IMAGINEERING PLASTICS WORKSHOP

IDEA • APPLICATION • PROBLEM • SOLUTIONS

2014 MICHIGAN

YOUR GLOBAL COMPOUNDER OF
CUSTOM ENGINEERED THERMOPLASTICS

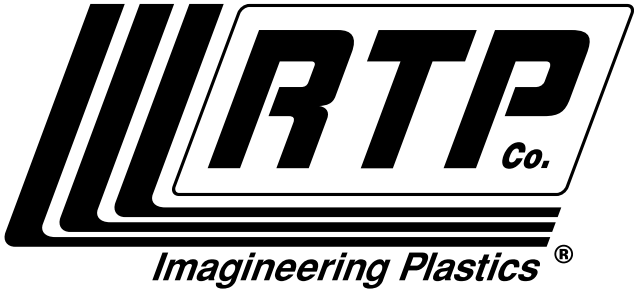
RTP Co.
Imagineering Plastics®

RTP Company
Imagineering Plastics Workshop

PDF copies of the presentations from today's workshop can be downloaded from our website at
www.rtpcompany.com/workshoppresentations

Schedule *Create your own schedule from the sessions listed below*

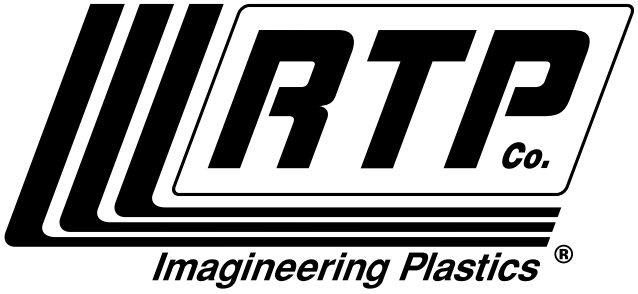
8:00 a.m.	**Registration and Continental Breakfast**		
8:40 a.m.	**Welcome and Introduction**	Kevin Jennings *Central Regional Sales Manager*	Pg 7
9:00 a.m.	**An Engineer's Guide to Specifying the Right Thermoplastic** Steve will explain how to use resin morphology, temperature performance, and cost to choose the right resin. Plus, how additives can further enhance performance. Case studies will test your knowledge.	Steve Maki *VP of Technology*	Pg 9
10:00 a.m.	**Track A - Tough or Strong? Short or Long? Dialing in Mechanical Performance** Many additive technologies can enhance the mechanical properties of plastics. Brennan will discuss the gamut from polymer blends to Very Long Fiber reinforcement, including the use of high performance engineering resins.	Brennan Ashton *Product Development Engineer*	Pg 27
	Track B - Conductive & EMI Thermoplastic Technologies Join Ned for a review of conductive and EMI technologies with an emphasis on the customization of compounds for automotive applications.	Ned Bryant *Sr. Product Development Engineer*	Pg 45
11:00 a.m.	**Track A - Live in the Wall Section: CAE Tools** Not all analysis is created equal; understand what you're getting and what it means. Barb will give a comprehensive review of CAE analysis tools and their capabilities for aiding part design and trouble-shooting.	Barb Matousek *CAE Analyst*	Pg 57
	Track B - Everything You Need to Know about TPEs Go beyond the acronyms and understand the world of thermoplastic elastomers, as Brandon explains what they are made of, how and why they do what they do, how they compare to one another, and where they can be used.	Brandon Bubak *Sales & Marketing Director*	Pg 83
12:00 p.m.	**Complimentary Lunch**		
1:00 p.m.	**Track A - The Long and Short of it: VLF (Very Long Fiber)** Karl takes a look at "stiff and tough" Very Long Fiber composites as a replacement for metal or other engineered materials. Learn about their unique benefits, performance, and processing.	Karl Hoppe *Sr. Product Development Engineer*	Pg 97
	Track B - Driving Solutions to Clear the Fog from Light Diffusion Anna provides a fresh review of design trends and proven solutions for the demanding optical needs required by the 21st century automotive infotainment applications, including light diffusion, wavelength attenuation, and color correction/control.	Anna Kreofsky *Color Division R&D Engineer*	Pg 109
2:00 p.m.	**Track A - Plastic Design Principles for Structural Composites** Keith offers a comprehensive overview of basic part design guidelines as well as important principles for designing with reinforced thermoplastics including material issues, tool design concerns, and processing challenges.	Keith Scales *CAE Analyst*	Pg 121
	Track B - Fundamentals of Thermoplastic Wear and Friction Ben will help you make sense of wear and friction principles that affect plastics. He'll explain additive solutions beyond PTFE, material evaluation and testing methods, and share exclusive results from Ultra Wear products.	Ben Gerjets *Product Development Engineer*	Pg 147
3:00 p.m.	**Track A - Eco-Friendly, Engineered Plastic Solutions** Will goes beyond "green" buzzwords and explains how bioplastic and recycled materials can be engineered to meet the performance requirements of semi-durable and durable goods.	Will Taber *Business Manager-Emerging Technologies*	Pg 167
	Track B - Flame Retardants and the Evolving Regulatory Landscape Jesse reviews the mechanisms for making plastics flame retardant while also showing what you need to know to meet both industry testing standards and changing environmental regulations.	Jesse Dulek *Product Development Engineer*	Pg 185
4:00 p.m.	**A Practical Guide to the Process of Selecting Materials** Karl focuses on the material selection process, from identifying important properties through qualification testing, highlighting steps to take (or not take!) to ensure a successful project. Lively examples will illustrate the process.	Karl Hoppe *Sr. Product Development Engineer*	Pg 197
4:50 p.m.	**Closing Remarks**		



Your Global Compounder of Custom Engineered Thermoplastics

Kevin Jennings
Central Regional Sales Manager
kjennings@rtpcompany.com
(864) 989-0168

8:40 a.m.



An Engineer's Guide to Specifying the Right Thermoplastic

Steve Maki
VP of Technology
smaki@rtpcompany.com
(507) 474-5371

9:00 a.m.

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

An Engineer's Guide to Specify the Right Thermoplastic

Steve Maki
Vice President Technology

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

Independent Specialty Compounder

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Compounder** → We blend thermoplastic resins with fillers, additives, and modifiers
- **Specialty** → We create engineered formulations
- **Independent** → We are unbiased in our selection of raw materials

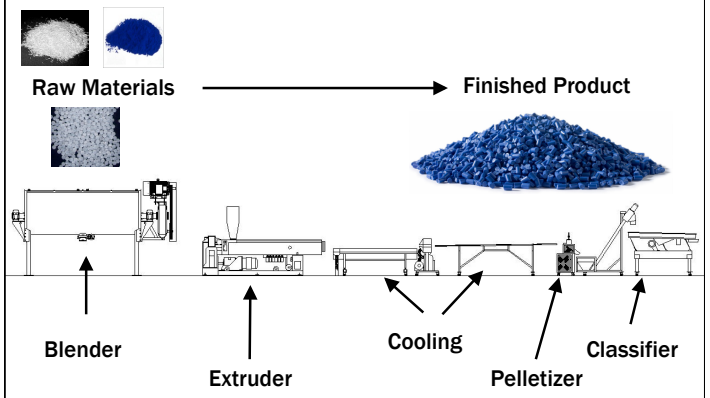
Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Define Compounding
- Plastic Resin Selection Process
- Application Case Studies
- Compounding Performance
- Engineered Thermoplastic Compounds

Compounding Process

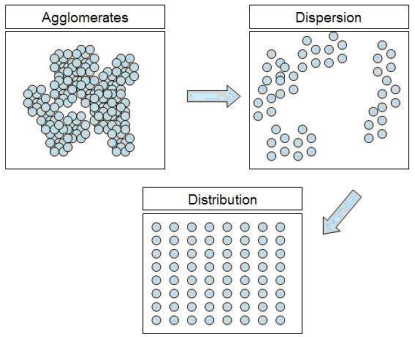
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Compounding Objectives

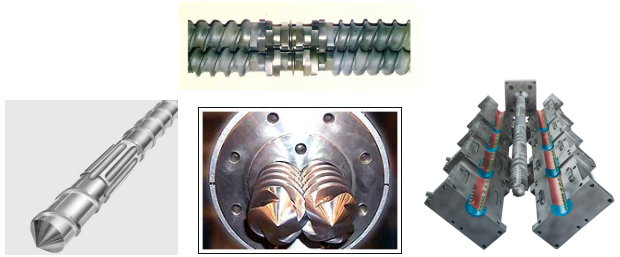
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Mixing
  - Dispersive
  - Distributive



Compounding Extruders

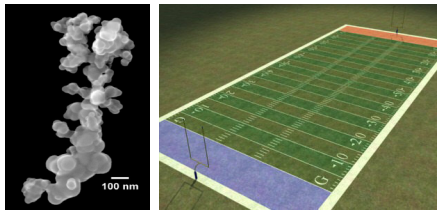
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Single Screw | Twin Screw | Co-Kneader

Putting Compounding Into Perspective

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



- Conductive carbon black surface area = 130 m^2/gram
- 34 grams carbon black = surface area of football field (4460m^2)
- Dispersing a 20% carbon black compound is similar to evenly coating a football field with 136 grams of plastic!

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Resin Selection

The Dilemma

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- 60 Thermoplastic Resins + 100 Additives = 1000's of Potential Compounds

Which **ONE** Do I Choose For My Application???

Plastic Selection Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

Plastic Selection Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

— Step 1: Use Resin Morphology —

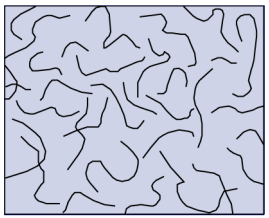
Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

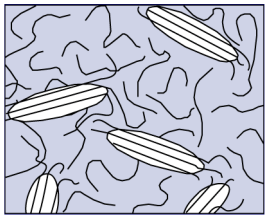
Morphology

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

The form and structure the molecules of a polymer take upon solidification



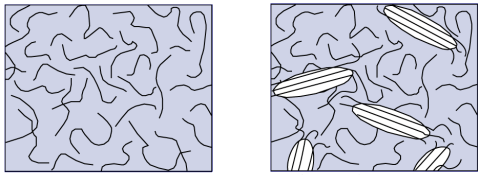
Amorphous



Semi-Crystalline

Morphology

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Amorphous Semi-Crystalline

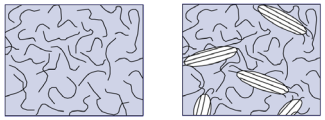
Compare

- Molecular Packing (Shrinkage)
- Resistance to Molecular Disentanglement (Chemical/Abrasion Resistance)
- Light Refraction (Opacity)
- Melting Characteristics (Flow)

Morphology Characteristics

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	Amorphous	Semi-Crystalline
Low Shrinkage	✸	
Low Warpage	✸	
Tight Tolerances	✸	
Transparency	✸	
Mold Flow Ease		✸
Chemical Resistance		✸
Wear Resistance		✸



Morphology Characteristics

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	Amorphous	Semi-Crystalline
Low Shrinkage	✸	
Low Warpage	✸	
Tight Tolerances	✸	
Transparency	✸	
Mold Flow Ease		✸
Chemical Resistance		✸
Wear Resistance		✸

- Lens?
- Fuel Float?
- Lamp Housing?
- Tool Housing?
- Pulley?
- Precision Printer Chassis?
- Intake Manifold?
- Grease Fitting?
- Laptop Cover?

Morphology Of Thermoplastics

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Amorphous	Semi-Crystalline
Polyetherimide (PEI)	Polyetheretherketone (PEEK)
Polyethersulfone (PES)	Polyphenylene Sulfide (PPS)
Polysulfone (PSU)	Polyphthalamide (PPA)
Amorphous Nylon	Polyamide (PA/Nylons)
Polycarbonate (PC)	Polyethylene Terephthalate (PET)
Acrylonitrile Butadiene Styrene (ABS)	Polybutylene Terephthalate (PBT)
Styrene Acrylonitrile (SAN)	Acetal (POM)
Polystyrene (PS)	Polylactic Acid (PLA)
High Impact Polystyrene (HIPS)	Polypropylene (PP)
Acrylic (PMMA)	Polyethylene (HDPE, LDPE, LLDPE)

Plastic Selection Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Step 1: Use Resin Morphology

— Step 2: Use Thermal & Cost Requirements —

Step 3: Fine Tune & Special Features

Morphology Vs Thermal/Cost

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Amorphous	Semi-Crystalline
Polyetherimide (PEI)	Polyetheretherketone (PEEK)
Polyethersulfone (PES)	Polyphenylene Sulfide (PPS)
Polysulfone (PSU)	Polyphthalamide (PPA)
Amorphous Nylon	Polyamide (PA/Nylons)
Polycarbonate (PC)	Polyethylene Terephthalate (PET)
Acrylonitrile Butadiene Styrene (ABS)	Polybutylene Terephthalate (PBT)
Styrene Acrylonitrile (SAN)	Acetal (POM)
Polystyrene (PS)	Polylactic Acid (PLA)
High Impact Polystyrene (HIPS)	Polypropylene (PP)
Acrylic (PMMA)	Polyethylene (HDPE, LDPE, LLDPE)

Thermal & Cost Increases

Commodity (<$1.50) • Engineered ($1.50-$4.00) • High Performance (>$4.00)

Plastic Selection Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

— Step 3: Fine Tune & Special Features —

Engineered & Commodity Resins

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Amorphous	Semi-Crystalline
Amorphous Nylon	Polyamide (PA/Nylons)
Polycarbonate (PC)	Polyethylene Terephthalate (PET)
Acrylonitrile Butadiene Styrene (ABS)	Polybutylene Terephthalate (PBT)
Styrene Acrylonitrile (SAN)	Acetal (POM)
Polystyrene (PS)	Polylactic Acid (PLA)
High Impact Polystyrene (HIPS)	Polypropylene (PP)
Acrylic (PMMA)	Polyethylene (HDPE, LDPE, LLDPE)

Commodity (<$1.50) • Engineering ($1.50-$4.00)

Styrenic Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Morphology Features – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent (except HIPS & ABS), Poor Chemical & Abrasion

- **PS** → Good Transparency @ Low Cost, Brittle
- **HIPS** → Moderate Impact Resistance @ Low Cost
- **SAN** → Good Transparency, Slightly Better Chemical Resistance, Brittle, Low Cost
- **ABS** → Excellent Impact Resistance & Gloss, Slightly Better Chemical Resistance, Low-Moderate Cost

Acrylic Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Morphology Features – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent, Poor Chemical & Abrasion

- **PMMA** → Optical Quality Transparency, Excellent UV Stability, Brittle, Low Cost

Polycarbonate Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Morphology Features – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent, Poor Chemical & Abrasion

- **PC** → Optical Quality Transparency, High Impact Resistance, Moderate Cost

Olefin Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Morphology Features – Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections, Poor Dimensions

- **PP** ⟶ Low Density, Better Thermal Resistance Than PE, Living Hinge Capable, Brittle @ Low Temperatures, Low Cost
- **HDPE** → Good Low Temp Impact Performance (Tg = -77^{0}C vs -9^{0}C for PP), Low Cost

Polyamide Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Morphology Features – Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections (Except Amorphous Nylon), Poor Dimensions

- **Nylon 6** ⟶ Strong/Stiff (But Humidity Dependent), Good Surface Finish Even When Reinforced, Moderate Cost
- **Nylon 66** ⟶ Strong/Stiff (But Humidity Dependent), Higher Thermal Than 6, Moderate Cost
- **Nylon 6/12, 11, 12, etc.** → Less Sensitive to Humidity, High Cost

Amorphous Nylon Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Morphology Features – Low Shrink, Low Warp, Tight Dimensional Tolerances, Transparent, Poor Abrasion

- **Amorphous Nylon** → Good Chemical Resistance for Amorphous Morphology, Moderate-High Cost

Polyester Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Morphology Features – Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections, Poor Dimensions

- **PET** → Difficult to Mold (Poor Nucleation & Hydrolysis), Good Electrical Resistance, Mod. Cost
- **PBT** → Easy to Mold, Good Electrical Resistance, Properties & Dimensions Do Not Fluctuate With Humidity (Same For PET), Moderate Cost
- **PLA** → "Green" Polymer, Poor Impact, Poor Heat Resistance, Difficult to Mold (Poor Nucleation & Hydrolysis), Low Cost

Polyoxymethylene (Acetal) Features

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Morphology Features – Excellent Chemical Resistance, Excellent Abrasion Resistance, Good Flow in Thin Mold Sections, Poor Dimensions

- **Acetal** → Low Friction & Wear, Excellent Resiliency & Fatigue Endurance, Moderate Cost

Putting It All Together

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Step 1: Use Resin Morphology

Step 2: Use Thermal & Cost Requirements

Step 3: Fine Tune & Special Features

Test Your Knowledge With Application Examples

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **CD Jewel Case**
  - Transparent
  - Flat & Dimensionally Stable
  - Low Cost
- **PS**

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Gas Tank**
  - Good Chemical Resistance
  - Good Low Temperature Impact
  - Low Cost
- **HDPE**

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Auto Tail Lamp Cover**
  - Transparent Colors
  - Dimensionally Stable
  - Excellent UV
  - Low Cost
- **PMMA**

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Plastic Glass Tumblers**
  - Transparent
  - Reasonable Thermal & Chemical Resistance (Dishwasher Cycles)
  - Low Cost
- **SAN**

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Sump Pump Housing**
  - Chemical Resistance
  - Reasonable Thermal Resistance
  - Low Cost
- **PP + GF**

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Safety Glasses**
  - Optical Transparency
  - High Impact
  - Moderate Cost OK
- **PC**

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Wheel Hubodometer Lens**
  - Transparent
  - Good Chemical Resistance
  - Moderate-High Cost OK
- **Amorphous Nylon**

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Chemical Beakers**
  - Excellent Chemical Resistance
  - Low Cost
  - Transparent
- **?????????**

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Nail Gun Housing**
  - Good Chemical Resistance
  - Excellent Strength, Stiffness & Impact
  - Good Surface Finish When Reinforced
  - Moderate Cost OK
- **Nylon 6 + GF**

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Automotive Intake Manifold**
  - Chemical Resistance
  - Excellent Strength, Stiffness & Impact
  - Moderate Heat Resistance
  - Moderate Cost OK
- **Nylon 66 + GF**

Case Study

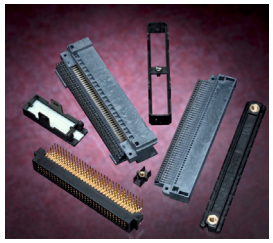
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Oil Pan**
  - Chemical Resistance
  - Excellent Strength, Stiffness & Impact
  - Moderate Heat Resistance
  - Moderate Cost OK
  - Extremely Tight Dimensions & Flat
- **?????????**

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

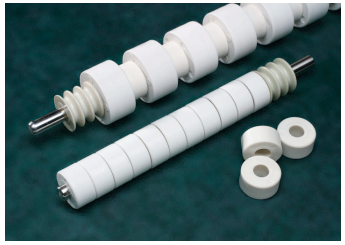
- **Electrical Connectors**
  - Good Flow in Thin Walls
  - Excellent Electrical Properties
  - Dimensionally Stable in Humidity
  - Moderate Cost OK
- **PBT (PET) + GF + FR**



Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Conveyor Rollers**
  - Good Abrasion Resistance
  - Low Wear & Friction
  - Moderate Cost OK
- **Acetal**

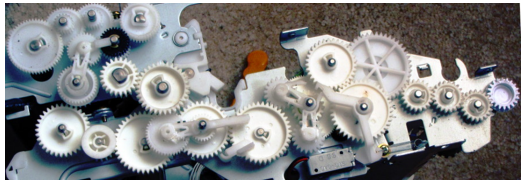


Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Printer Gears**
  - Extremely Tight Dimensions
  - Moderate Cost OK
  - Good Abrasion Resistance
  - Low Wear & Friction

?????????



Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Lawn Tractor Hood**
  - Tight Dimensions & Low Warp
  - Moderate Cost OK
  - Chemical Resistance
  - Good Mold Flow
  - High Impact
- **?????????**

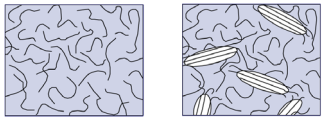
THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Overcoming Morphology Deficiencies Via Compounding

Morphology Deficiencies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

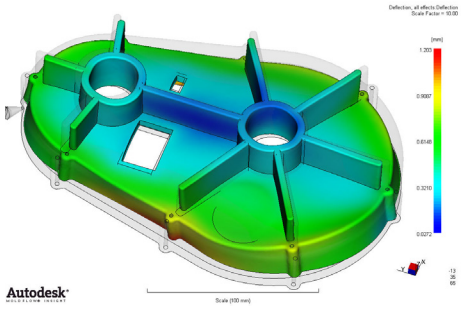
	Amorphous	Semi-Crystalline
Low Shrinkage	✸	D
Low Warpage	✸	D
Tight Tolerances	✸	D
Transparency	✸	D
Mold Flow Ease	D	✸
Chemical Resistance	D	✸
Wear Resistance	D	✸



Dimensional Stability

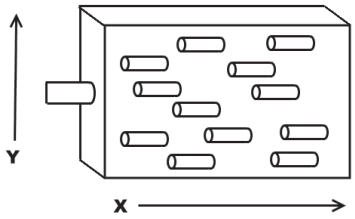
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Can We Reduce Shrink Rate & Improve Dimensional Stability of Semi-Crystalline Resins?



Fiber Reduces Shrink

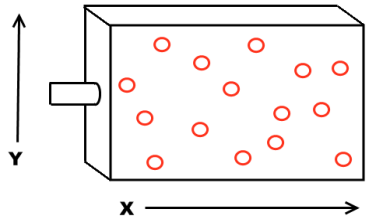
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Shrink Rate X ≠ Shrink Rate Y → Warp

Warp Control

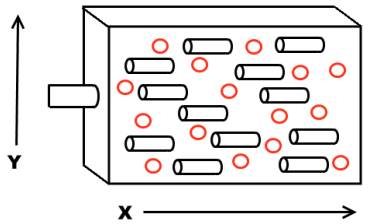
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Shrink Rate X = Shrink Rate Y → Flat Part
But Low Strength!

Strength & Warp Control

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Common Loading = 15% Glass Fiber & 25% Mineral or Beads

Case Study

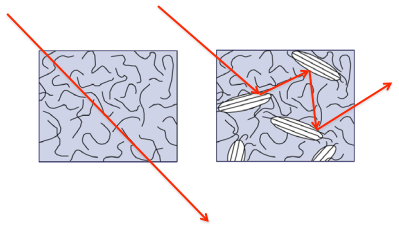
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Oil Pan**
  - Chemical Resistance
  - Excellent Strength, Stiffness & Impact
  - Good Heat Resistance
  - Moderate Cost OK
  - Extremely Tight Dimensions & Flat
- **Nylon 66 + 15% GF + 25% Mineral**

Transparency

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

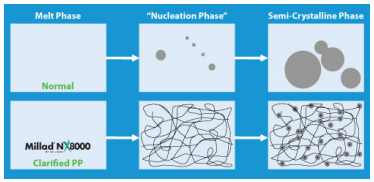
- **Can We Make A Semi-Crystalline Resin Transparent?**



Nucleation/Clarification

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Compounding nucleator into PP or PE controls crystal size to less than wavelength of light = Transparency



Courtesy Milliken Chemical

Case Study

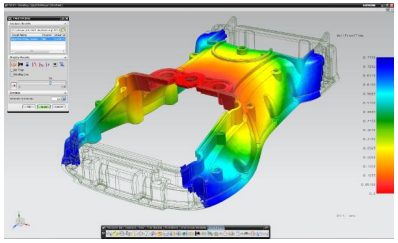
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Chemical Beakers
  - Excellent Chemical Resistance
  - Low Cost
  - Transparent
- PP + Nucleator

Chemical Resistance/Mold Flow

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Can We Improve Chemical Resistance & Mold Flow of Amorphous Resins?



Alloying

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Alloy PC with ABS

- RTP 2500 A Series

	PC	PC/ABS
Tensile Strength, psi	9000	8900
Flexural Mod, E6 psi	0.34	0.40
Izod Impact, ft lb/in	15	13
HDT @ 264 psi, ^{0}F	270	210
Fuel Resistance	Poor	Poor
Melt Flow, gm/10 min	10	15
Clarity	Transparent	Opaque

Alloying

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Alloy PC With Polyester (PBT or PET)

– RTP 2099 X 63578 B

	PC	PC/PBT
Tensile Strength, psi	9000	8700
Flexural Mod, E6 psi	0.34	0.35
Izod Impact, ft lb/in	15	15
HDT @ 264 psi, °F	270	250
Fuel Resistance	Poor	Fair
Melt Flow, gm/10 min	10	20
Clarity	Transparent	Opaque

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Lawn Tractor Hood**
  - Tight Dimensions & Low Warp
  - Moderate Cost OK
  - Chemical Resistance
  - Good Mold Flow
  - High Impact
- **PC/PBT Alloy**

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **GPS Housing**
  - Tight Dimensions & Low Warp
  - Moderate Cost OK
  - Good Mold Flow
  - High Impact
- **PC/ABS or PC/PBT Alloy**
  - Want Sustainability
- **PC/PLA Alloy (30% Bio)**
  - Want More Sustainability
- **Recycled (PCR) PC/PLA Alloy (30%Bio + 60% PCR = 90% Sustainable)**

Wear Resistance

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Can We Make An Amorphous Resin Wear Resistant?**

PTFE Lubricated

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Compound PTFE Into PC

– RTP 300 TFE 15

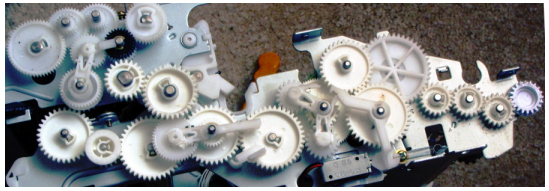
	PC	PC/15 PTFE	Acetal
Wear Factor	560	130	90
Dynamic Coef. of Friction	0.60	0.33	0.40

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Printer Gears**
  - Extremely Tight Dimensions
  - Moderate Cost
  - Good Abrasion Resistance
  - Low Wear & Friction

PC + PTFE



Review

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

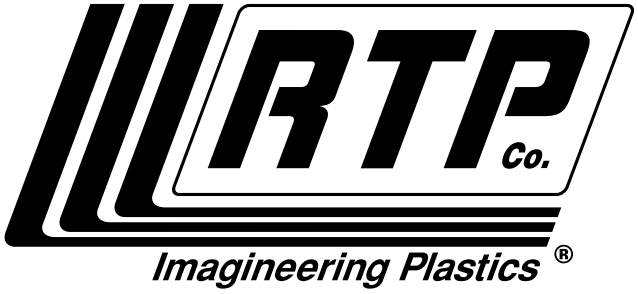
- **Intro To Compounding**
- **The Dilemma**
- **Resin Selection Procedure**
  - Resin Morphology
  - Resin Performance (including cost)
  - Unique Resin Features
- **Application Case Studies**
- **Compounding in Performance**
  - Overcoming Resin Deficiencies

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Questions?

Steve Maki
smaki@rtpcompany.com
(507) 474-5371

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Winan Corporation • + 1 320-259-3554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383



Tough or Strong? Short or Long? Dialing in Mechanical Performance

Brennan Ashton
Product Development Engineer
bashton@rtpcompany.com
(507) 474-5441

10:00 a.m.

STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

Tough or Strong? Short or Long? Dialing in Mechanical Properties

Brennan Ashton
Structural Product Development Engineer
RTP Company

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

What are we solving?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Strength

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Stiffness

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Impact

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

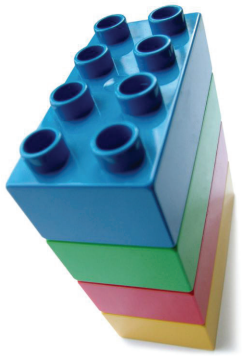
Structural Composites Formula

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Resin + Additives = Change in Properties

Structural Additives: Foundation

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Modifiers
- Fillers
- Lightweighting
- High Temperature Materials

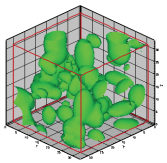
In this Presentation

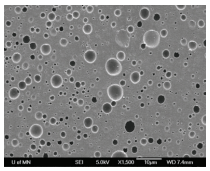
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

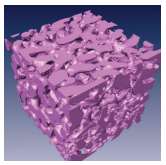
Modifiers

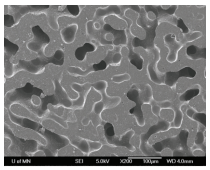
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Polymer Blends
Impact Modifiers









Polymer Blends

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

PC/ABS → **ABS brings**
- Improved flow
- Chemical resistance
- Cost reduction

Nylon / PP → **PP brings**
- Improved flow
- Chemical resistance
- Cost reduction

PC/PBT → **PBT brings**
- Improved flow
- Chemical Resistance

Polymer Blends

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

ABS / PC → **PC brings**
- Toughness
- Strength

PP / Nylon → **Nylon brings**
- Strength
- Stiffness

PBT / PC → **PC brings**
- Toughness
- Dimensional stability

Polymer Blends

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	PC	PC/ABS (RTP 2500 A)	ABS
Specific Gravity	1.19	1.15	1.05
Tensile Strength (MPa)	59	59	45
Notched Izod Impact (J/m)	850	740	250

Polymer Blends

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Application: Housing for Hearing Tester

Problem: Toughness and chemical resistance

Solution: Polycarbonate/ABS Alloy

Benefit: Strength and toughness of PC with the added chemical resistance of ABS

Polymer Blends

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Applications in Automotive

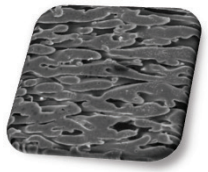
Modifiers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Impact properties

Impact Modifiers

Strength
Stiffness



Impact Modifiers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	PA 6/6	IM PA 6/6
Specific Gravity	1.14	1.08
Notched Izod Impact (J/m)	55	900
Tensile Strength (MPa)	80	45
Flexural Modulus (MPa)	2.8	1.8

Impact Modified

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Application: Housing for Wireless Workstation

Problem: Toughness and abrasion resistance

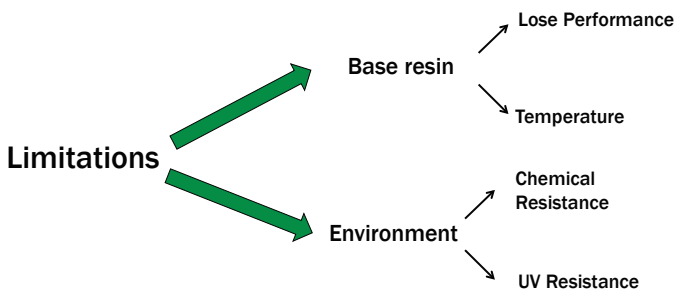
Solution: Impact Modified PA 6/6

Benefit: Wear and abrasion resistance of Nylon 6/6 with added toughness from impact modifier

Automotive Ex.: Airbag Housings

Impact Modifiers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

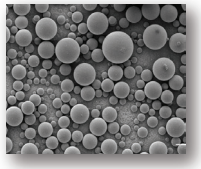


In this Presentation

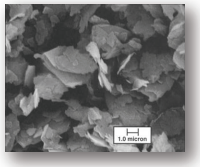
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Fillers

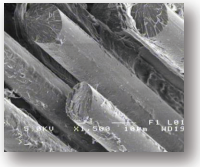
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Beads (Glass)
(photo: Potters, Inc.)



Minerals (Talc)

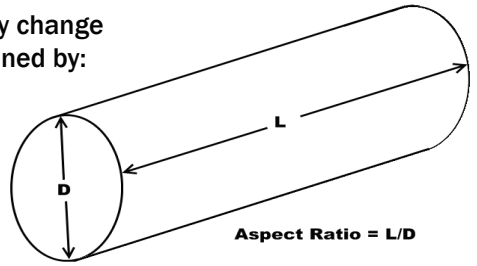


Fibers (Glass)

Fillers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Property change determined by:

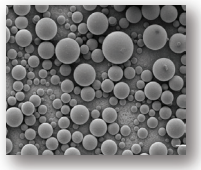


Aspect Ratio

Reinforcing

Low Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



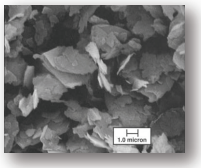
Beads (Glass)
(photo: Potters, Inc.)

Aspect Ratio = 1

	PC	PC + 10% Glass Beads	PC + 30% Glass Beads
Specific Gravity	1.19	1.27	1.42
Tensile Strength (MPa)	59	55	48
Notched Izod Impact (J/m)	850	100	80
Flexural Modulus (MPa)	2.4	2.6	3.4

Low Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



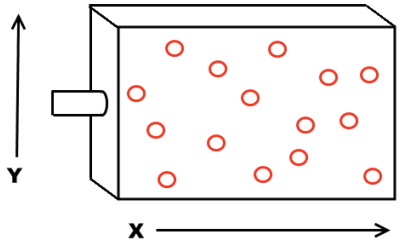
Minerals (Talc)

Aspect Ratio = 2-50

	PP	PP + 20% Talc	PP + 40% Talc
Specific Gravity	0.91	1.05	1.25
Tensile Strength (MPa)	32	32	30
Notched Izod Impact (J/m)	47	45	34
Flexural Modulus (MPa)	1.5	2.5	3.8

Warp Control

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Shrink Rate x = Shrink Rate y ⟶ Flat Part

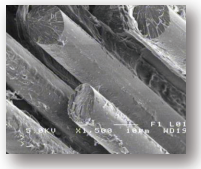
Low Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Application: Key Fob
Problem: Dimensional stability
Solution: PA66 + Glass Beads
Benefit: Uniform shrinkage

High Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



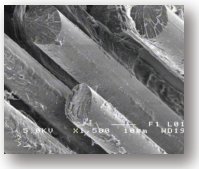
Fibers (Glass)

Aspect Ratio = 50-250

	PC	PC + 30% Glass Beads	PC + 30% Glass Fiber
Specific Gravity	1.19	1.42	1.42
Tensile Strength (MPa)	59	48	124
Notched Izod Impact (J/m)	850	80	160
Flexural Modulus (MPa)	2.4	3.4	7.6

High Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



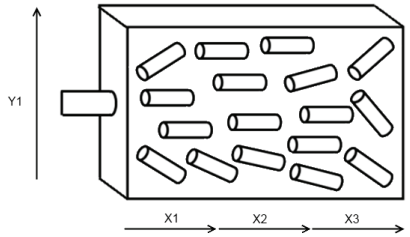
Fibers (Glass)

Aspect Ratio = 50-250

	PP	PP + 40% Talc	PP + 40% Fiber
Specific Gravity	0.91	1.25	1.22
Tensile Strength (MPa)	32	30	84
Notched Izod Impact (J/m)	47	34	108
Flexural Modulus (MPa)	1.5	3.8	7.5

Non-Uniform Shrink = Warp

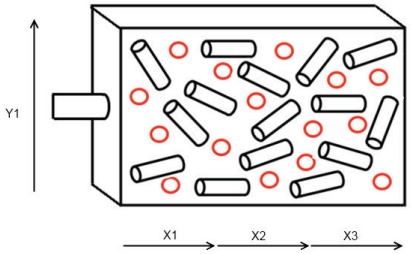
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Shrinkage X1 & X2 ≠ X3 ⟶ Warp

Strength & Warp Control

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Shrinkage X1 = X2 = X3 ⟶ Flat Part

High Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Application: Air Registers

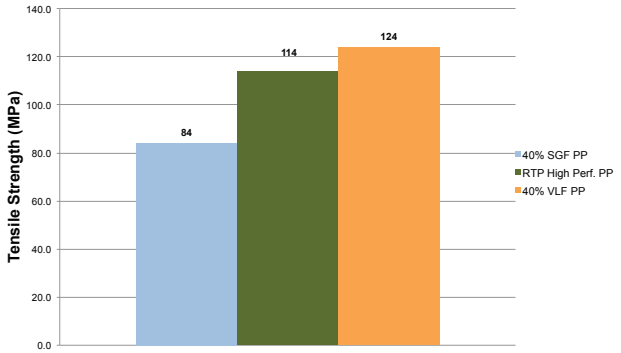
Problem: Stiffness and dimensional stability

