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Optimizing Thin Part Production: Beyond Lightweighting to Rightweighting Excellence

May 8, 2024

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THE MADISON GROUP
PLASTIC CONSULTING ENGINEERS

Optimizing Thin Part Production:

Beyond Lightweighting to Rightweighting Excellence

Erik Foltz
Senior Managing Engineer ● The Madison Group

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- M.S. from Polymer Engineering Center UW-Madison
- 17 Years Experience Designing and Manufacturing
- Injection and Compression Molding
- Certified Moldflow Consultant
- Thermoset, Thermoplastic, Thermoplastic Elastomers

Erik Foltz

Senior Managing Engineer ● The Madison Group

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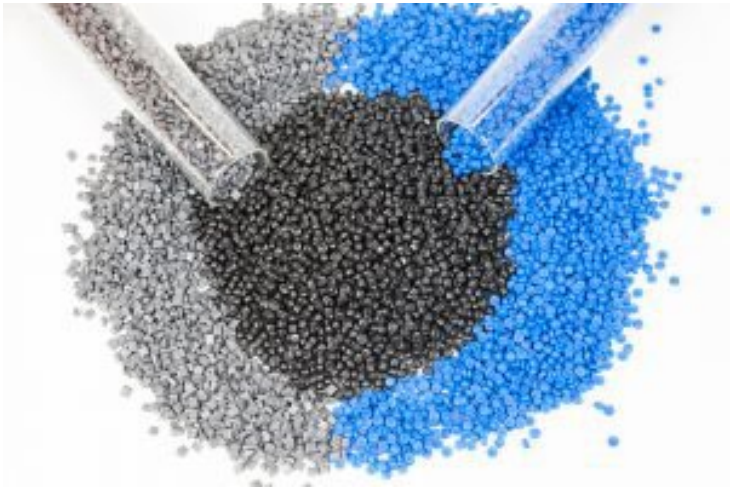
Goals for Today

Today's talk….

- Highlight Opportunities with Lightweighting of Plastic
- Learning Simple Design Guidelines for Properly Lightweighting Plastic Components and Assemblies
- Understand the Key Material Performance Metrics Required for
- Recognizing the Role of Manufacturing Constraints on Light-Weighting
  - Specifically, Injection Molding

Lightweighting

- Process of Lowering Component or Assembly Weights to Create Greener and More Economical Products.
- Popular Initiates for:
  - Automotive Industry
  - Aerospace
  - Packaging
- Common Materials:
  - Aluminum
  - Plastics
  - Composites

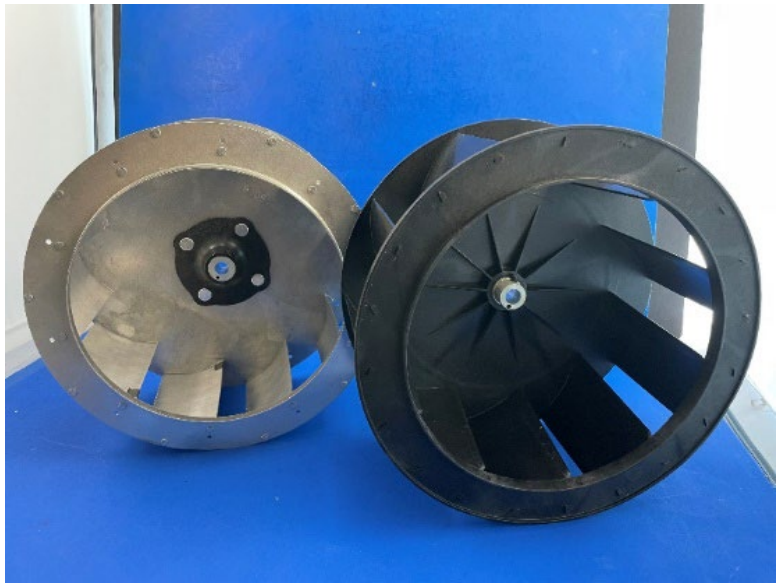


Where are There Opportunities for Lightweighting?

Automotive

Reduced Part Weight/Improving Part Performance

Industrial



Reduced Assembly Complexity and Cost

Rigid Packaging

Reduced Material Consumption and Cost

Why Are We Talking About Lightweighting?

- Values & Crossroads
  - Why Plastics
  - Plastics Paradox
- Ethics & Economics
  - Sustainability
  - Profit
- Compliance & Risks
  - Coming Soon

A More Sustainable World

California: Voluntary Ca

1 January 01, 2024 - Date of entry into

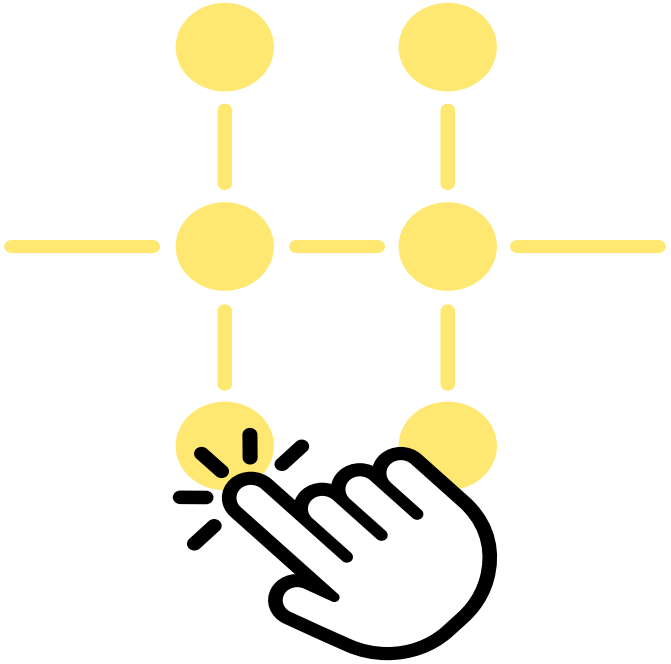
2 January 01, 2024 Entities operating emissions or simila accuracy/achiever

Our Commitment

We're committed to reducing our carbon emissions, energy consumption and waste; accelerating the transition to a circular economy; and helping drive sustainability efforts that deliver lasting change.

net zero

What Consumers Are Asking For?

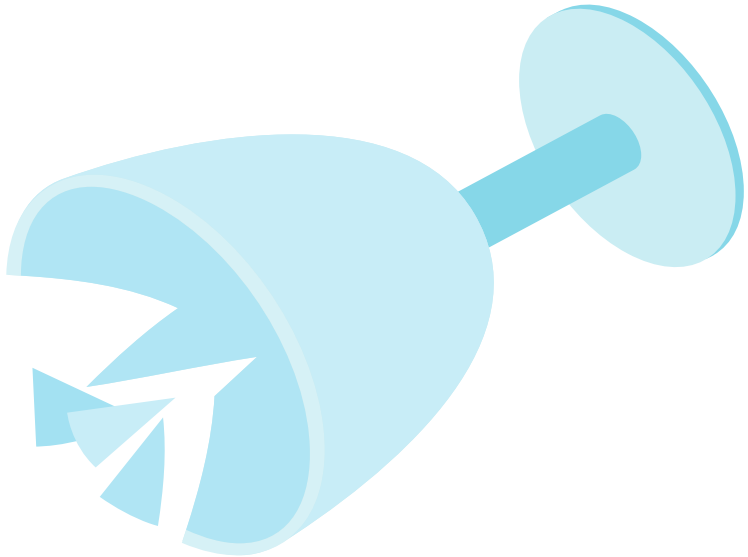


Responsible Material Selection

Less Plastic

Less Waste/End of Life Strategy

What Are Non-Negotiables?

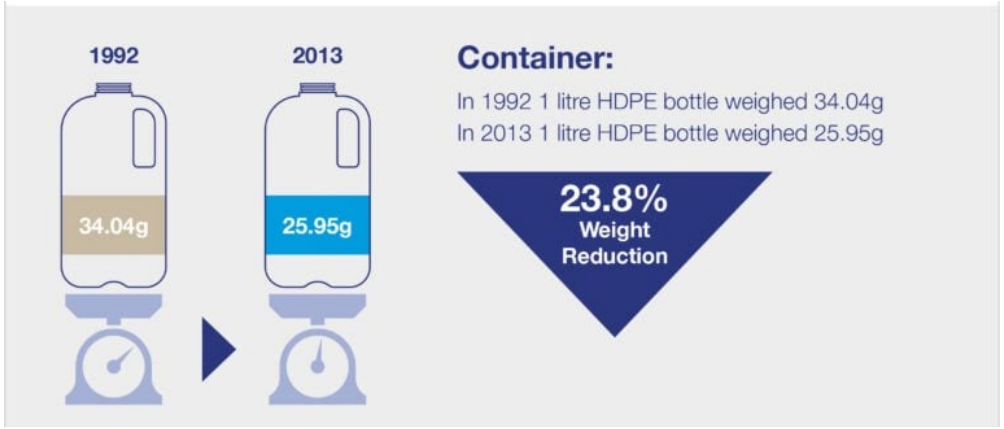


Inferior Performance

Substantial Change in Cost

Can it Be Done?

- Traditional Packaging Industry Has Been Successful in Achieving Consumer Demands.



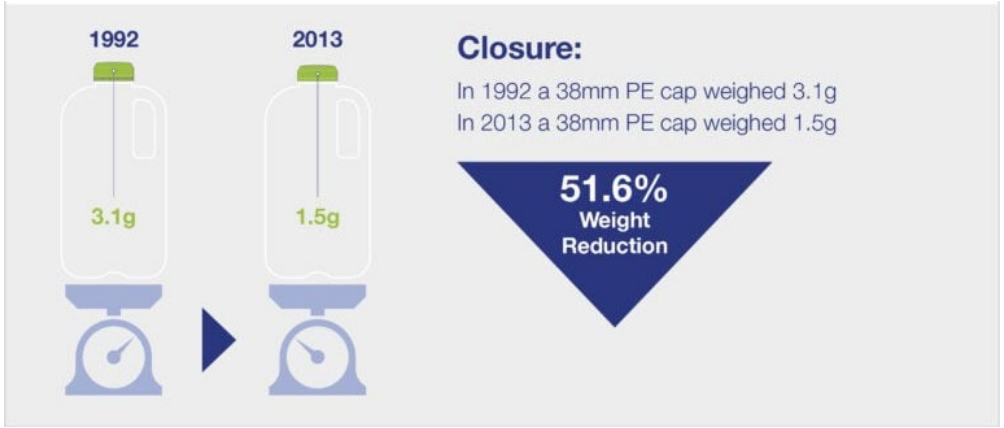
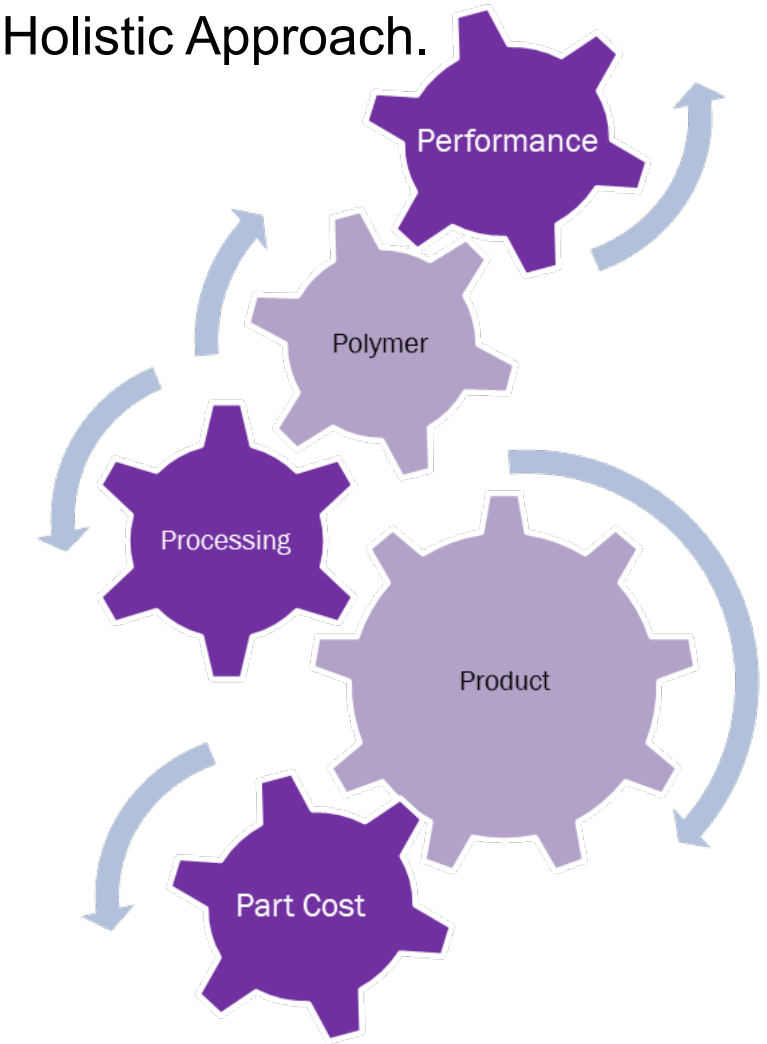


Image Source:
https://meyers.com/meyers-blog/lightweighting-in-packaging-pros-and-cons/

What Needs to Be Considered?

