



**Geometric**

| People Building Partnerships



# **Robust Plastic Product Design A Holistic Approach**

*Webinar Hosted By  
Society of Plastics Engineer (SPE)*



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# About Presenters



**Vikram Bhargava**

Vikram is a fellow of the Society of Plastics Engineers and past chairman of its product design and development division. He recently retired as the director of mechanical engineering services at Motorola Solutions in Holtsville, NY. He has over 40 years of experience in product design, development, manufacturing and management, especially in plastics. He is a sought after trainer and has trained thousands of engineers and suppliers in the proper design and manufacturing of plastic parts and assemblies in the US, China, Taiwan, Canada and India. He is a certified Six Sigma Black Belt and has led or mentored numerous projects resulting millions of dollars in savings. He is currently authoring a book on Holistic Product Design to be published by Hanser in 2016. He holds or has pending over 21 US and International patents.



**Nikhil Dalvi**

Nikhil Dalvi is a senior subject matter expert at Geometric. With a diverse experience in manufacturing, development, project management, Nikhil now provides consultative solutions for customers in the US around our suite of technologies and products addressing the design and manufacturing space.

# Webinar Instructions

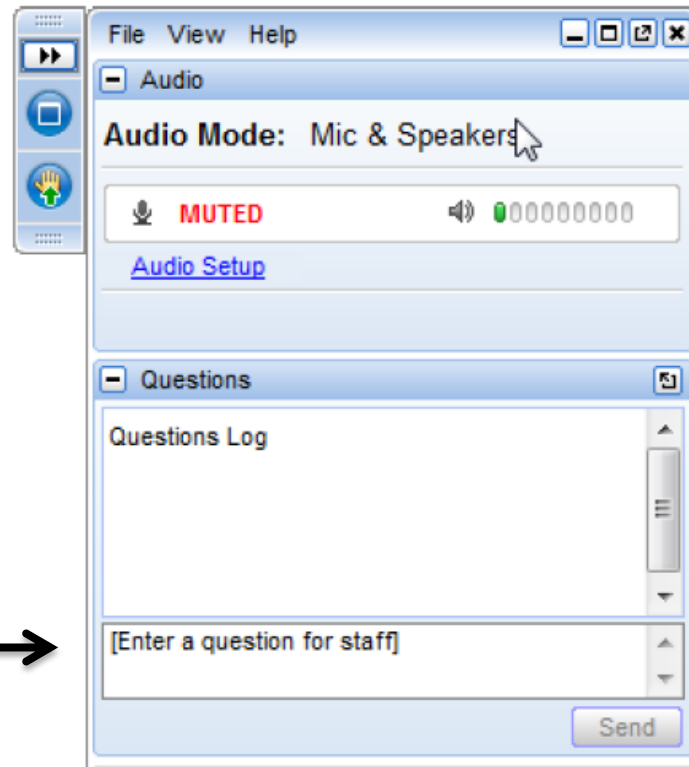
Full Screen



Raise Hand



Enter your questions



## Logistics

Submit your questions via the chat window during the Q&A session

The recorded version of the webinar will be available on DFMPRO website – [www.dfmp.com](http://www.dfmp.com)

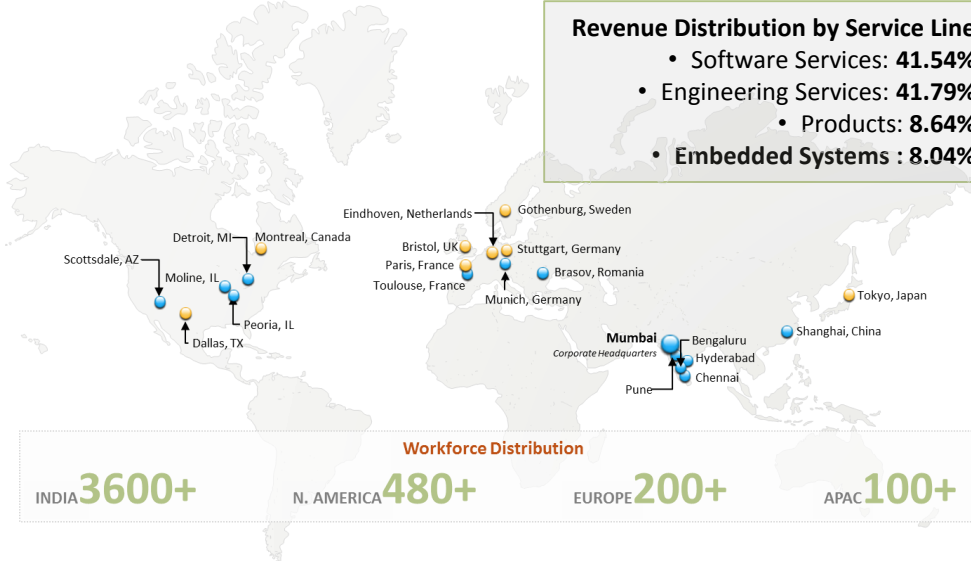
# Geometric : An Overview

## Global Presence

Delivery locations: 13

### Revenue Distribution by Service Line

- Software Services: **41.54%**
- Engineering Services: **41.79%**
  - Products: **8.64%**
- Embedded Systems : **8.04%**



## Snapshot



- Part of the Godrej group
- > 181 Mn USD revenues in FY15
- Over 4800 people
- Global delivery model with delivery centers in US, Eastern Europe, China and India
- Portfolio spread covers Engineering IT, product and manufacturing engineering and manufacturing operation services

## Alliances, Partnerships and Relationships



- DS Gold Partner
- Product development for all Dassault Systèmes brands
- A joint venture, 3D PLM Software Solutions Ltd, established in 2002, with 58% ownership by Geometric



- Strategic relationship since 1998
- Multifaceted Partnership – Product R&D, Foundation, Consulting & SI and Alliance Partner
- Software R&D leading to Co-innovation and Customer Success



- Gold Tier Partner since 2004



- Solution Partnership for Anark Core™ MBEWeb™



- Preferred software development partner for expedited development of next generation engineering software for joint customers



- Industry alliance providing access to specialized manufacturing infrastructure for our aerospace customers with our Build-to-Spec offering

**DFMPro**  
A Geometric Product

An automated intuitive tool for designers to accurately predict the manufacturability of models

**GeomCaliper**  
A Geometric Product

Integrated, automated and easy-to-use thickness checker for models

**Design Solutions**

**Glovius**  
A Geometric Product

An extensible - customizable framework to enable consumption of 3D data

**eDRAWINGS Publisher**

A lightweight intuitive collaboration tool for 3D models

**MBEWeb™**

Joint solution developed with Anark to re-purpose 3D data for downstream usage

**Visualization Solutions**

**CAMWorks**  
A Geometric Product

An automated intuitive CAM solution designed to maximize machining productivity

**FeatureRecognition**  
A Geometric Technology

A tool designed to automate the extraction of feature intelligence from models

**NestLib**  
A Geometric Technology

Fast, flexible and easy-to-integrate true shape nesting libraries designed to maximize raw material utilization

**Manufacturing Solutions**

**IP Products and Technologies**

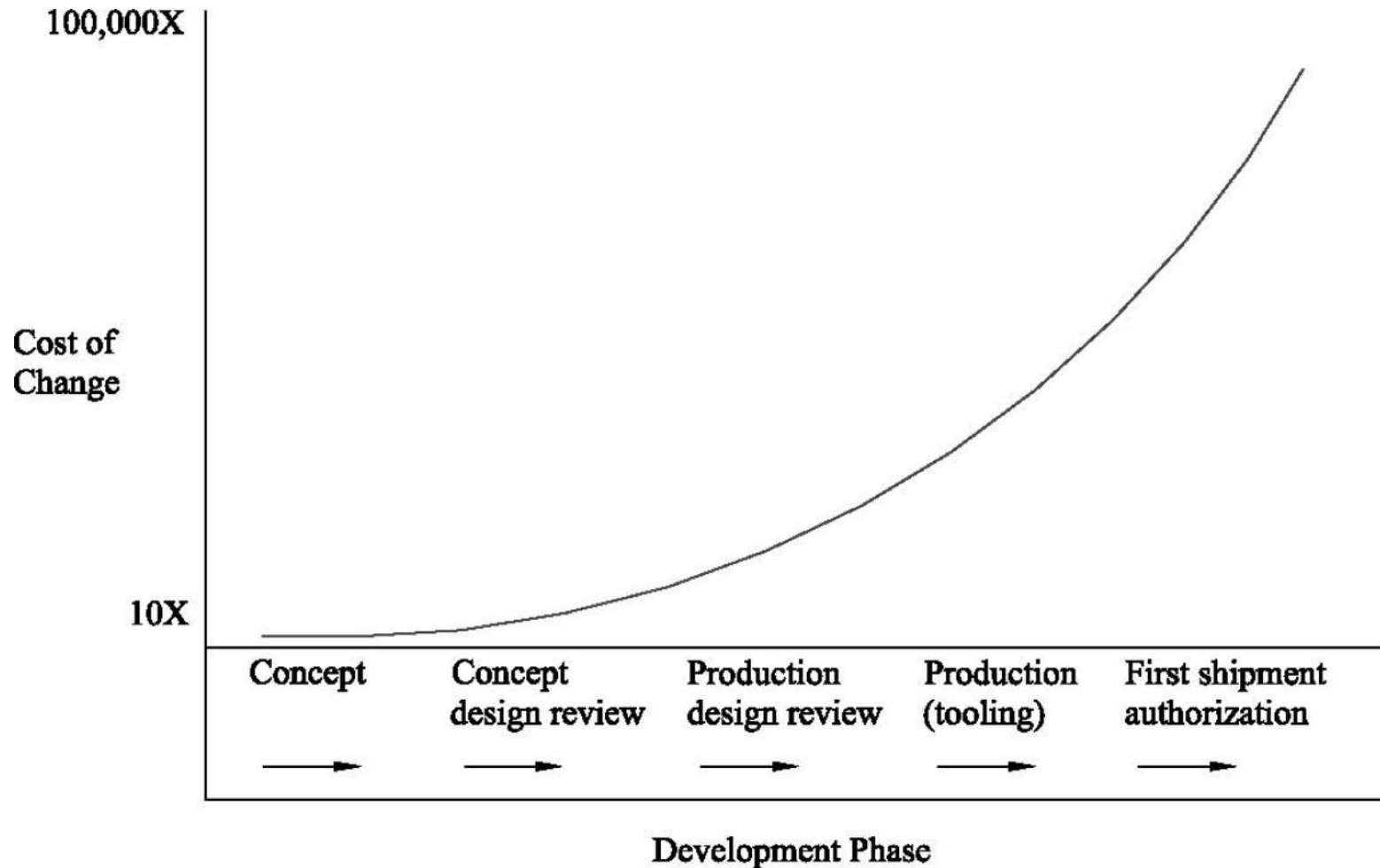
# What Is a Robust Design?