Solution: Glass Fiber/Mineral Filled PP

Benefit: High strength, Great Surface Finish

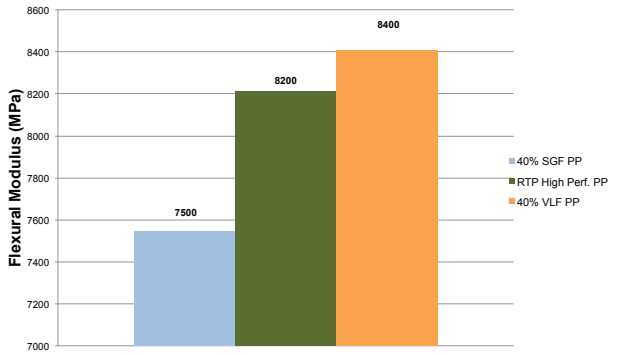
Improvements in SGF PP

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



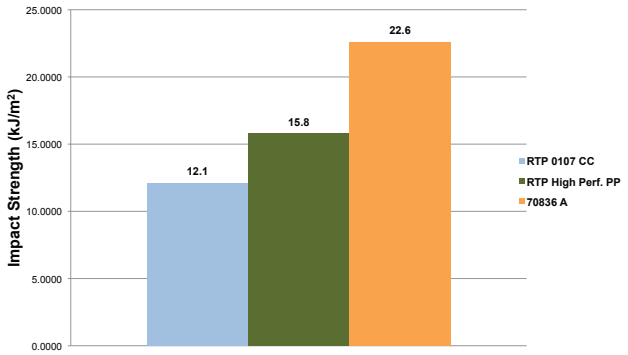
Improvements in SGF PP

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Improvements in SGF PP

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Extreme Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

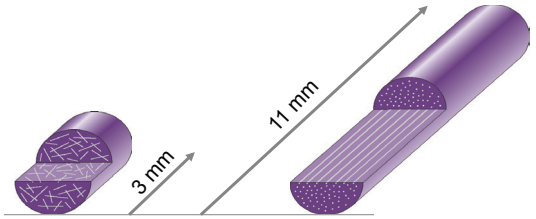
Long Glass Fiber

Aspect Ratio = 300+

	PP + 40% Short Glass	PP + 40% Long Glass
Specific Gravity	1.22	1.22
Tensile Strength (MPa)	84	124
Notched Izod Impact (J/m)	108	228
Flexural Modulus (MPa)	7.5	8.4

Pellet Comparison

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



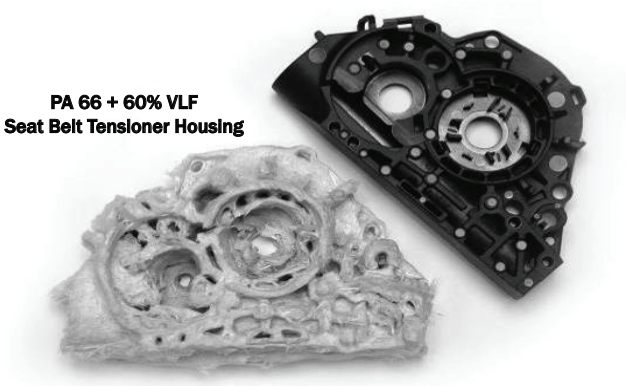
Short Fiber **VLF**

Fiber Length
~ 1-2 mm
11 mm

Secret to Success: The Skeleton

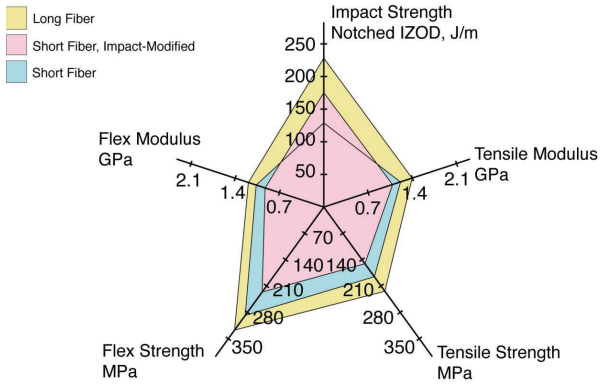
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

PA 66 + 60% VLF
Seat Belt Tensioner Housing



Polyamide 6/6 – 40% Glass Fiber

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



VLF Applications in Automotive

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

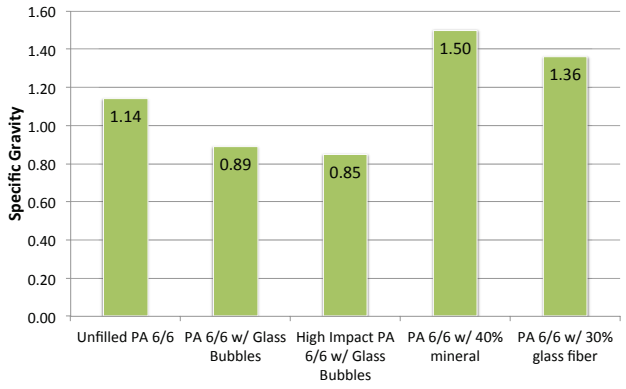
Hollow Glass Microspheres

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Lightweighting where properties are less demanding

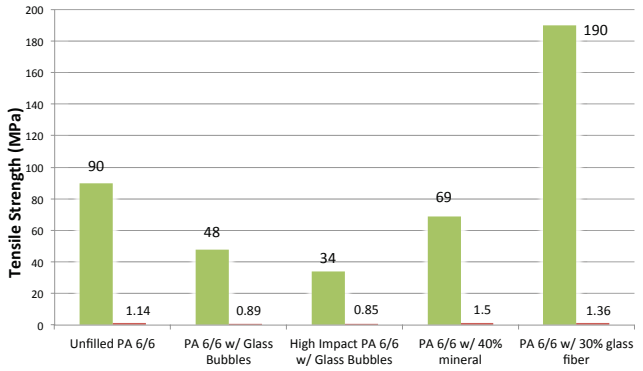
Hollow Glass Spheres

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



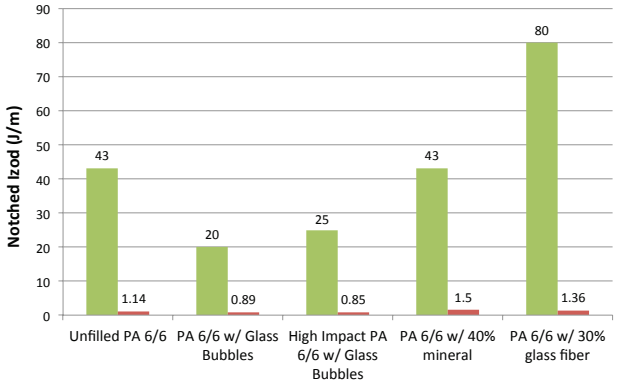
Hollow Glass Spheres

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Hollow Glass Spheres

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



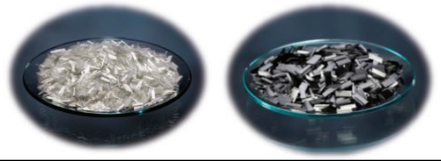
STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

Carbon Fiber

Carbon Fiber

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Fiber	E-Glass Fiber	Std. Modulus Carbon Fiber
Typical Diameter (μm)	10-17	5-10
Density (g/cm^3)	2.55	1.81
Est. Tensile Strength (MPa)	3400	4100
Est. Flexural Modulus (MPa)	73	240



Carbon Fiber - Polypropylene

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	PP 40% GF	PP 40% VLF	PP 30% CF
Tensile Strength (MPa)	85	120	105
Flexural Modulus (MPa)	6900	8250	11800
Notched Izod Impact (kJ/m^2)	12.1	22.8	10.2
Specific Gravity	1.21	1.21	1.06

Fiber Comparison – PA 6/6

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	PA 6/6 60% VLF (Long Fiber)	PA 6/6 35% Carbon Fiber
Flexural Modulus (MPa)	19.3	19.0
Tensile Strength (MPa)	275	244
Tensile Elongation (%)	2.0	2.0
Specific Gravity	1.71	1.29

Fiber Comparison – PPS

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	PPS 40% Glass	PPS 20% Carbon
Flexural Modulus (MPa)	15.1	15.8
Tensile Strength (MPa)	169	172
Tensile Elongation (%)	1.5	1.0
Specific Gravity	1.68	1.40

High Temperature Polymers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Amorphous	Semi-Crystalline
Polyetherimide (PEI)	Polyetheretherketone (PEEK)
Polyethersulfone (PES)	Polyphenylene Sulfide (PPS)
Polysulfone (PSU)	Polyphthalamide (PPA)
Polycarbonate (PC)	Polyethylene Terephthalate (PET)
Acrylonitrile Butadiene Styrene (ABS)	Polybutylene Terephthalate (PBT)
Styrene Acrylonitrile (SAN)	Polyamide (PA/Nylons)
Polystyrene (PS)	Acetal (POM)
High Impact Polystyrene (HIPS)	Polypropylene (PP)
Acrylic (PMMA)	Polyethylene (HDPE, LDPE, LLDPE)

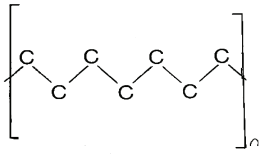
Thermal & Cost Increases

High Performance — Engineering — Commodity

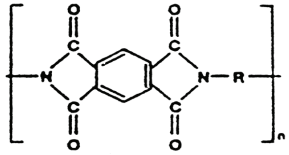
Chemical Structure

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Polyethylene
Tg -5 °F



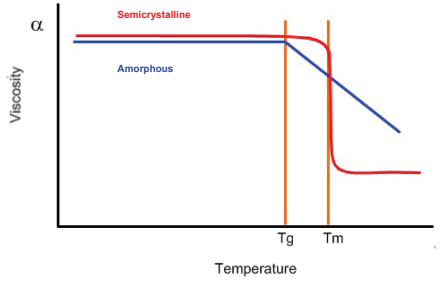
Polyimide
Tg 482 °F



Tg

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

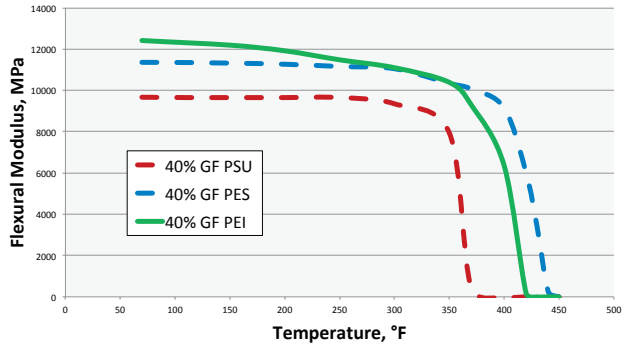
- **Tg = the softening point.**
  - **There is a drop in strength and modulus above the Tg**
  - **Crystalline materials will tend to creep above the Tg**
  - **Amorphous materials will start to flow above the Tg**



Amorphous Materials

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

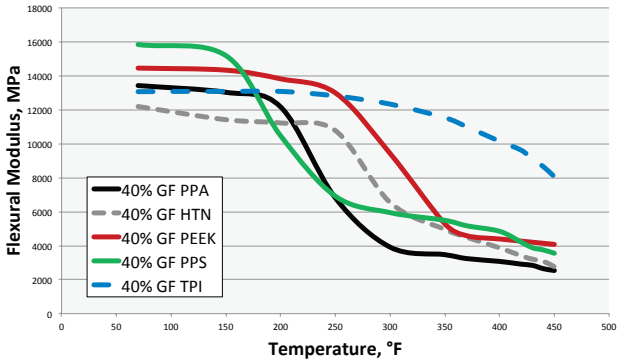
Flexural Modulus Vs. Temperature



Semi-Crystalline Materials

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

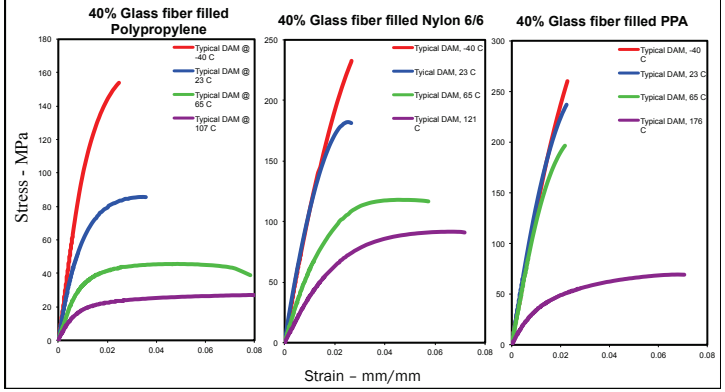
Flexural Modulus Vs. Temperature



Elevated Temp Properties

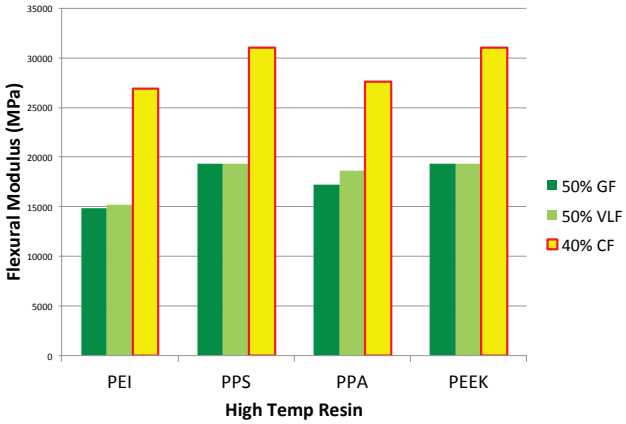
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Multiple Temperature Tensile Stress/Strain



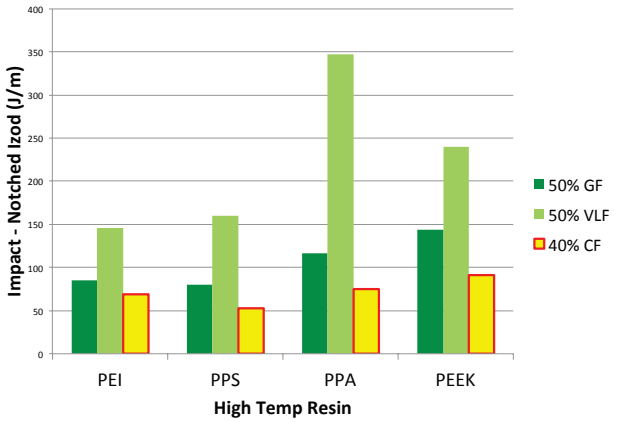
Flexural Modulus

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Impact – Izod Notched

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



High Temperature Applications

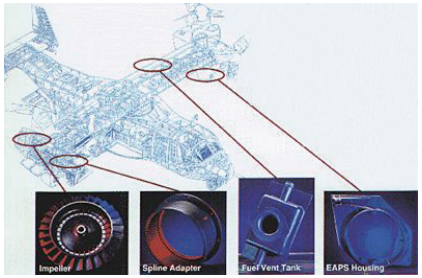
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Application: Multiple Components on V-22 Osprey

Problem: Environment

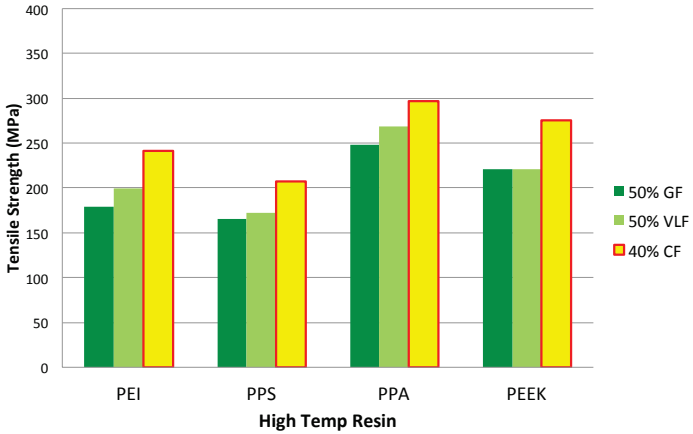
Solution: Carbon fiber reinforced TPI and PEEK

Benefit: Flame retardant, temperature resistance, strength/stiffness



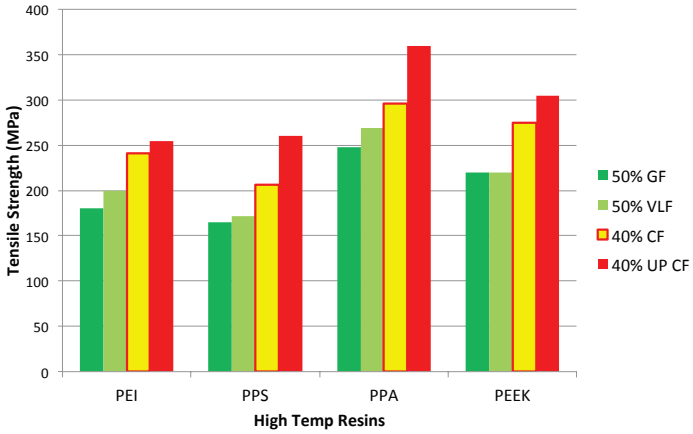
Tensile Strength

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Tensile Strength

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



High Performance Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Application: Brake Rotor Measuring Probe

Problem: Casting replacement

Solution: Carbon fiber reinforced PPA

Benefit: High strength and stiffness

Summary

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

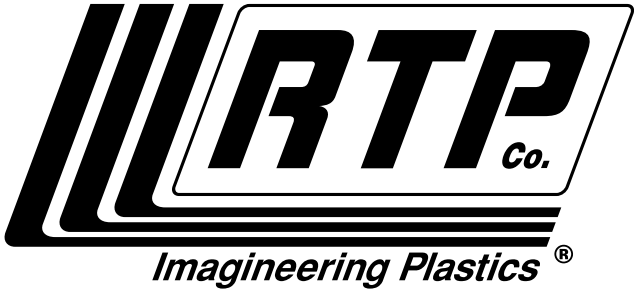
- Modifiers
  - Polymer Blends
  - Impact Modifiers
- Fillers
  - Performance driven by aspect ratio
- High Temperature
  - Wide range of polymers with varying performance
  - Understanding environment and stress levels is key to success

STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

Questions?

Brennan Ashton
bashton@rtpcompany.com

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383



Conductive & EMI Thermoplastic Technologies

Ned Bryant
Senior Product Development Engineer
nbryant@rtpcompany.com
(507) 474-5361

10:00 a.m.

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Conductive & EMI Thermoplastic Technologies

Ned Bryant
Senior Product Development Engineer

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Winsan Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

Outline

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Conductive Classification & Testing
- Overview of Conductive Modifiers
- EMI Shielding
- Wrap Up and Questions

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

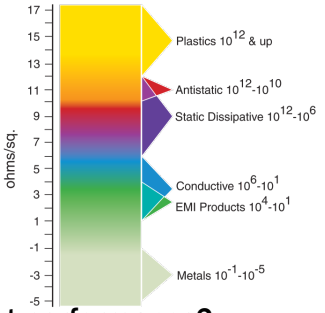
Conductive Classification & Testing

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Winsan Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

Conductive Classification

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

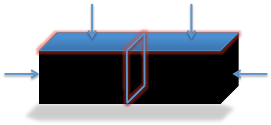
- Classification
  - Anti-static
  - Static dissipative (ESD)
  - Conductive/EMI Shielding
- The application will fit into one of these…
- How do you Qualify/test performance?