- Success With Optimization of Plastic Part Design Requires a Holistic Approach.
- Need to Consider:
  - Performance Requirements
  - Product Design Features
  - Material Selection
  - Manufacturing/Processing
  - Assembly Constraints
  - Part Cost



What Does Product/Assembly Need to Do?

- Significant Time and Cost Can Be Saved By Developing a Good Product Profile.
  - Part Function
    - Operating Temperature Range
    - Expected Service Life
    - Expected Loading Conditions
    - Load Duration
    - Assembly Methods

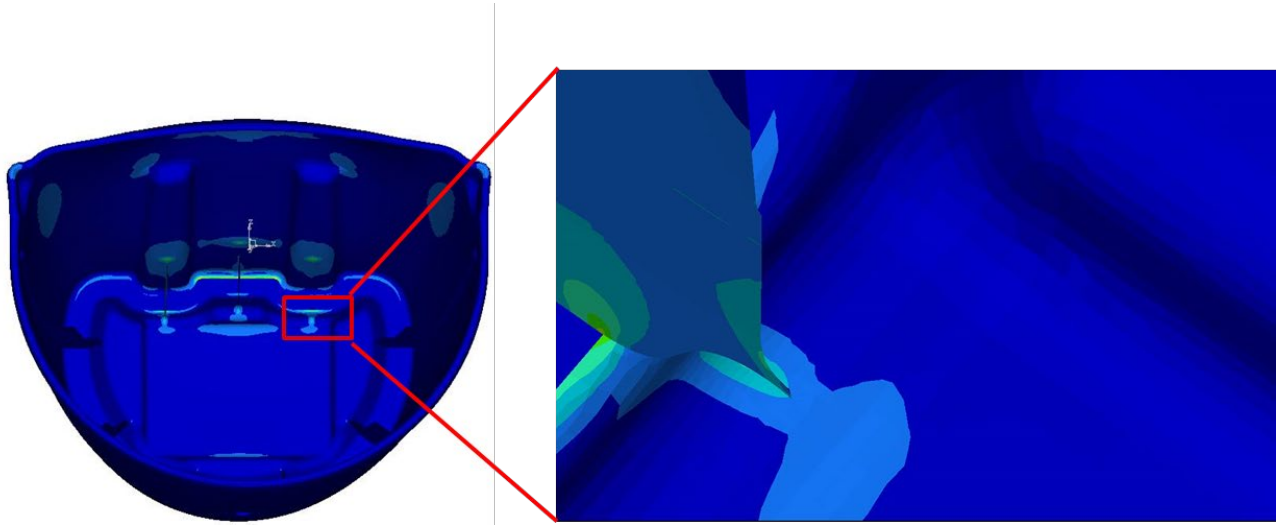
Tools to Help Optimize Design

- Design is Often Dictated by Performance Metrics.
- Use Tools Like FEA, or Topology Optimization to Help Optimize the Design.
  - Still Need a Target Stress or Displacement Value.

Topology Optimization

AUTODESK

Structural FEA



What Can Go Wrong?

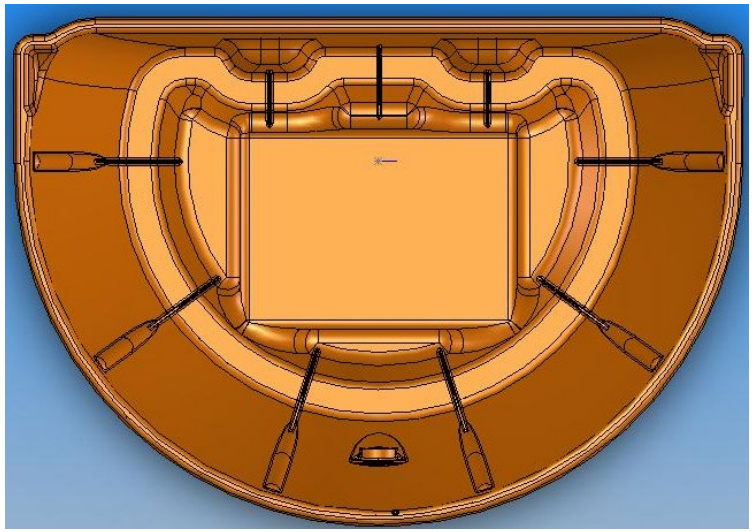
- Customer Wanted to Eliminate Need for Stand.
  - Liability Concerns
  - Reduce Part Cost
  - Reduce Price

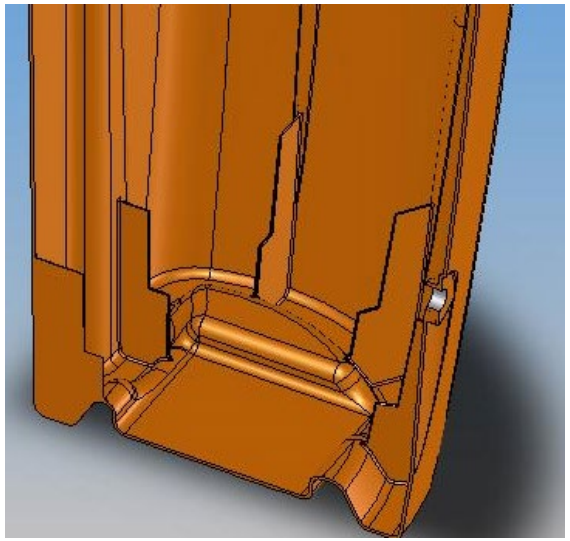
Current State

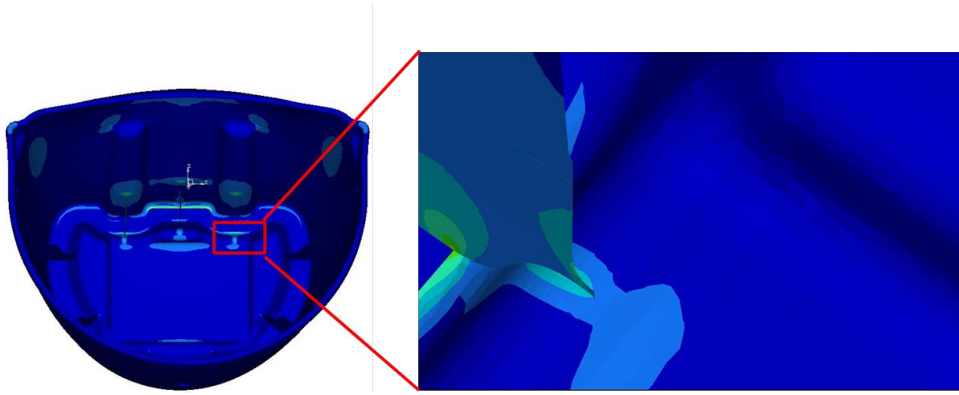
Desired State

What Can Go Wrong?

- Developed Design Concept
  - Expected Service Life: 2 Years
- Selected Material
  - HDPE
- Performed FEA, and Yield Stresses Appeared Well Below Short-Term Yield Stress of Material, at Temperatures of Interest.



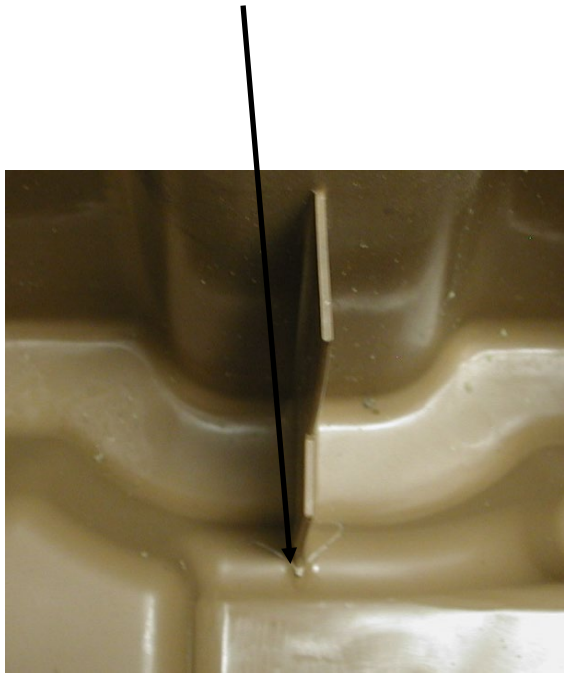


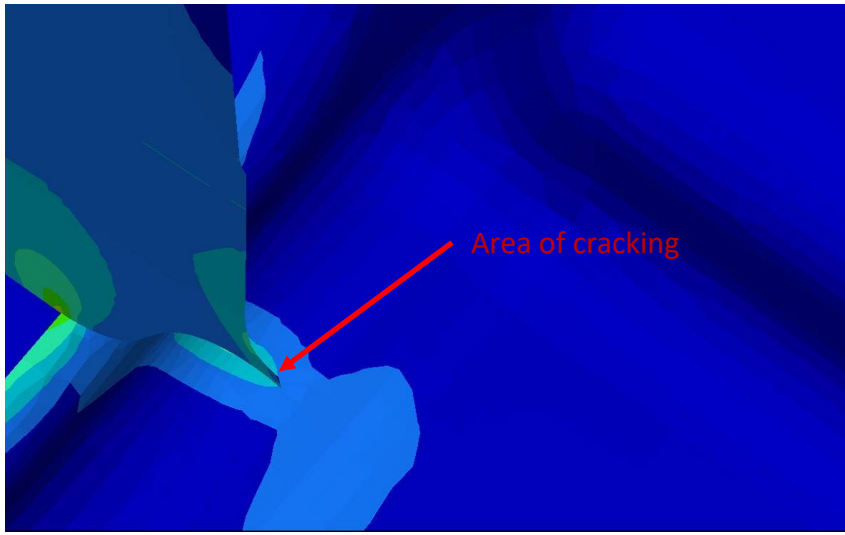


What Can Go Wrong?