- Perform as intended over the projected life and intended environmental conditions
- Meet the appearance requirements
- Be as cost effective as possible

# Total Cost of a Part

- Total life of the product:  $n$
- Legitimate Costs:  
Normal Development Costs + Tool Cost + (Cost of Plastic, Processing, Material and Profit per part) \*  $n$
- Avoidable Costs:  
Additional resources spent to fix errors + Additional Tooling Costs + Scrap Cost
- Beyond Avoidable Costs:  
Warranty Costs + Liability Costs + Opportunity Costs

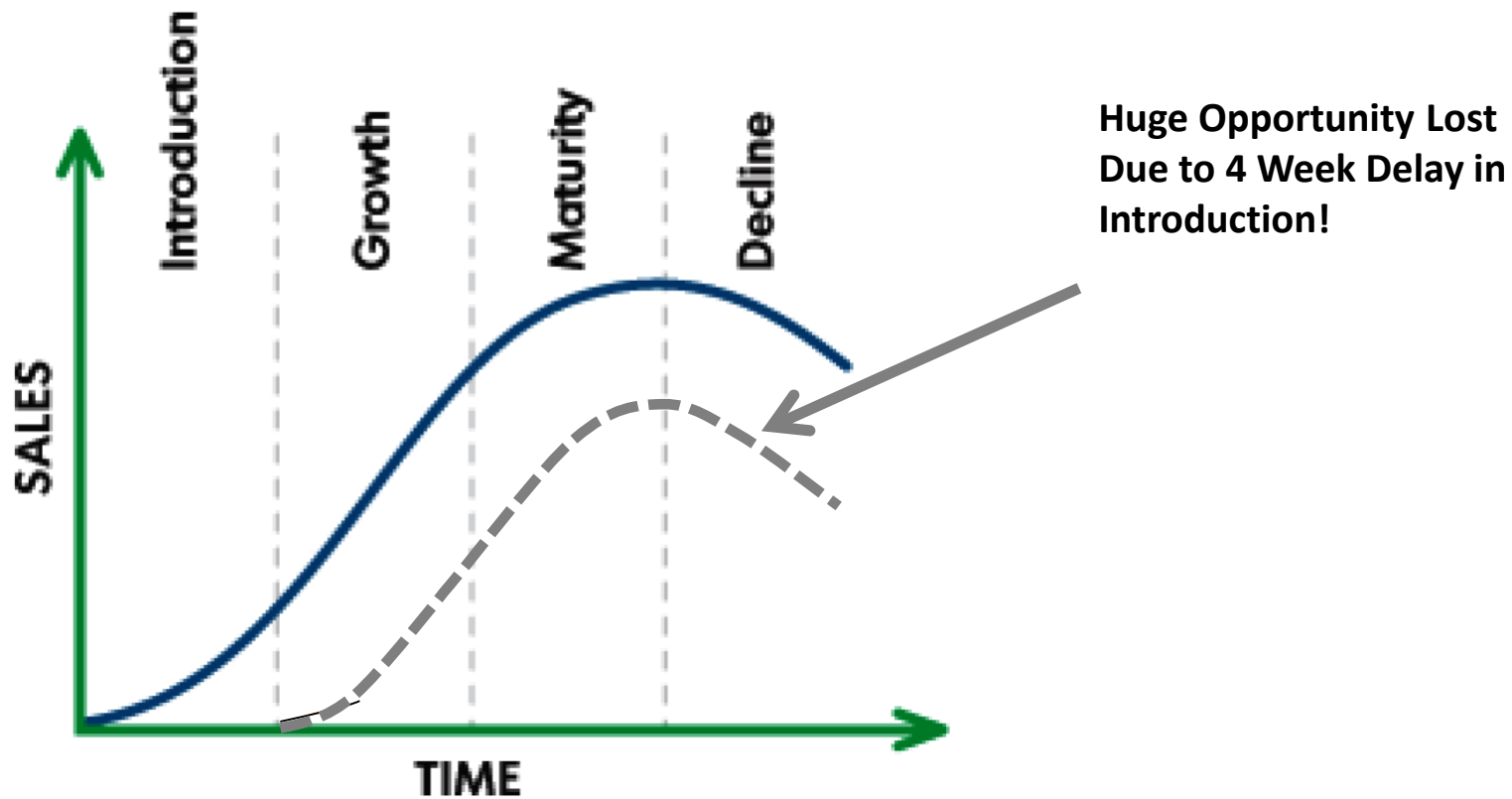
# Cost of Fixing Errors in Design



**Note: Time Needed to Fix Issues in General Proportional to Cost of Fixing Issues**



# Cost of Fixing Errors in Design

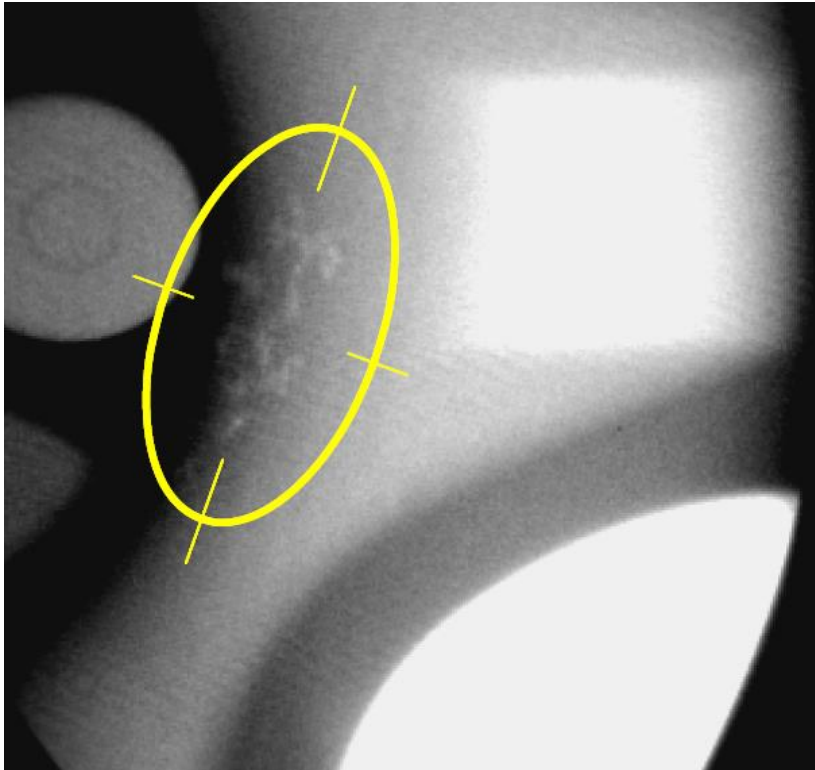


- What about the competitors getting a head start in introducing their product?
- Additionally, what about effect on future sales due to the bad reputation earned?

# Why Plastic Parts Are Different from Conventional Metal Parts

Plastic	Metal
<u>Published properties are only guidelines *</u>	Published properties are reliable for design
Properties affected by environment, temperature, time and are relatively unpredictable	Properties not affected by NORMAL environment, temperature, time. Even if they are, they are more readily predictable
Unique design requirements	Conventional design requirements
Tooling and processing can have dramatic effect on performance	Tooling and processing have relatively little effect on performance
Many latent defects that can not be detected with routine quality control	Few latent defects that can not be detected with routine quality control

# Metal Defects Example (Diecasting)



Void in a radiosopic image of an aluminum wheel.

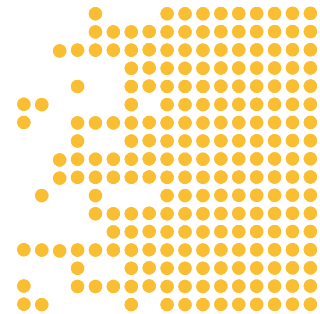


Porosity in an aluminum diecasting.

X-Ray Courtesy Domingo Mary, Santiago de Chile



# Given all the complexities of Plastics....



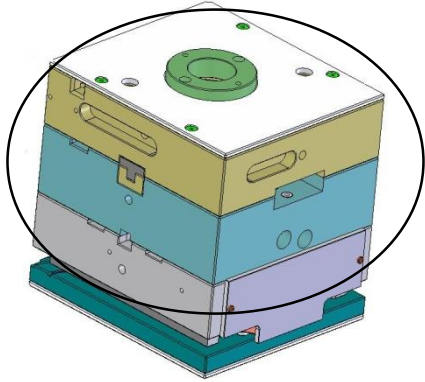
# Holistic Approach for Plastic Product Development

ho-lis-tic (ho-listik)adj. 1. Of or relating to holism. 2. Emphasizing the importance of the whole and the interdependence of its parts. Concerned with wholes rather than analysis or separation into parts: *holistic medicine; holistic ecology.*--ho-lis'ti-cal-ly adv.

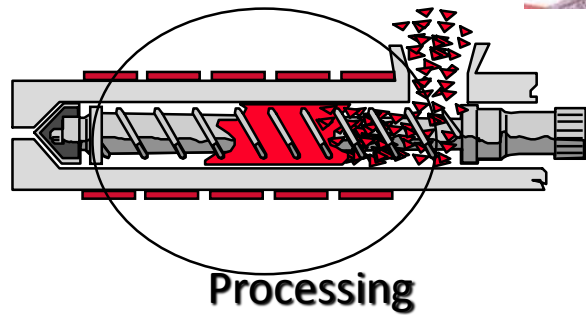
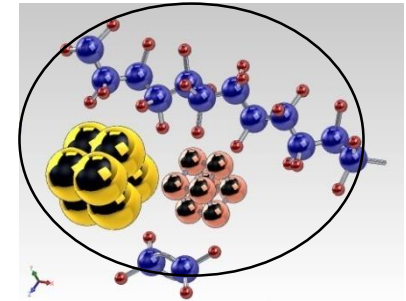
# In Other Words....