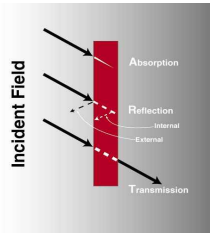


Qualification Testing

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Anti-static**
  - Decay rate (seconds to decay)
- **Static dissipative (ESD)**
  - Surface resistivity (ohm/square)
  - Surface resistance (ohm)
- **Conductive/EMI**
  - Volume resistivity (ohm-cm)
  - Shielding effectiveness (dB)

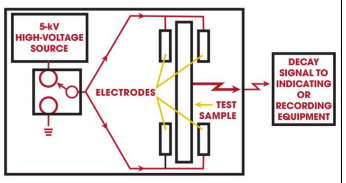




Anti-Static Testing

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Static decay rate**
  - Measures seconds to decay
  - 5000 to 50 V
  - 12% relative humidity
- **Standards/specifications**
  - MIL PRF 81705 D
  - NFPA 56A
  - Numerous others



Static Dissipative Testing

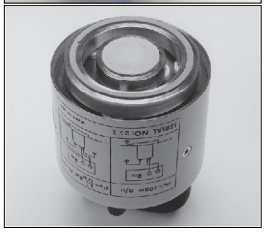
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Surface resistivity (ohm/square)**
- **Surface resistance (ohm)**
- **Standards/specifications**
  - ASTM D257
  - ESD STM11.11
  - IEC 60079-0
  - Numerous others

Surface Resistivity Test

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Voyager SRM-110**
  - Small samples
  - Irregular parts
  - In-field test
  - Units = ohm/square
- **Guarded Ring**
  - Flat specimen
  - Precise measurement
  - Units = ohm/square



Surface Resistance Test

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Surface resistance**
  - Point-to-point
  - Measuring small & critical areas on part
  - Units = ohm

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

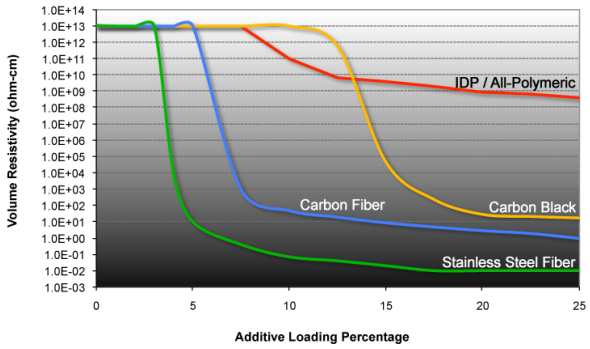
Conductive Modifiers

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

Percolation Curve

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Conductivity Percolation Curve



Migratory Anti-Static Agents

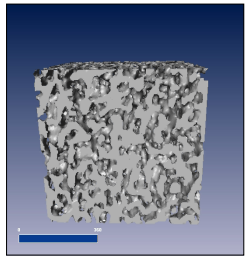
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Migrating surfactant based – not bonded to resin**
- **Temperature & humidity dependent**
  - Best at room temperature & high humidity
- **Colorable**
- **Liquids & semi-solids with low boiling points**
- **Compatible only with low-temp resins**
  - Olefins, Styrenics, PVC
- **Economical/commodity materials**

Inherently Dissipative Polymers (IDP)

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **All-polymeric, based on IDP**
  - Typically consist of PE oxide
  - Other block dictates compatibility
  - Forms a co-continuous morphology with the base resin
- **Over 20 different resin systems**
  - Limited process temps (< 520 °F)
- **Surface resistivity**
  - Standard: 10^{10} to 10^{12} ohm/sq
  - PLUS: 10^{8} to 10^{9} ohm/sq
- **Static decay rate**
  - Standard < 2.0 s
  - PLUS < 0.5 s



PermaStat®

PermaStat® Technology Benefits

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Permanent ESD protection**
- **Cleanliness (non-sloughing, non-migratory)**
- **Humidity independent**
- **Fully colorable**
- **Transparent grades available**
- **FDA grades available**
- **Base resin properties retained**

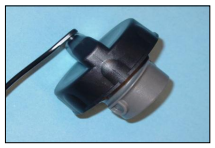
Typical Applications

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Reticle boxes
ABS/PMMA

Inhalers
ABS/PP/PMMA

ATEX IBC
PE

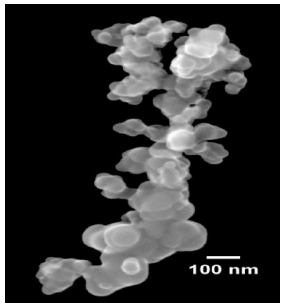


Gas cap
POM

Conductive Carbon Black

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Defined by**
  - Structure
  - Size of particles
  - Porosity
  - Surface chemistry
- **Numerous choices**



Conductive Carbon Black

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Permanent
- Black color
- Sloughing / Marking / Crayoning
- Economical
- Dissipative or conductive
  - SR 10^3 to 10^9 ohm/sq
  - VR 10^0 to 10^6 ohm-cm

Carbon / Graphite Fiber

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Non-sloughing
- Colorable
- Anisotropic shrinkage
- Reinforcing
- Dissipative or conductive
  - SR 10^2 to 10^6 ohm/sq
  - VR 10^{-1} to 10^4 ohm-cm

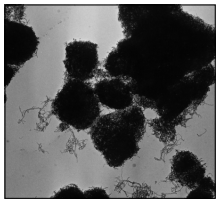
Chopped Fiber – ¼" long "bundles"

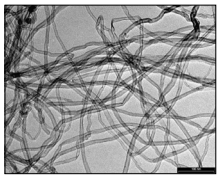
Milled Fiber – pulverized

Carbon Nanotubes (CNT)

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

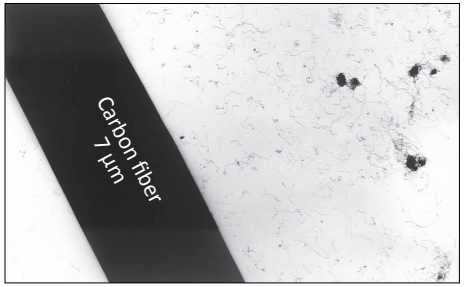
- > 90% graphite
- Hollow
- 10 nanometer diameter
- High L/D ratio
- First produced in 1987





CNT Size Difference

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



A carbon fiber surrounded by CNTs, emphasizing just how different CNTs are from carbon fiber technology

4 Primary Benefits of CNTs

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

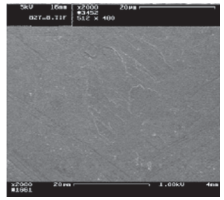
- Electrical conductivity
- Eliminate residual voltage, "Hot spots"
- LPC cleanliness
- Low outgassing & ionic contamination
- Effective at low loadings
- Lower specific gravity than CF compounds
- Good surface appearance
- Mold thinner wall thicknesses
- Isotropic properties
- Ability to use regrind

Electrical Conductivity

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

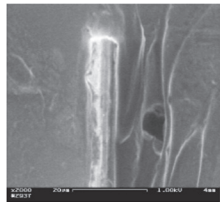
SEM (2000x) of typical CNT compound

- Smooth surface finish
- Uniform shading is a direct result of uniform electrical conductivity



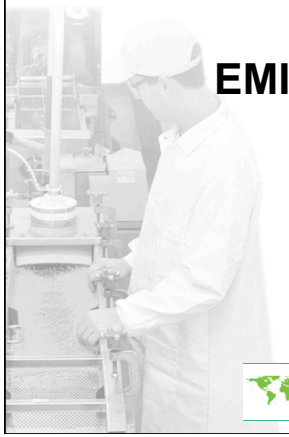
SEM (2000x) of typical CF compound

- Rough surface finish
- White shading indicates a point of high conductivity - "Hot spot"
- Possible conductive particle generation site



THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

EMI Shielding



RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Winsan Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

ISO 9001 CERTIFIED

What is EMI?

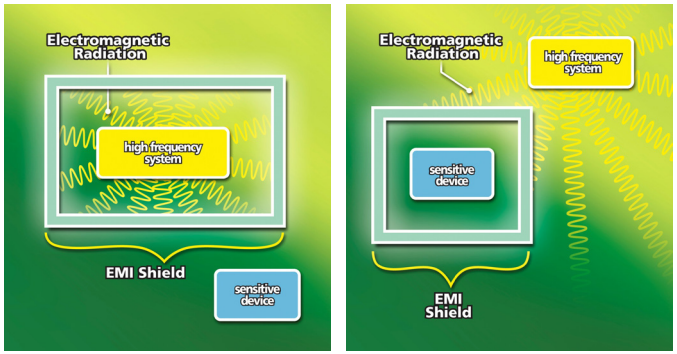
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **E**lectro**M**agnetic **I**nterference = EMI
- Emitted from a source *or* Received by a device
- Frequency range of 1 kHz to 10 GHz
- Faraday Cage Principle:
  - Barrier that reflects or conducts signals to ground
- Shielding provides "Immunity"

EMI in Action

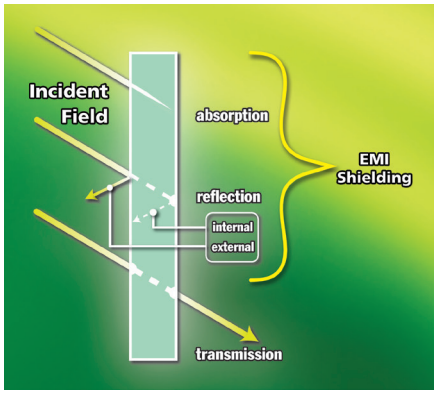
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

EMI shields protect sensitive devices



EMI in Action

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Controlling EMI

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

EMI Shielding is a function of 4 variables:

- Thickness of the material (Design)
- Frequency of the interference (Design)
- Distance between source & shield (Design)
- **Conductivity of the material (RTP)**

EMI Shielding Fillers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Electrically Conductive modifiers:

- Carbon Powder
- Carbon fiber
- Graphite
- **Stainless steel fiber**
- **Nickel-coated carbon fiber**
- Other metallic additives

Key Additive Comparison

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Stainless Steel Fiber

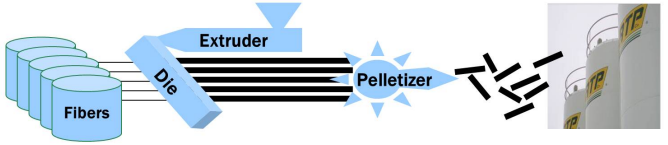
- Minimal affect properties
- **Neat resin shrinkage**
- Good shielding
- **Cost effective**
- Colorable

Nickel Coated Carbon Fiber

- Similar to CF Compounds
- High Shielding Performance
- Higher Cost
- Less Colorable
- **Light Weight**

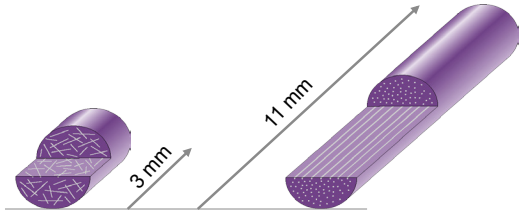
The Long Fiber Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Pellet Comparison

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Short Fiber **VLF**

- The process results in very long, oriented fibers
- Creates better shielding than randomized short fibers

The Long Fiber Compound

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Optimized via "Cube Blends"

"A" Pellet – LF Product provides EMI shielding

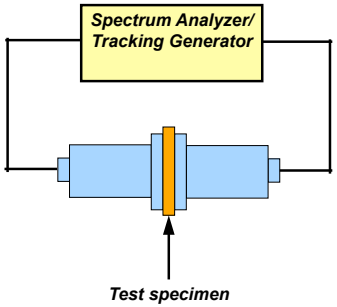
"B" Pellet – All other properties (Color, FR, Impact, etc.)

Cube Blends Maintain Fiber Length in Molded Part

Coaxial Trans. Line Test

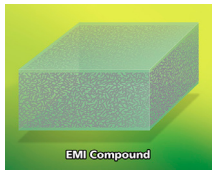
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- ASTM D4935
- Direct measurement
- Frequency from 300 to 1500 MHz
- Results in dB of SE

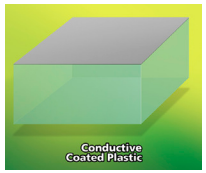


Review of Shielding Options

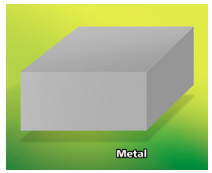
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



- VR is key parameter
- SR is misleading
- SE dependent on filler loading and wall thickness
- Easily Grounded



- SR key parameter
- Other surfaces insulative
- SE depends on coating Conductivity & Thickness
- Care in grounding required



- Uniform Conductivity
- SR easily measured
- Easily grounded

Challenges in Auto Sensors

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Weight reduction
- Consistent shielding and quality
- Low frequency shielding
- Thermal management
- Global manufacturing and tech. support

Sensor Application Successes

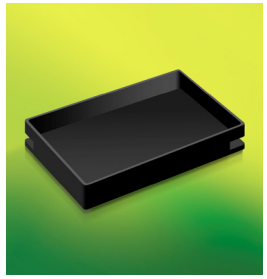
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

RTP Conductive EMI Resin:

Stainless Steel Filled PBT (SE through Reflection & Absorption)

Results:

- Uniform SE, even in corners
- Better grounding
  - All surfaces are conductive
- Eliminated process steps
- Eliminated a supplier (Paint)
- Improved yields
- Reduced total cost



Combining EMI + TC

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- SSF is a poor thermal conductor
- Thermal fillers can provide some EMI shielding
- Custom formulations can balance design requirements

RTP Formulation	Shielding Effectiveness (300 MHz – 1.5 GHz)	Thermal Conductivity (Through-plane)	Thermal Conductivity (In-plane)
RTP EMI 2562	60 – 85 dB	0.3 W/mK	N/A
299X124222C	30 – 55 dB	3.4 W/mK	25 W/mK
299X124222D	32 – 38 dB	3.1 W/mK	19 W/mK
299X124222E	40 – 60 dB	5.3 W/mK	32 W/mK
299X124223B	45 – 55 dB	1.4 W/mK	4.1 W/mK

Modifier Pros & Cons

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Technology	Pros	Cons
Migratory Antistats	• Economical	• Non-permanent • Process temperature limited • Humidity dependent
Inherently Dissipative Polymer PermaStat®	• Permanent • Transparent availability • Colorable • No loss of mechanical properties	• Limited to dissipative range • Process temperature limited
Carbon Black	• Economical • Dissipative or conductive • Resists Tribocharging	• Sloughing • Black only • Lower impact strength
Carbon Fiber	• Dissipative or conductive • Reinforcing • Non-sloughing	• Anisotropy • Poor tribocharging
Carbon Nanotubes	• Dissipative or conductive • Superior tribocharging performance • Minimal effect on mechanical and viscosity • Low LPC	• Cost • Black only
Metallic Additives	• EMI/RFI shielding • Highly conductive	• Limited colorability • Higher specific gravity

Wrap-Up

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Need to understand what conductive property you are testing and what regime you are targeting
- All conductive additives need a percolated network
- Wide variety of additives to solve most conductive problems
- Each have pros and cons

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Questions?

Ned Bryant
nbryant@rtpcompany.com
(507) 474-5361

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wirsan Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380 253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

Live in the Wall Section: CAE Tools

Barb Matousek
CAE Analyst
bmatousek@rtpcompany.com
(507) 474-5301

11:00 a.m.

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

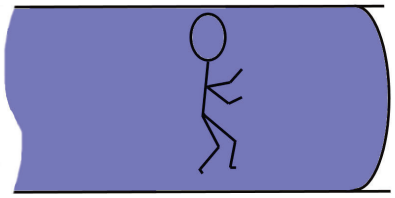
Live in the Wall Section: CAE Tools

Barbara Matousek
CAE Analyst

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

ISO 9001

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Live in the Wall Section

What We'll Cover

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Moldflow Analysis

- What is it?
- Why do it?
- Types of Moldflow analysis
- When should you do Moldflow?
- Getting the most from your analysis

What We'll Cover

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

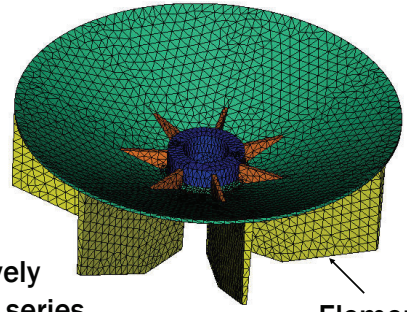
Structural Analysis – FEA

- What is it?
- Why do it?
- Case study

What is Autodesk Moldflow?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Autodesk Moldflow is FEA Software.



FEA iteratively performs a series of calculations on these elements.

Elements

What is Autodesk Moldflow?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Moldflow analysis solves fluid flow and heat transfer equations to simulate…
the MOLDING PROCESS

- Injection
- Packing
- Cooling/Shrink

Why Do Moldflow?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Moldflow simulation of injection molding process helps to…

- Avoid potential problems
- Increase your confidence in your design
- Reduce part cost
- Optimize part quality

Why Do Moldflow?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Moldflow allows simulation of possible manufacturing problems BEFORE you cut steel.

This saves $$$!

