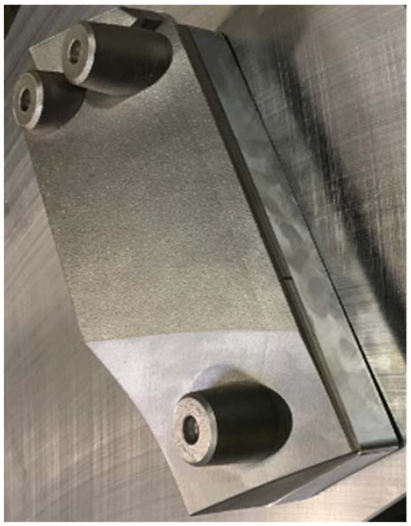
Design



Simulated



Manufactured



Measured

THE BAD

THE BAD – DEFINITION

Team Misunderstood or Ignored Predicted

Simulation Recommendations That

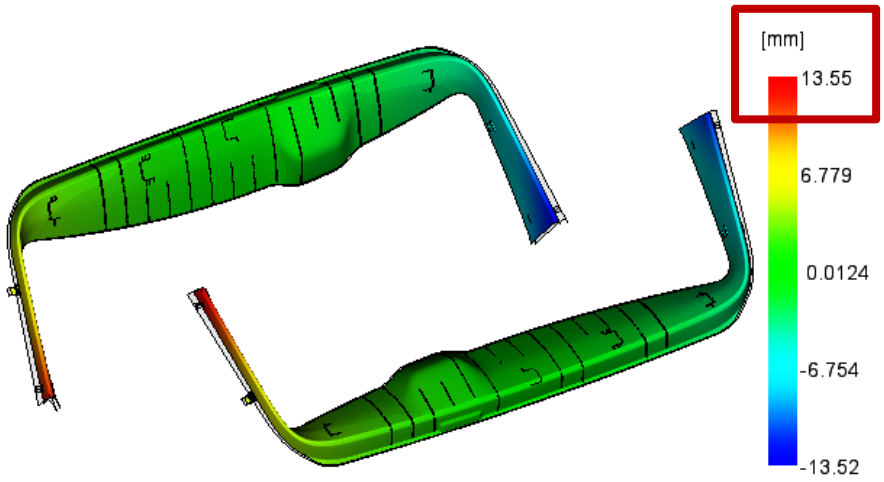
Resulted in a Less Than Flawless Launch

THE BAD – EXAMPLE 1

Part: Lift Gate Trim

Issue: Moldflow Predicted Large Warpage and No Action Taken

Large X-Axis Warpage



Gap and Flush Issues

THE BAD – EXAMPLE 1

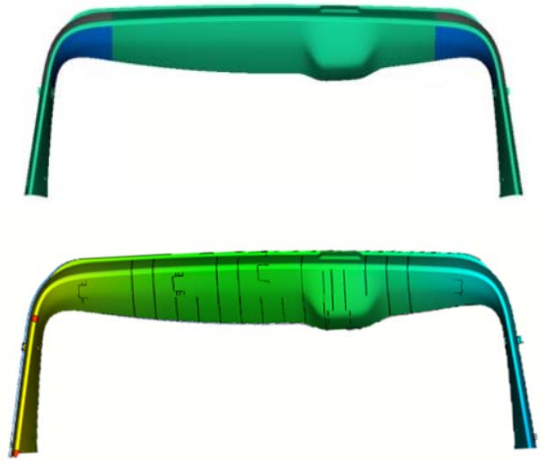
Solution:	**Major Part Changes**
Result:	**Reduced Warpage From ~13mm to ~5mm**

Item	Cost	Days
Clip Interference	$25,530	14
Tower Height	$18,525	8
Part Thickness and Styling Change	$57,250	21
Total	**$101,305***	**43****

*Does Not Include GM's Internal Cost and Time

**Took 140 Days to Identify Problem

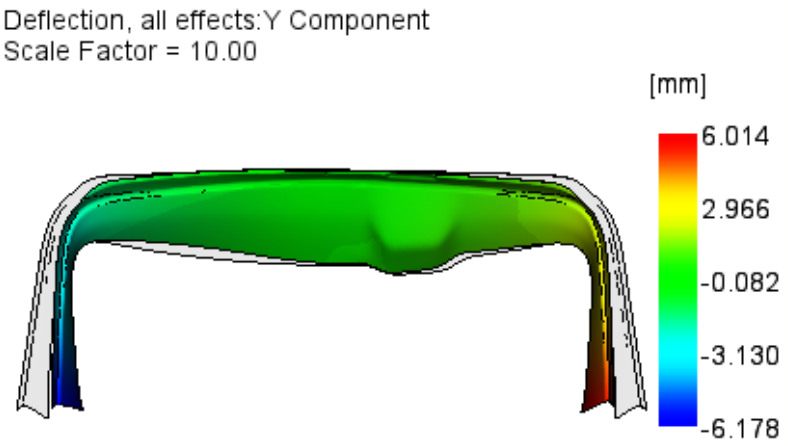
Part Thickness and Styling Change



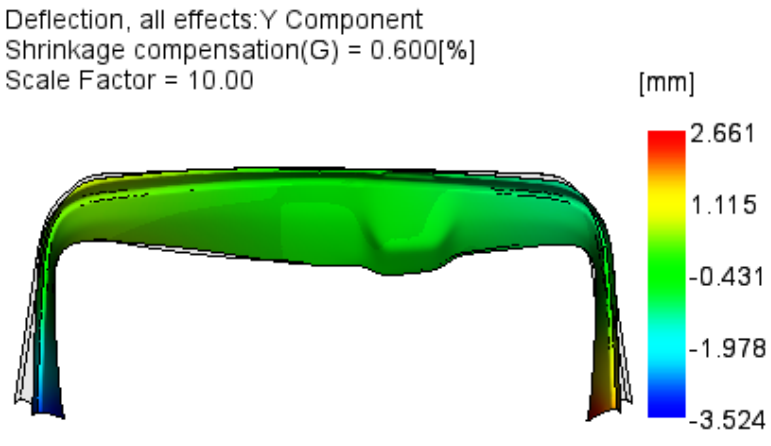
LESSON LEARNED

Tip: Apply Shrinkage Compensation to Deflection Results

Revised: Added TIS 3.1 #30 to Evaluate Out of Shape Warpage



Shrinkage Compensation

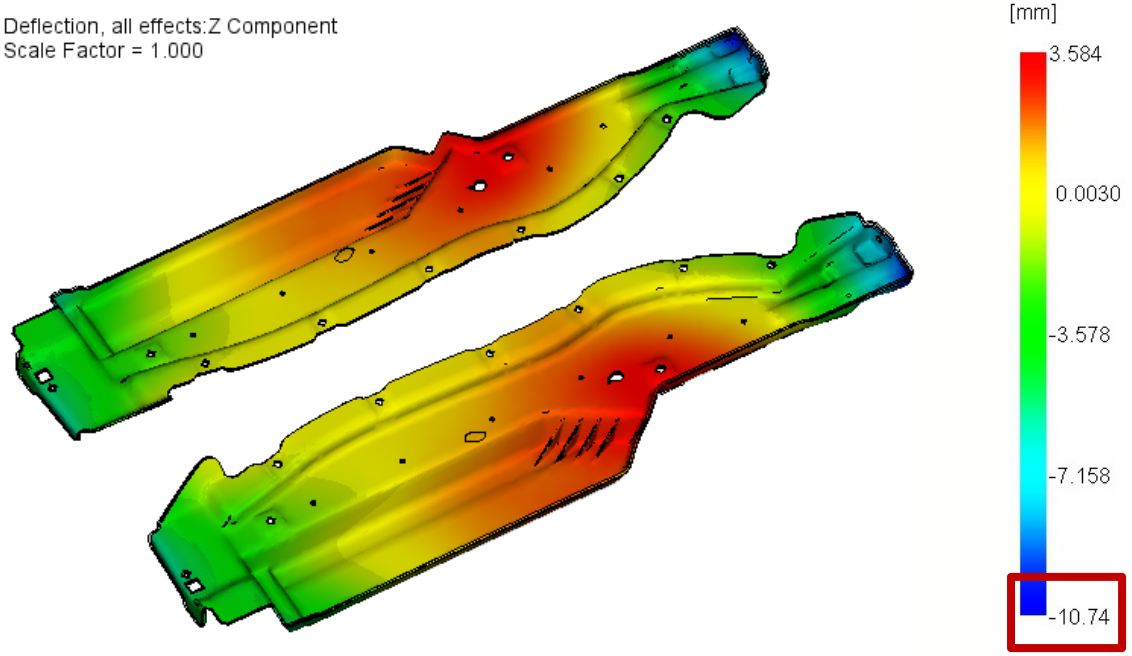


Use Tool Shrinkage Rate **Do Not Use Automatic**	Do Not Take Dimensions Across Part