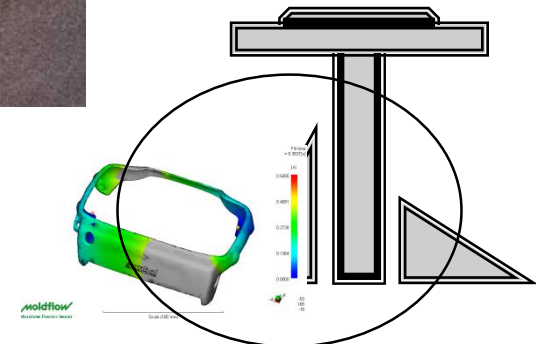
## Tooling



## Material



## Processing



## Design

# One bad wheel and...

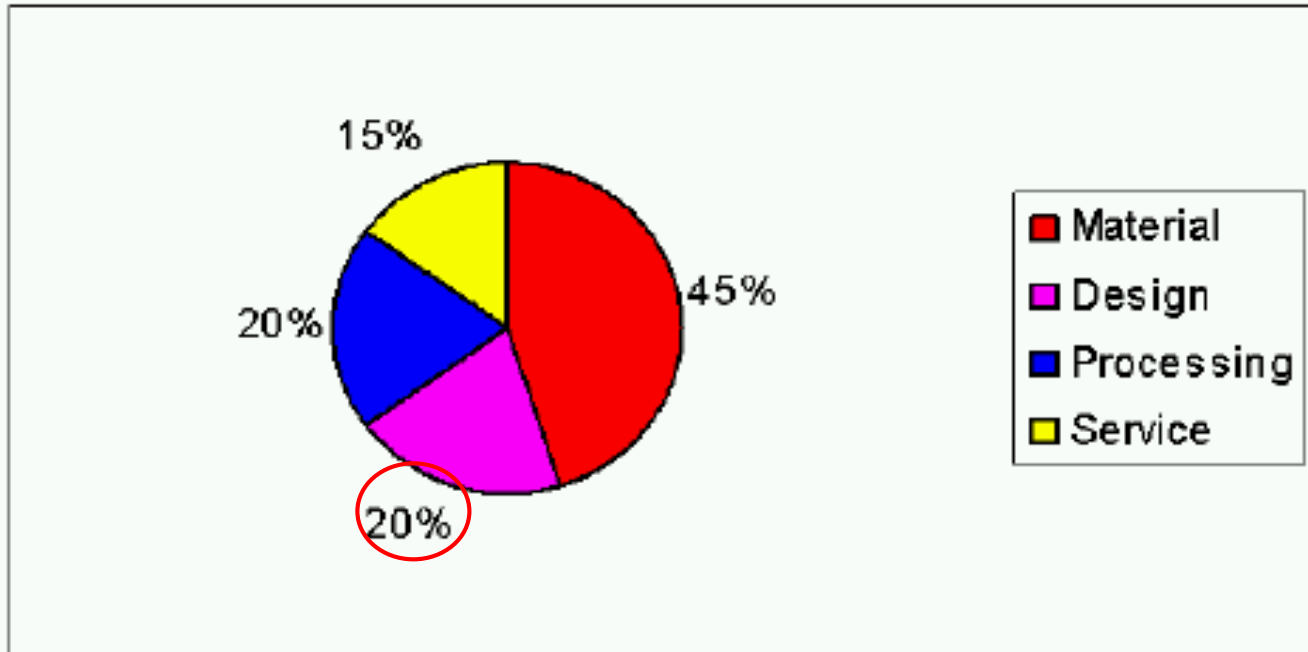


# On the Other Hand





## Plastic Failure Factors



Taken From "Failure of Plastics and Rubber Products" by David Wright

## Basic Physical Properties:

- Static
  - Mechanical – Tensile Strength, Toughness, Elongation, etc.
- Dynamic
  - Wear
  - Modulus at high impact rate
  - Fatigue
- Electrical
  - Dielectric Strength
  - Resistance, etc.
- Long term
  - Color Retention
  - Embrittlement

## Environmental Properties:

- Chemical Resistance
- Color and Appearance

## Thermal Properties

- High and Low Temperatures
- Temperature Cycling

## Agency Properties

- UL
- FDA
- RoHS
- Country Specific Requirements

## Molding Properties

- Flow
- Bonding between Materials (over molding)
- Directional Shrinkage

## Purely Physical Requirements

- Mechanical – Tensile Strength, Toughness, Elongation, Thermal, etc.
- Electrical – Dielectric Strength, Resistance, etc.
- ESD

## Molding and Tooling Dependent Requirements

- Gate Size, Appearance and Location
- Knit Line Location and Appearance
- Wall Thickness Uniformity (Up to 50% of Failures)
- Wall Thickness Ratio
- Thick to Thin Flow
- Sharp Internal Corners
- Knit Line
- Orientation
- Draft
- Boss Lengths – Unsupported Cores

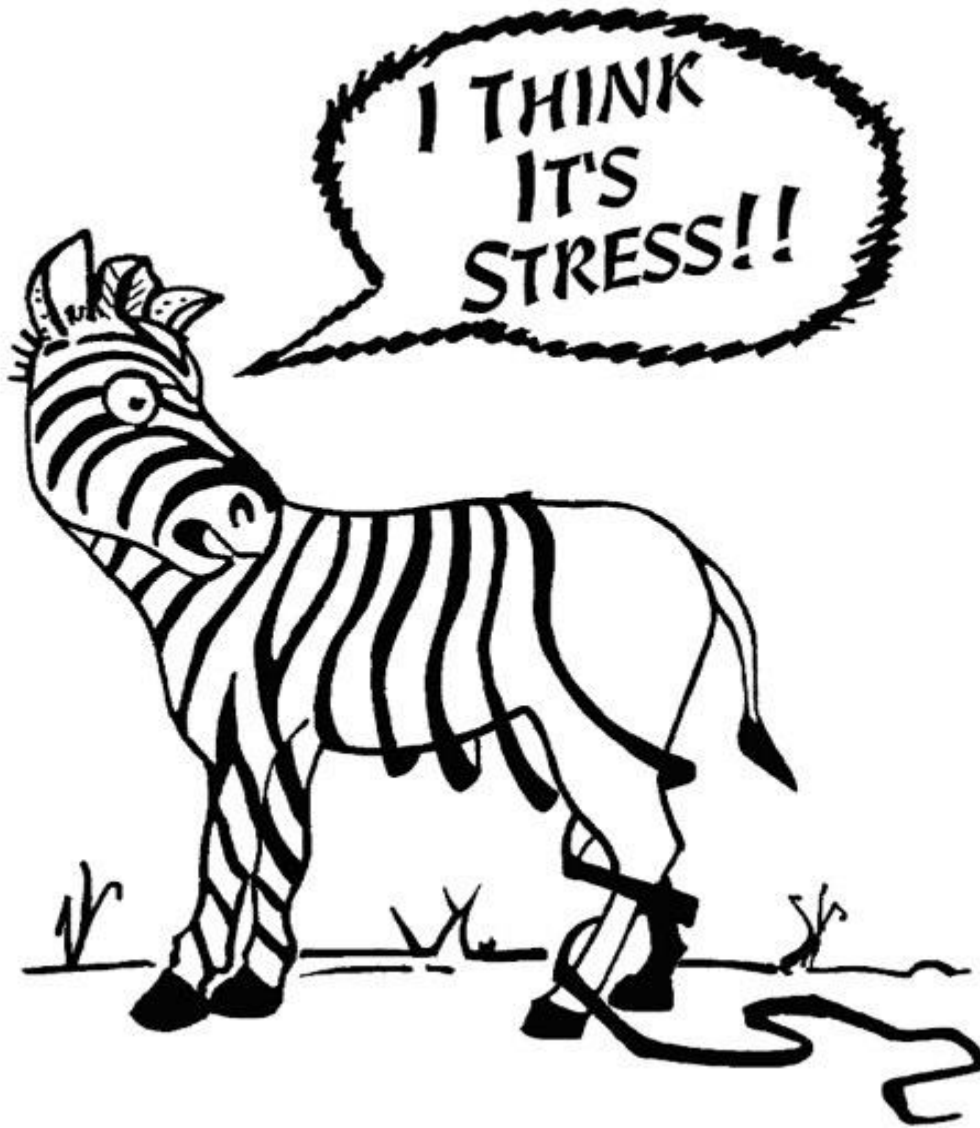
# Processing

- Material Drying
- Residence Time
- Material Heating
- Shear Rate
- Injection Time
- Packing Time and Pressure
- Gate Freeze
- Mold Heating and Cooling
- Cavity Balancing
- Venting
- Cooling

- Runner and Gate
- Flow Balancing
- Cooling
- Ejection
- Multi Cavity Balancing
- Vents

# Assembly and Secondary Operations

- Ultrasonic Assembly
- Heat Staking
- Insert Molding
- Screws
- Silk Screening
- Pad Printing
- Hot Stamping
- Painting

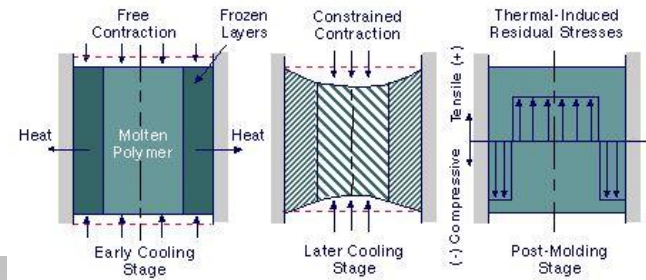
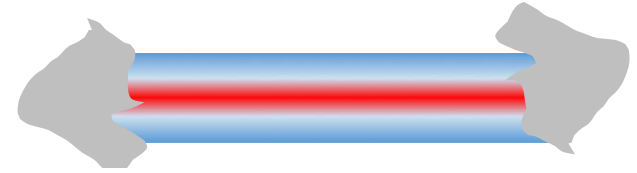


Plastics do not take long term stresses well. These stresses can be the result of a continuous load, warpage, or many other design, material, processing, or tooling related issues. Therefore any design, tooling or processing issues that induce avoidable long term stresses should be avoided.

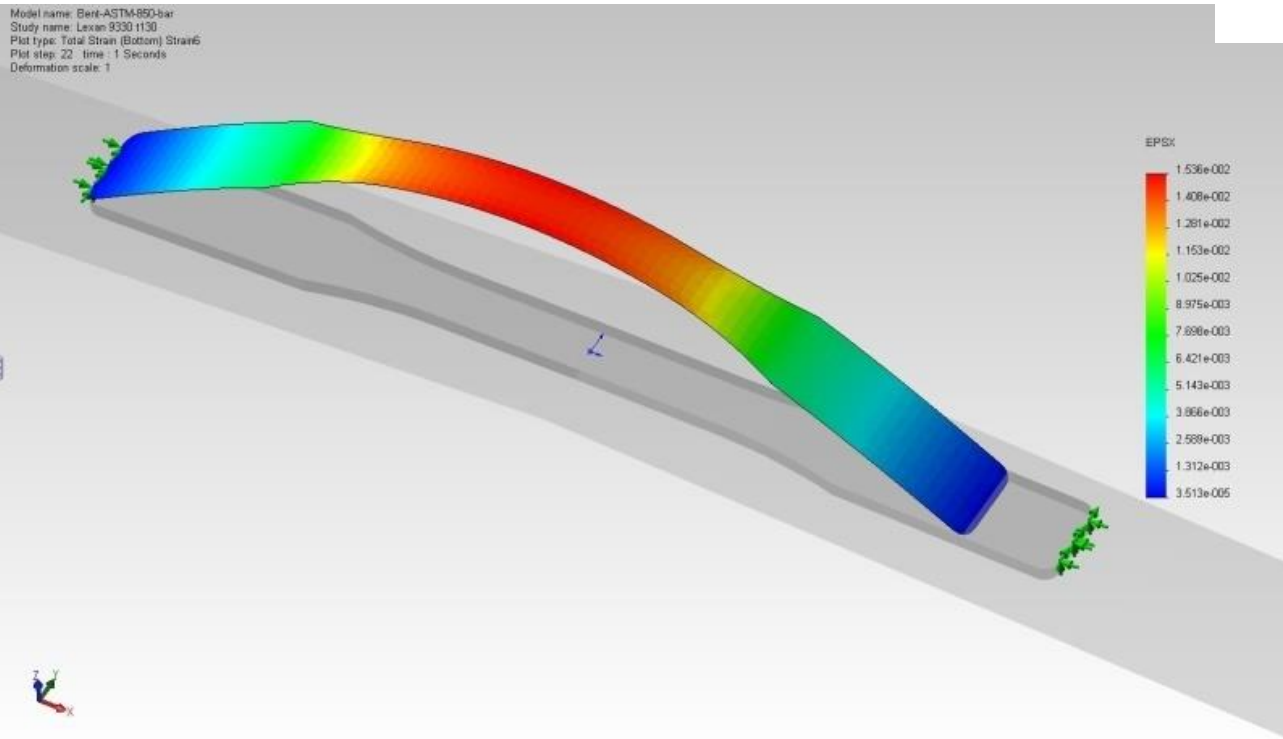
Source: <http://www.wolfescape.com>



# Environmental Properties: Chemical Resistance



<http://www.dc.engr.scu.edu/>



According to materials expert David Wright again, 25% of plastic product failures are caused by environmental stress cracking (ESC) with an additional 7% from chemical attack