Types of Moldflow Analysis

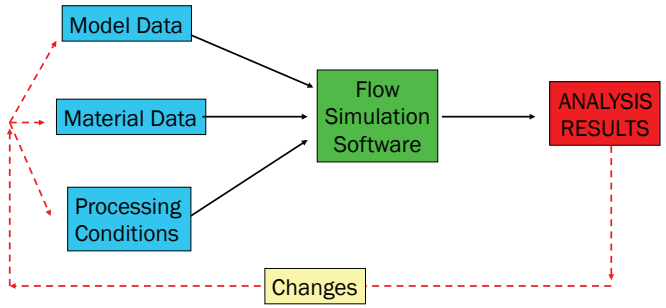
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Not all Moldflow analysis is the same

Understand what you're getting

Flow Analysis Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Flow Analysis Software

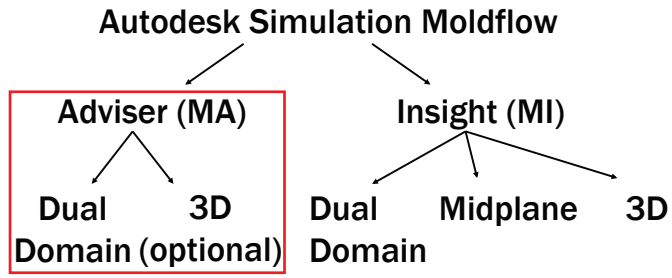
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

There are several flow analysis packages that simulate the injection molding process

- Autodesk® Simulation Moldflow®
- Sigmasoft
- Moldex
- Solidworks Plastics (Simpoe Xpress)

Autodesk Simulation Moldflow

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Autodesk Moldflow Advisers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- MA Design – part/cavity analysis
- MA Manufacturing – analysis of feed system
- MA Advanced – cooling, packing and warp
- Easy to learn
- 3D geometry-based
- Quickly check manufacturability

Autodesk Moldflow Advisers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Provides confidence of fill plot
- Shows possible sink locations
- Shows weld line locations
- Estimates pressures
- Estimates flow front temperatures

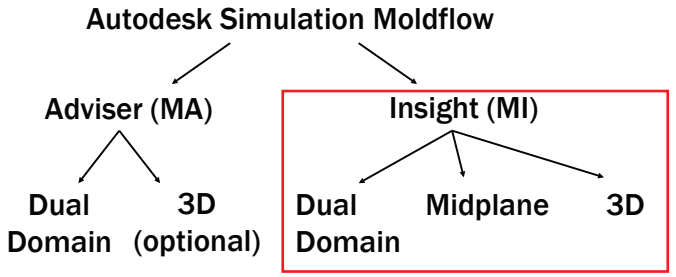
Moldflow Adviser Limitations

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Uses a less rigorous “simplified” representation of the polymer
- Doesn’t allow as much flexibility
- Makes assumptions that might not apply
- Limited results output

Moldflow Software Summary

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Autodesk Moldflow Insight

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- In-depth simulations
- Can simulate filling, packing and cooling as well as fiber effects
- Allows simulation of more complex molding processes

Autodesk Moldflow Insight

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Reactive injection and transfer molding
- Rubber, liquid silicone injection molding
- Microchip encapsulation
- Gas-assisted injection molding
- Injection-compression molding
- Compression molding
- Co-injection molding
- Mu-Cell
- Core shift analysis

Autodesk Moldflow Insight

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Allows more flexibility with design and material changes
- More rigorous solver than Adviser
- Provides more analyses capabilities
- Results available through the thickness
- Requires translation and manipulation of solid model

Autodesk Moldflow Insight

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

3 Ways of Modeling in Insight

Dual Domain

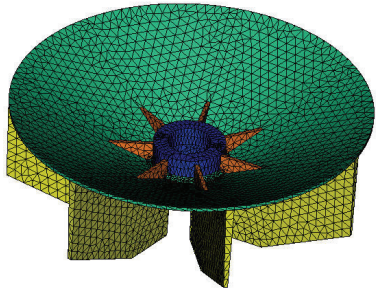
Midplane

3D

Moldflow Insight Dual Domain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Dual Domain Technology



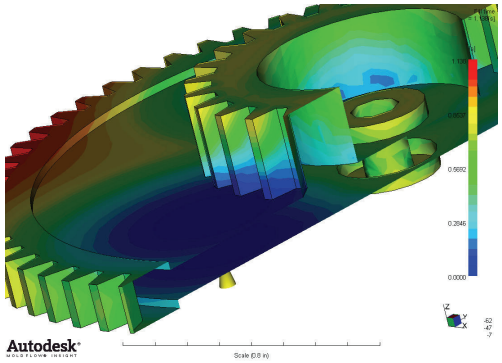
Moldflow Insight Dual Domain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Less model build time than Midplane
- Allows flexibility with design and material changes
- Warp predictions not as accurate as Midplane or Insight 3D

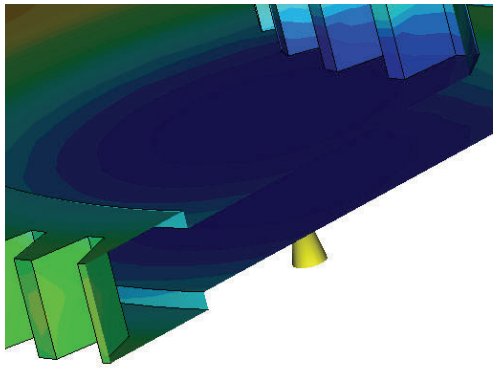
Moldflow Insight Dual Domain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Moldflow Insight Dual Domain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



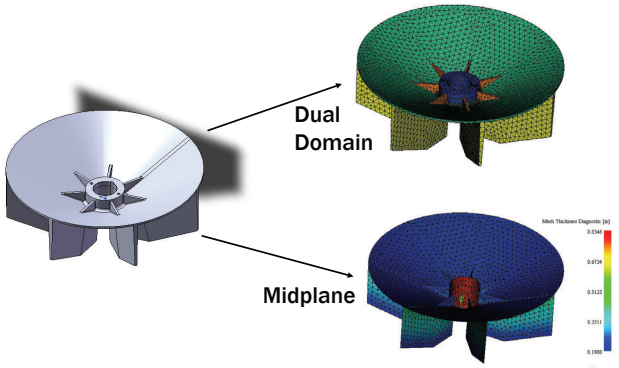
Moldflow Insight Midplane

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Uses shell elements
- Increased model build time

Dual Domain vs. Midplane

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Moldflow Insight Midplane

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Uses shell elements
- Increased model build time
- Allows flexibility with design and material changes
- Warp predictions more accurate than Dual Domain

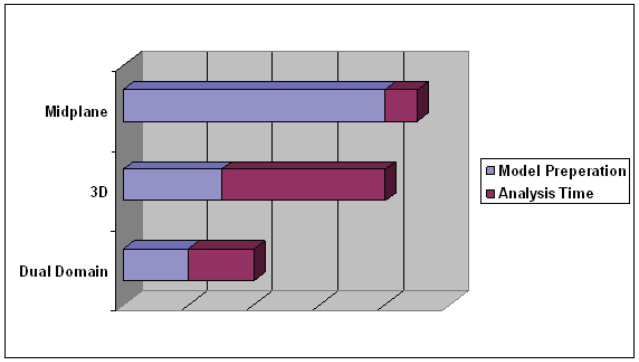
Moldflow Insight 3D

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Uses solid tetrahedral mesh
- Decreased model build / increased runtime
- Design changes require remodeling
- More accurate with thick, chunky parts
- Warp predictions more accurate for parts that are not well modeled by Dual Doman or Midplane

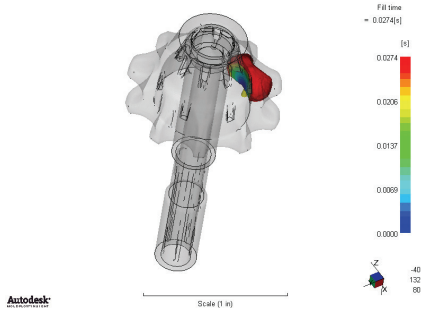
Moldflow Insight 3D

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



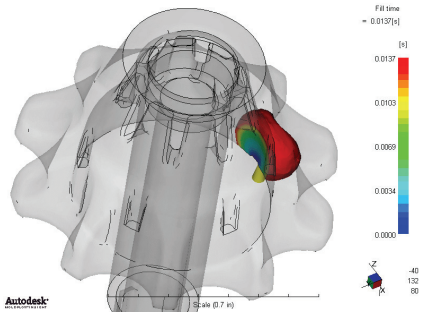
Moldflow Insight 3D

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



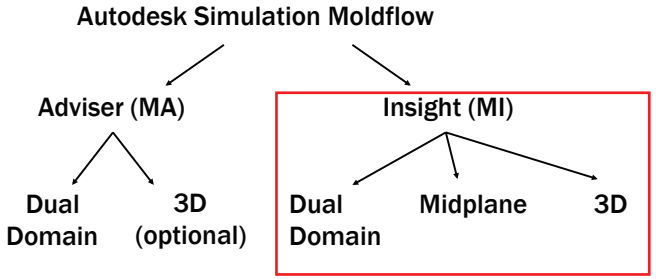
Moldflow Insight 3D

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Moldflow Software Summary

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Moldflow Filling Analysis

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Design plastic parts for manufacturing
- Optimize gate size and location
- Determine or relocate welds
- Estimate molding parameters
- Identify undesirable fill patterns that lead to warpage

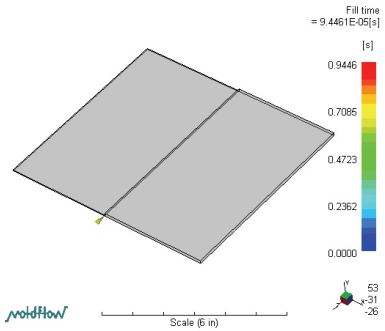
THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Hesitation & Racetracking

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Winona Corporation • +1 320-259-2514
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

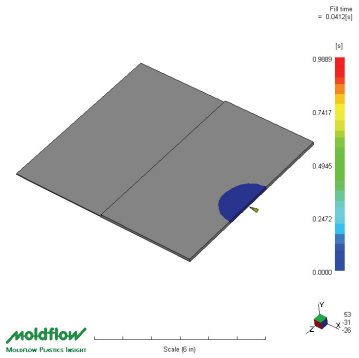
Moldflow Filling Analysis

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



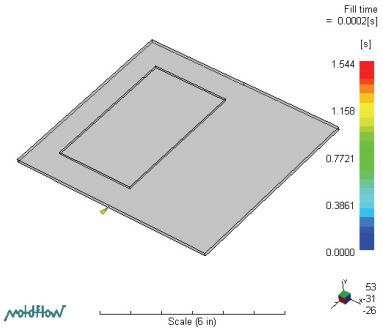
Moldflow Filling Analysis

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Moldflow Filling Analysis

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Filling Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Filling Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Large part, complex geometry
- High viscosity conductive polycarbonate
- How many gates are required to fill the part? Where?
- What can be done to improve the molding process?

Filling Analysis Example

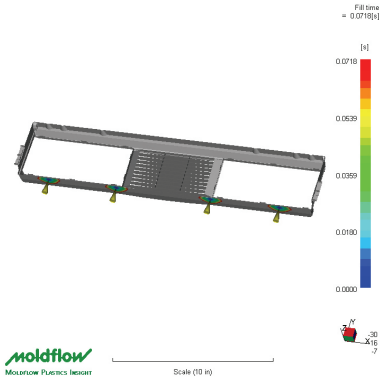
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Proposed Gating

Filling Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

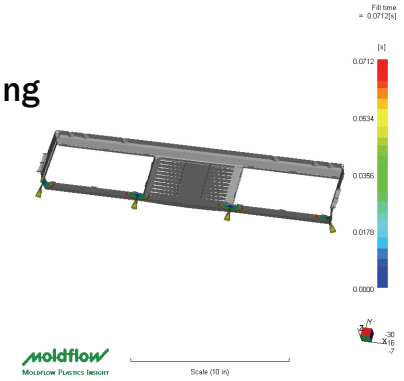
Edge Gating



Filling Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

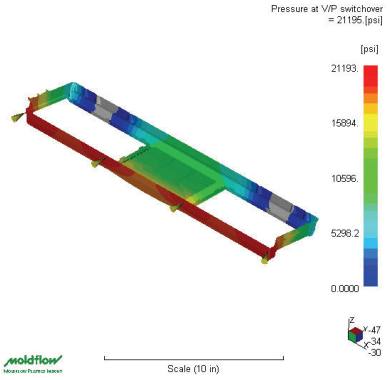
Final Gating



Filling Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Original Wall Thickness 0.080”

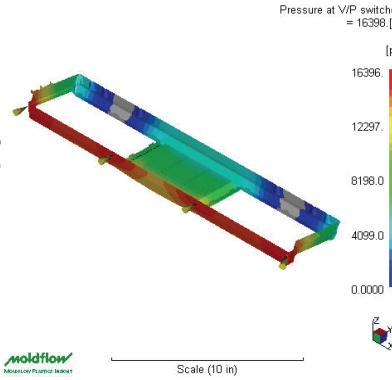


21,195 psi

Filling Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Increased Wall Thickness to 0.090”

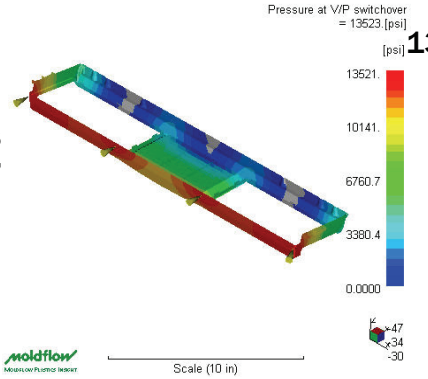


16,396 psi

Filling Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Increased Wall Thickness to 0.100”



13,521 psi

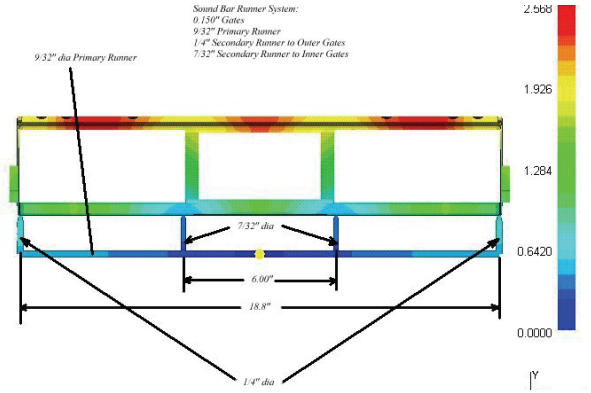
Example Conclusions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Regardless of gating, pressures will be high
- Increasing thickness by 0.010-0.020” significantly improves molding process
- 4 gates for optimum molding process
- Size runners for balanced filling pattern

Filling Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Moldflow Warpage Analysis

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Dual Domain and Midplane and Insight 3D
- Compare effects of gate locations on warp
- Compare part shape/warpage with various materials
- Design parts to minimize warpage issues during molding
- Diagnose and solve current warp problems

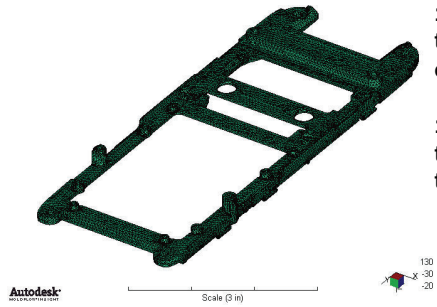
Moldflow Warpage Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Large part
- Structural part
- Concerned about weld lines
- Concerned about flatness

Moldflow Warpage Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



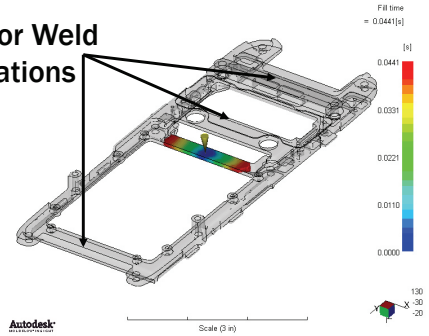
1,010,685 tetrahedral elements

10 elements through the thickness

Moldflow Warpage Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

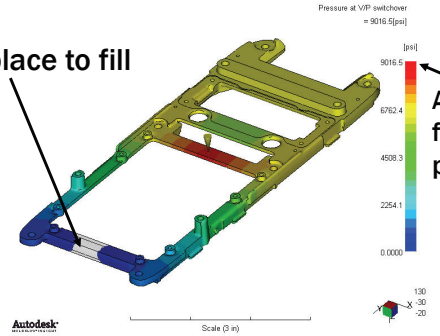
Major Weld Locations



Moldflow Warpage Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Last place to fill

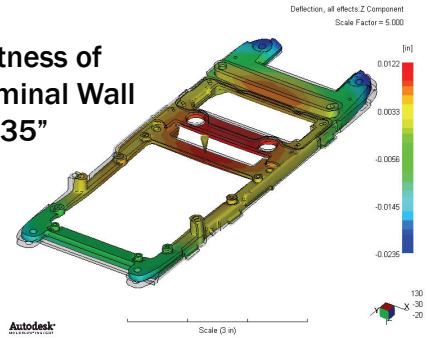


Acceptable fill pressure

Moldflow Warpage Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Flatness of Nominal Wall 0.035”

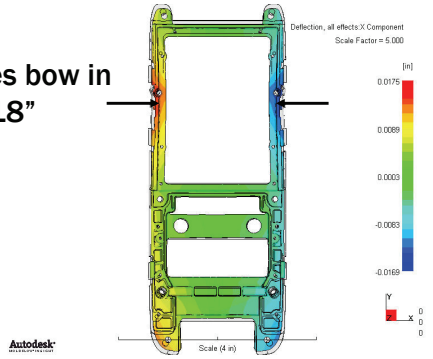


Deflections magnified by five to allow easier viewing

Moldflow Warpage Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

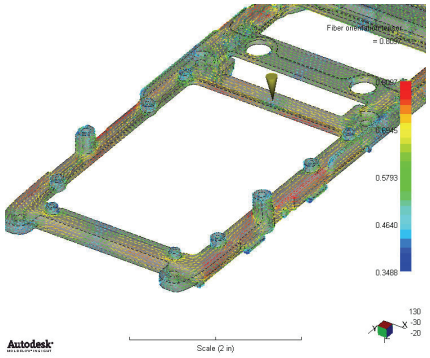
Sides bow in 0.018”



Deflections magnified by five to allow easier viewing

Moldflow Warpage Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Fiber Orientation in areas of concern

Warpage Results Summary

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Material	Flatness	Side Bow
40 Long Glass PA (edge gate)	0.039”	0.016”
40 Long Glass PA (center gate)	0.035”	0.018”
50 Short Glass PA	0.030”	0.017”
50 Long Glass RTPU	0.020”	0.011”
60 Short Glass PA	0.042”	0.017”

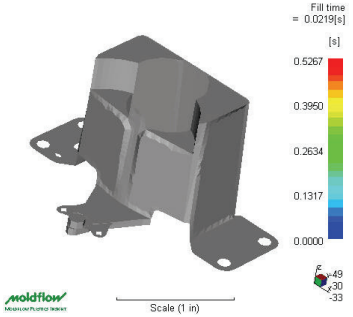
Warpage Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Existing parts sampled with several carbon filled nylons
- 0.003” flatness spec
- Existing part warps >0.020” with nylon
- Existing part warps >0.008” with CF PC
- Looking for part/gate changes to reduce warp