- Manufacture Mold, and Tested Product.
  - 14 Days Later…

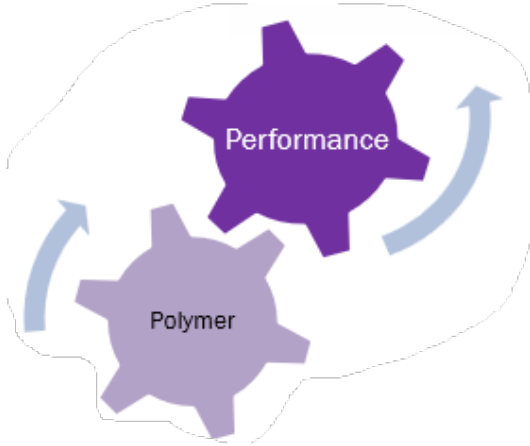
Crack Location

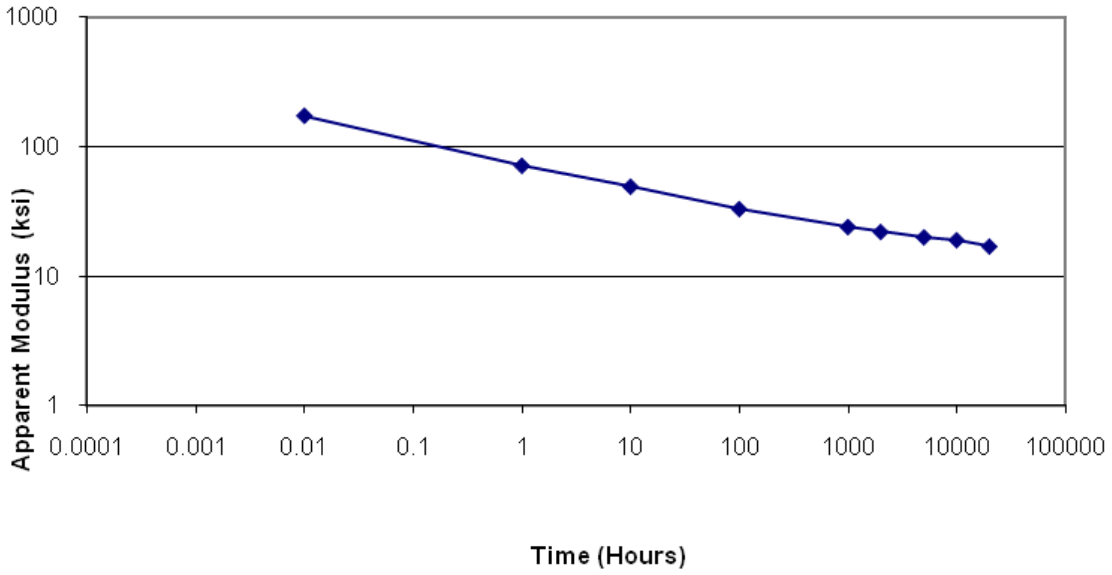


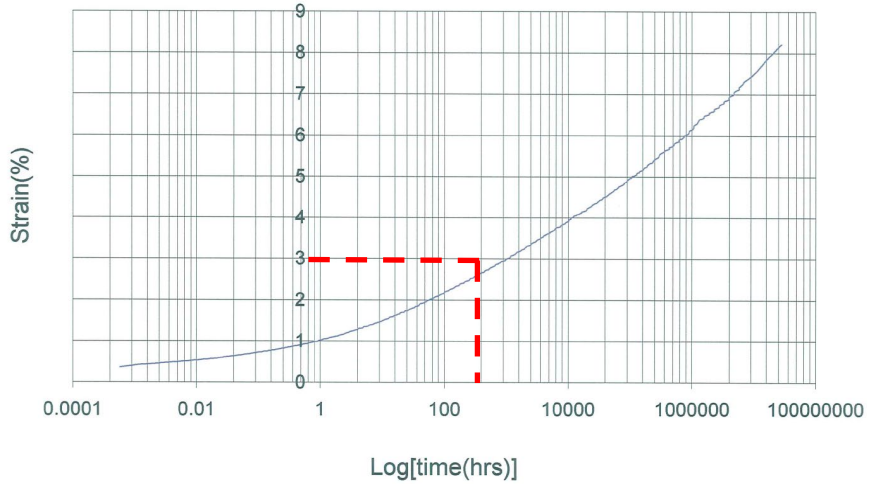


What Is Sustainable Stress?

- When Determining Sustainable Stress in Thermoplastic Need to Account for Time. (Creep)
  - Loss in Sealing Force
  - Increasing Displacement Over Time
  - Reduced Working Strength

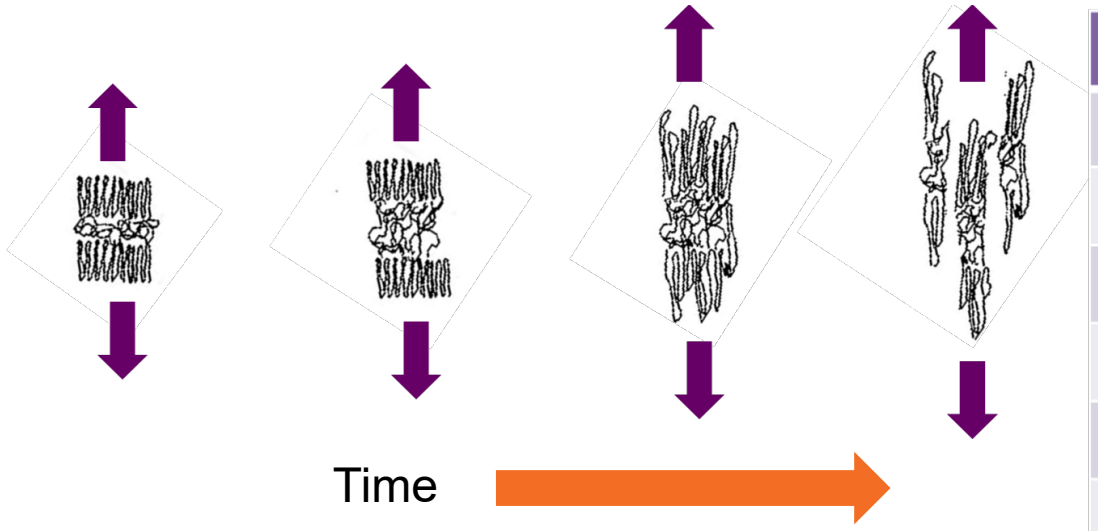






How to Account for Creep?

- Creep
  - Continual Deformation Over Time That Can Lead to Cracking Over Time.
  - Higher Molecular Weight Materials Tend to Have Better Creep Studies.
    - Can Use Accelerated Testing to Determine These Target Stress Levels.
      - Need to Account for Sufficient Factor of Safety.



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0.1	8.5 MPa	10.5 MPa
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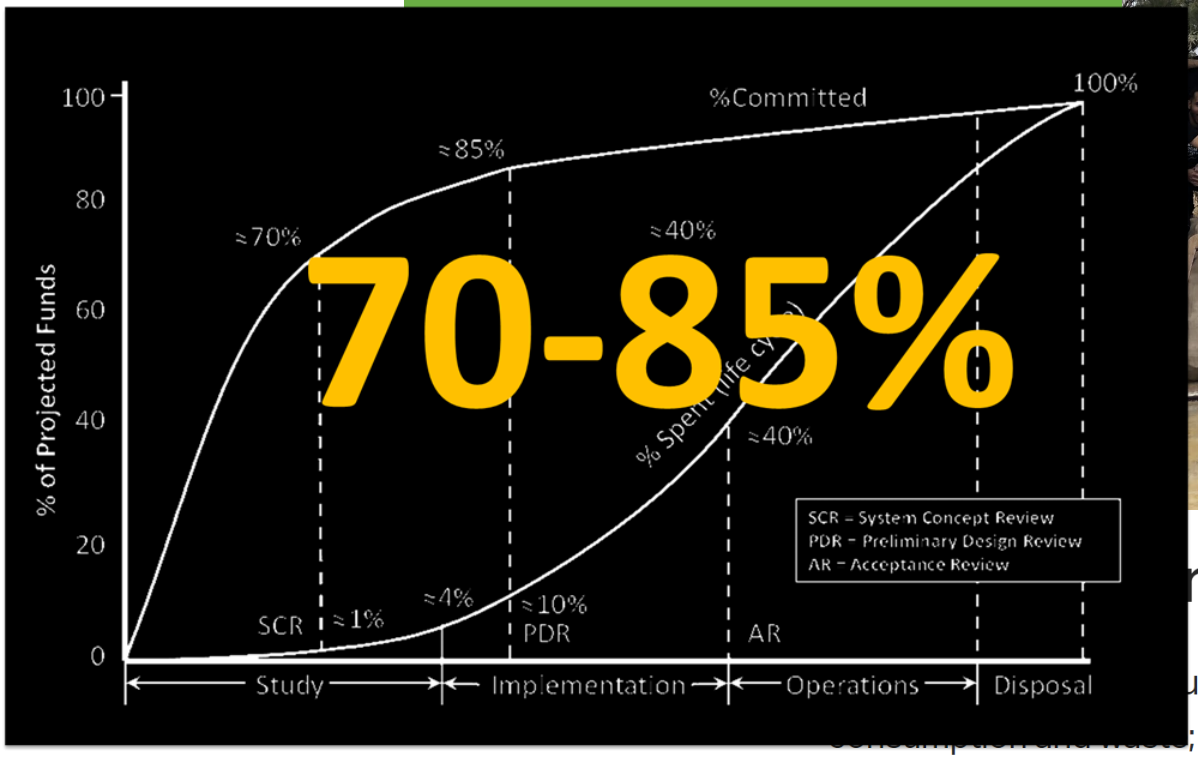
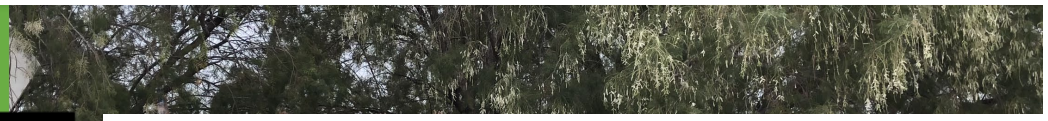
10	4.1 MPa	2.9 MPa
100	3.0 MPa	2.0 MPa
1000	2.3 MPa	1.5 MPa
10000	1.9 MPa	0.8 MPa

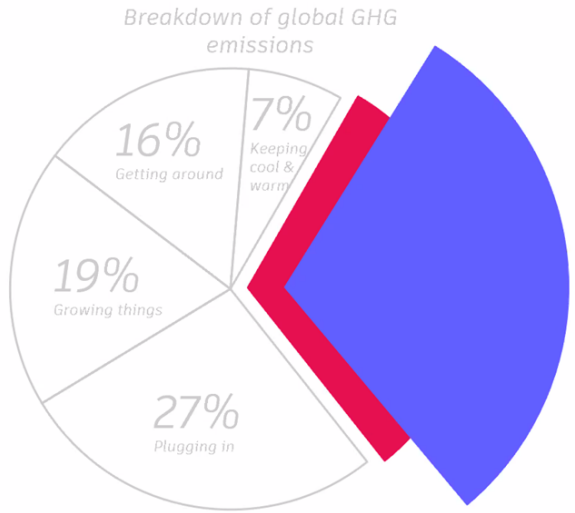
Where Can We Have Most Impact on Sustainability?



References:
Breaking Down the Barriers to Simulation: Autodesk Broadens Simulation Offerings, CIMdata



What We Make Has The Biggest Impact



31%

of total greenhouse gas emissions come from what we make

80%

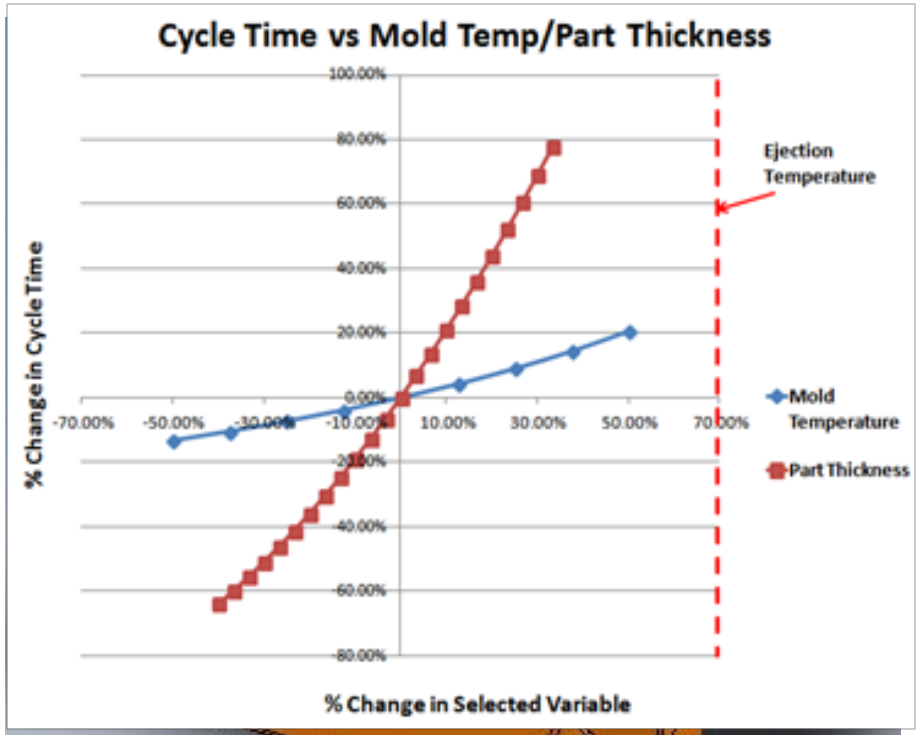
of greenhouse gas emissions are embedded at design stage

Source:
- Gates, B. (2021). How to avoid a climate disaster: The solutions we have and the breakthroughs we need. Allen Lane.
- McKinsey (2020) 'Design cost-effective, carbon-abated products with resource cleansheets'

…; accelerating the transition to a circular economy; and helping drive sustainability efforts that deliver lasting change.