## Plastic Material Failures

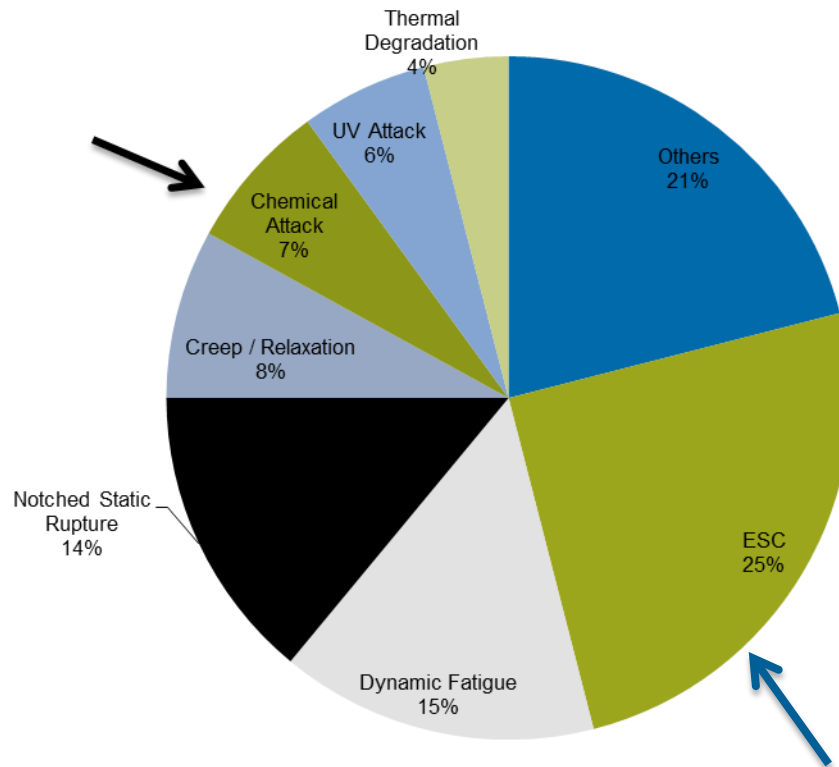


Chart created based upon Rapra's David Wright sampling of 5000 plastic parts which have "failed".

# Environmental Stress Cracking



# Key Design Rules to Remember

- Wall thickness to vary no more than 25% for amorphous materials (PC, PC/ABS, Acrylic) and 15% for semi crystalline materials (Nylon, PE, PP)
- Rib thickness at the base to be no more than .5 - .6 of wall thickness

# Non-Uniform Wall

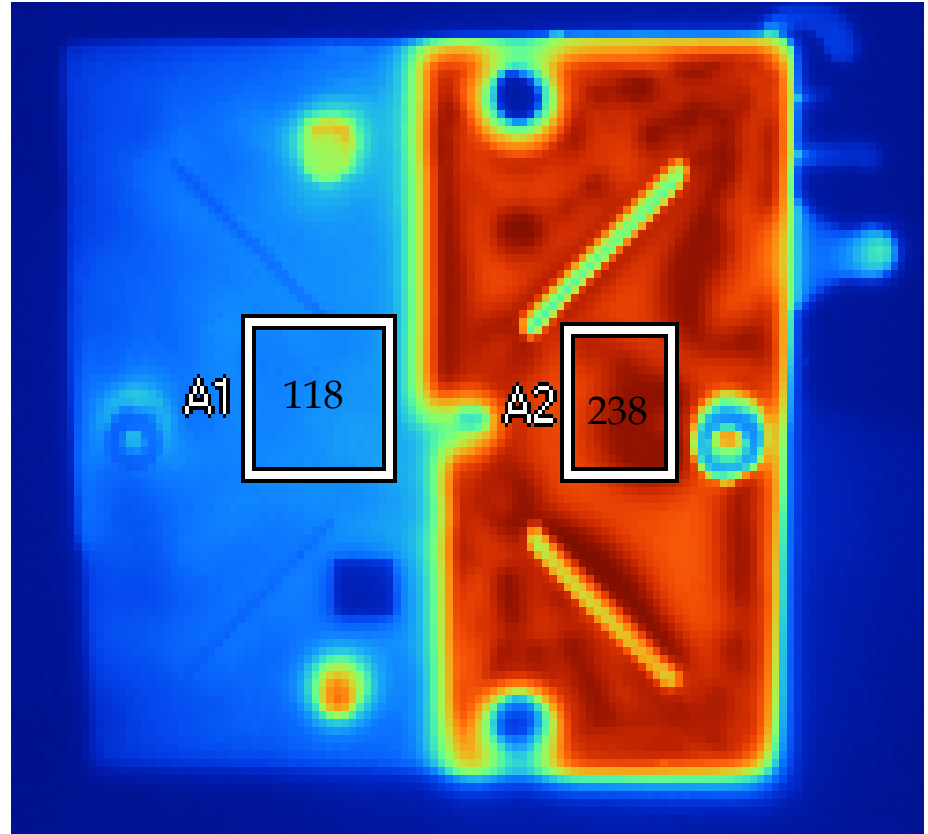
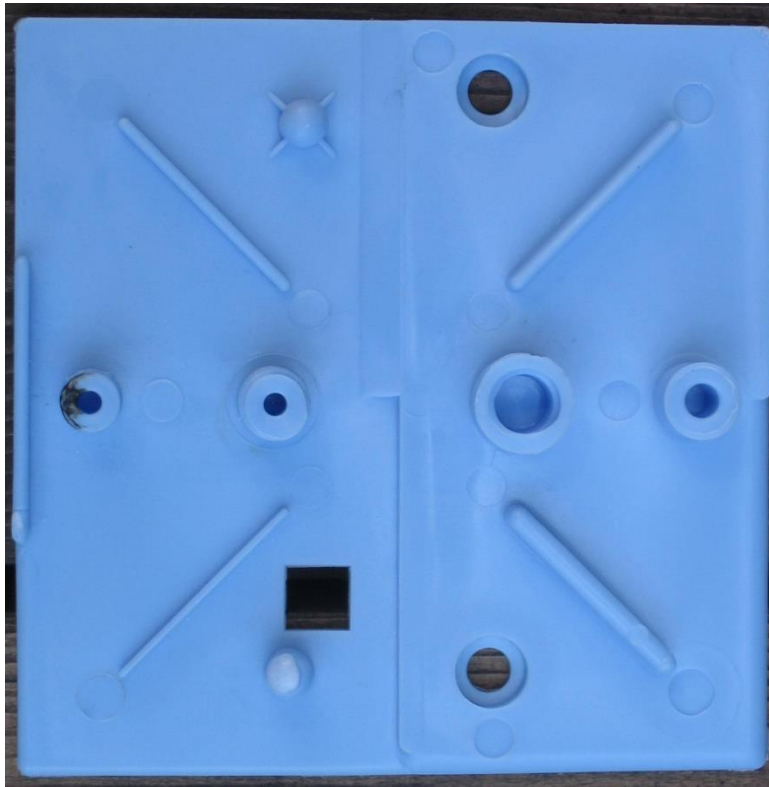
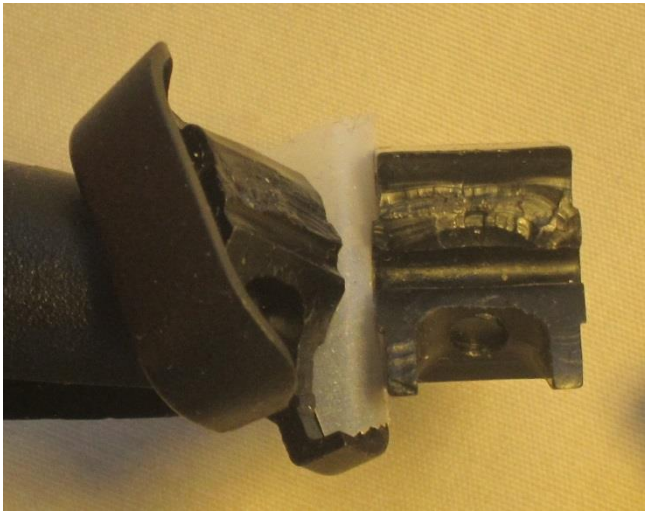


Photo Courtesy of John Bozzeli

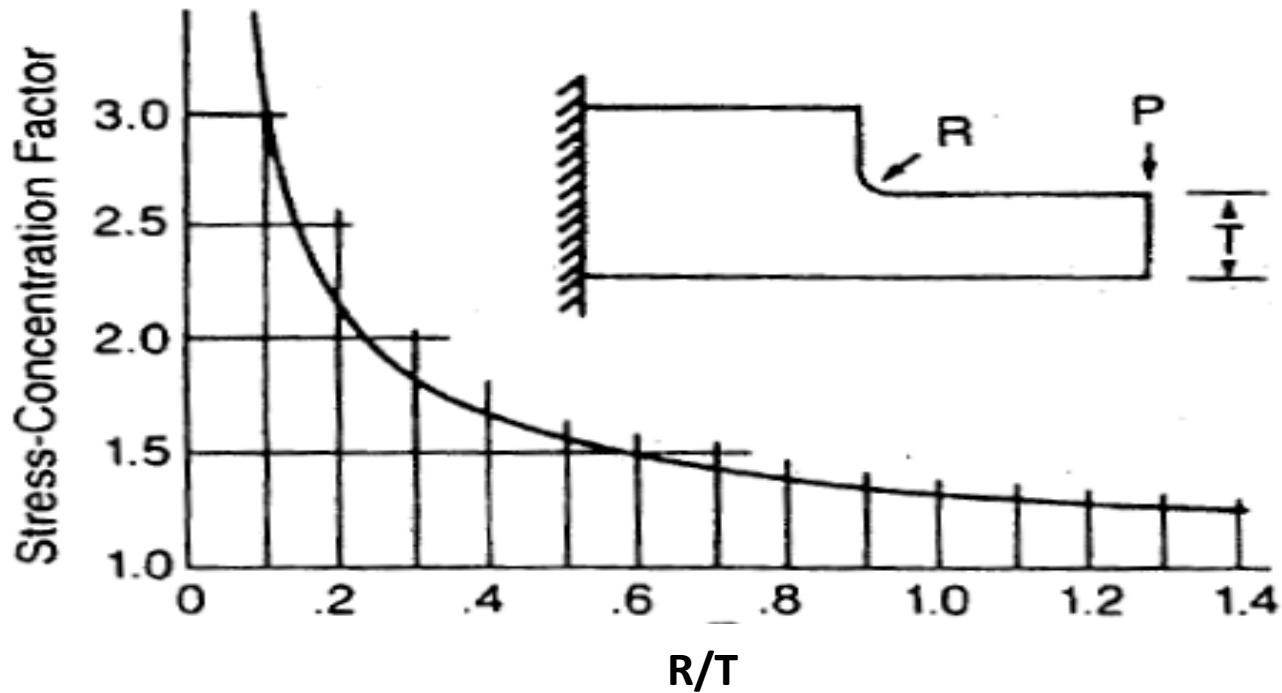
# Non-Uniform Wall ( continued)