THE BAD – EXAMPLE 2

Part: Structural

Goal: Moldflow Predicted Large Warpage and No Action Taken

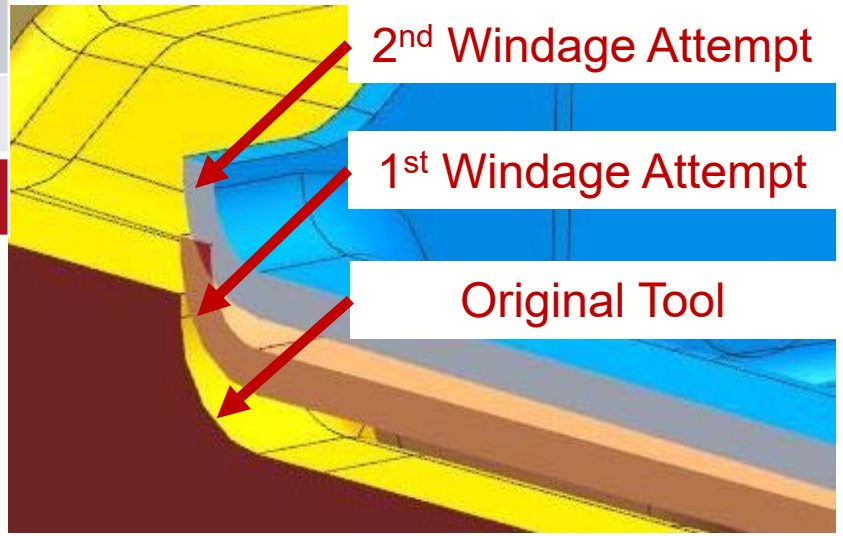


THE BAD – EXAMPLE 2

Solution:	**Added Windage After Mold Construction and Molding**
Result:	**Reduced Warpage From ~11mm to ~1mm**

Item	Cost	Days
2 Windage Iterations	$60,000	
Multiple Tryouts	$4,000	
Total	**$64,000***	**40+**

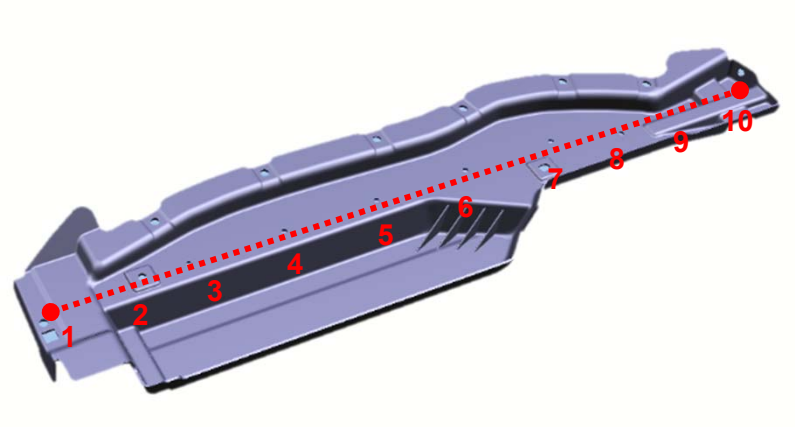
*Does Not Include GM's Internal Cost and Time

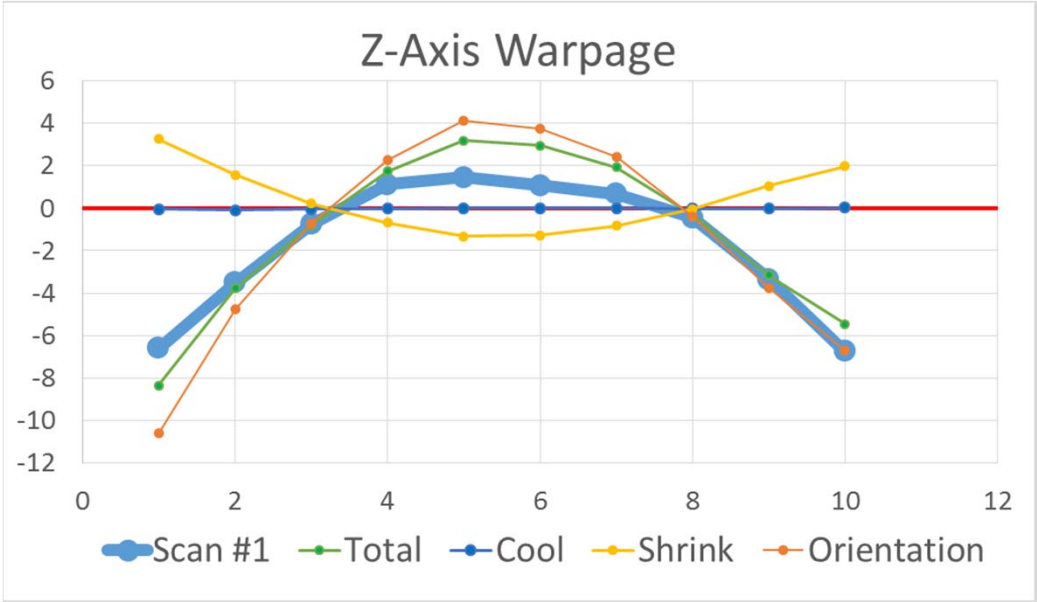


LESSON LEARNED

Tip: Use Path Plot to Determine Warpage Causes

Revised: Added TIS 3.1 #31 Evaluate Path Plots for GD&T

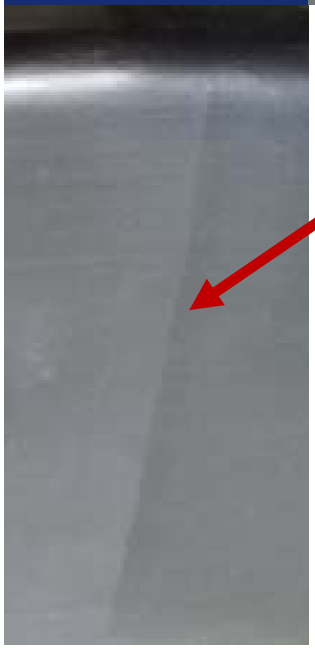




THE BAD – EXAMPLE 3

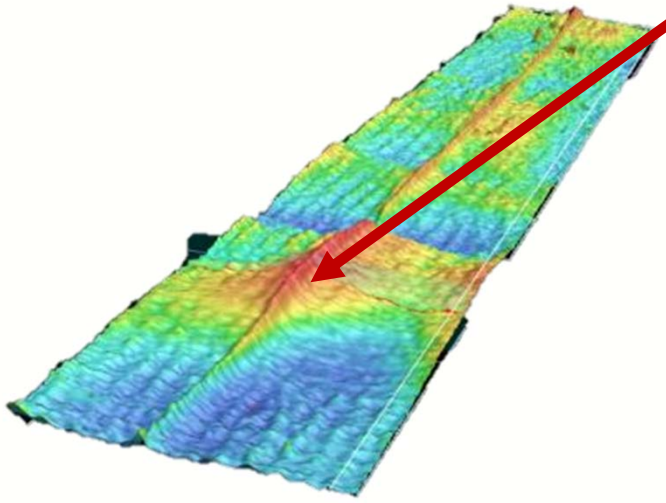
Part: Rear Fascia

Issue: Unacceptable Weld Line

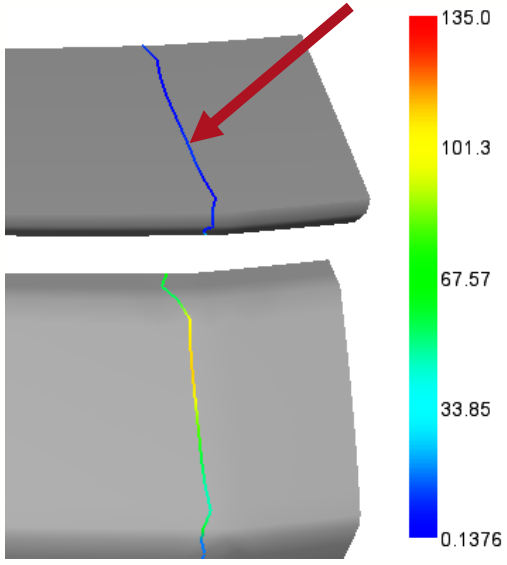


Weld Line

~0.04mm



0 Degree



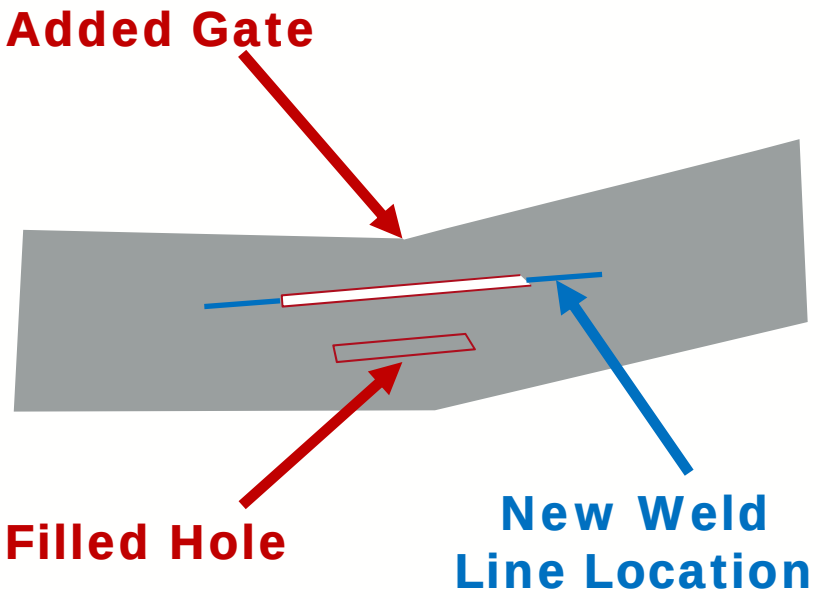
THE BAD – EXAMPLE 3

Solution:	**Added Gate and Filled in Hole**
Result:	**Relocated and Eliminated Weld Lines**