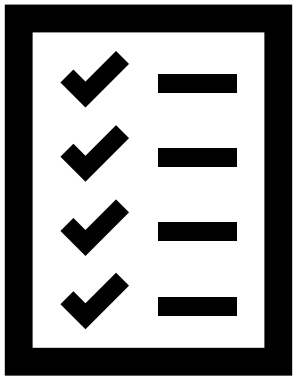
Role of Processing In Lightweighting?

- Regardless of Polymeric Material, Effort Should Be Given to Establish and Maintain Uniform Wall Thickness.
- Nominal Wall Dictates:
  - Envelope Dimensions
  - Rib and Boss Design
  - Manufacturing/Gating Constraints
  - Cycle Time
  - Part Cost

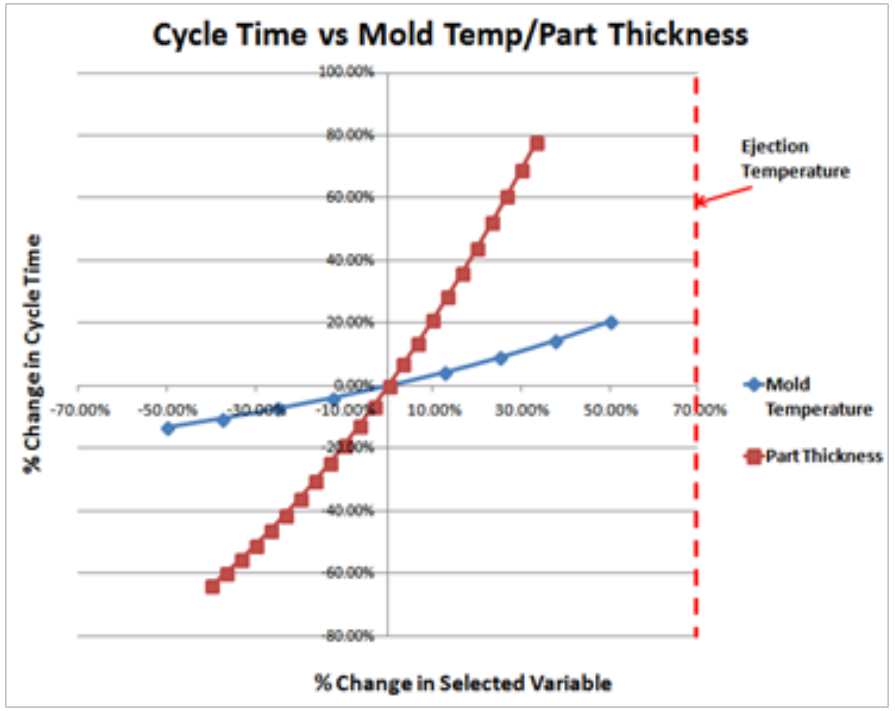


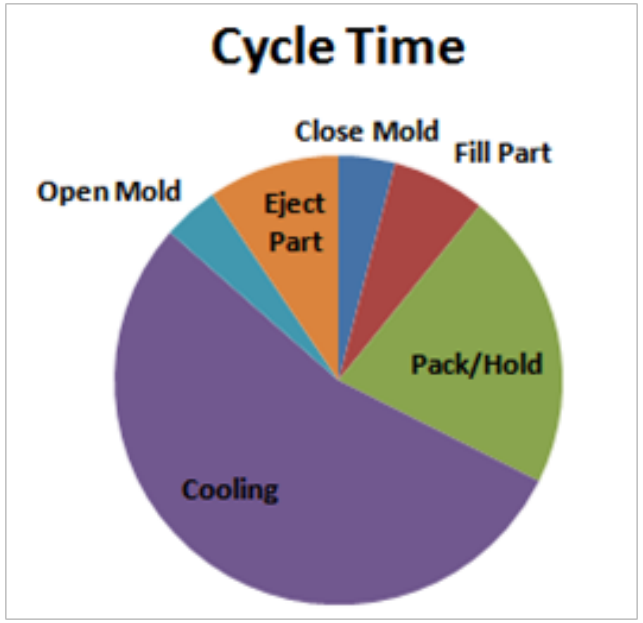
Consequence of Thinner Walls

- Going to Thinner Wall Sections for OEM:
  - Minimizes Material Consumption
  - Faster Cycle Times
  - Reduced Production Costs



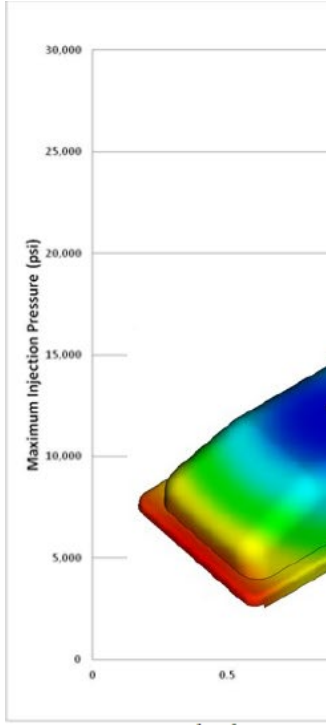
$$t_{cooling} \propto \frac{thickness^2_{part}}{Density}$$

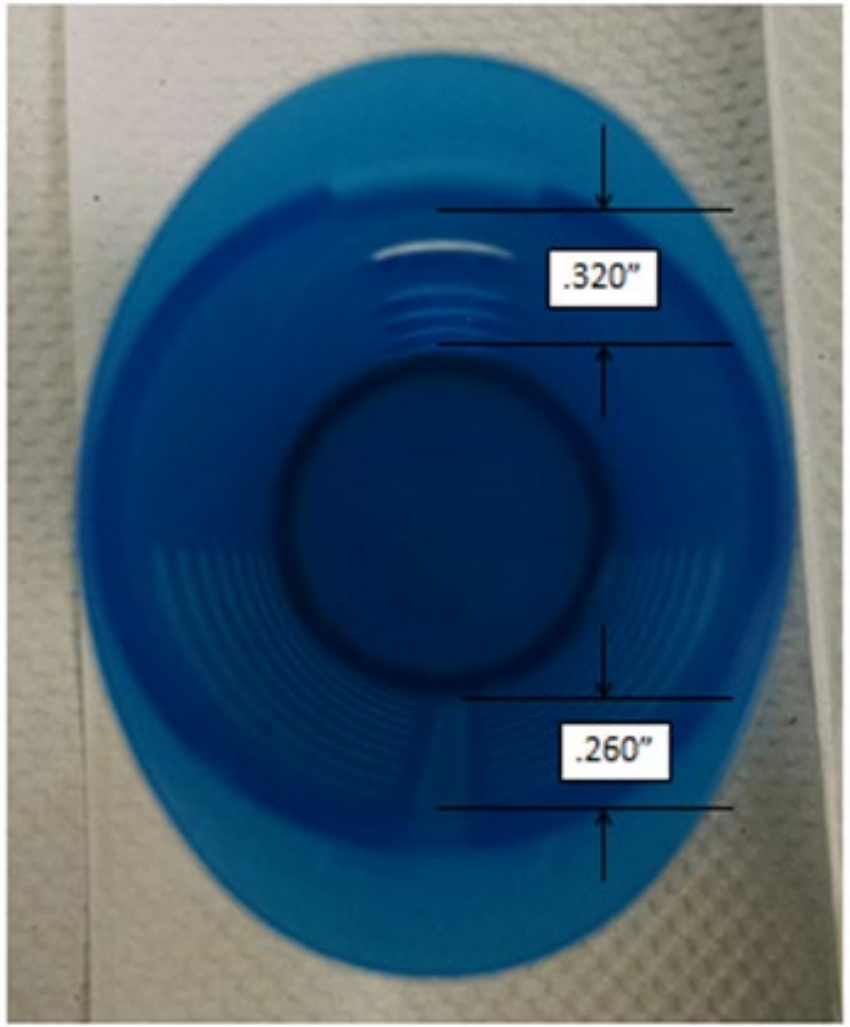




Consequence of Thinner Walls

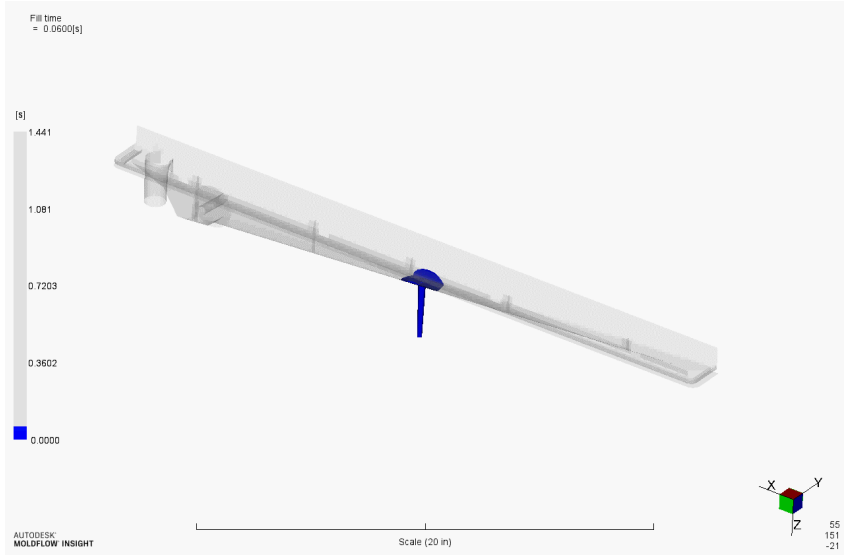
- Going to Thinner Wall Sections for Molder:
  - Higher Injection Pressure
  - Larger Tonnage Machines
    - (Increases Cost and Energy)
  - Narrower Process Window
  - Increased Potential for Warpage

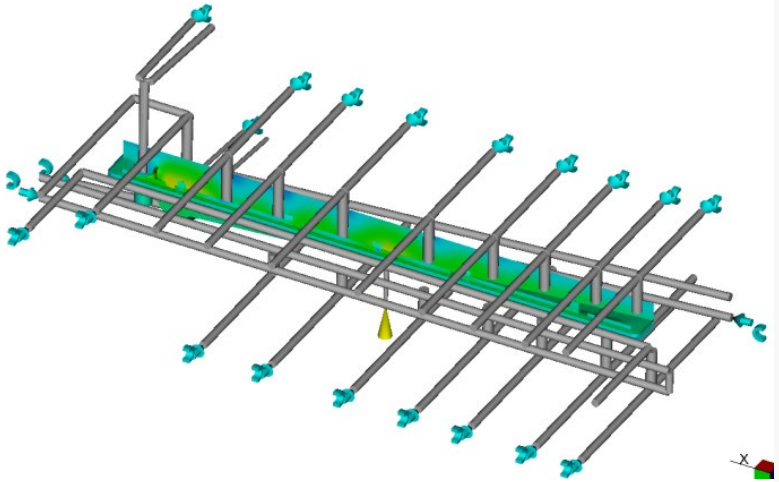


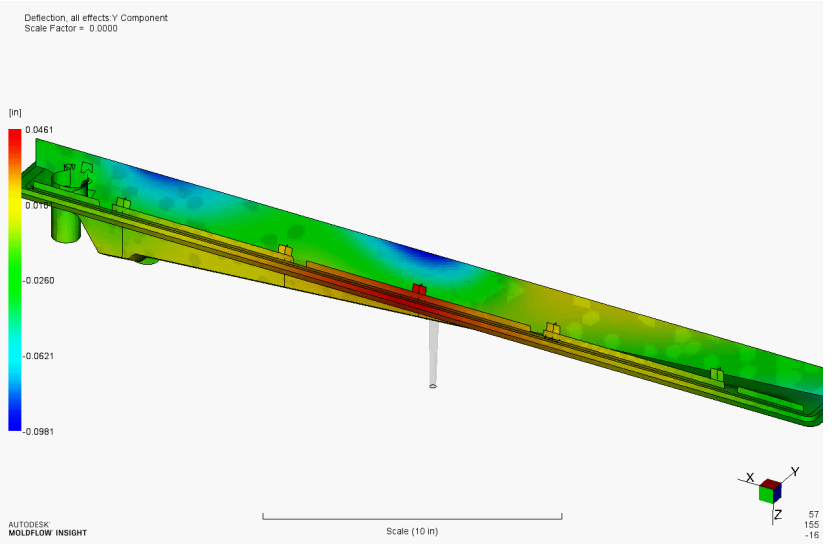


Tools to Evaluate Feasibility of Designs

- Injection Molding Simulation (Moldflow) Allows for Almost Entire Process to Be Simulated.