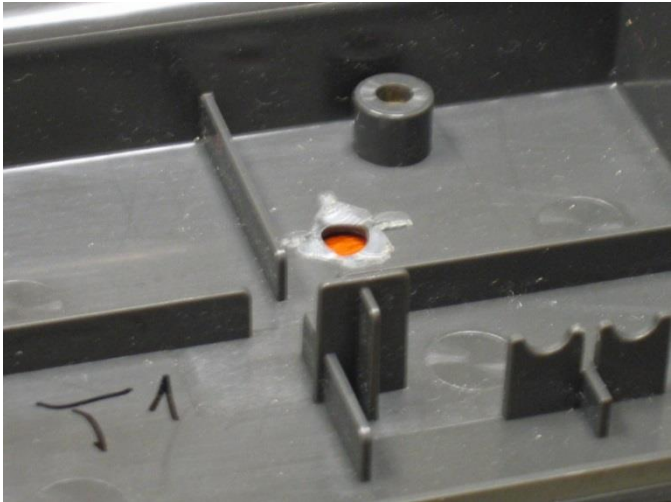
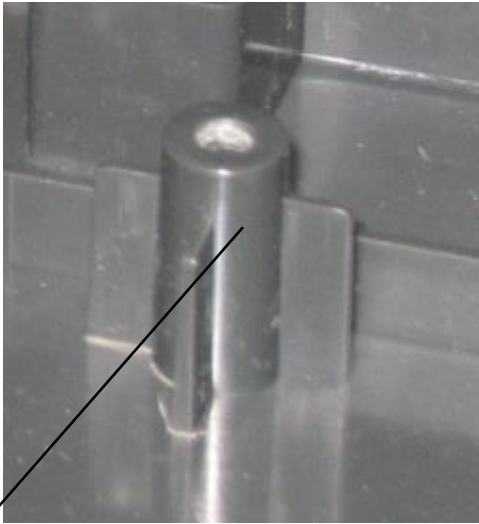
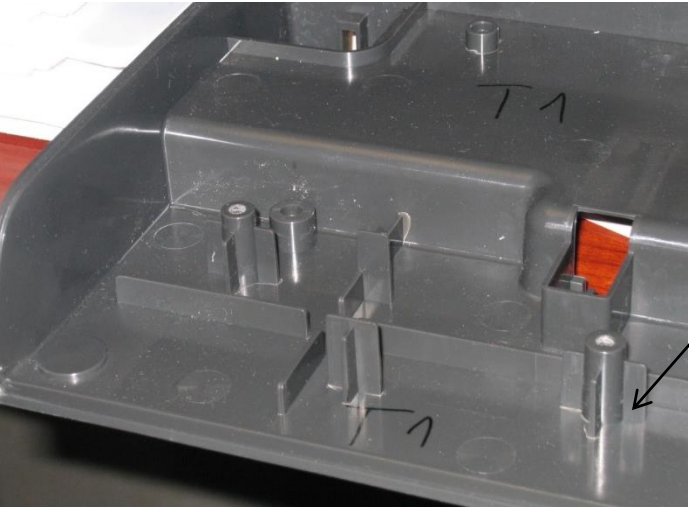
# Inside Radius

Rule: Minimum Recommended:  $.5t$

P = Applied load  
R = Fillet Radius  
T = Thickness



# Lack of Inside Radius



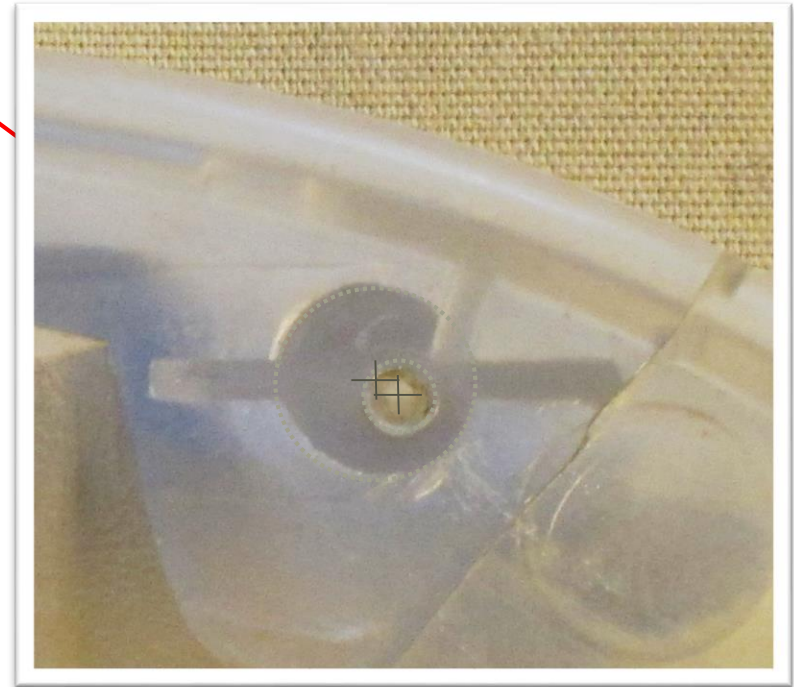


# What Is the Issue Here?

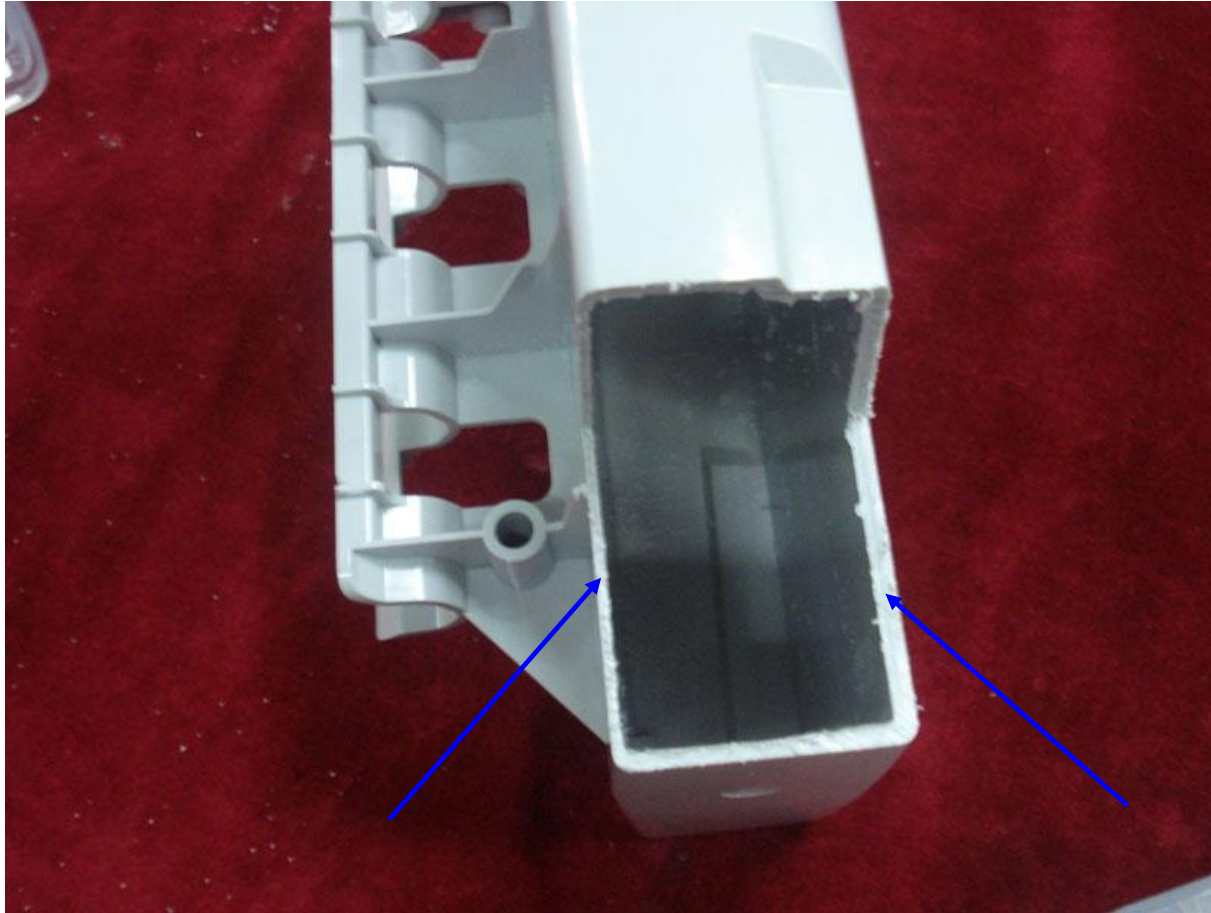


# Long Unsupported Boss

- When possible maximum length of the boss to be  $< 3d$  or  $t$
- When possible material to enter on the fixed end of the boss
- Fillet core at the base for strength



# Core Roughly 10" x 5" x 1.5" (250 x 125 x 38 mm)

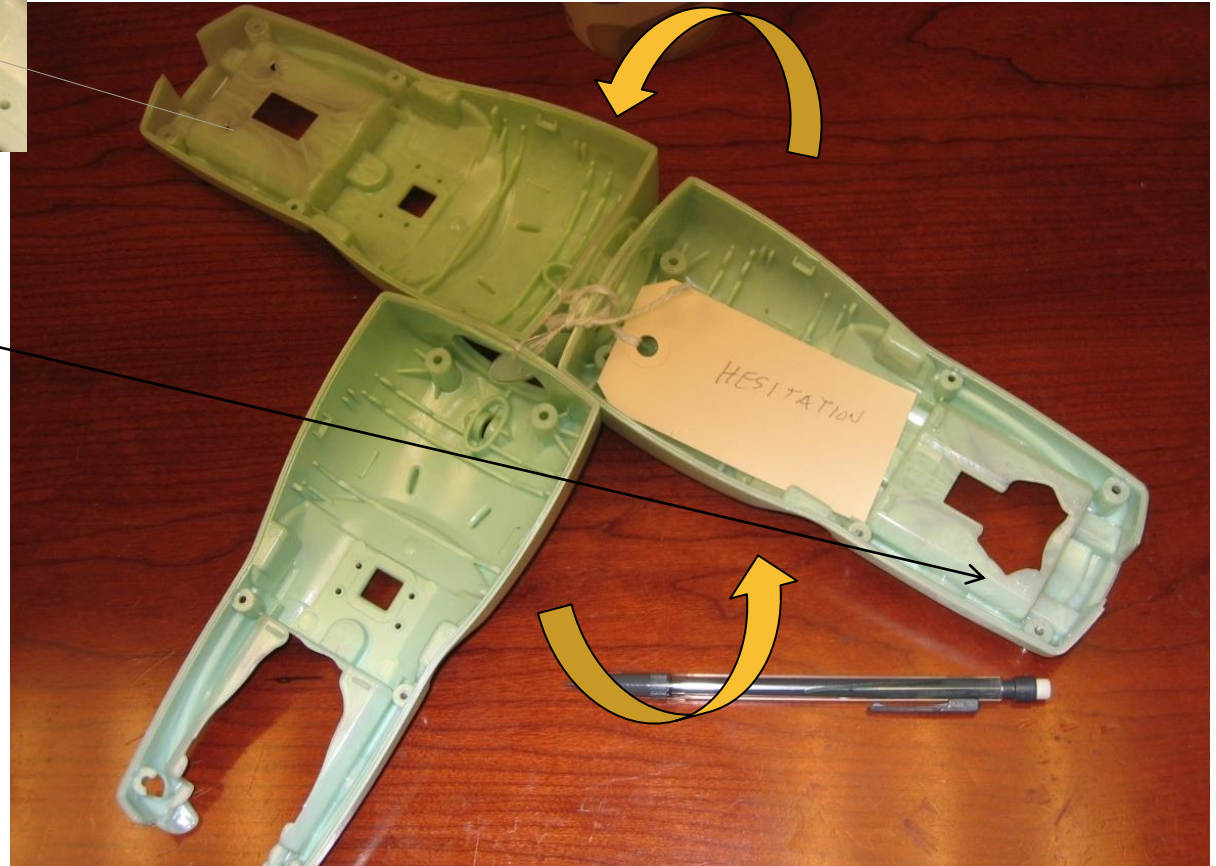


“The thickness is 2.5mm in the print, but now is different, due to the core shift during molding...”