Item	Cost	Days
Mold Change	$170,000	
Resin Piece Price^	$10,800	
Punch Cost^	$250,000	
Punch Piece Price^	$679,200	
Total	**$1,110,000***	**50+**

*Does Not Include GM's Internal Cost and Time

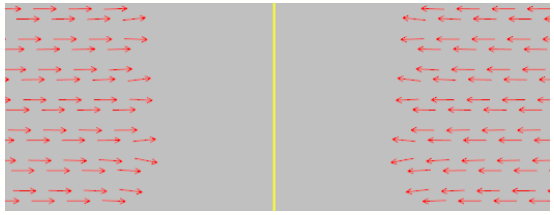
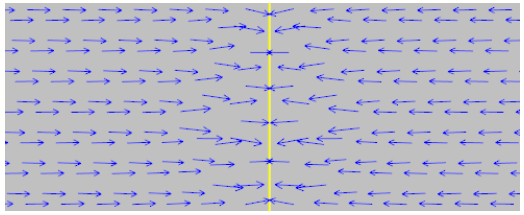
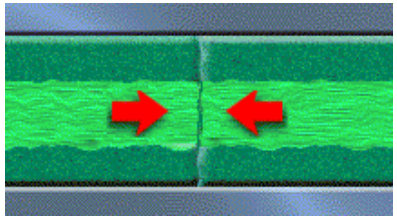
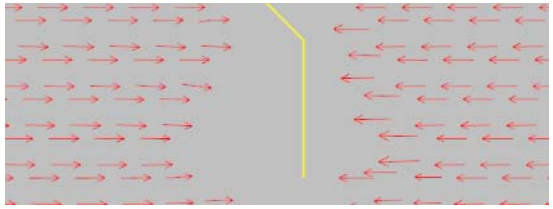
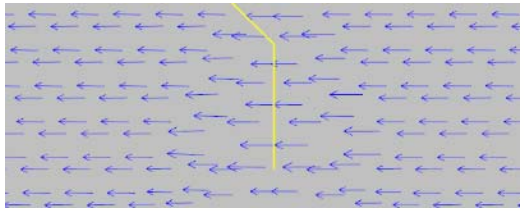
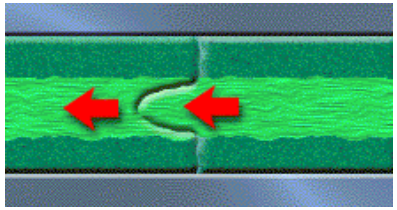
^Cost Required to Make Good Part Was Unexpected



LESSON LEARNED

Tip: Review Velocity Vectors at Weld Lines

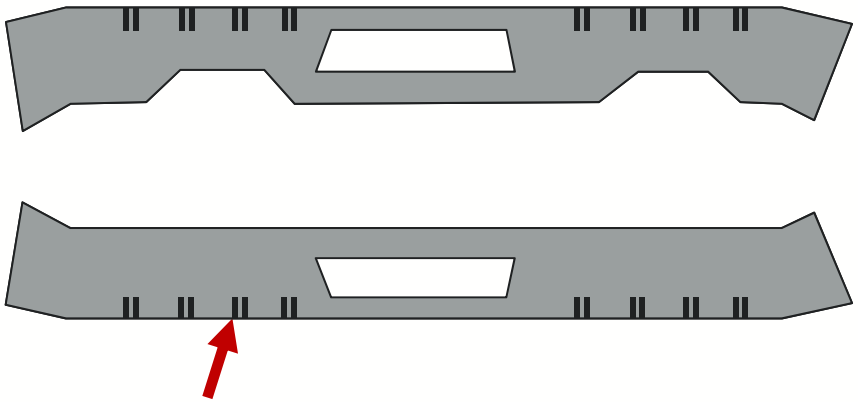
Revised: Investigating Required Standard Updates

	Top View – Before Weld	Top View – After Weld	Section View
Hard Weld Lines			
Soft Weld Lines			

