Robust Plastic Product Design
A Holistic Approach

Webinar Hosted By
Society of Plastics Engineer (SPE)
Copyright Notice

© Geometric Limited. All rights reserved.

No part of this document (whether in hardcopy or electronic form) may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, to any third party without the written permission of Geometric Limited. Geometric Limited reserves the right to change the information contained in this document without prior notice.

The names or trademarks or registered trademarks used in this document are the sole property of the respective owners and are governed/protected by the relevant trademark and copyright laws.

This document is provided by Geometric Limited for informational purposes only, without representation or warranty of any kind, and Geometric Limited shall not be liable for errors or omissions with respect to the document. The information contained herein is provided on an “AS-IS” basis and to the maximum extent permitted by applicable law, Geometric Limited hereby disclaims all other warranties and conditions, either express, implied or statutory, including but not limited to, any (if any) implied warranties, duties or conditions of merchantability, of fitness for a particular purpose, of accuracy or completeness of responses, of results, of workmanlike effort, of lack of viruses, and of lack of negligence, all with regard to the document.

© Vikram Bhargava All rights reserved.

No part of this document (whether in hardcopy or electronic form) may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, to any third party without the written permission of Vikram Bhargava
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.dfmpro.com
Geometric : An Overview

Global Presence

Revenue Distribution by Service Line
- Software Services: **41.54%**
- Engineering Services: **41.79%**
- Products: **8.64%**
- Embedded Systems: **8.04%**

Workforce Distribution
- India: **3600+**
- N. America: **480+**
- Europe: **200+**
- APAC: **100+**

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
- 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
- PTC®
- Gold Tier Partner since 2004
- Solution Partnership for Anark Core™ MBEWeb™
- Tech Soft 3D
- Preferred software development partner for expeditied 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
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
Huge Opportunity Lost Due to 4 Week Delay in Introduction!

- 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

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

Void in a radioscopic image of an aluminum wheel.

Porosity in an aluminum diecasting.

X-Ray Courtesy Domingo Mary, Santiago de Chile
Given all the complexities of Plastics....
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 – Industry

Plastic Failure Factors

- Material: 45%
- Design: 15%
- Processing: 20%
- Service: 20%

Taken From “Failure of Plastics and Rubber Products” by David Wright
Materials

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
Materials

Agency Properties
• UL
• FDA
• RoHS
• Country Specific Requirements

Molding Properties
• Flow
• Bonding between Materials (over molding)
• Directional Shrinkage
Design

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
Tooling

- 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.

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 Bozizzeli
Non-Uniform Wall (continued)
Inside Radius

Rule: Minimum Recommended: .5t
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
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**

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?

Common Plastic Part Defects

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

<table>
<thead>
<tr>
<th>Cause Type</th>
<th>Code</th>
<th>Effect Type</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rib Thickness</td>
<td>1</td>
<td>Low Yield</td>
<td>A</td>
</tr>
<tr>
<td>Wall Thickness Variation</td>
<td>2</td>
<td>Drop Failure</td>
<td>B</td>
</tr>
<tr>
<td>Sharp Corners</td>
<td>3</td>
<td>Environmental Stress Cracking</td>
<td>C</td>
</tr>
<tr>
<td>Long Thin Ribs</td>
<td>4</td>
<td>Burnt Material, Incomplete Filling</td>
<td>D</td>
</tr>
<tr>
<td>Thin to Thick Flow</td>
<td>5</td>
<td>Short Shots, Hesitation</td>
<td>E</td>
</tr>
<tr>
<td>Inadequate Draft</td>
<td>6</td>
<td>Warpage</td>
<td>F</td>
</tr>
<tr>
<td>Steel Height to Base Ratio</td>
<td>7</td>
<td>Scuff Marks</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Premature Failure</td>
<td>H</td>
</tr>
</tbody>
</table>
Let us Look at These Again

Chemical Attack

Part Warpage

Voids

Core Shift

Hesitation

Core Roughly 10” x 5” x 1.5” (250 x 125 x 38 mm). Notice the wall thickness variation due to core shift.
Wouldn't it be nice to have a magic wand check the solid model, just as the “Spell Checker” checks for spelling and grammar in Microsoft Word?
Voila!! A CAD Integrated Design Assistant
“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)
Get Started with Pre-configured Global Best Practices ...

- Machining
- Injection Molding
- Assembly
- Additive manufacturing
- Casting
- Sheet Metal
Adapting to Organizational Best Practices ...

Configuration of Organizational Best Practices
Can Lead to Following Benefits

- Availability of global best practices
- Framework to capture knowledge within organization
- Statistics on common mistakes made by specific engineer which identifies training needs
- Identification of areas in design which are difficult, expensive or impossible to manufacture
- Reduction in Rework cost
- Clear communication through reports
- Output with reduced number of defects
- Reduction in design iterations
- Savings in DFM analysis time

Knowledge, Competency

• Existing process
• Expected improvement
• Final objective
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 Processing

Tooling

Design

Processing Engineers

Tooling Engineer

Design Engineer

Bayer Materials Engineer

DFMPro

Geometric | People Building Partnerships
Q&A

Raise Hand →

Enter your questions →
For more information write to us at

Email: info@dfmpro.com
Phone: +1.480.367.0132
Website: www.dfmpro.com

Email: smarko@4SPE.ORG
Phone: +1 203.775.0471
Website: www.4spe.org

VikramBhargava@gmail.com
www.linkedin.com/in/bhargavavik/

Thank You

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