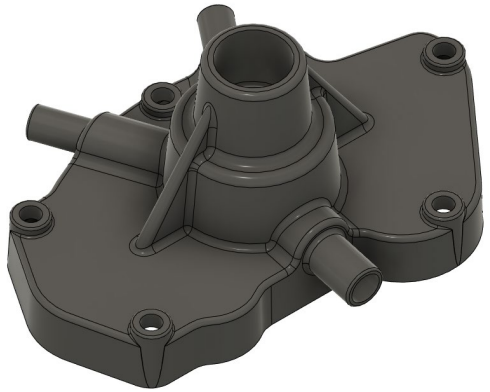




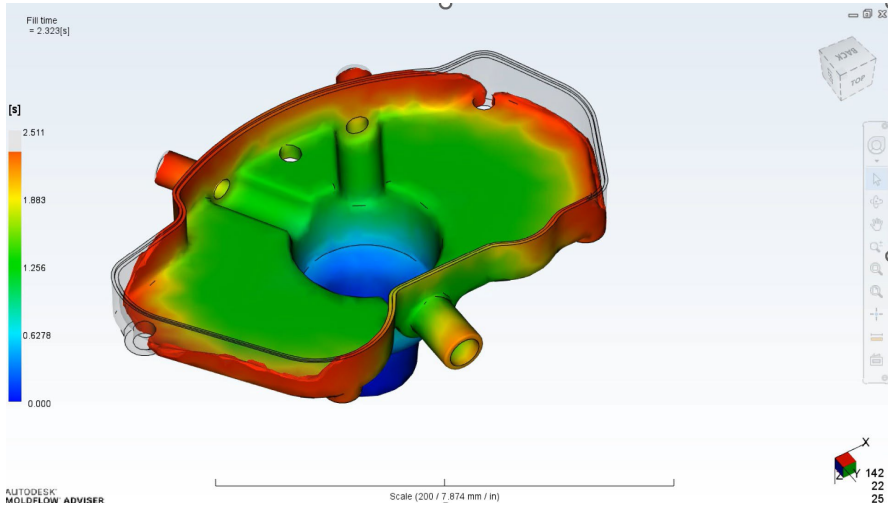


Benefits of Injection Molding Simulation

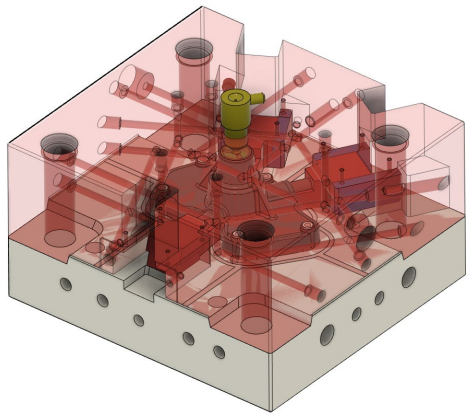
- OEM/ID
  - Part Performance
  - Part Design
  - Assembly
  - Material Selection
  - Gate Location



- Molder
  - DFM
  - Cavitation/Cost
  - Machine Selection
  - Material Selection
  - Process Development
  - Assembly/Secondary Operations
  - Automation

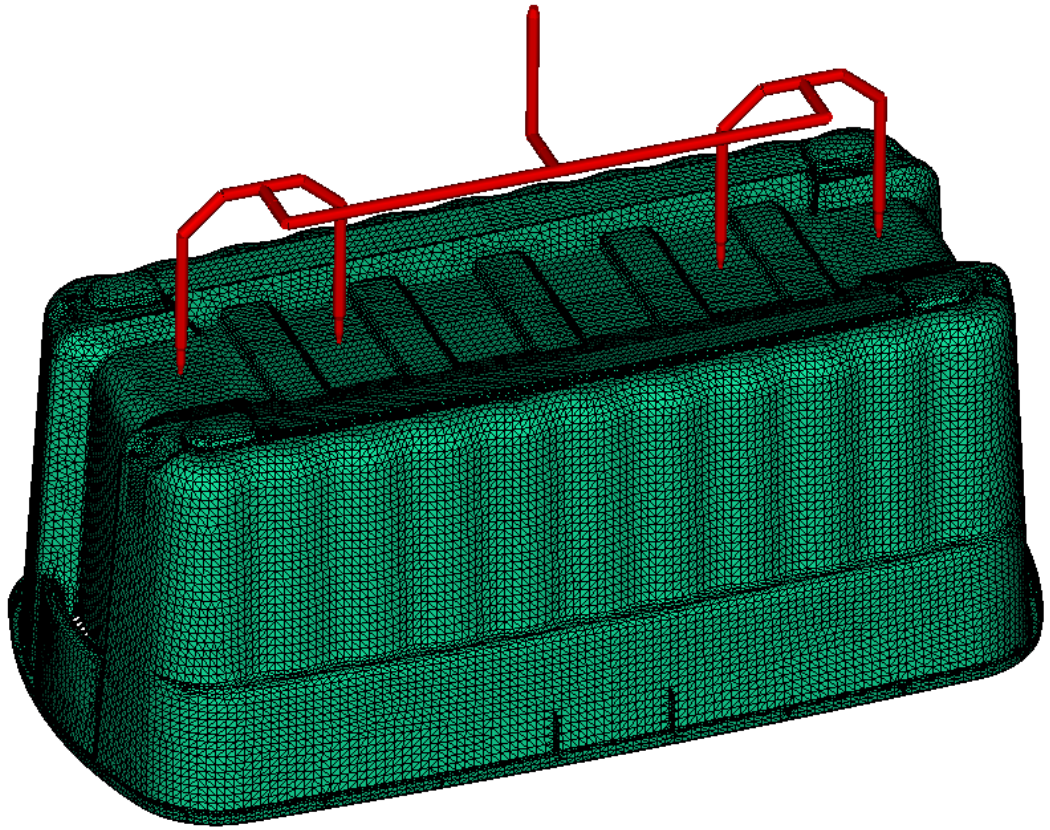


- Toolmaker
  - Mold Design
    - Steel Selection
    - Feed System
    - Cooling Line Layout
    - Ejection System
    - Shrinkage



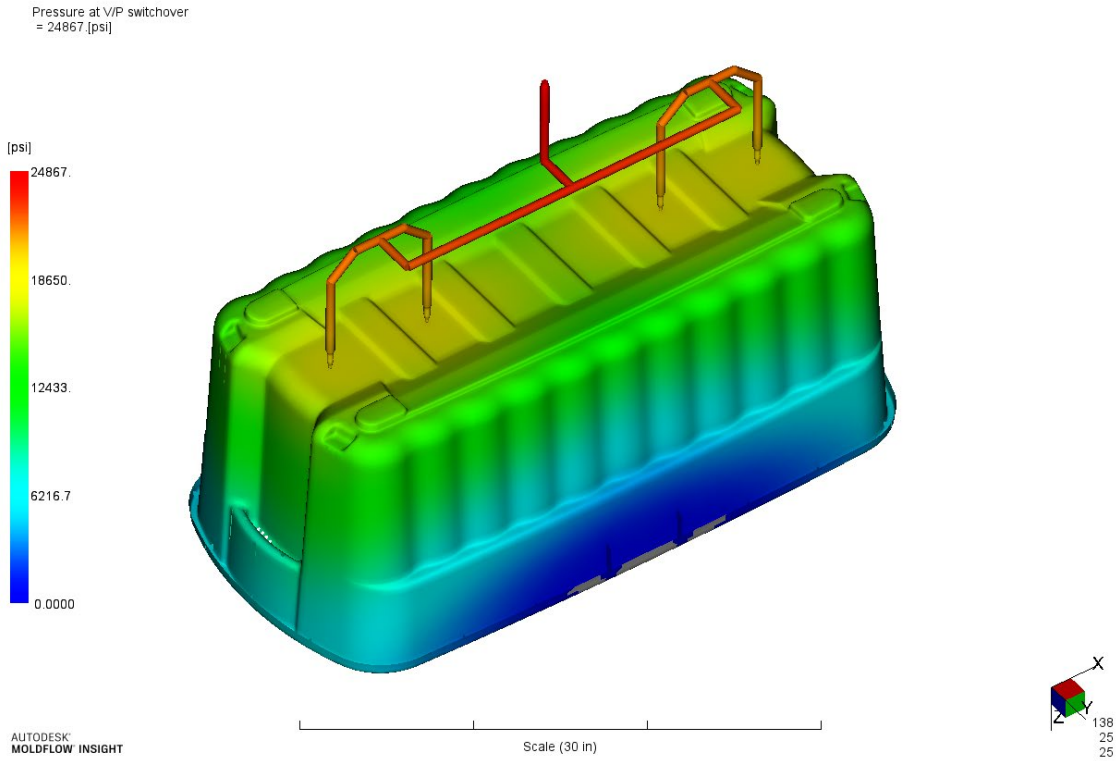
Consequence of Thinner Walls

- Customer Wanted to Reduce Wall Thickness of Container, Without Going to Larger Press.
  - 6,000 US Tons
- Resin: 12 MI HDPE
- Based on Customer FEA, Wall Section Could Be Reduced from 0.100” to 0.080” and Still Provide Adequate Performance.



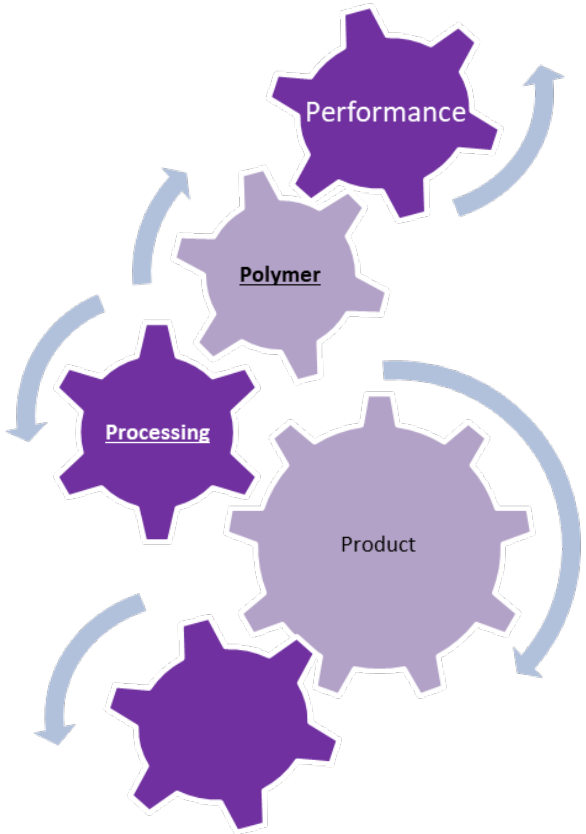
Consequence of Thinner Walls

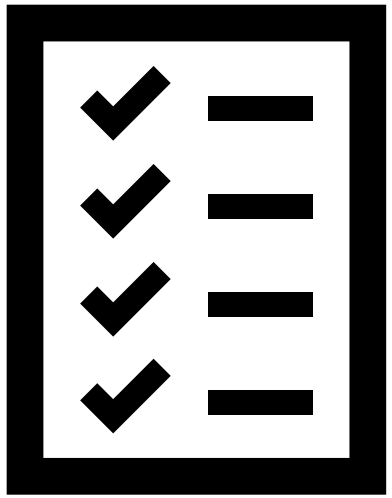
- Injection Molding Simulation Was Performed Prior to Change to Determine Injection Pressure and Tonnage Requirements.
- At 0.080” Wall Thickness, Process Would Become Pressure-Limited and Tonnage Would Be Exceeded.