Review Velocity in Addition to Pressure, Temperature, and Angle

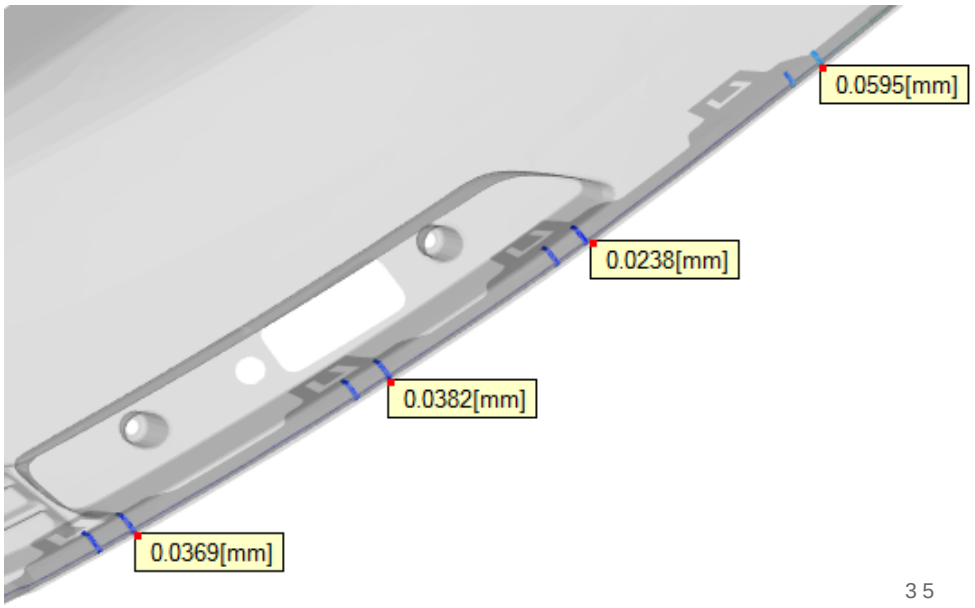
THE BAD – EXAMPLE 4

Part:	**Rear Fascia**
Issue:	**Unacceptable Sink Marks**



Sink Marks

Mid-Plane Sink Mark Depth

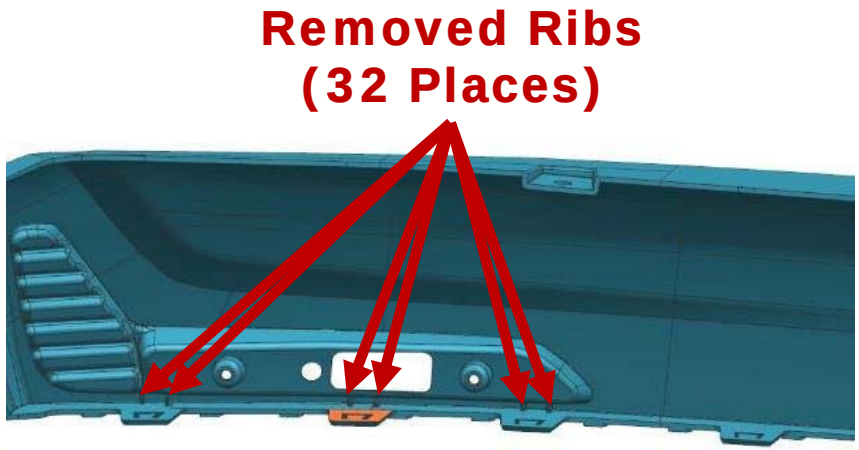


THE BAD – EXAMPLE 4

Solution:	**Removed Ribs**
Result:	**Eliminated Sink Marks**

Item to Fix	Cost	Days
Mold Change	~$25,000	
Total	**~$25,000***	**~20**

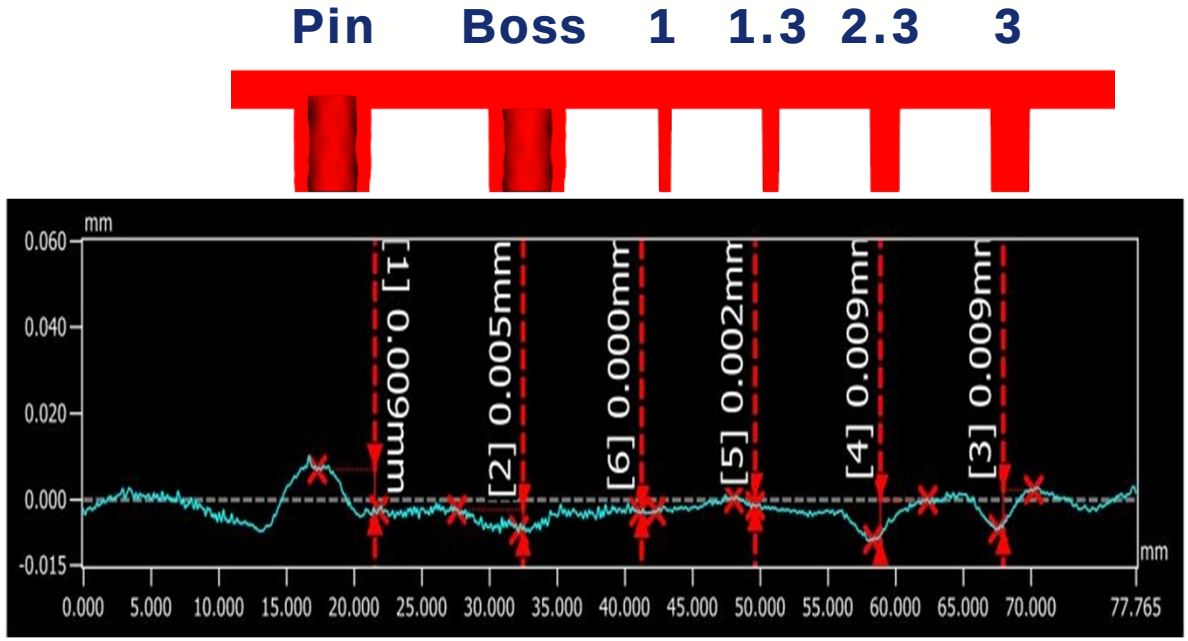
*Does Not Include GM's Internal Cost and Time



LESSON LEARNED

Tip: Define Allowable Sink by Correlating Moldflow to Actual

Revised: Revising TIS 3.1 #20 Sink Mark Guidelines



THE UGLY

THE UGLY – DEFINITION

Team Unaware of Defects Due to

Inaccurate Model Settings That

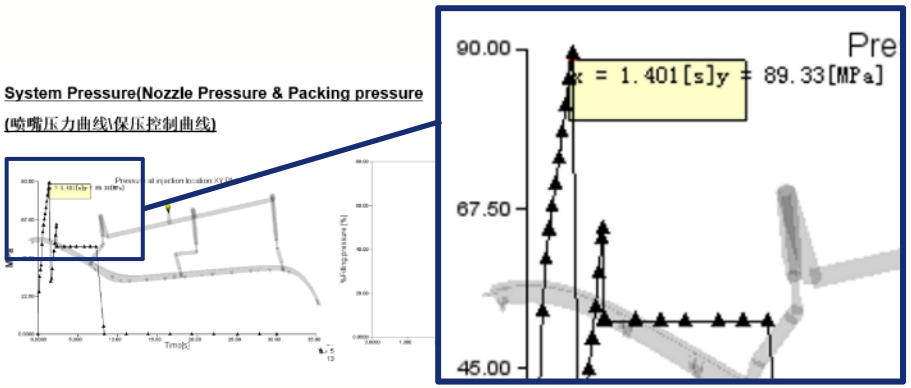
Resulted In Unexpected Launch Issues

THE UGLY – EXAMPLE 1A

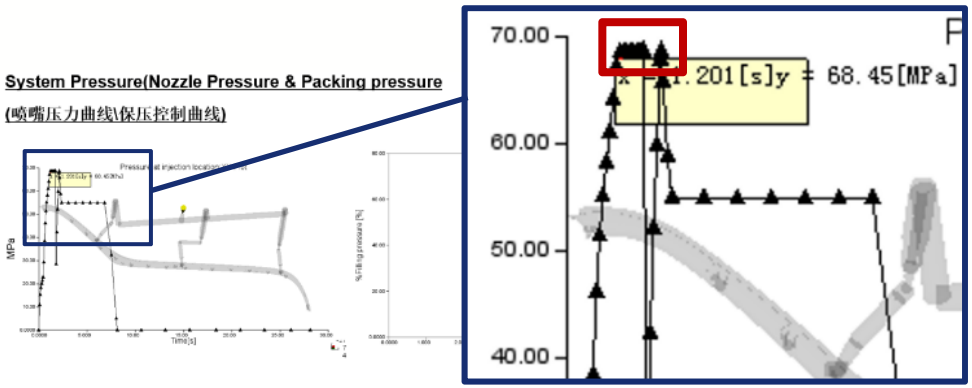
Part: Interior Part

Issue: Excessive Pressure Predicted

12,956 psi



9,928 psi



THE UGLY – EXAMPLE 1B

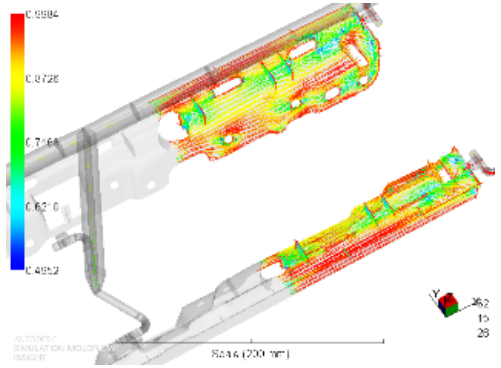
Part: Long Fiber Interior Part

Issue: Inaccurate Warpage

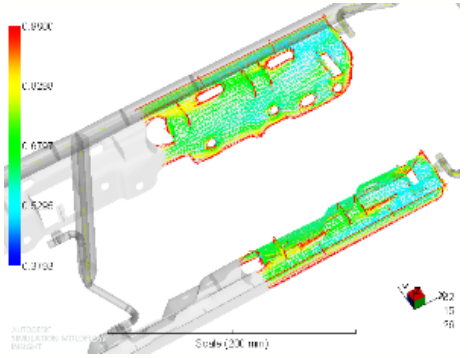
MFR Communicator Log Error

```
The material selected for this analysis is a long-fiber-filled
material, a short fiber orientation model should not be used for the
long fiber orientation.
Continuing analysis with the selected fiber orientation model.
```