# Uneven Flow and Hesitation



Hesitation



## Last, But Not Least - Drying

All polymers consist of random chains of molecules. The longer the chains, the tougher the plastic.

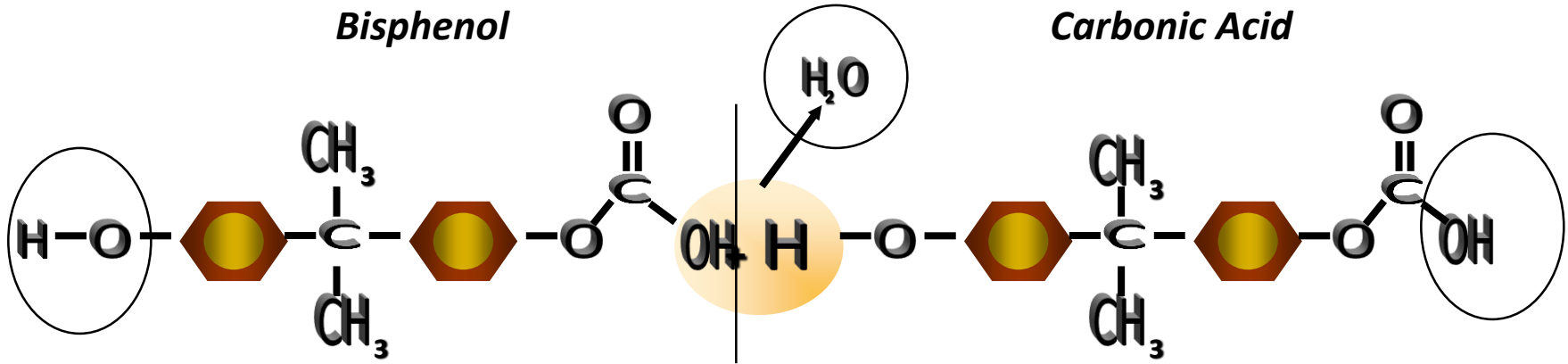


# Condensation polymerization occurs via removal of molecules of water

## Polycarbonate Chain

*Bisphenol*

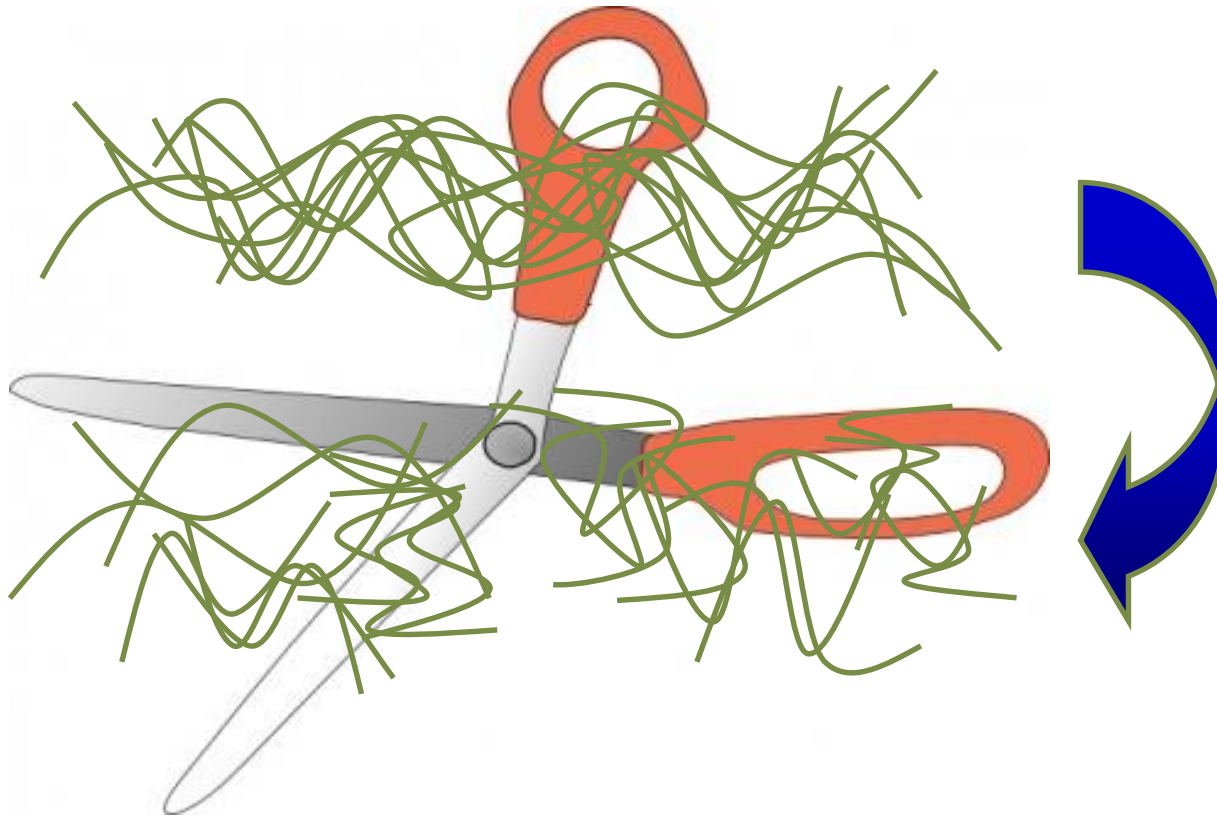
*Carbonic Acid*



The reverse of this reaction is the mechanism by which PC can degrade in the presence of water and high heat and pressure.

**Normal average Molecular Weight of Polycarbonate  
50,000 - 1 Molecule of water will make it 25,000!**

If the plastic pellets are not dried properly prior to molding, the drop in molecular weight (polymer chain length) will dramatically reduce the strength and impact resistance of the molded parts.



# Poor Drying

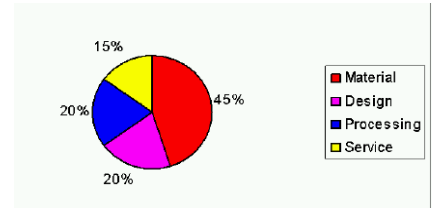
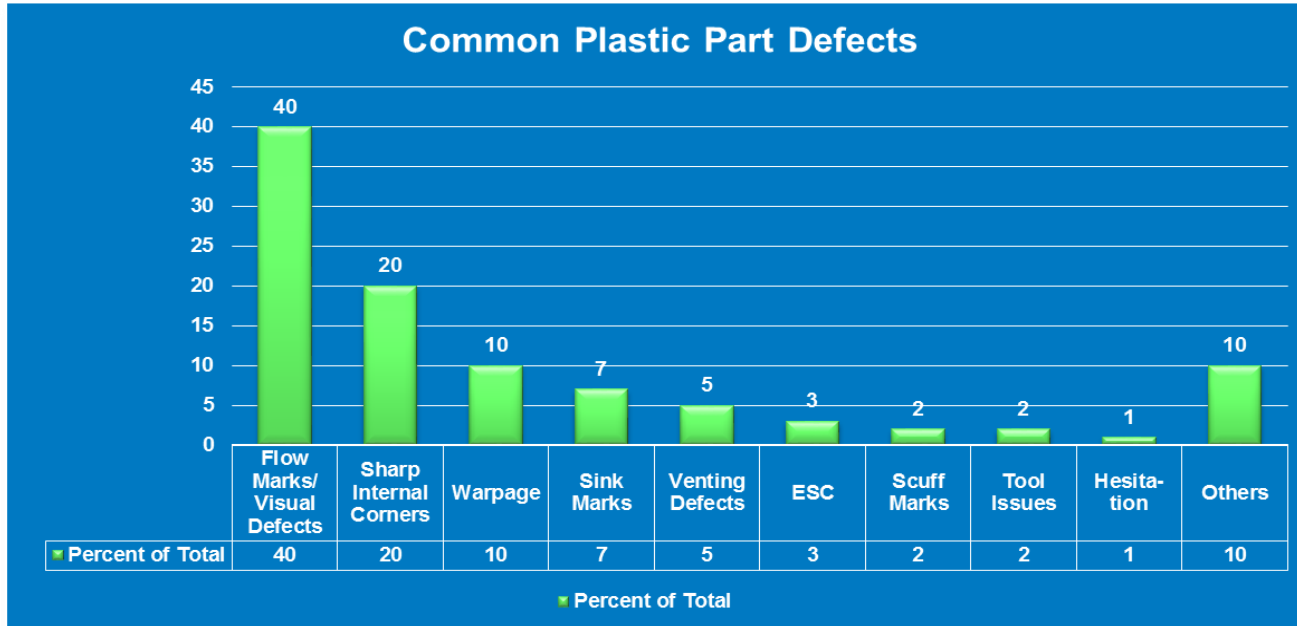


36 inches Drop to Carpet!





# Are Materials, Tooling, Processing Issues Just That?



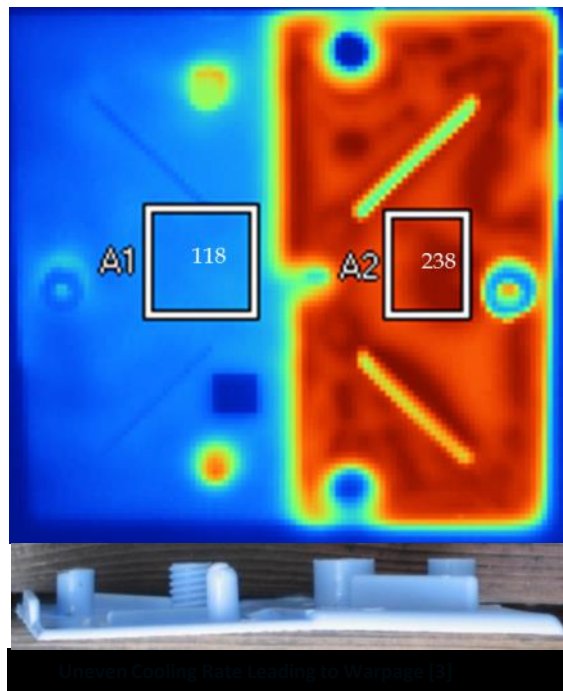
Defect Type	Percent of Total	High Level Cause	Effect
Flow Marks/ Visual Defects	40	1, 2, 3, 4	A, B, C,
Sharp Internal Corners	20		B, C
Warpage	10	1, 2, 3, 4, 7	A, C
Sink Marks	7	1	A, C
Venting Defects	5	2, 4, 5	A
ESC	3	2, 3, 5,	H
Scuff Marks	2	6	A
Tool Issues	2	7	A
Hesitation	1	2, 5	A, C, H
Others	10		
<b>Total</b>	<b>100</b>		

Cause Type	Code	Effect Type	Code
Rib Thickness	1	Low Yield	A
Wall Thickness Variation	2	Drop Failure	B
Sharp Corners	3	Environmental Stress Cracking	C
Long Thin Ribs	4	Burnt Material, Incomplete Filling	D
Thin to Thick Flow	5	Short Shots, Hesitation	E
Inadequate Draft	6	Warpage	F
Steel Height to Base Ratio	7	Scuff Marks	G
		Premature Failure	H