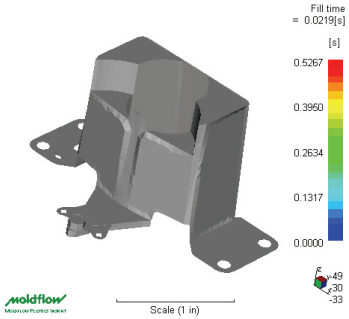
Warpage Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



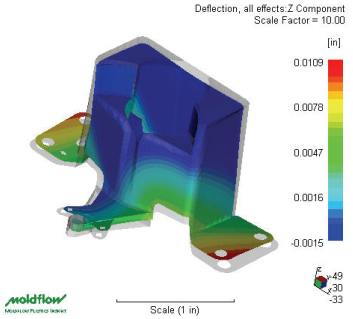
Warpage Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



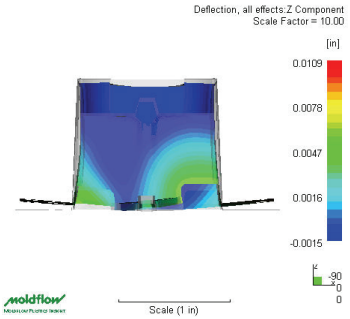
Warpage Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Warpage Analysis Example

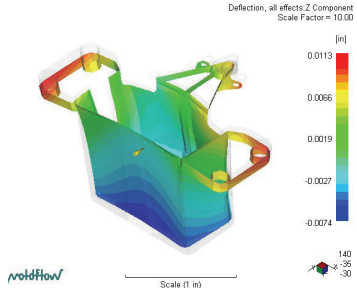
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Warpage Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

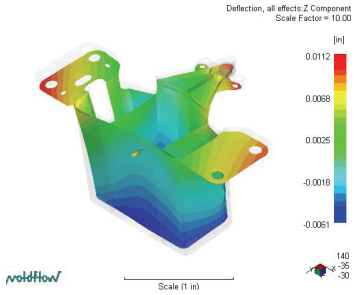
Open Flanges



Warpage Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

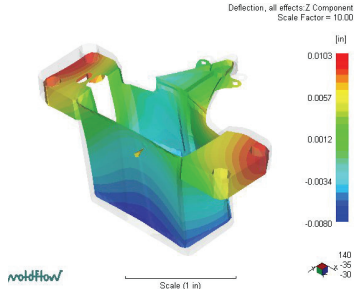
Internal Ribs



Warpage Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

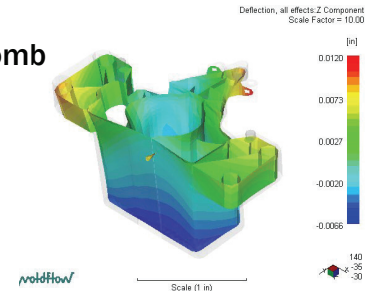
Gussets



Warpage Analysis Example

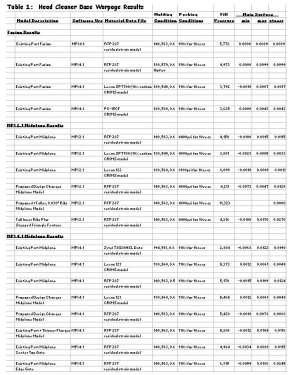
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Honeycomb



Warpage Analysis Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Warpage Analysis Conclusions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Moldflow predictions matched molded parts
- Cause of warp was fiber orientation
- Gate location changes will not reduce warp significantly with either material
- Worked extensively with designer to look at part design changes but flattest was 0.005”

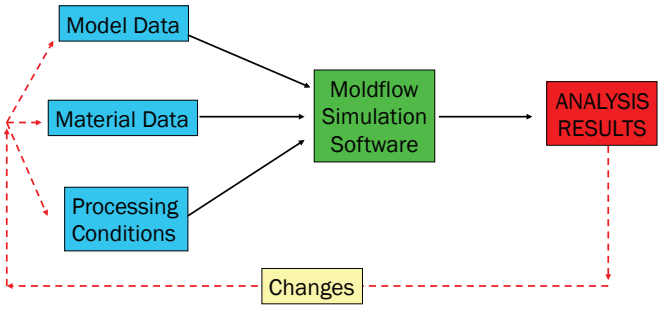
Warpage Analysis Conclusions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Fiber orientation effects can be reduced using lower shrink, more isotropic material
- Customer Sampled ESD 300 EM FR

Moldflow Analysis Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Moldflow Analysis Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Material Data

- Rheology (viscosity vs. shear rate)
- Thermal properties
- Mechanical properties
- Fiber properties
- CRIMS (shrinkage data)

When Should You Do Analysis?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Moldflow analysis during part design helps design the part for manufacturability

Do analysis EARLY before the part design is locked in and changes can't be made

When Should You Do Analysis?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Early analysis is especially important when the part has…

… complex geometry

… thin walls

… significant thickness variations

… structural requirements

… tight tolerances

… critical weld lines

When Should You Do Analysis?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Early analysis is especially important when the material...

... is high viscosity (low melt flow)

... is a fiber-filled structural material

... is thermally conductive

... shrinks anisotropically

Getting the Most from Moldflow

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Analyze early
- Use good material data (CRIMS)
- Understand the limitations of the software
- Understand what the results mean and ask questions of the analyst

What We'll Cover

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Structural Analysis – FEA

- What is it?
- Why do it?
- Case Study

What is Structural Analysis?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Structural (FEA) analysis simulates behavior of a structure under load

What is Structural Analysis?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Structural (FEA) analysis simulates:

- Deformations
- Forces
- Stresses

Why Do Structural Analysis?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

FEA allows simulation of part's behavior under load, which helps to…

- Avoid potential problems
- Increase your confidence in your design
- Optimize part quality
- Choose a suitable material

Why Do Structural Analysis?

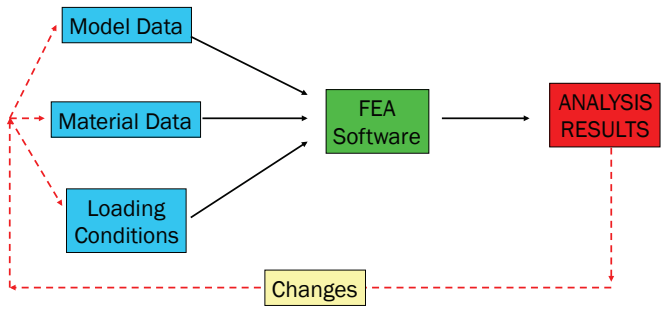
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

FEA allows simulation of possible structural problems BEFORE you cut steel.

This saves $$$!

Structural Analysis Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Structural Analysis

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Metal-to-plastic conversion
- Structural failure analysis
- Analysis considering non-uniform composite properties
- Gate location for best structural properties
- Part design for best mechanical performance

Case Study – Structural Analysis

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Telecommunications Connector

Case Study – Structural Analysis

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Analysis Goals

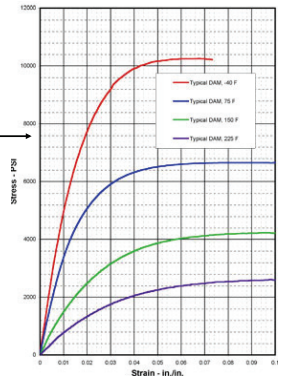
- Simulate assembly
- Identify maximum stress/strain areas
- Design revisions to reduce stress
- Evaluate materials to optimize cost performance

Case Study – Structural Analysis

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

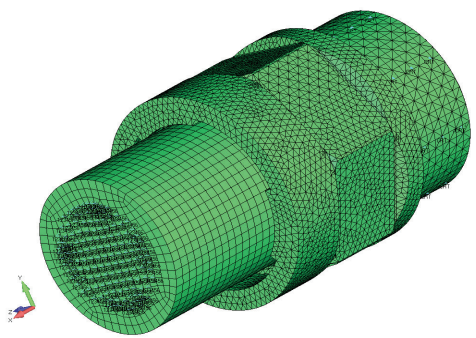
Performed an:

- Isotropic → Same in all directions
- Non-Linear →
- Contact → Mating Parts Modeled
- Structural Analysis



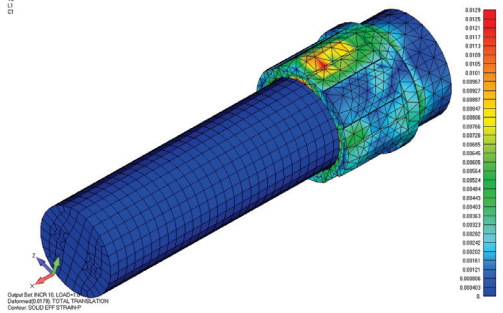
3D FE Model

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



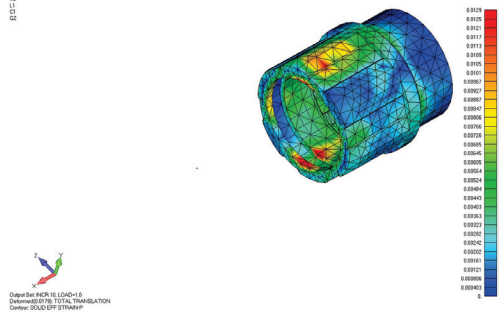
Original Design – Max Strain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



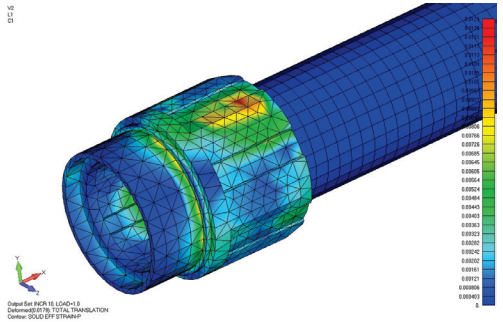
Original Design – Max Strain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



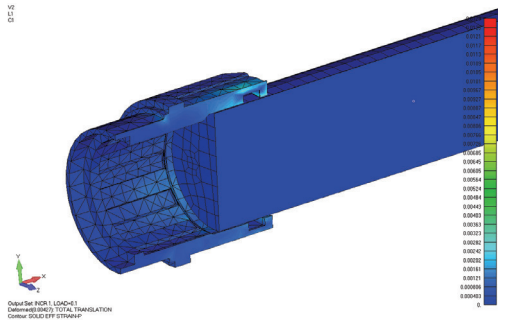
Original Design – Max Strain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



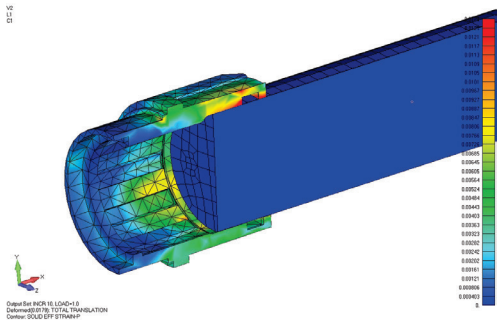
Original Design – Max Strain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



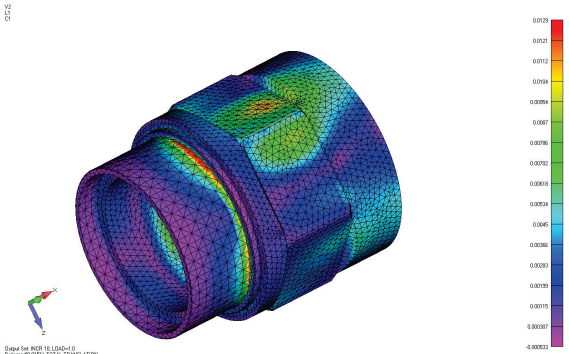
Original Design – Max Strain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



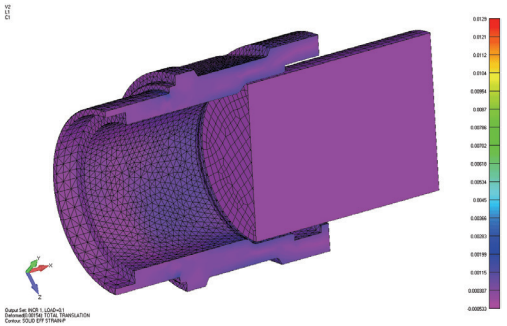
New Design - Max Strain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



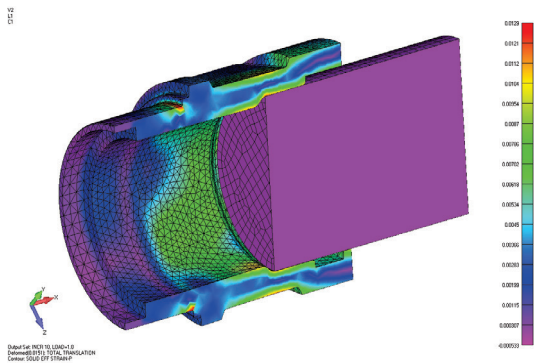
New Design – Max Strain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



New Design – Max Strain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Results

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Initial design stress exceeded material capability
- Multiple design revisions and analyses performed using various materials
- Final design meets the OEM's criteria for assembly torque
- Samples from prototype tooling passed testing requirements

Summary

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Not all analysis is the same – understand the analysis results you're getting
- Analyze early – Saves time and $$$
- Understand the material – involve your material supplier ***EARLY***
- Live in the wall section!

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Questions?

Barb Matousek
bmatousek@rtpcompany.com
(507) 474-5301

Everything You Need to Know about TPEs

Brandon Bubak
Sales & Marketing Director
bbubak@rtpcompany.com
(248) 914-0776

11:00 a.m.

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Understanding TPEs

Brandon Bubak
Sales & Marketing Director

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Winman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

Workshop Goals

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

1. Establish a definition
2. Understand how TPEs work
3. Classification & nomenclature
4. Performance
5. Compounded TPEs

Definition

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

ThermoPlastic Elastomer

"…Having the property of softening or fusing when heated and of hardening again when cooled…"

"…Any of various elastic substances resembling rubber…"

Int'l Inst. of Synthetic Rubber Producers (IISRP) definition:

"Polymers, polymer blends or compounds which, above their melt temperatures, exhibit thermoplastic character that enables them to be shaped into fabricated articles and which, within their design temperature range, possess elastomeric behavior without cross-linking during fabrication. This process is reversible and the product can be reprocessed and remolded."

How TPEs Work

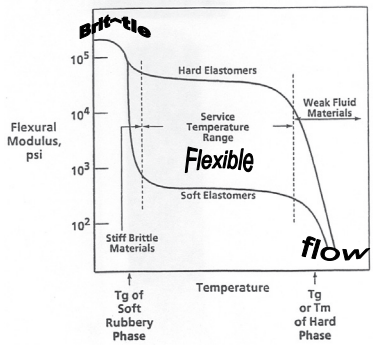
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

TPEs are composed of hard and soft domains; they are multiphase materials in their solid state.

- Hard phase contributes "plastic" properties such as:
  - High-temperature performance
  - Thermoplastic processability
  - Tensile strength
  - Tear strength
- Soft phase contributes "elastomeric" properties:
  - Low-temperature performance
  - Hardness
  - Flexibility
  - Compression & tension set

But Why Are TPEs Rubbery?

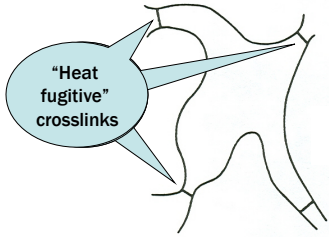
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



The design temperature range of a TPE is bounded by the glass transition temperature of the rubbery phase and the glass transition or melt temperature of the hard phase.

So, How Can TPEs Be Melt Processable?

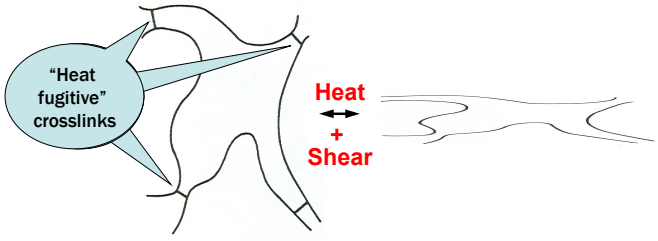
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



By raising the temperature of the TPE above the glass transition or melting temperature of the plastic phase.

So, How Can TPEs Be Melt Processable?

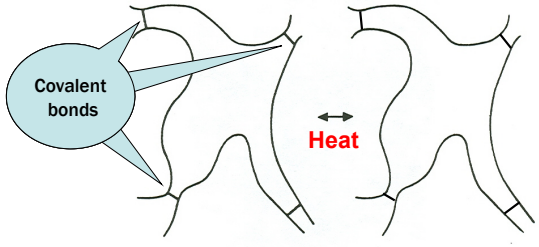
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



And applying shear forces typical of thermoplastic processes.

Unlike Thermoset Rubber...

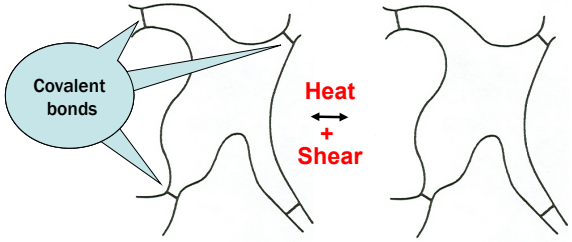
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



By comparison, thermoset rubbers (TSRs) are single phase materials with non-reversible chemical (covalent) bond cross-links.

Unlike Thermoset Rubber...

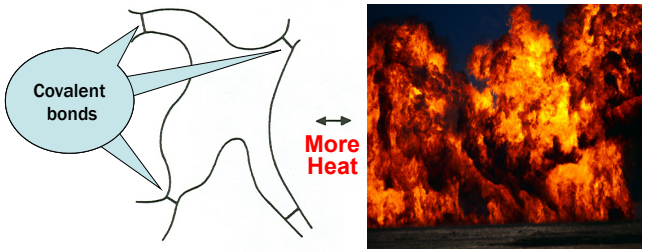
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



And are unaffected by shear forces.

Unlike Thermoset Rubber...

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Or increasing heat...