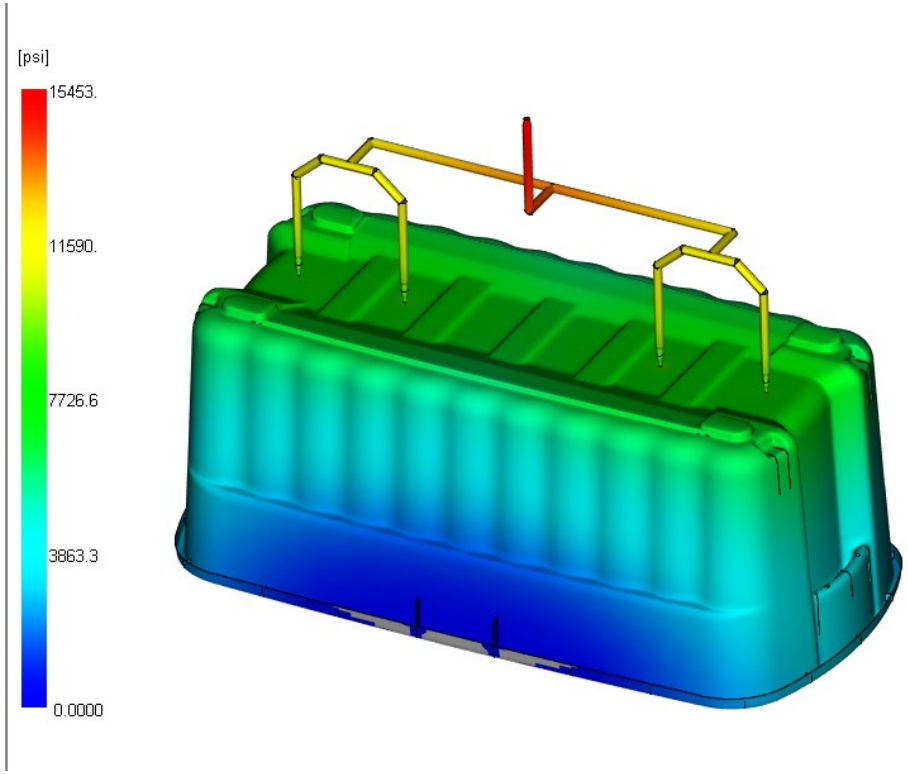


Consequence of Thinner Walls

- Alternative 30 MI HDPE Resin Was Evaluated To See If Pressures Could Be Reduced.

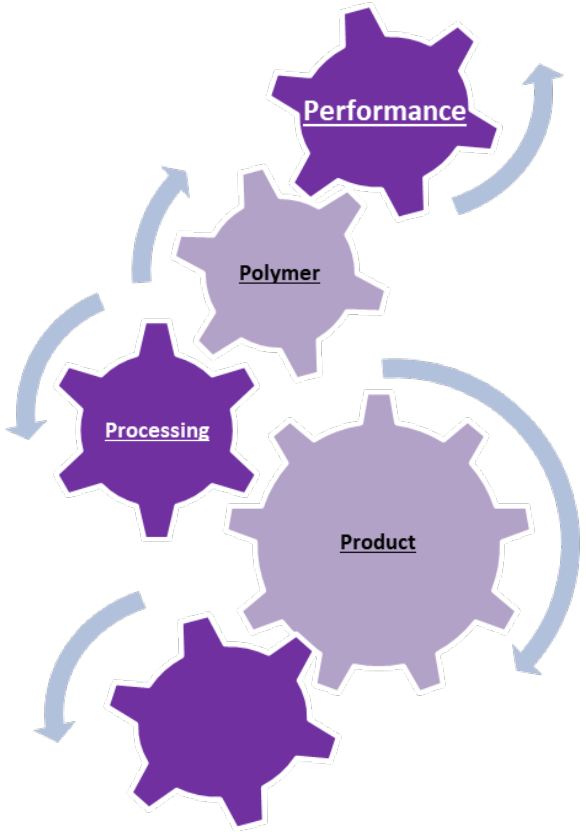


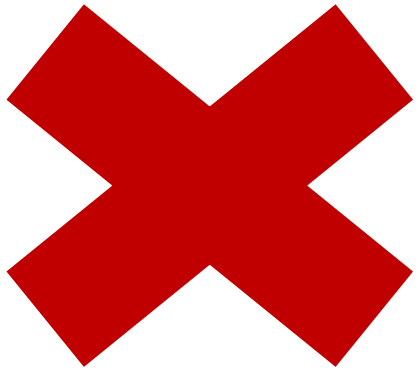




Potential of Easier Flowing Resin

- Using Higher Melt Index Resin Only Allowed for a 5% Reduction in Wall Thickness for Sustainable Design.





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100	3.0 MPa	2.0 MPa
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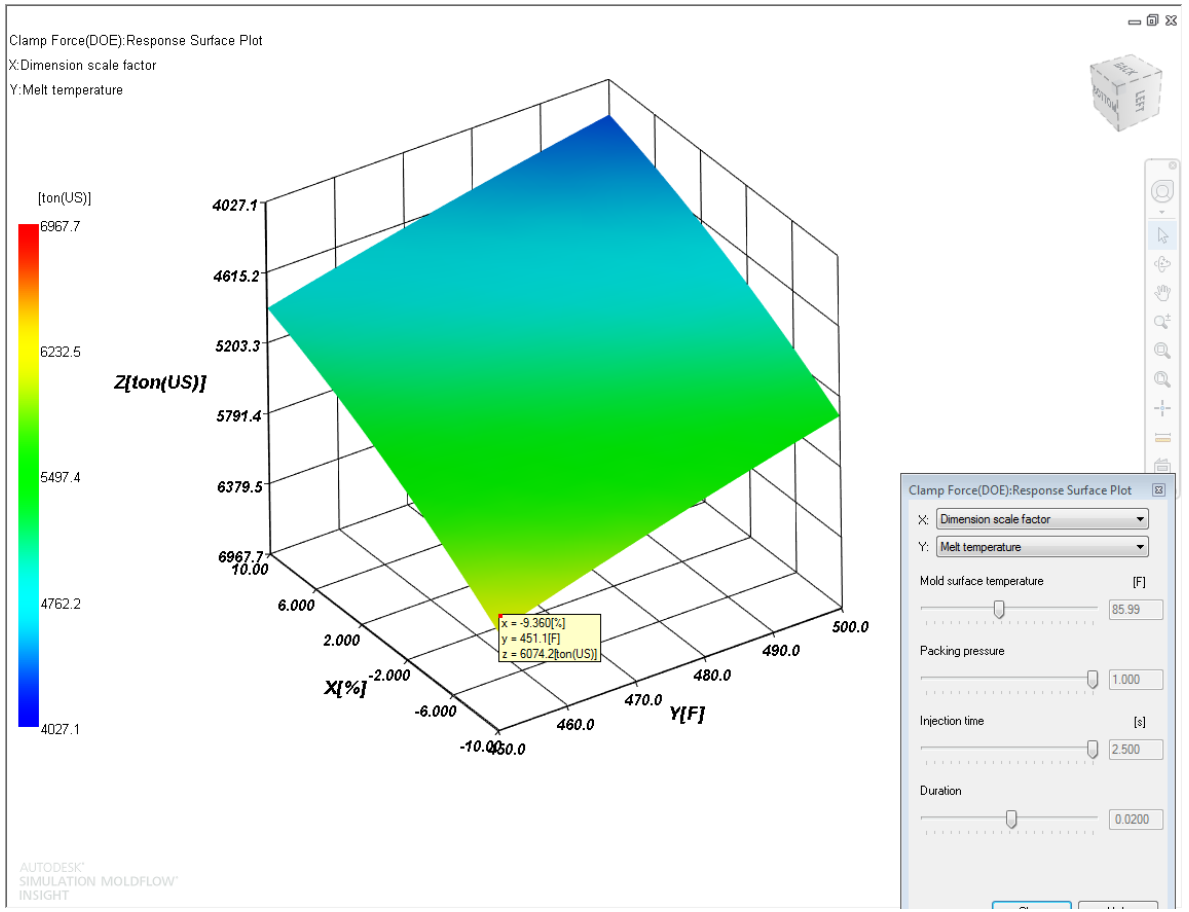
10000	1.9 MPa	0.8 MPa

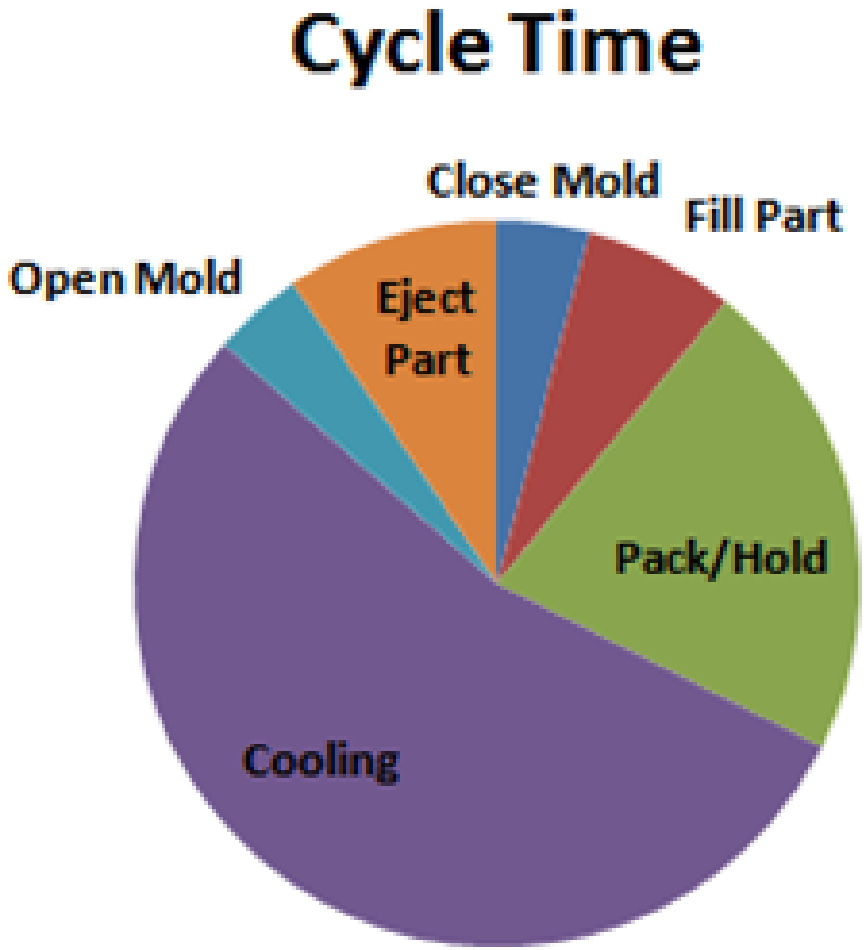
Finding a Viable Manufacturable Wall Thickness

- Performed a Virtual DOE to Determine Minimum Thickness with 12 MI HDPE Material Without Excessive Injection Pressure of Tonnage.
  - Could Reduce Wall Thickness by 10%!



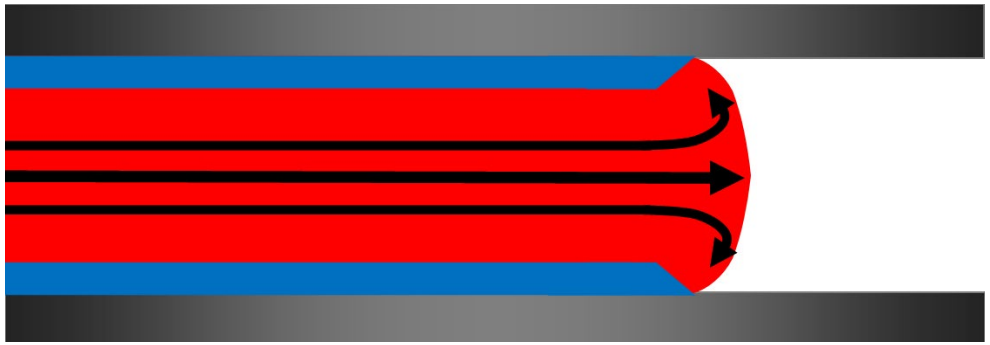
Lightweighting and Dimensional Stability

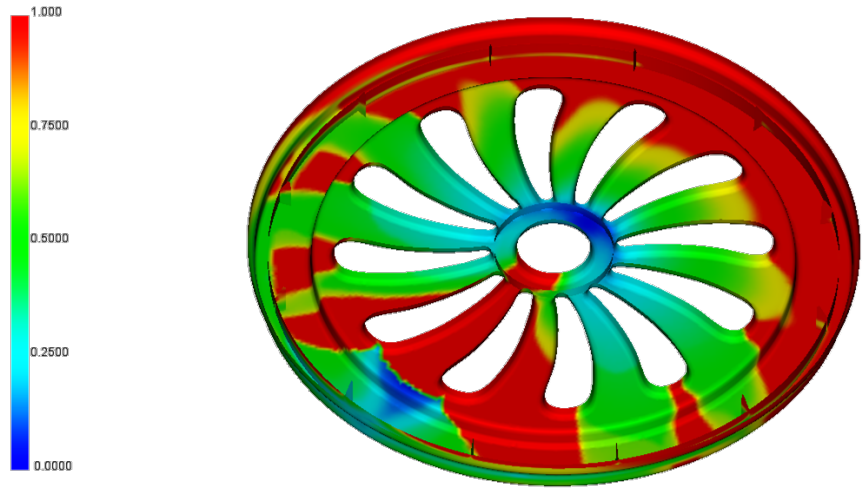
- When Light Weighting Injection-Molded Components, Often Injection Pressure is Main Parameter Used to Evaluate Feasibility.
- Dimensional Stability is Just as Critical, Which Makes Packing and Cooling Just as Important.