Moldflow Model



ARD-RSC Model

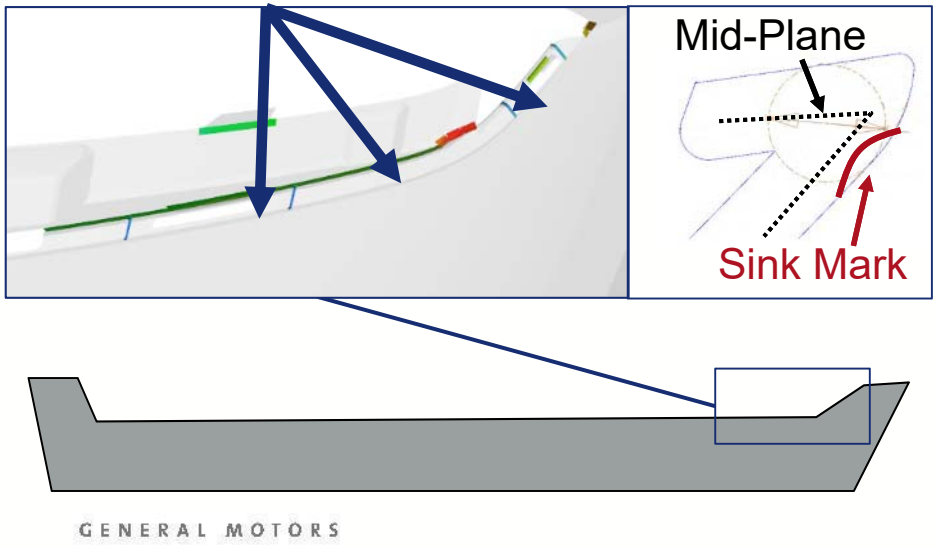


AMI 2019 Includes Fiber Orientation Inside Resin .udb

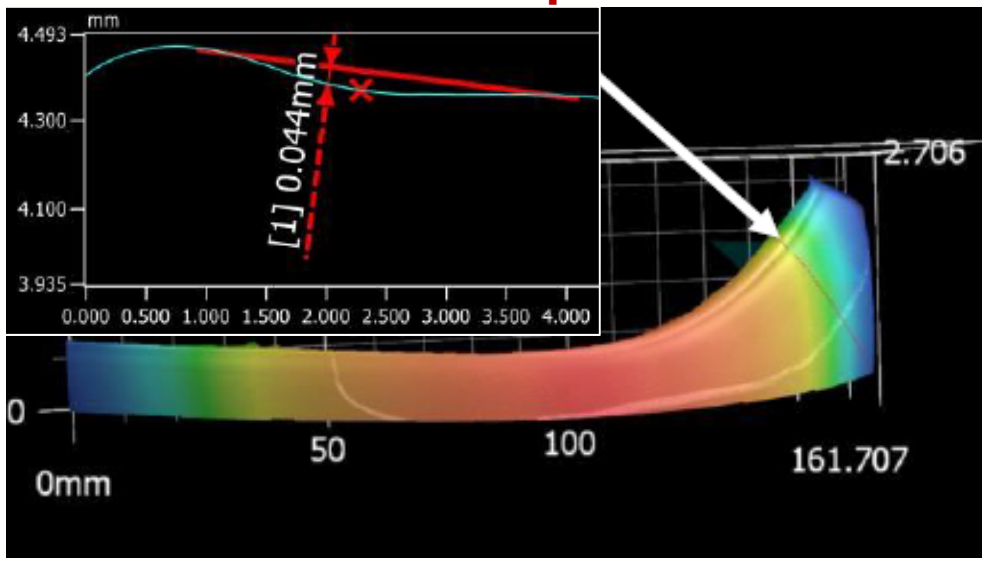
THE UGLY – EXAMPLE 2

Part:	**Fascia**
Issue:	**Unacceptable Sink Mark**

Final Report
No Sink Mark Identified



Measured Part
~0.044mm Deep Sink Mark

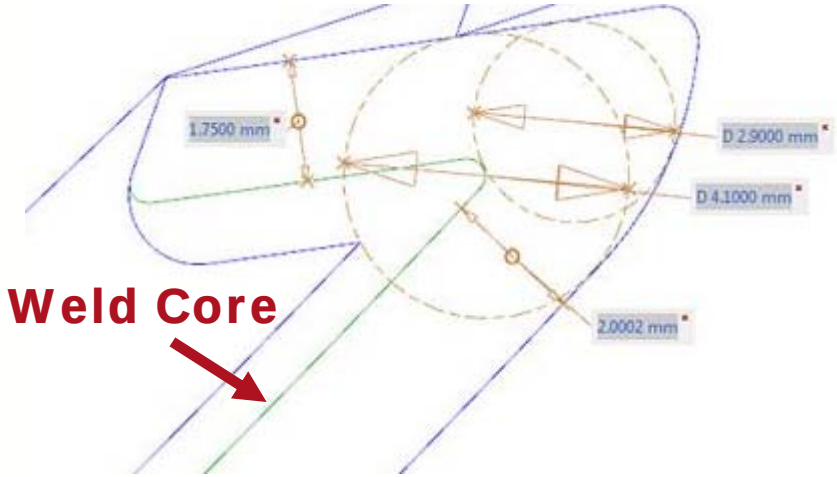


THE UGLY – EXAMPLE 2

Solution:	**Welded Core Side to Core Out Thick Area**
Result:	**Eliminated Sink Mark**

Item to Fix	Cost	Days
Mold #1 Change	$25,000	
Mold #2 Change	$25,000	
Total	**$50,000***	**~30**