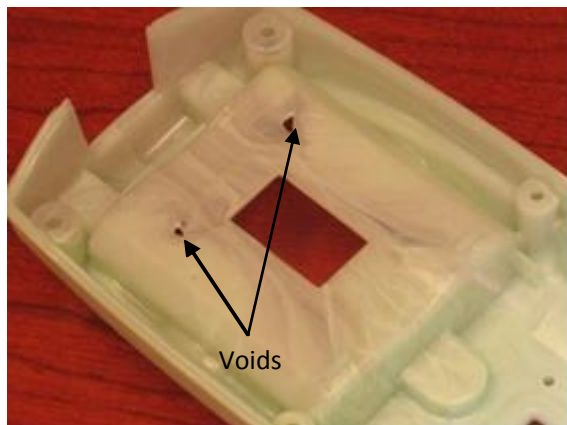
# Let us Look at These Again



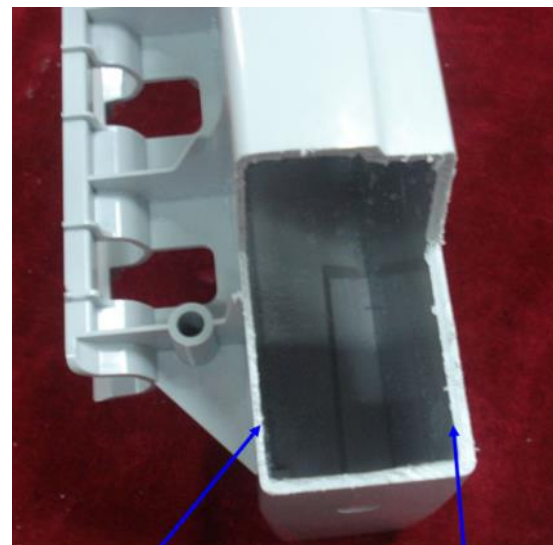
**Chemical Attack**



**Part Warpage**



**Hesitation**

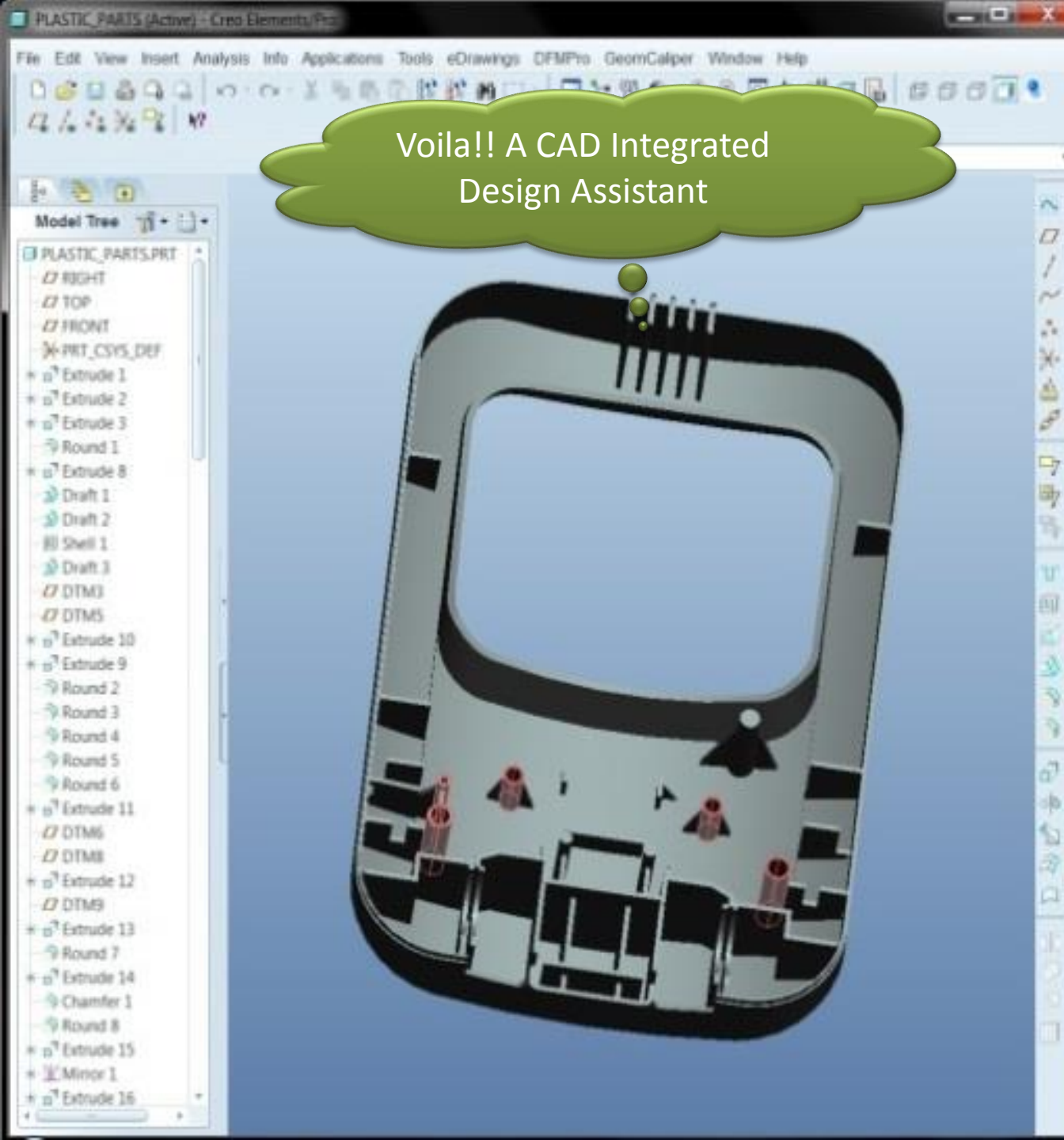


Core Roughly 10" x 5" x 1.5" (250 x 125 x 38 mm). Notice the wall thickness variation due to core shift.

**Core Shift**

Wouldnt it be nicce to have a magic wand check the solid model,  
just as the “Spell Checker” checks for speling and grammer in Microsoft Word?





Voila!! A CAD Integrated Design Assistant



Unanalyzed Regions

## Not Just Plastics...

“Engineer cannot live by plastics alone. He must have stampings, castings, machined parts....” (apologies to James A Garfield)



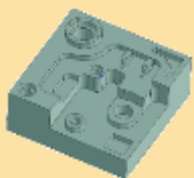
Man cannot live by bread alone; he must have  
peanut butter.

(James A. Garfield)

izquotes.com

# Get Started with Pre-configured Global Best Practices ...

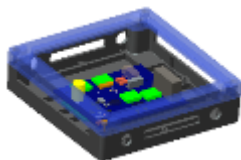
Machining



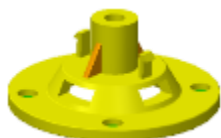
Injection Molding



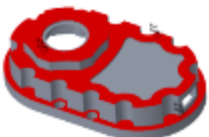
Assembly



Additive manufacturing



Casting



Sheet Metal



Detect slot parameters and issues



Bend parameters and allowance



Hole parameters and allowance and distance between holes and other features



Multiple bends and manufacturing challenges



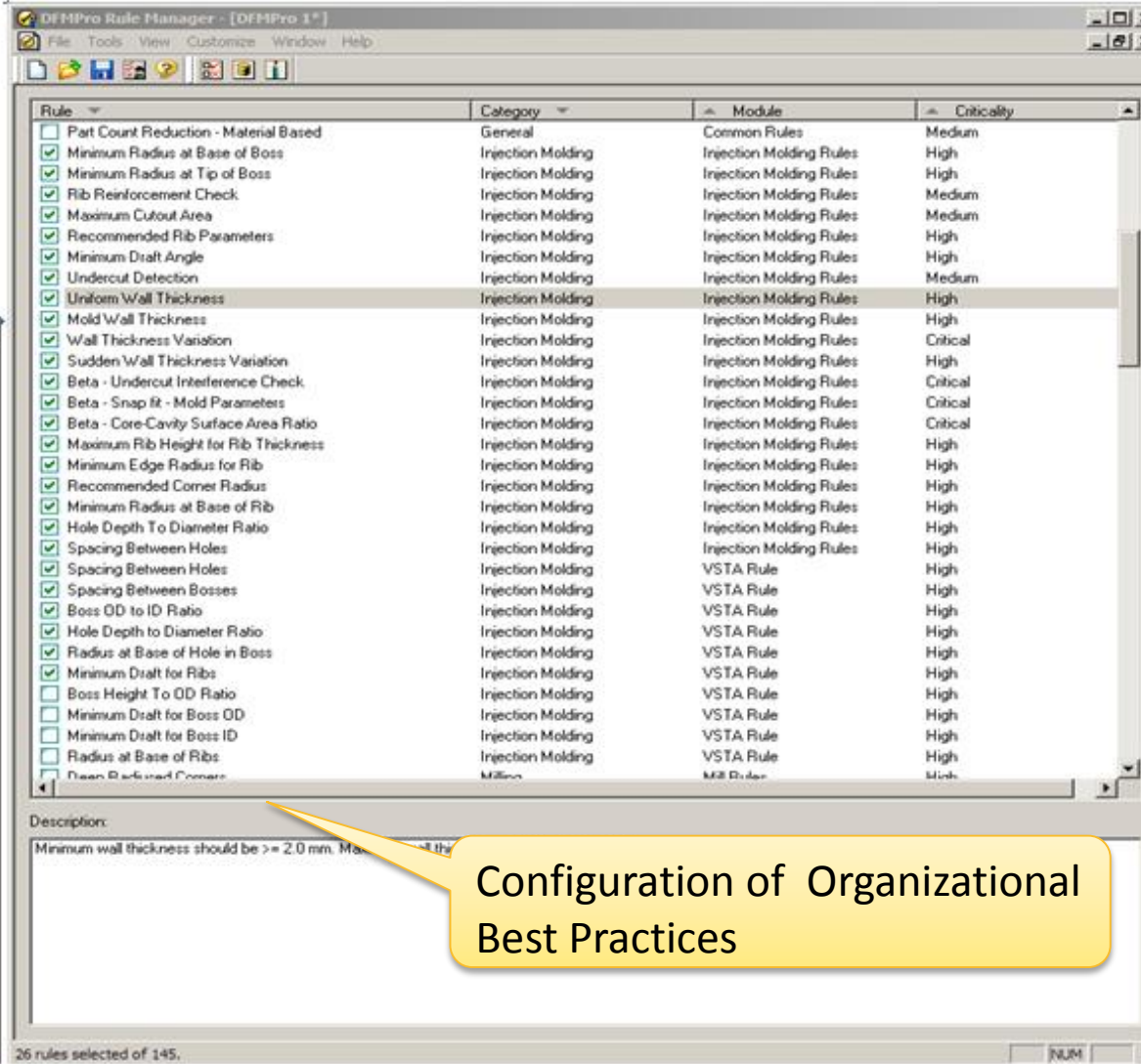
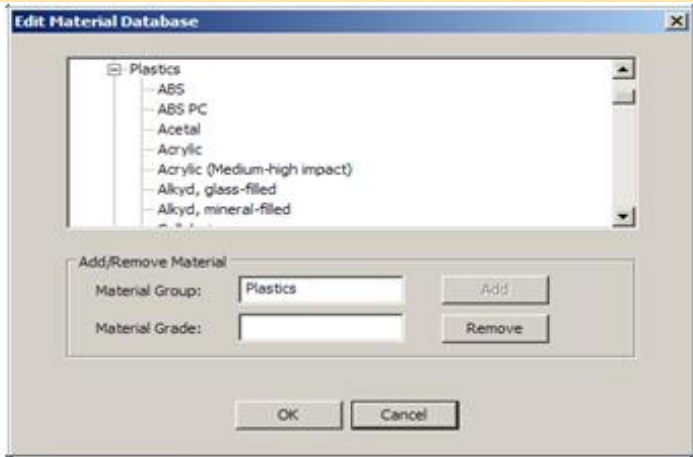
Cut outs and distance between features



Hem parameters and allowance rolled, tear drop and open hem



# Adapting to Organizational Best Practices ...



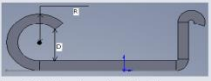
Configuration of Organizational Best Practices

# Can Lead to Following Benefits

**Rolled Hem**

**Rule**

- The ratio of the external radius of a rolled hem to material thickness should be greater than or equal to the specified value, which is configurable. The default ratio is 2.0.
- The ratio of the rolled hem opening to material thickness should be greater than or equal to the specified value, which is configurable. The default ratio is 1.0.