Lightweighting and Dimensional Stability

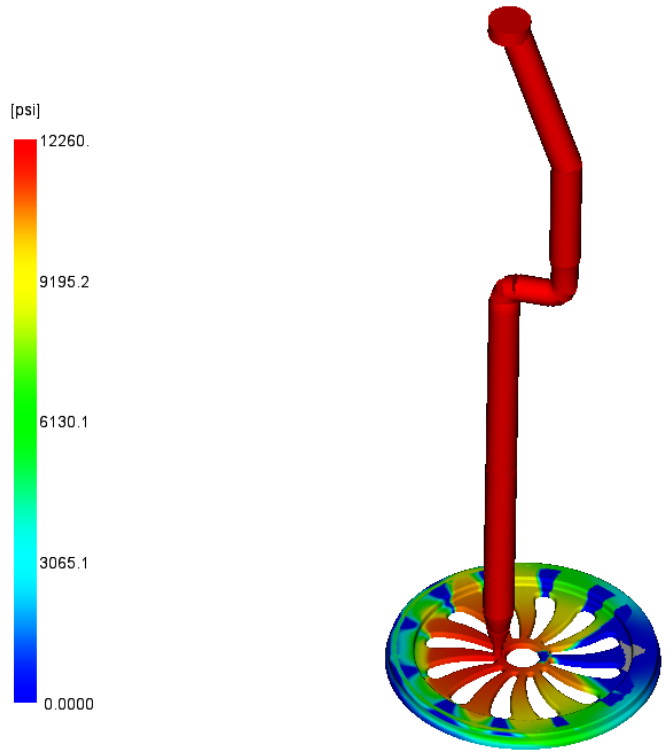
- Hot Molten Plastic Freezes upon Contact with Mold Wall.
  - Reduces Cross-Section of Part to Fill and Pack the Part Out.
    - Minimizes Ability to Control Shrinkage During Packing.
- Filling Faster or Increasing Melt of Mold Temperature Are Only Ways of Minimizing.
  - Besides Increasing Part Wall Thickness.

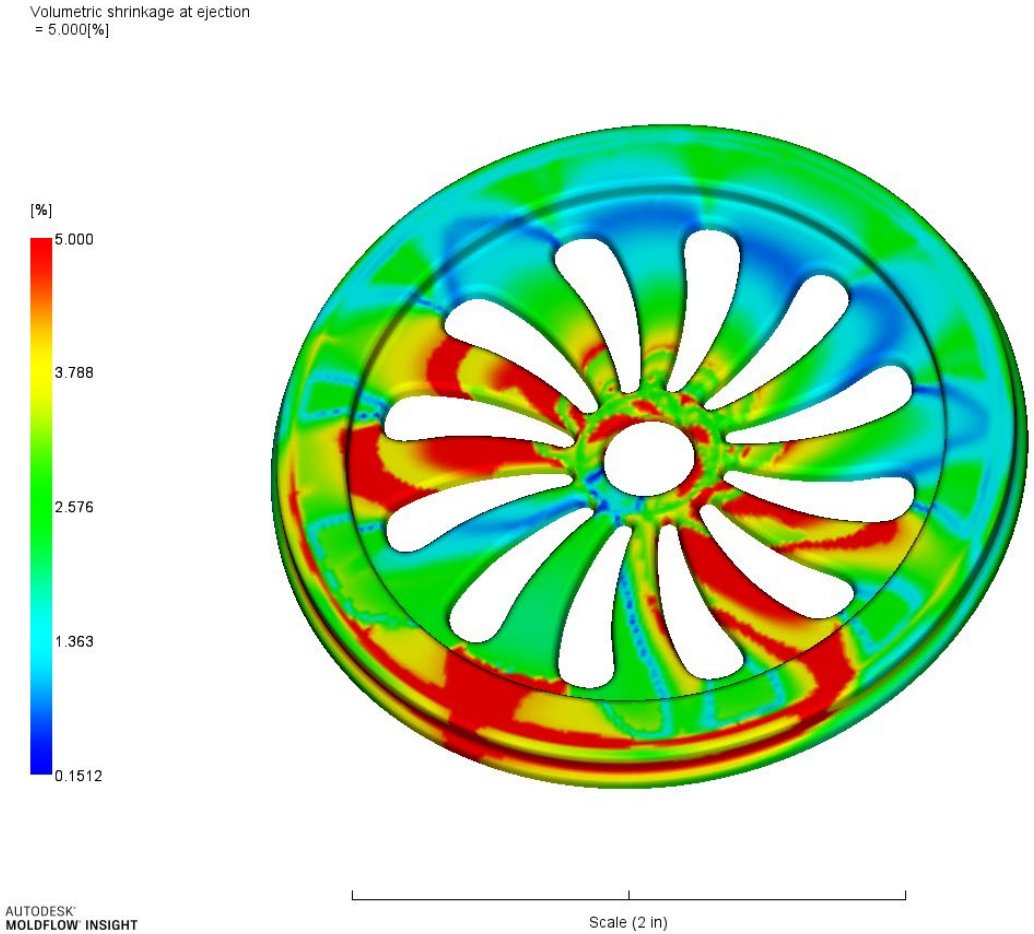




Lightweighting and Packing

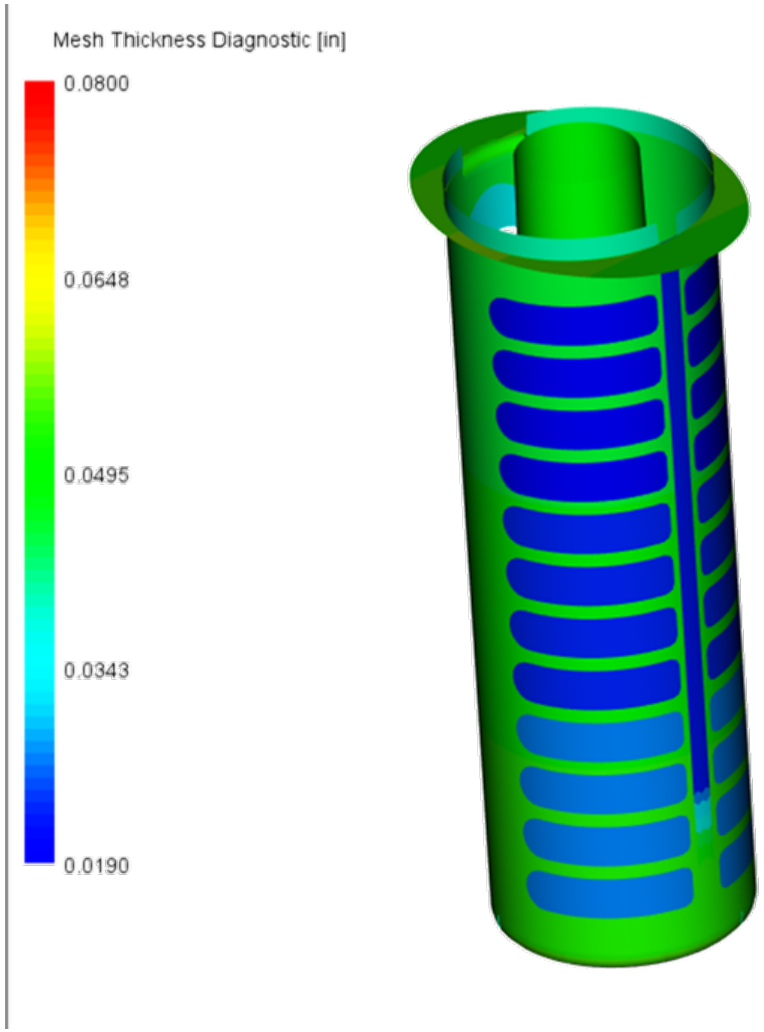
- Relying on Pressure to Fill Does Not Support Ability to Pack The Part
- Can Lead to Variable Shrinkage and Warpage





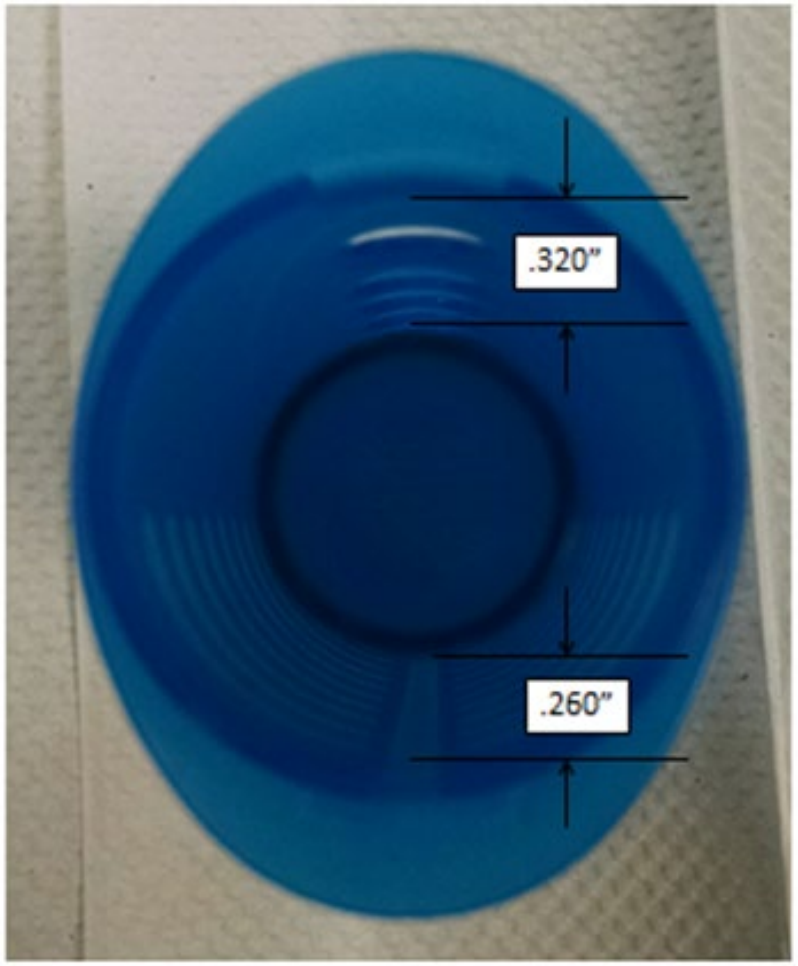
Lightweighting Case Study

- Customer Wanted to Reduce the Material Consumption in a Consumer Good Disposable Part.
- Material: 8 MI PP [CO]
- Modified Designs Included Stock Savers that Acted as Finger Grips.
  - Stock Savers Were 30% of Nominal Wall.