Classification & Nomenclature

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Performance (heat & oil resistance following ASTM, SAE, etc.)**
- **Chemistry (styrenic, olefinic, urethane, etc.)**
- **Structure**
  - Block copolymers
  - Blends & alloys
  - Dynamic vulcanizates

Architecture of Block Copolymers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Polymers – molecular chains of repeating units**

  a-a-a-a-a-a-a-a
- **Copolymers – polymer made up two or more different units along the chain**

  a-b-a-b-a-b-a-b
- **Block copolymers – copolymers in which the different units congregate in clusters or blocks**

  a-a-a-a-b-b-b-b-a-a-a-a-b-b-b-b

Block Copolymers - Mechanism

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

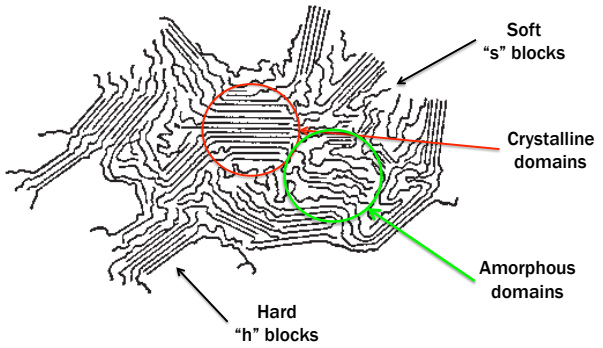
- Block copolymer based TPEs are made of polymers that have both hard (semi-crystalline or glassy) blocks and soft (amorphous) blocks along the backbone

  s-s-s-s-s-h-h-h-h-h-s-s-s-s-s-h-h-h-h-

- In the bulk, as they cool from the melt, the hard blocks will coalesce into crystalline or glassy domains creating physical crosslinks
- The soft blocks are left to form amorphous rubbery domains that provide the elastomeric bridges between the crystalline domains

Block Copolymers - Morphology

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Block Copolymers - Examples

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Styrenic block copolymers "SBC"
  - SBS, SEBS, SIS, SIBS, SEEPS
  - Rarely used in their neat form
- Polyolefin elastomer "POE"
- Reactor thermoplastic olefins "r-TPO"
- Thermoplastic urethane "TPU"
- Copolyether-ester "COPE"
- Polyether-block-amide "COPA" or "PEBA"

Blends & Alloys - Architecture

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Blends of:

- Homopolymers and/or
- Copolymers
  either of which may be the elastomeric component
- Plasticizers
- Fillers
- Compatibilizers

Blends & Alloys - Mechanism

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- One of polymers has a melting or glass transition temperature well above room temperature
- In the bulk, as it cools from the melt, it will coalesce into crystalline or glassy domains creating physical crosslinks
- The other polymer forms the rubbery domains that provide the elastomeric character of the blend
- Fillers and plasticizers are generally excluded from the crystalline domains
- Compatibilizers - if used - concentrate at the interface of the crystalline & amorphous phases

Blends & Alloys - Morphology

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Discrete hard domains in a sea of soft elastomeric polymer
- Discrete soft elastomeric domains in a sea of hard polymer
- Co-continuous (interpenetrating) network of hard polymer entangled with soft elastomeric polymer
- What you get is a function of the relative surface energy of the polymers, volume fraction, and relative viscosity during mixing

[ref: Jordhamo, et.al., "Phase Continuity and Inversion in Polymer Blends and Simultaneous Interpenetrating Networks", Polymer Engineering and Science, April 1986, Vol. 26, No. 8]

Blends & Alloys - Examples

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Styrenic block copolymers "SBC"
  - SBS, SEBS, SIS, SIBS, SEEPS
  - Most frequently compounded with PP, PE, or POE
- Thermoplastic olefins "TPO"
- PVC / NBR blends
- Melt processable rubber "MPR"

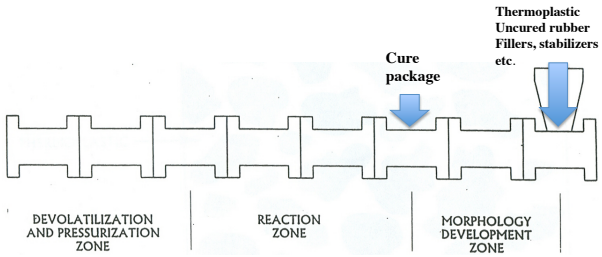
Dynamic Vulcanizates - Architecture

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Dynamic vulcanization is a process by which a cross-linkable material is cured in-situ during a melt mixing process
- The result is a dispersion of micron scale particles of cross-linked rubber dispersed in a polymer matrix
- With significant entanglement of the matrix polymer into the surface of the cured particles

Dynamic Vulcanizates – the process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

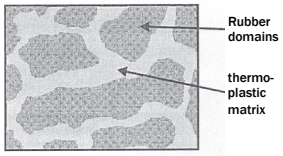


- Final product is process dependent
- Two phase morphology on a micro-scale

Dynamic Vulcanizates - Morphology

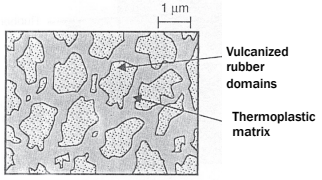
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Simple melt-mixing



Coarse *morphology - TPO*

Dynamic vulcanization



Fine *morphology - TPV*

Dynamic Vulcanizates - Mechanism

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- The thermoplastic polymer matrix has a melting or glass transition temperature well above room temperature but conducive to thermoplastic processability
- The concentration and modulus of the cured rubber particles is such that they impart the elastomeric character to the solid
- Entanglement of matrix material into the surface of the cured particles enables stress transfer between the phases

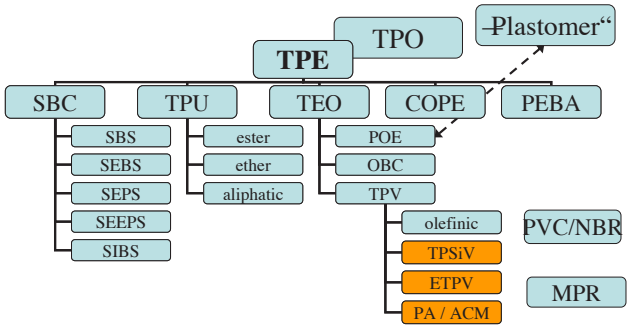
Dynamic Vulcanizates - Examples

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- PP / EPDM
- PP / NBR
- PA / ACM
- Silicone
  - PA matrix
  - TPU matrix
- COPE / ACM
- PVDF / FKM

Lineage (Alphabet Soup)

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



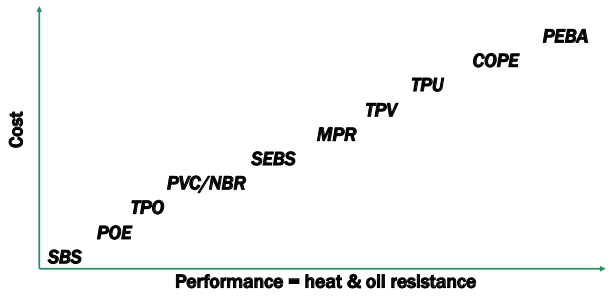
Performance

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- TPEs "possess elastomeric behavior" not thermoset rubber properties
- Performance should be considered in terms of part function, not material specification

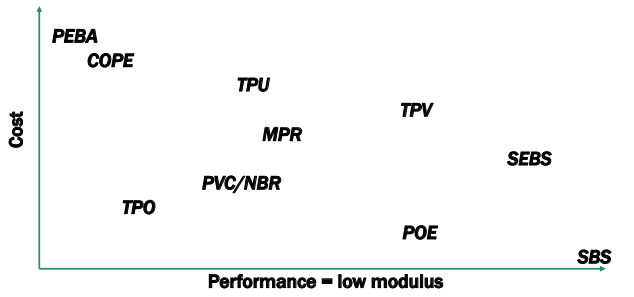
Relative Value of TPEs

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



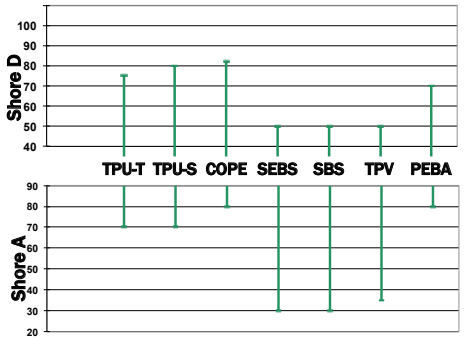
Relative Value of TPEs

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



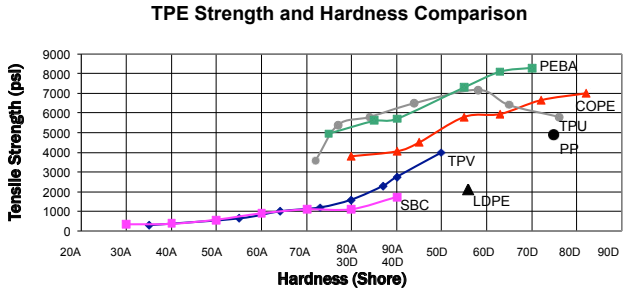
Performance – Hardness

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



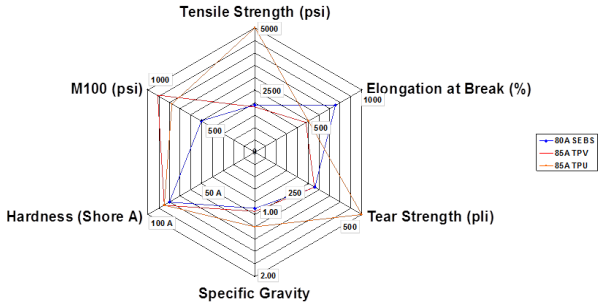
The Problem with Hardness

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



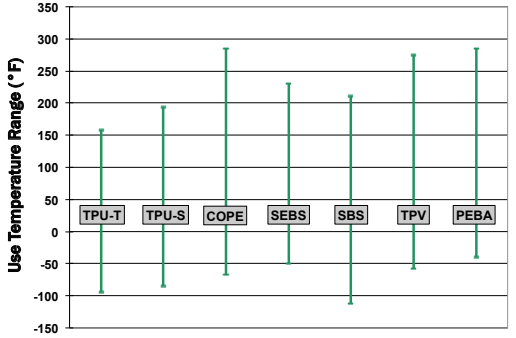
The Problem with Hardness

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



(Static) Use Temperature

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Performance - SBC

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Hardness range: Shore 00 (gels) – 40D**
  - SBC-based TPEs used in molded or extruded articles are compounds of SBC, olefin, oil, and (often) mineral filler
- **Strengths**
  - Lowest Tg of any TPE
  - Very soft and low stiffness compounds possible
  - Very high elastic limit and elongation at break
  - Translucency/clarity possible
- **Weaknesses**
  - Low continuous use temperature (210 - 230°F)
  - Poor chemical resistance (organic solvents/oils)

Applications - SBC

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Toothbrush handles & pen grips**
- **"Cause" bracelets & produce bands**
- **Injection molded synthetic wine corks**
- **Appliance knobs**
- **Light duty gaskets**
- **Vibration damping**
- **Gel inserts for shoes**

Performance – Olefinic TPV

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Hardness range: 35 Shore A – 50D**
- **Strengths**
  - Best balance of properties of all TPEs
  - Most rubber-like surface feel of all TPEs
  - Highly shear-thinning flow behavior provides an added dimension of process control
- **Weaknesses**
  - Opaque
  - Shear-thinning behavior yields process sensitivity
  - Crosslinked rubber domains are unavailable for additives incorporation

Applications – Olefinic TPV

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Automotive isolation systems -**
- **Extruded synthetic wine corks**
- **Industrial Power Tools**
- **Automotive sensors & airflow ducts**
- **Light duty power transmission belts**
- **Gaskets**
- **Rack and pinion boots**
- **Automotive weather seals**
- **Electric power transmission connectors & switch gear**

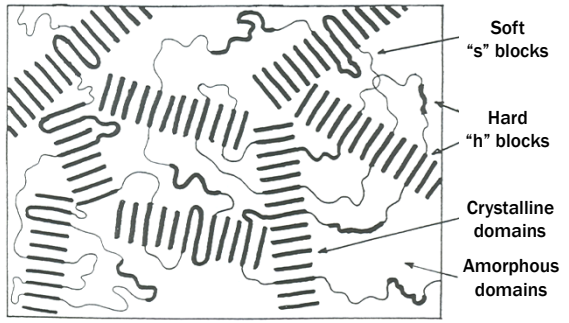
Performance - TPU

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Hardness range: 70 Shore A – 70D
- Strengths
  - Best abrasion and tear resistance of all TPEs
  - Very high strength vs. other TPEs of similar hardness
  - Excellent rebound & impact resistance
- Weaknesses
  - Processability
    - Drying is required
    - Hydrolysis, shear & thermal stability & tackiness can be problematic
    - Long cycle times
  - Peak performance is achieved by annealing the molded part (look at the hard blocks that haven't made it into the crystalline domains…)

Performance - TPU

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Applications - TPU

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Athletic shoe uppers and arches
- Roller blade & caster wheels
- Conveyor belts
- Ball joint boots
- Livestock ear tags
- Synthetic fletchings
- Medical tubing
- Prosthetic fingers
- Automotive shifter handle

Performance - COPE

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Hardness range: 75 Shore A – 75D
- Strengths
  - Highest use temperature of the most common TPEs
  - Excellent flex life
  - Easier to process than TPU
- Weaknesses
  - Generally stiffer than any other TPE of similar hardness
  - Lowest elastic limit of any TPE
  - Solvent / grease resistance is hardness dependent

Applications - COPE

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Semi truck wiring harness
- Constant velocity joint boots
- Coiled pneumatic tubing
- Light duty low noise gears
- Boxed wine & detergent dispensers
- Ski and snow shoe bindings
- Automotive clean & charged airducts (cold side)
- Gas cap tether
- Automotive mounting clip

Performance - PEBA

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Hardness range: 75 Shore A – 70D
- Used in specialty applications (catheters, ski bindings, breathable films, high-speed belting) where cost-performance is justified
- Strengths
  - Excellent flex life w/ low hysteresis
  - Good oil resistance at higher temperatures
- Weaknesses
  - Arguably not a TPE at all
  - Best properties correspond w/ highest hardness grades

Compounded TPE's

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Modification / customization of properties
  - Strength / stiffness (hardness)
  - Compression set / stress relaxation
  - Tear strength
  - Puncture resistance
- Aesthetics
  - Color effects (color, glow-in-the-dark, sparkle)
  - Laser marking effects
  - Feel (rubbery, soft & silky)

Compounded TPE's

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Processability
  - Viscosity adjustments
  - Two shot or overmolding adhesion
  - Cycle time improvements
- Value-added
  - Electrical conductivity (anti-stat, ATEX, EMI shielding)
  - Flame retardant (halogen free, RoHS compliance)
  - Abrasion & wear resistance / coefficient of friction
  - Specific gravity tuning
  - Structural reinforcement

The Future of TPES

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **TPEs are growing at double the rate of TP market**
  - "demand for TPEs to rise 5.5% per year through 2017"
    - Freedonia market study, "World Thermoplastic Elastomers", published August 2013
- **Key areas of growth continue to be:**
  - Rubber replacement through innovative design
  - Bondable TPE's for overmolding
- **The winners will be**
  - Rubber part suppliers who learn to process thermoplastic elastomers and
  - Thermoplastic part suppliers who learn to incorporate TPEs into part designs

What Does RTP Bring To The Table?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

The broadest offering of TPE chemistries –

- Styrenics
- Olefinics
  - Co-polymers &
  - Vulcanizates
- Thermoplastic urethanes
- Co-polyetheresters
- Co-polyamides
- Custom Alloys to fit an application

In conjunction with the most comprehensive slate of specialty additives around –

- Color effects
  - Edge glow
  - Laser mark
- Conductives
- Anti-stats
- Abrasion and wear resistance
- Flame retardants
- High gravity fillers

What to take away from today.

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **What is the operating temperature range for my application?**
- **What chemical and/or environmental exposures might there be?**
- **What are the key performance requirements for the application (beyond just shore hardness)?**

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Questions?

Brandon Bubak
bbubak@rtpcompany.com
(248) 914-0776

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Winan Corporation • + 1 320-259-2534
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

The Long and Short of it: VLF (Very Long Fiber)

Karl Hoppe
Senior Product Development Engineer
khoppe@rtpcompany.com
(507) 474-5367

1:00 p.m.

STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

The Long and Short of It: VLF (Very Long Fiber)

Karl Hoppe
Sr. Product Development Engineer
RTP Company

Presentation Overview

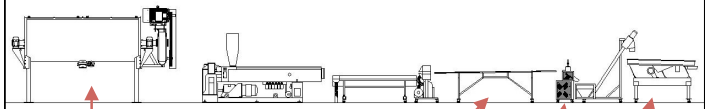
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Very Long Fiber (VLF) Intro
- Property comparisons
- Metal replacement
- Case studies

Standard Compounding Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

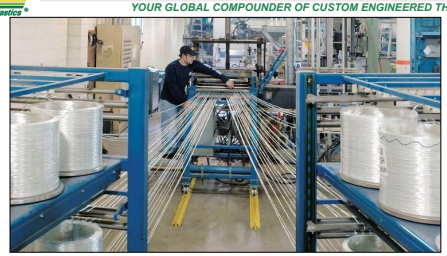
Raw Materials → *Finished Product*



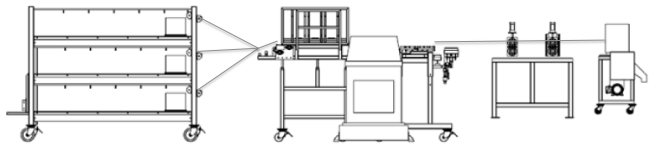
Blender *Extruder* *Cooling* *Pelletizer* *Classifier*

VLF Manufacturing Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

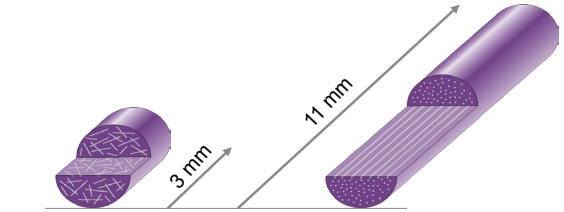


Fiber Extruder/Die Puller Pelletizer



Pellet Comparison

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Short Fiber **VLF**

Fiber Length
~ 1-2 mm **11 mm**

Advantages of Long Fiber

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

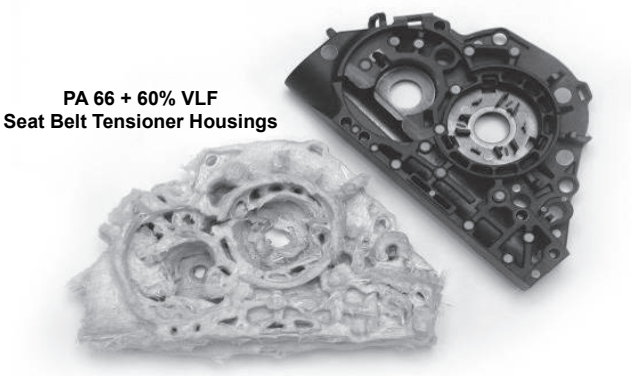
Impact Performance Strength/Stiffness

Creep resistance Reduced Warpage

Fiber Skeleton

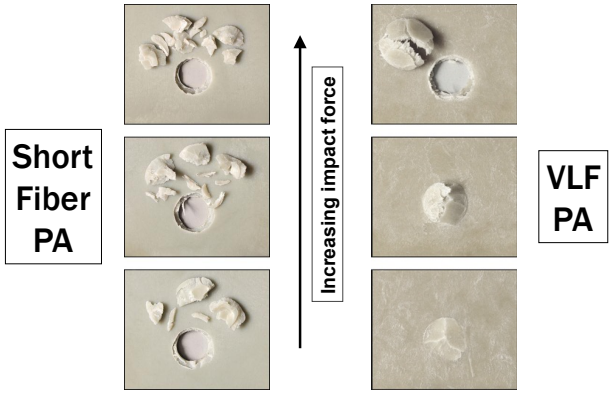
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

PA 66 + 60% VLF
Seat Belt Tensioner Housings



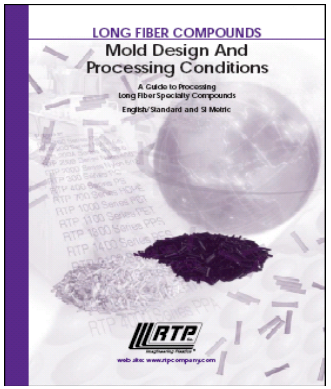
Drop Impact Test

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Molding Considerations

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Avoid starting with long fiber and finishing with short fiber!