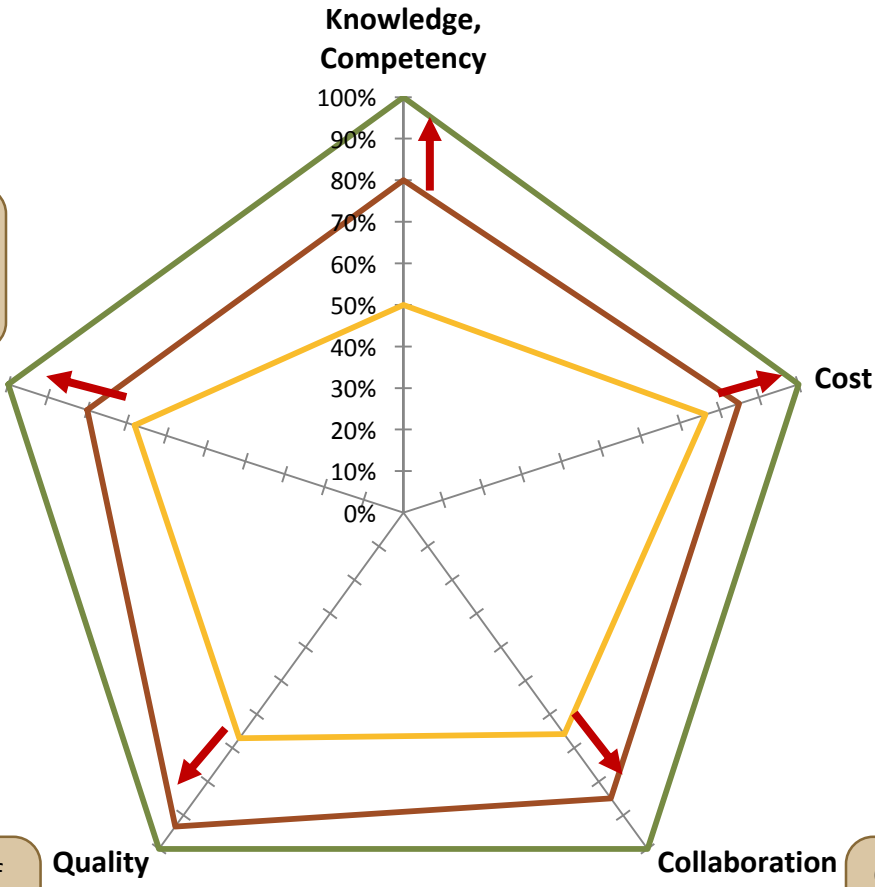


R = Rolled hem's external radius  
D = Rolled hem's opening

- Availability of global best practices
- Framework to capture knowledge within organization
- Statistics on common mistakes made by specific engineer which identifies training needs

- Existing process
- Expected improvement
- Final objective

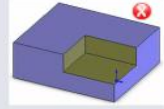
- Reduction in design iterations
- Savings in DFM analysis time



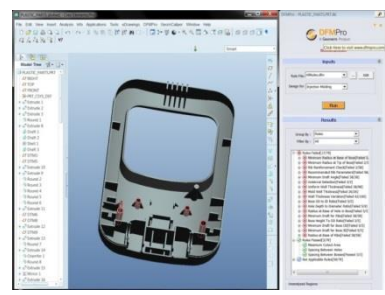
**Sharp Internal Corners**

**Rule**  
Avoid sharp internal corners.

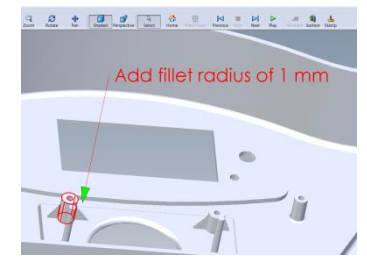
**Explanation**  
Sharp inside corners cannot be produced by milling and  
When designing a three-edged inside corner, one of the



- Identification of areas in design which are difficult, expensive or impossible to manufacture
- Reduction in Rework cost



- Output with reduced number of defects



- Clear communication through reports



# Synergy!!!

DFMPro optimizes the overall inherent design to prevent short and long term visual, functional, processing or tooling issues.

Flow simulation takes a sound design and optimizes it for performance through proper flow, cooling, heating, venting, ejection, gate(s), and location and strength of knit line, etc.

***Together, they provide a powerful – a one, two punch!***

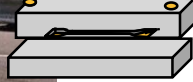


# Concluding Thought:

Material



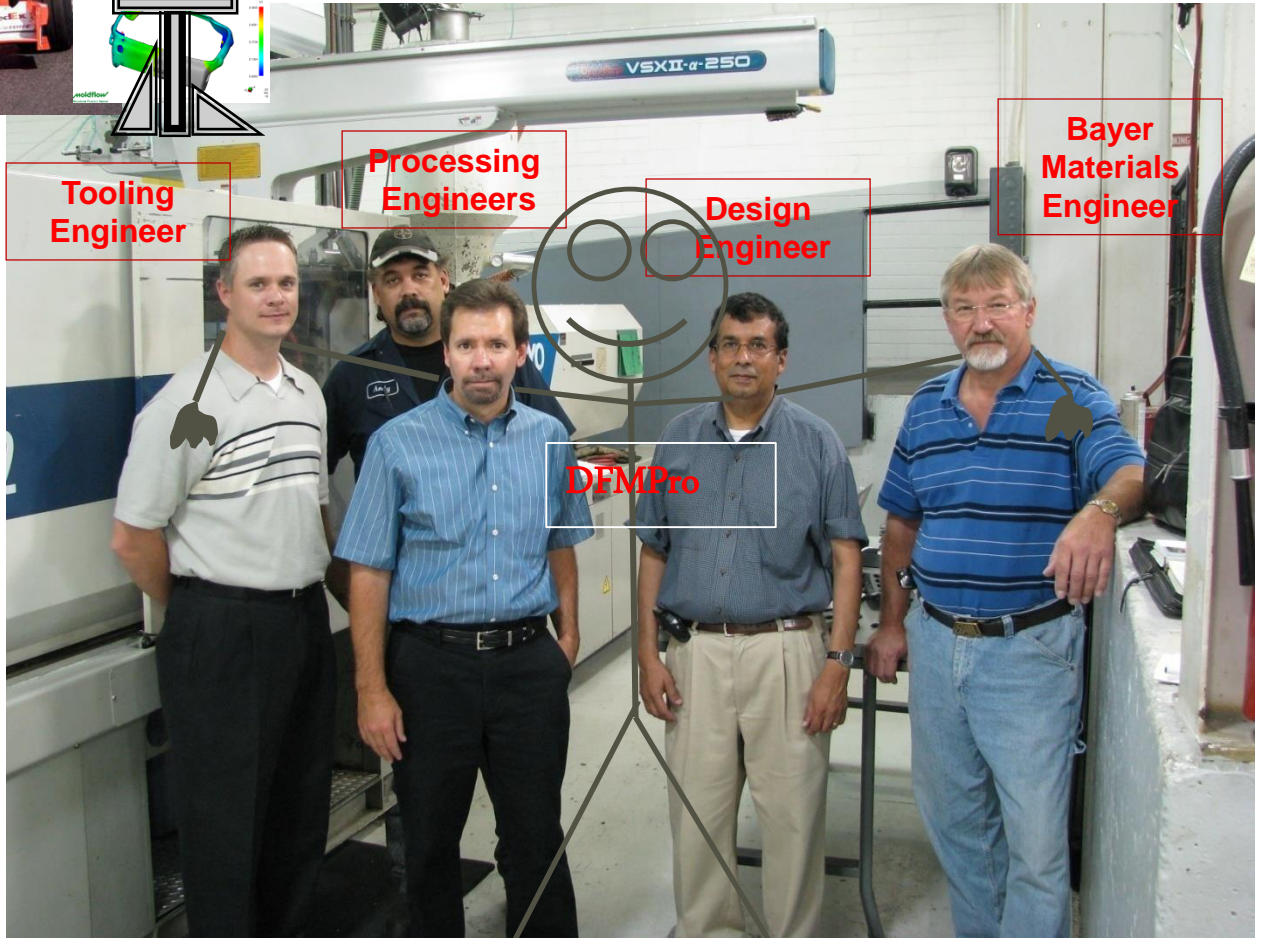
Tooling



Processing



Design



Tooling Engineer

Processing Engineers

Design Engineer

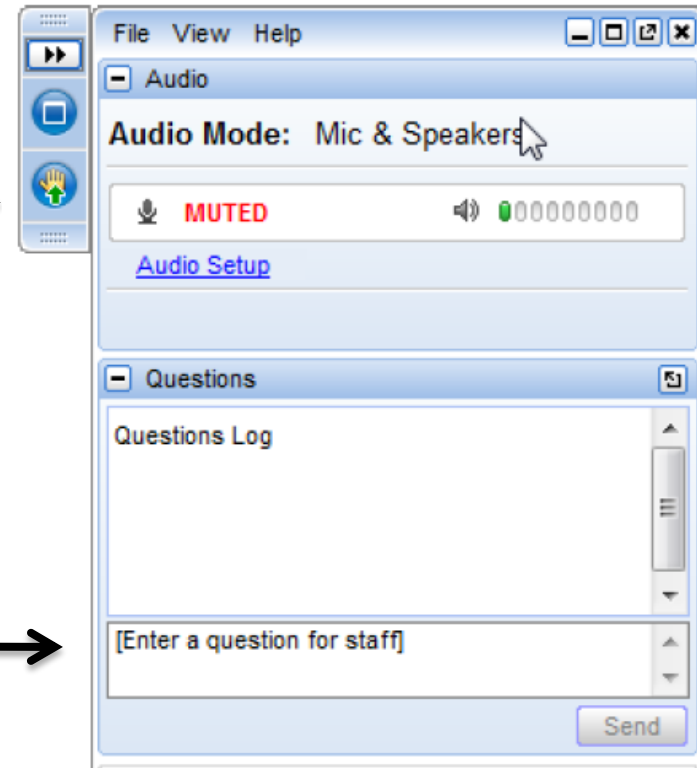
Bayer Materials Engineer

DFMPro



# Q&A

Raise Hand →



Enter your questions →

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**Thank You**

The recorded version of this webinar will be available on ***www.dfmpro.com***