*Does Not Include GM's Internal Cost and Time



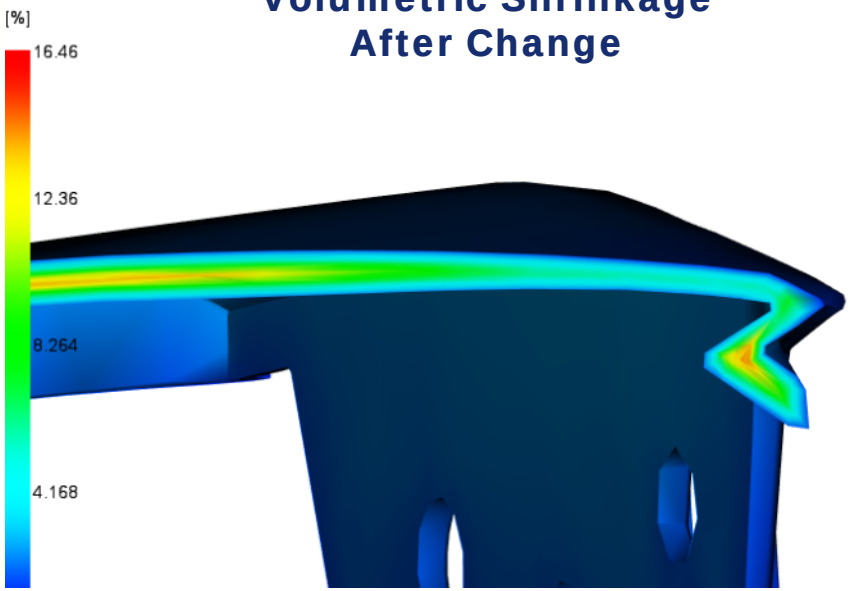
LESSON LEARNED

Tip: Create and Analyze 3D Volumetric Shrinkage Sections

Revised: Refining TIS 1.0 Rolling Ball Requirements

Volumetric Shrinkage Before Change

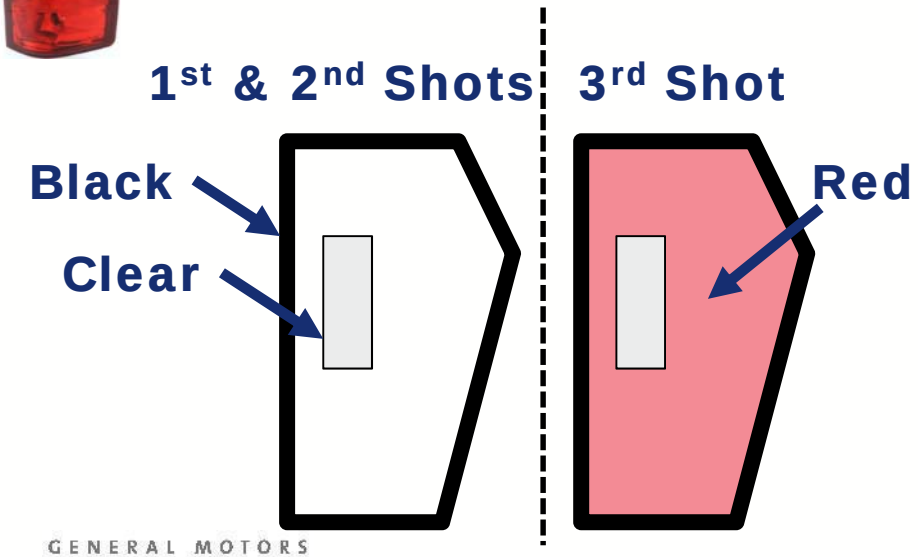
Volumetric Shrinkage After Change

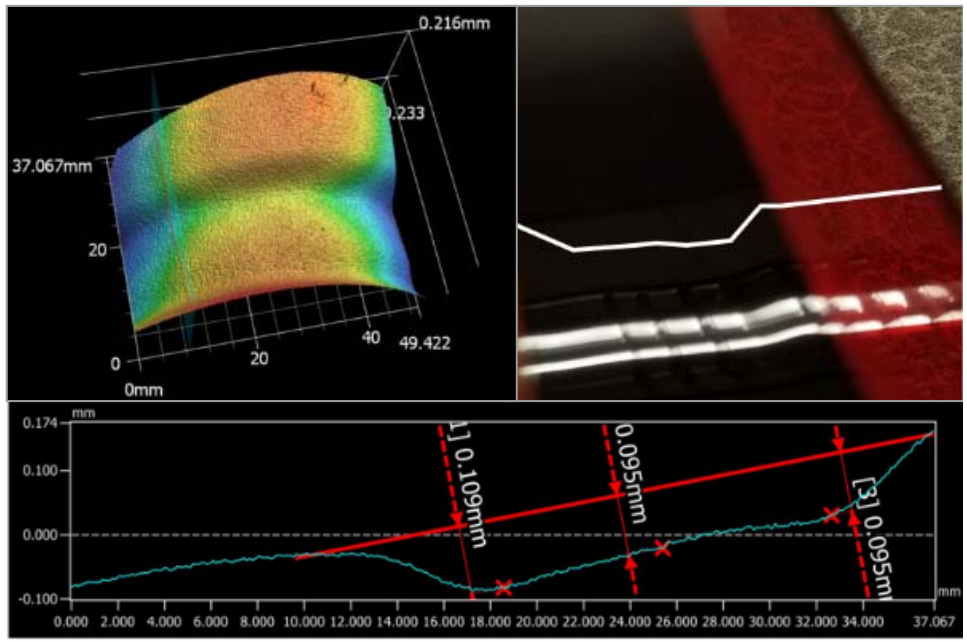


THE UGLY – EXAMPLE 3

Part:	**3-Shot Tail Lamp Lens**
Issue:	**Unacceptable Sink Mark**

Similar Part





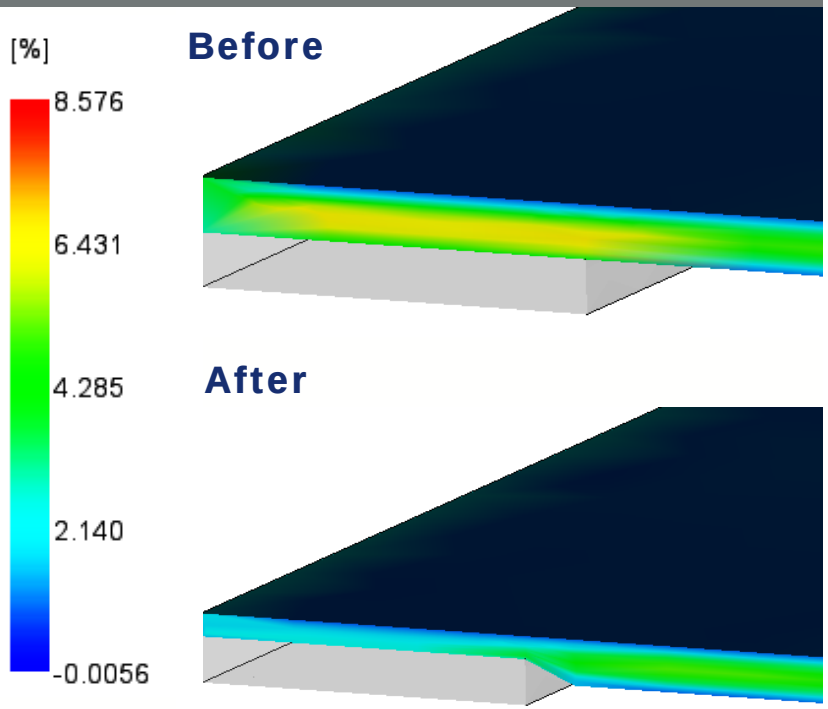
THE UGLY – EXAMPLE 3

Solution: Reduced Thickness of Red Shot at Frame

Result: Eliminated Sink Marks

Item to Fix	Cost	Days
Mold Change	$60,000	
Total	**$60,000***	**~30**

*Does Not Include GM's Internal Cost and Time

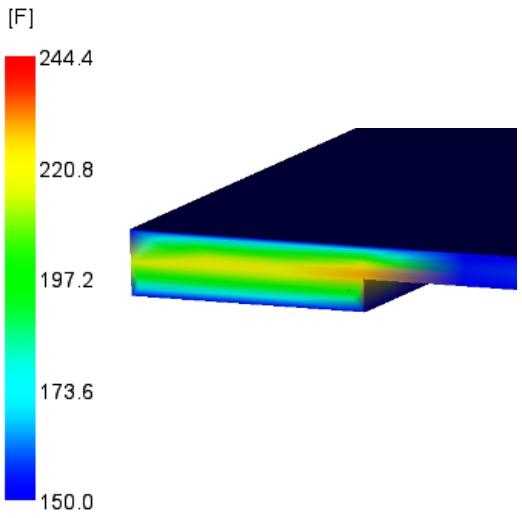


LESSON LEARNED

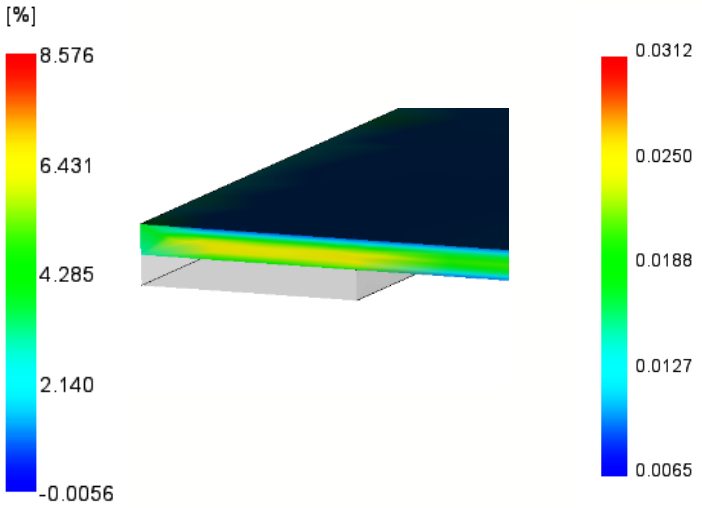
Tip: Evaluate 2-Shot Parts by Over-Molding or 2-Shot

Revised: Adding TIS 3.1 Requirement for Multi-Shot Molding

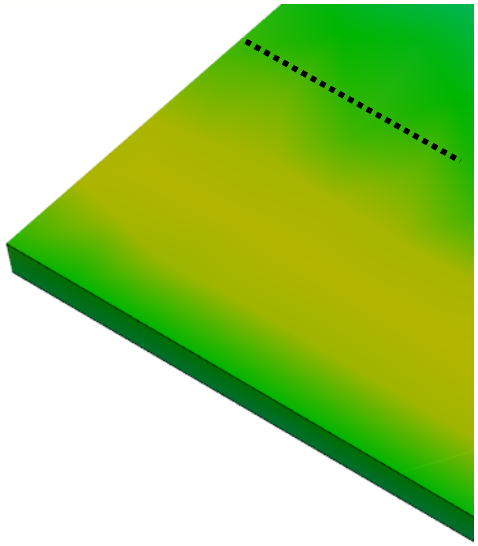
Temperature



Volumetric Shrinkage



3D Sink Surface Sink Mark



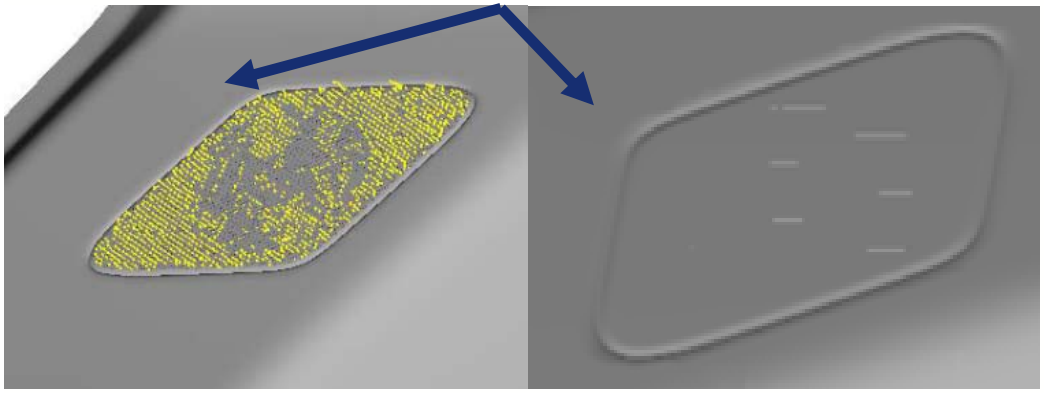
THE UGLY – EXAMPLE 4

Part:	**Door Trim Speaker Grille**
Issue:	**Unacceptable Weld Lines**

Initial Moldflow Dual Domain

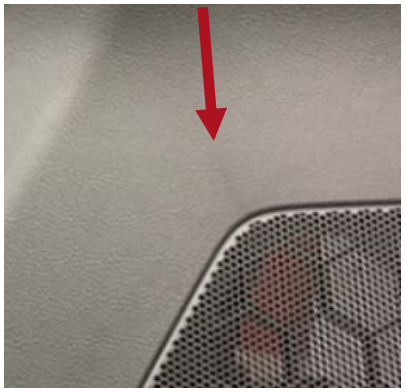
Final Moldflow Mid-Plane

No Weld Predicted



Molded Part

Weld Line



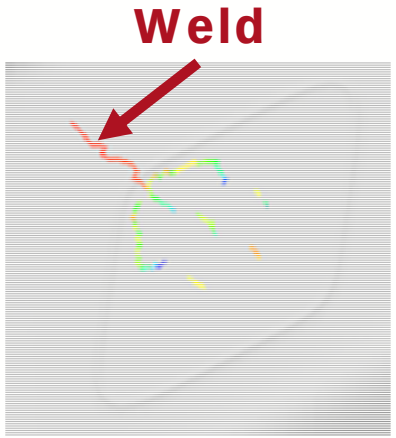
THE UGLY – EXAMPLE 4

Solution:	**Increased Thickness and Moved Gate**
Result:	**Improved Weld Line Strength and Appearance**

Item to Fix	Cost	Days
Mold Change	$10,000	
Tryouts	$2,000	
Total	**$12,000***	**~40**