Lightweighting Case Study

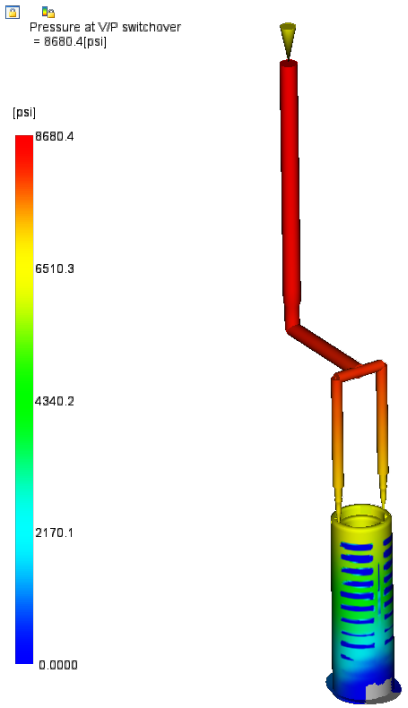
- Customer Built Prototype Mold, but Experienced Excessive Deflection of Center Core that Adversely Affected Assembly.



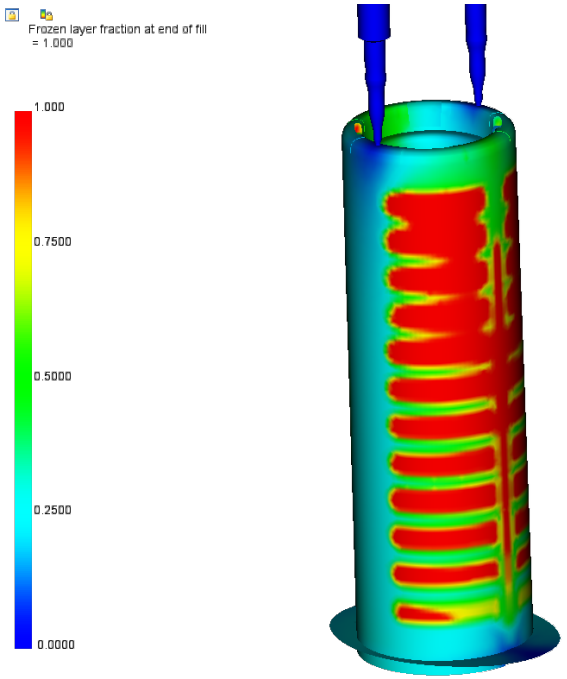
Lightweighting Case Study

- Initial Mold Filling Simulation Highlighted that While Pressure Remained Low to Fill the Cavity, the Thin Stock Savers Completely Froze Prior to the End of Fill.

Pressure to Fill



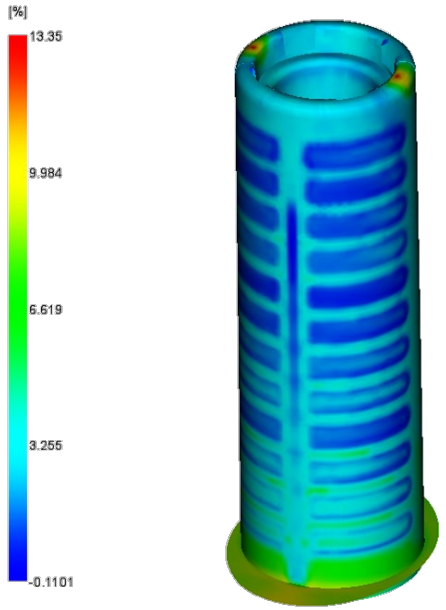
Frozen Layer Fraction



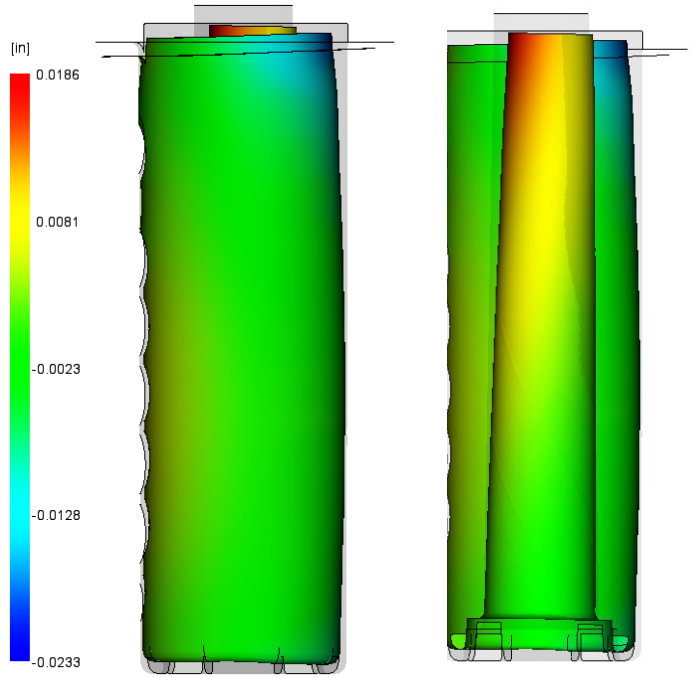
Lightweighting Case Study

- Premature Freezing of Wall Section Led to Variable Shrinkage and Deflection of The Center Core.

Volumetric Shrinkage



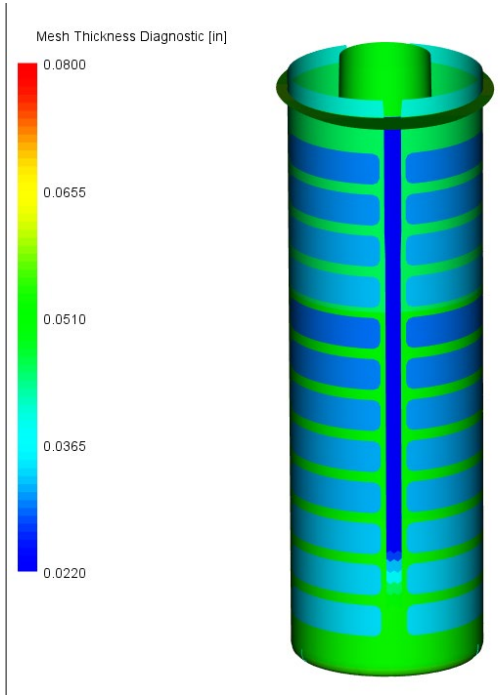
Part Warpage



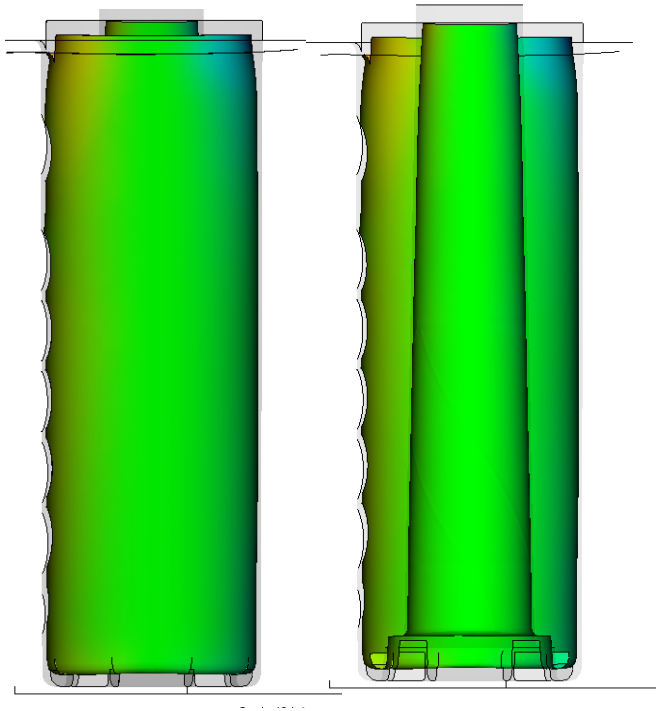
Lightweighting Case Study

- Increasing the Thickness of the Stock Savers by 0.007” Minimized the Material Shrinkage Variation And Minimized the Part Warpage.

Thickness Distribution

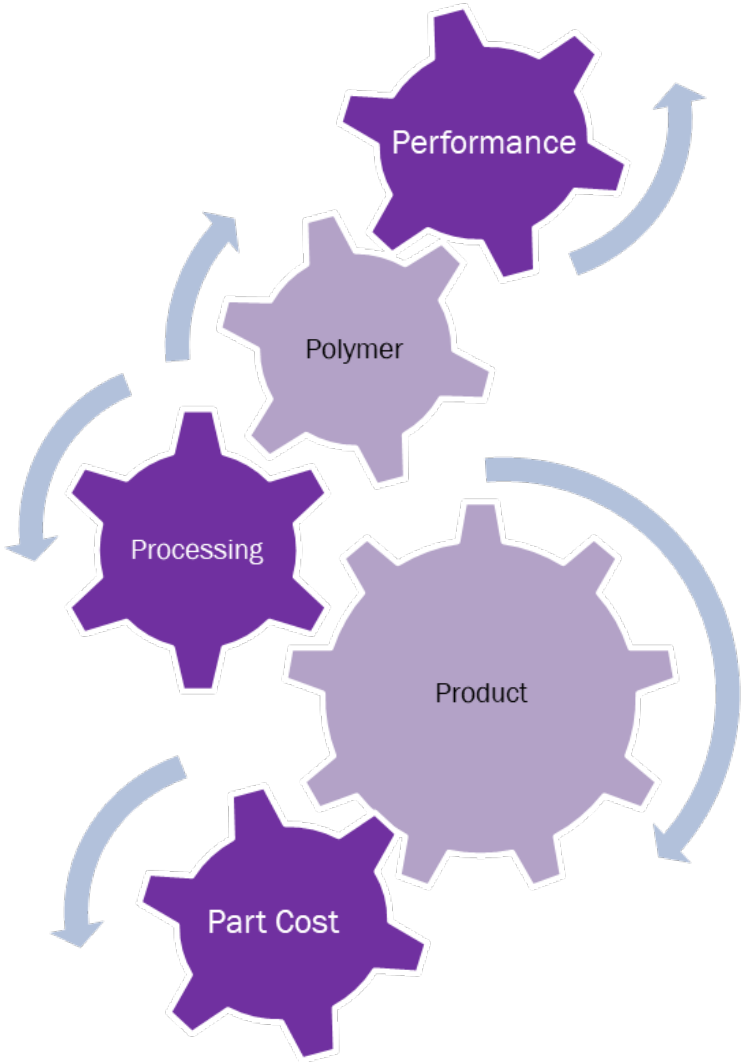


Part Warpage



Lightweighting Case Study

- Increasing Taking a Holistic Approach Helps Optimize the Design for Material Consumption and Manufacturing, Which Will Help Control Cost.
- Ensuring a Good Product Profile Can Help Accelerate Material Selection and Allow for Proper Properties to Be Generated for Design Optimization.
- Utilizing Simulation During Product Development Can Help Explore Full Design Space of Light Weighting.



Thank you!

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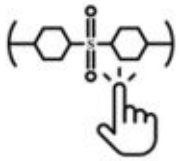
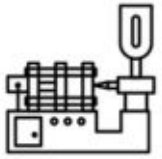
Design Review


Material Support


Product Testing


Manufacturing Support


Failure Analysis


Customized Training

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	Tuesday, May 7th	Wednesday, May 8th
10:00 AM	**THERMAL ANALYSIS FOR MATERIAL SELECTION AND TROUBLESHOOTING** Jeffrey Jansen, TA Instruments Booth, Location: S10179 **CUSTOM MECHANICAL TESTING FOR PLASTIC PRODUCTS** Jack DeSousa, MTS Corporation Booth, Location: W2669	
11:00 AM	**DESIGNING FOR CIRCULARITY FROM CRADLE TO GRAVE** Melissa Kurtz, Location: W414CD **OPTIMIZING THIN PART PRODUCTION: BEYOND LIGHTWEIGHTING TO RIGHTWEIGHTING EXCELLENCE** Erik Foltz, Location: W331A	**SHIFTING FROM METAL TO PLASTIC SEAMLESSLY** Dr. Paul Gramann, Location: W415A **WHAT'S REALLY HAPPENING DURING YOUR ACCELERATED AGING TESTS** Jeffrey A. Jansen, Location: W414CD
1:00 PM	**PUSHING THE LIMITS OF PLASTICS APPLICATIONS** Dr. Javier Cruz, Location: W330	
2:00 PM	**MATERIAL STRENGTH AND DURABILITY FOR PRODUCT DEVELOPMENT** Jeffrey Jansen, TA Instruments Booth, Location: S10179 **CUSTOM MECHANICAL TESTING FOR PLASTIC PRODUCTS** Jack DeSousa, MTS Corporation Booth, Location: W2669	