*Does Not Include GM's Internal Cost and Time

Mid-Plane With Correct Shape Factor



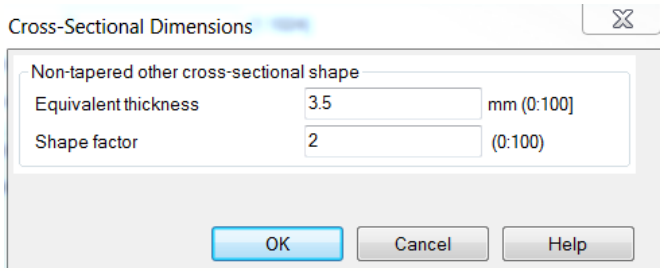
LESSON LEARNED

Tip: Use Correct Shape Factor for Speaker Grille Modeling

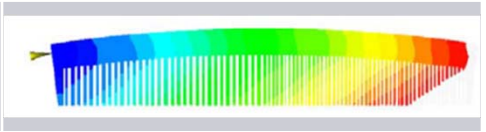
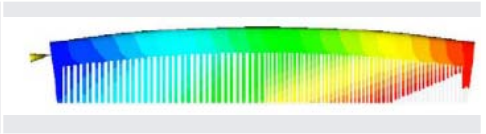
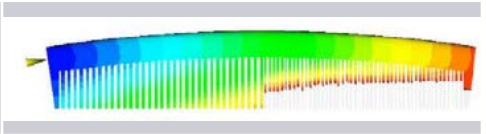
Revised: Investigating Requiring 3D Mesh for Phase 4 Moldflow

$$\text{Equivalent Thickness} = \frac{\text{Volume of Area}}{\text{Projected Area}}$$

$$\text{Shape Factor} = \frac{\text{Grille Contact Area}}{\text{Model Contact Area}}$$



Review Moldflow Help

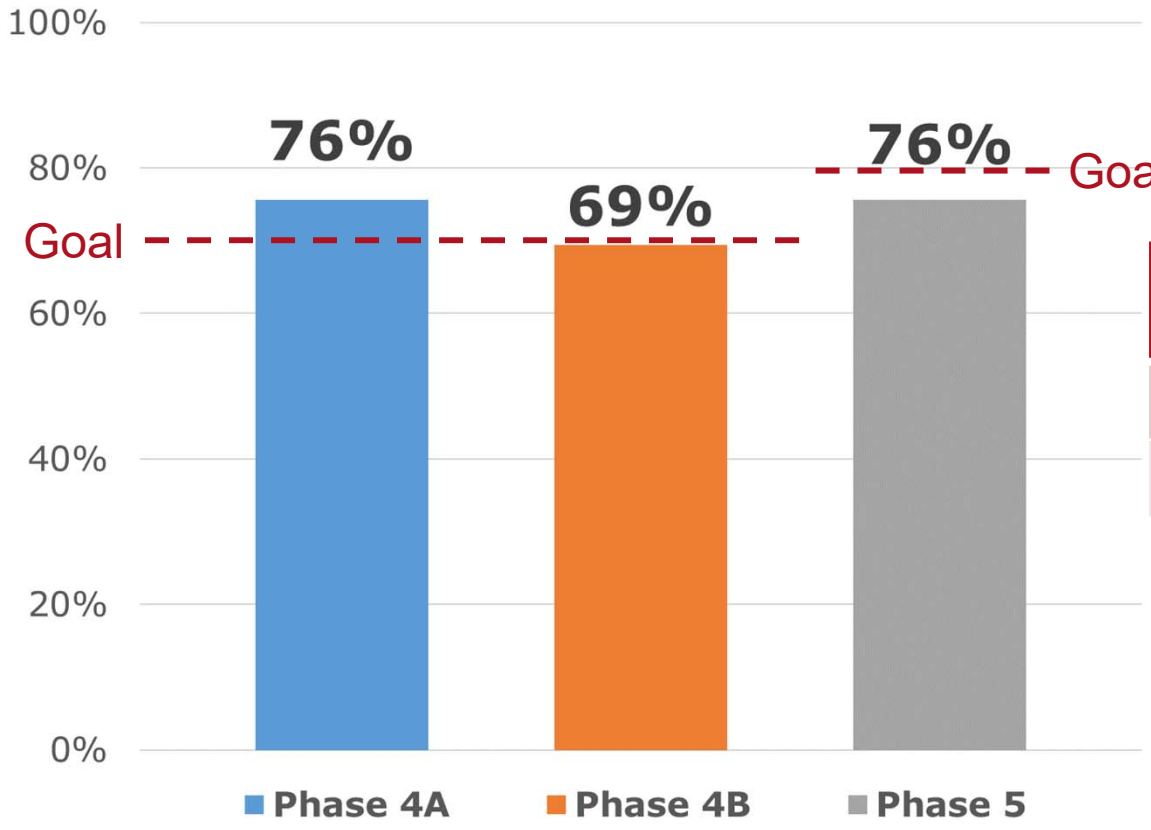
Mesh Type	Shape Factor	
Mid-Plane	Must Calculate	
Dual Domain	Cannot Simulate	
3D Tetra	Auto	

Images Courtesy of Matthew J. Jaworski and Zhongshuang Yuan, Moldflow Corporation

BONUS MATERIAL

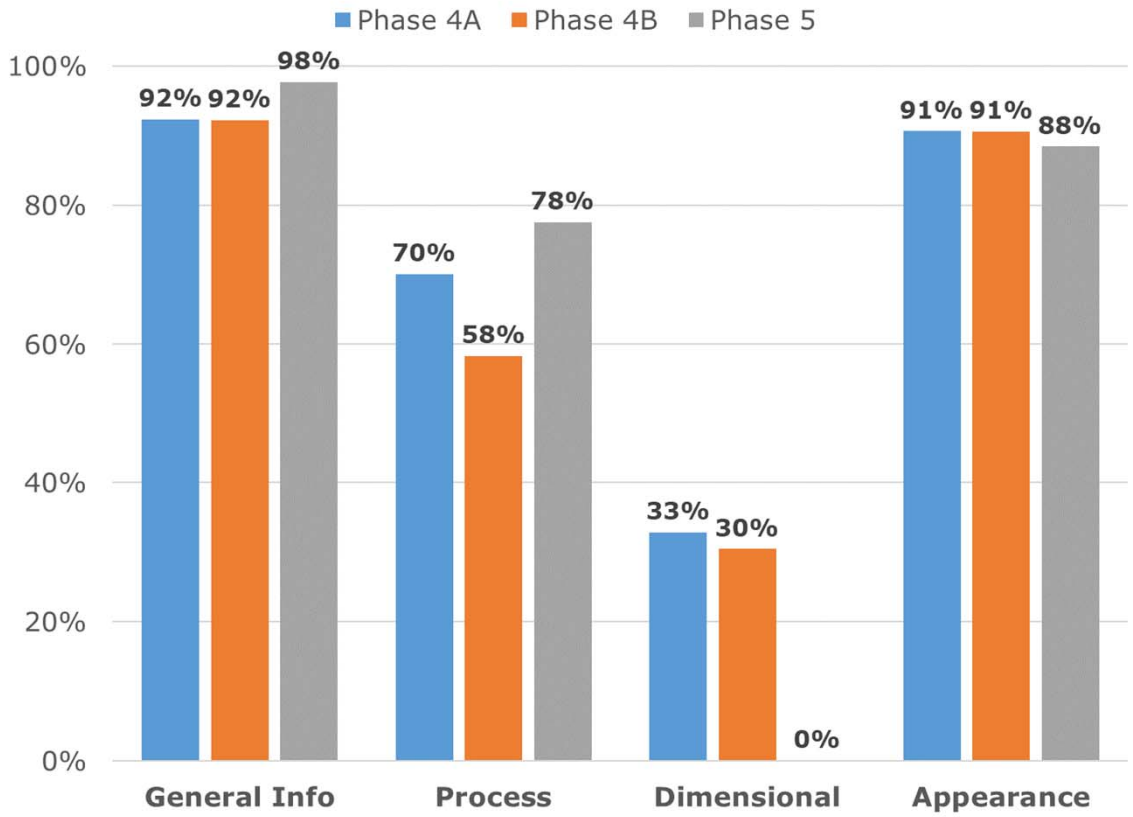
How Do You Determine the Accuracy of Your Moldflow Analysis?

CORRELATION – FINAL SCORE

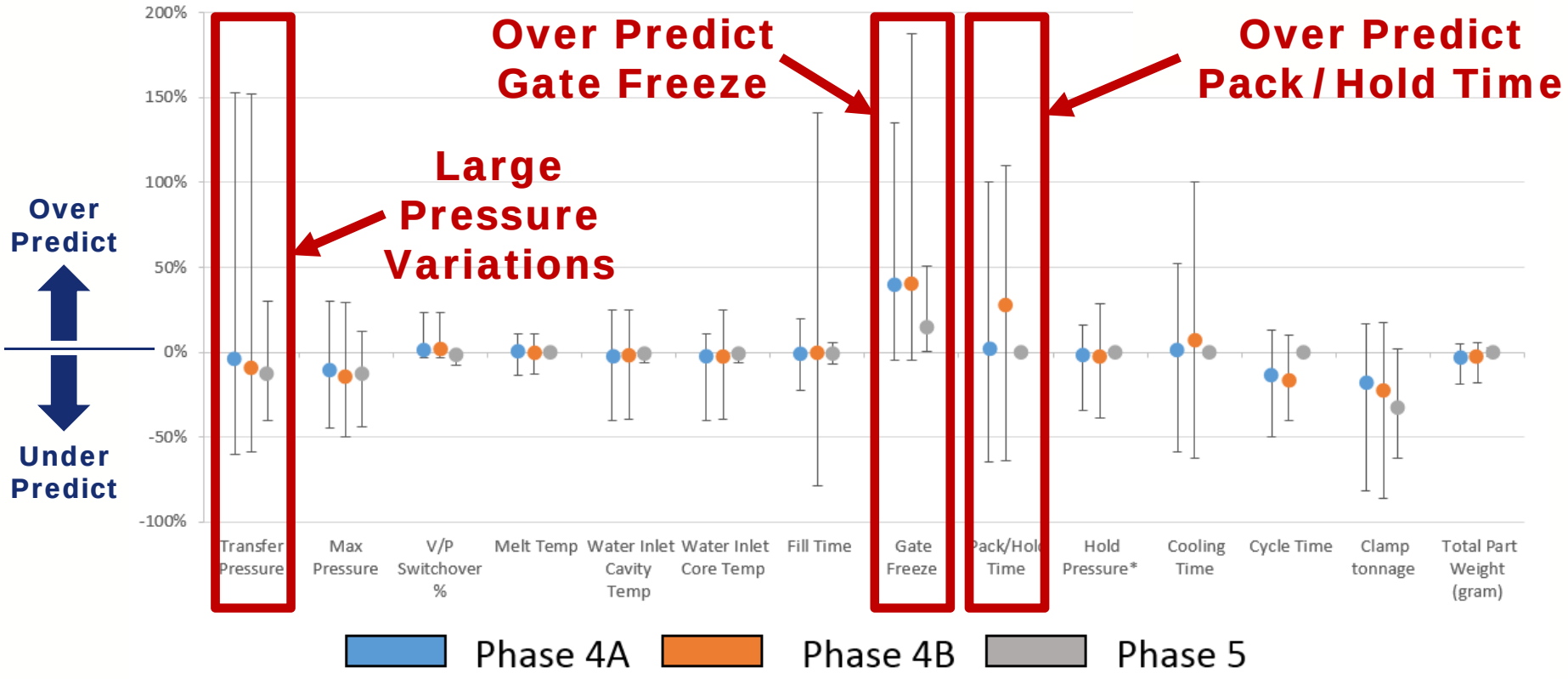


Phase	Min. Score
4A/B	70
5	80

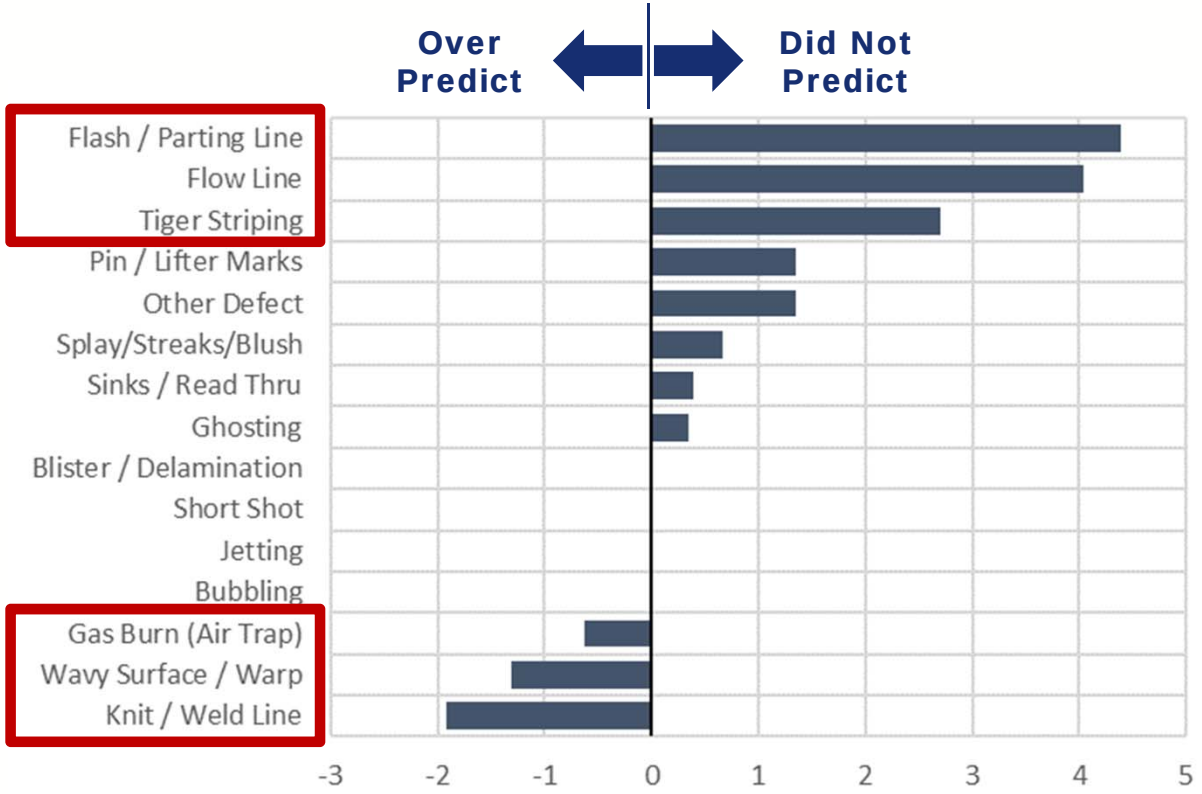
CORRELATION – PROCESS SCORE



CORRELATION – PROCESS DETAIL

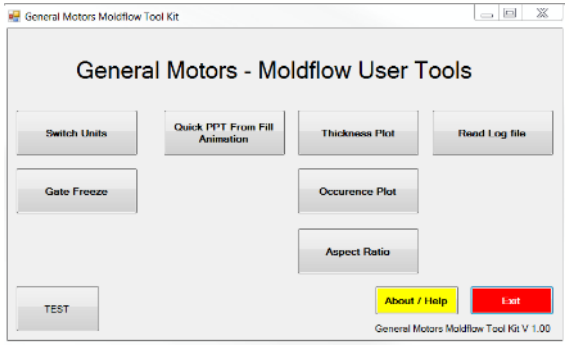


CORRELATION – APPEARANCE DETAIL



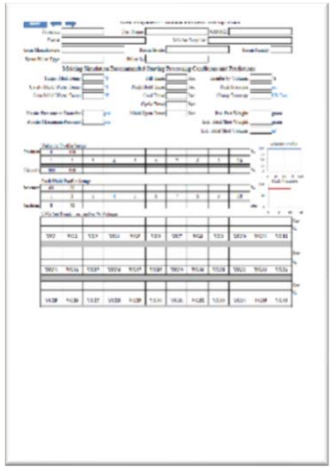
MOLDFLOW TOOLS

GM Moldflow Tool Kit

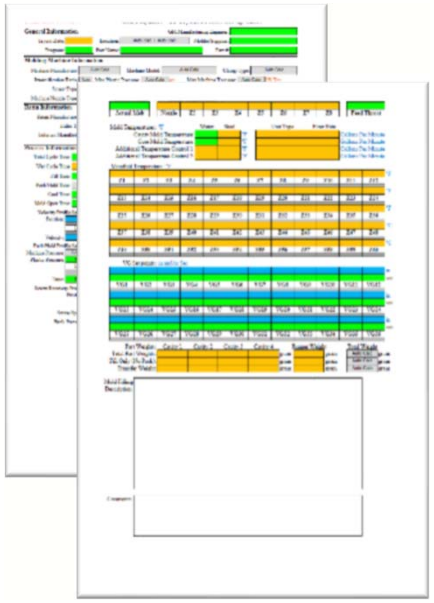


Process Sheets

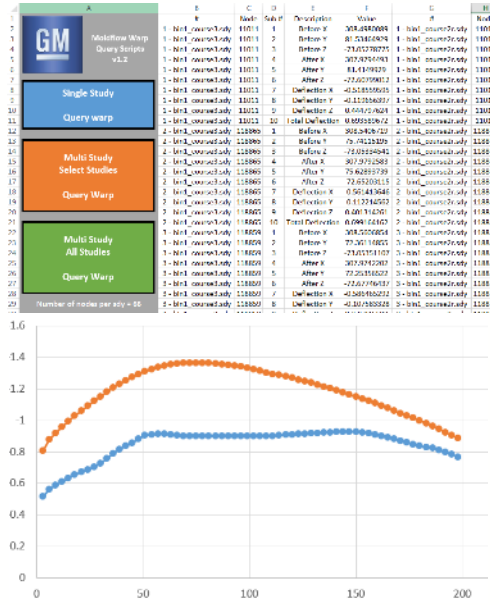
Moldflow



Machine



Warpage Query Tool



TAKE-AWAY CONCLUSIONS

1. Act on Moldflow Results
2. Utilize 3D Mesh
3. Perform Gate Freeze Study Correctly

Thank You!