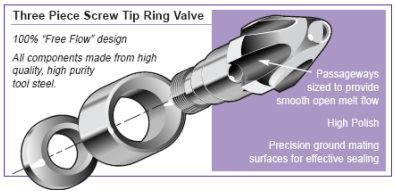
Molding Considerations

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

General guidelines:

1. General purpose screw OK (low compression preferred)
2. Reduce shear: low back pressure and rpm's
3. Reverse barrel temperature profile

preferred:



Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Recreation
Application: Side Block Plate
Problem: Dimensional stability due to moisture, mechanical performance
Solution: VLF Nylon 6/10
Benefit: Stiff and tough with low moisture absorption

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

First Question Break

Fiber Retention

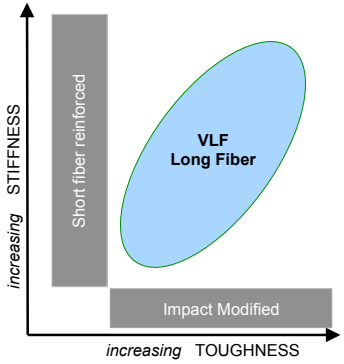
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

Property Comparisons

Strength/Impact Advantage

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

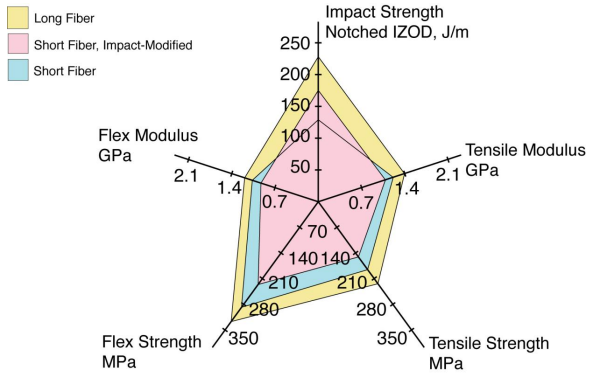


Polypropylene with 40% glass fiber

	short	LONG
Tensile Strength	90 MPa	120 MPa
Flexural Modulus	6.90 GPa	8.25 GPa
Notched Izod	100 J/m	270 J/m
HDT @ 1.8 MPa	140 ℃	155 ℃

PA 6/6 – 40 Glass Fiber%

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



PA vs. PP

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	30% Short Glass Polyamide 6/6		40% Long Glass PP
	(Dry as Molded)	(50% RH)	
Tensile Strength (MPa)	186	124	120
Flexural Modulus (GPa)	9.0	6.2	8.25
Izod Impact (J/m)	120	135	270
Specific Gravity	1.38		1.21
HDT (°C)	250		155

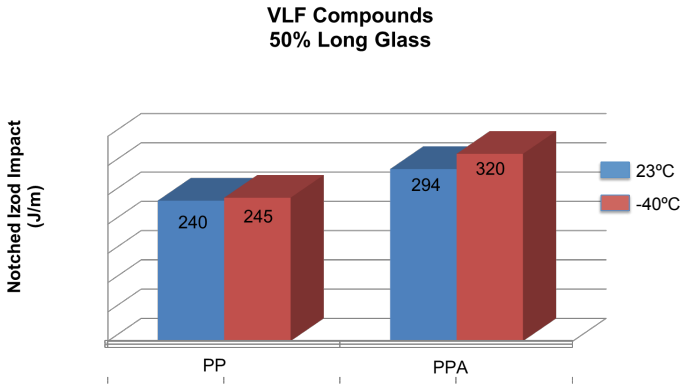
Application: Auto Shifter Base

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Automotive
Application: Shifter Base
Problem: Cost reduce from metal part
Solution: VLF PP
Benefit: Selected over Short Glass Nylon for better cost position. Net molded part offered part consolidation.

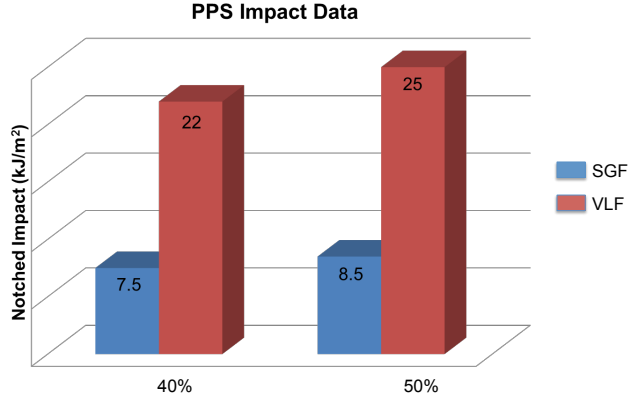
Low Temperature Impact

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



VLF PPS

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

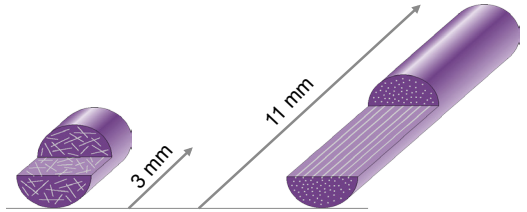


STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

Second Question Break

Pellet Comparison

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Short Fiber VLF

Fiber Comparison

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Short Fiber

VLF

STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

Metal Replacement

Metal Replacement Objectives

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Reduce cost
- Reduce weight
- Design freedom
- Corrosion and chemical resistance
- Sound and vibration dampening

ZAMAK

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **ZAMAK alloys are the designer's first choice when considering die casting.**
  - Z for Zink (zinc)
  - A for Aluminum
  - MA for Magnesium
  - K for Kupfer (copper)
- **ZAMAK 3: This is the most widely used general purpose zinc die casting alloy**

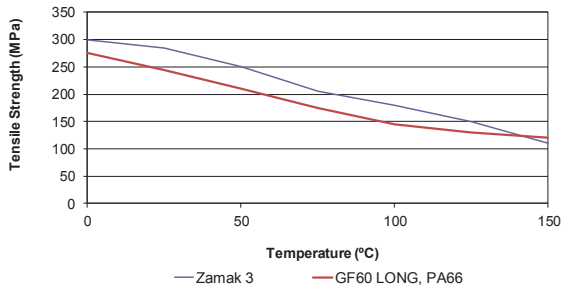
Instantaneous Properties at 23 °C

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	Zamak 3	60% VLF PA 6/6
Specific Gravity	6.6	1.7
Tensile Strength (MPa)	282	275
Flexural Modulus (GPa)	85.5	19.3

VLF PA6/6 vs. ZAMAK 3

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Application: Fastening Tool

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Industrial

Application: Fastening Tool

Problem: Metal design too heavy, slow to fire and reload

Solution: VLF Nylon

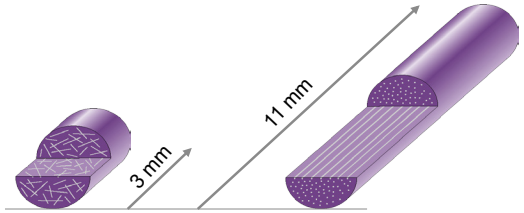
Benefit: Redesign in VLF Nylon reduced weight and improved efficiency for reloading and firing, also reduced worker fatigue.

STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

Third Question Break

Pellet Comparison

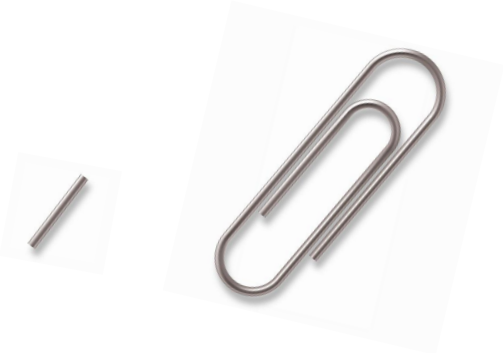
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Short Fiber **VLF**

Fiber Comparison

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

Combining Technologies

Combining Technologies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Polymers	Additives	Long Cut dry blends
PEEK PPS PBT TPU PP PA PC	Your color – Your way Impact enhancement Flame retardants Wear & lubricity Heat stabilizers Nano particles UV resistance Conductivity Taggants Spheres Anti-stat	

Application: Axe Handle

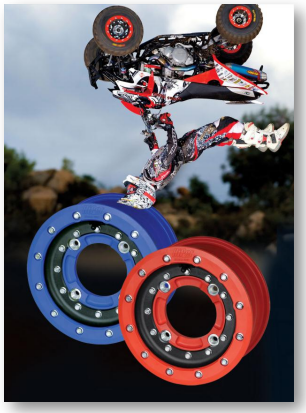
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Consumer
Application: Axe Handle
Problem: Wood handles lack innovative design, ability to mass produce
Solution: VLF PP/TPE overmold
Benefit: Strength and stiffness with compatibility with TPE overmold for ergonomics.

Application: ATV Bead Lock Rings

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Recreational Vehicle
Application: Bead Lock Ring
Problem: Carbon fiber material too expensive
Solution: Impact Modified, VLF Nylon
Benefit: Improved ductility over standard VLF. Offered cost-effective, colorable solution to previous material



Summary

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Increase impact, retain stiffness
- Take advantage of plastic design
- Combine technologies

STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

Thank you!

Driving Solutions to Clear the Fog from Light Diffusion

Anna Kreofsky
Color Division R&D Engineer
akreofsky@rtpcompany.com
(507) 474-5382

1:00 p.m.

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Driving Solutions to clear the fog from Light Diffusion

Anna Kreofsky
Color Division R&D Engineer
RTP Company

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

ISO 9001

Today's topics

- **Introducing RTP's Color Division**
  - More than color
  - Common measurement scales
  - Equipment
- **Light Diffusion**
  - Product families
  - Applications
  - Design pathway
- **Related technologies brief**
  - Near infrared attenuation
  - Laser Welding
  - Laser Marking
- **Questions**

RTP Automotive

Instrument Panels
Retainers
Center Stacks
Back-lit buttons and Switches

Sunroofs
Rails
Slides
Housings

Seating
Arm Rests
Seat Pans
Slides
Handles

Airbag Retainers
Housings
Brackets

Door Systems
Module Carriers
Lift Components
Latches
Handles

Shifter Bases
Housings
Levers
Frames

Front End Modules
Carriers
GOR's
Cooling Modules

Pedal Boxes
Housings
Brackets
Wear Components

Sensor Housings
Drivetrain
Emission
Safety & Security

Drivetrain
Seal Rings
Thrust Washers
Bushings

Fuel Systems
Gas Caps
Clips
Connectors
Filler Tubes

RTP AUTOMOTIVE

Product Families

COMPREHENSIVE PRODUCT LINE


STRUCTURAL


WEAR RESISTANT


CONDUCTIVE


ELASTOMERS


FLAME RETARDANT


COLOR


FILM/SHEET

Compounds formulated to meet your needs

RTP Company Color Division

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Color virtually all resins**
  - Engineering resins
  - Styrenic resins
  - Polyolefin resins
- **Color in multiple formats**
  - Masterbatches
  - Precolored resins
  - Cube blends
- **Global color management**
  - Global color synchronization
  - Color standards
  - Fast color matching service

Coloring Options

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

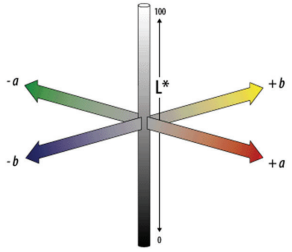
- **Masterbatches**
  - Custom
  - Standard Engineering
  - Unicolor
  - Commodity Blacks & Whites
  - Engineering Blacks for Sheet
- **Precolor**
- **Cube blend**
- *Your Color – Your Way*

Color Specification & Tolerances

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Numeric Color Modeling

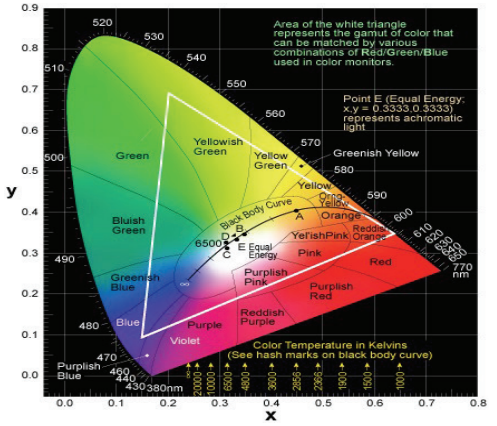
- **CIE L*a*b* is most popular**
- **Numeric model provides**
  - 3 dimensional color space
  - Quantify colors numerically
  - Can be used for specification, identification, comparison
- **Identified by L* a* b* values**
  - L* = lightness to darkness
  - a* = redness to greenness
  - b* = yellowness to blueness
  - DE = total color difference



$$DE = \sqrt{DL^{*2} + Da^{*2} + Db^{*2}}$$

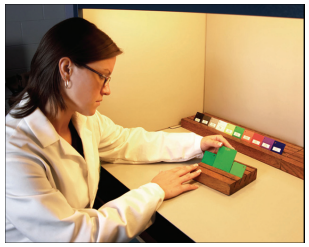
CIE 1931 xy

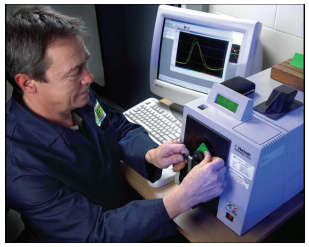
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Color Evaluation & Control

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



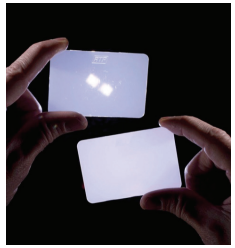


Visual Color Evaluation
- Confirmed color vision
- Color standards for reference
- Controlled light
- Agreed upon color space

Instrumental Color Evaluation
- Calibrated machine
- Color standards for reference
- Controlled temperature
- Agreed upon color space

Light Diffusing

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



- Electronics, outdoor lighting & signage, automotive
- More consistent and pleasing light for consumers
- Eliminates Hot Spots
- LED Color Variation
- Protects/hides light source
- Expands Design Space
- Popular for LEDs
- PC, Acrylic

Light Diffusion

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Two basic automotive applications…

  Attenuation and color

Various buttons

HVAC Displays

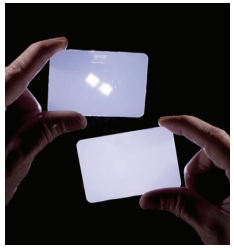
Light Diffusion

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Or is it three?

  How do we eliminate projected “hot spots”?

  Light pipes are used to direct source lighting, balancing output to achieve a consistent harmonious display!



Light Diffusion Types

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Brilliant

Emergence & Chromergence

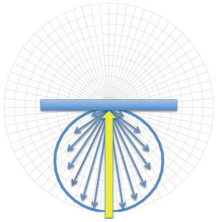
Veil & Eclipse

Pure

Brilliant

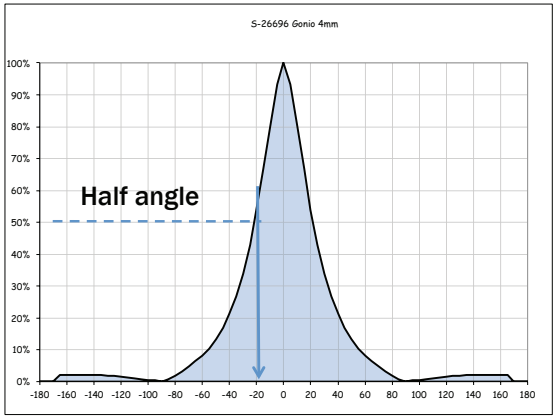
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Features**
  - High opacity
  - 95%+ reflectivity
  - Spectrally neutral
- **Common Uses**
  - LED Reflectors
  - Light boxes for LCD backlighting
  - Illuminated pushbutton actuators
  - Reflective light guides
  - Light isolators



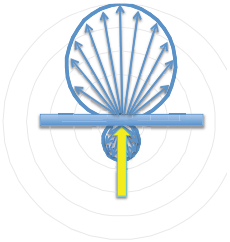
Orthographic plot of light scatter data

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

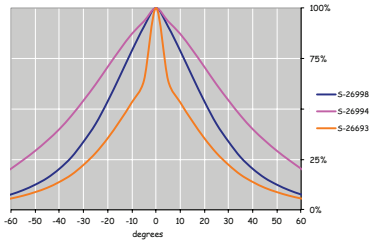


Wide Angle Diffusion

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



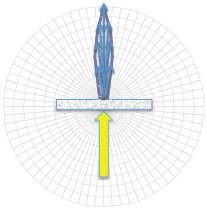
Example of Veil
Luminance vs. viewing angle

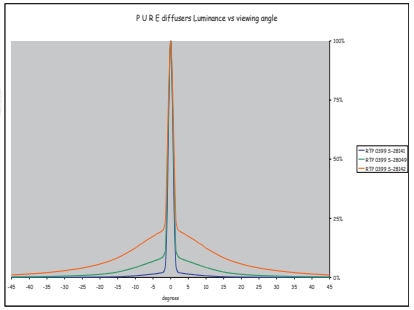


Narrow angle diffusion

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Example of Pure Luminance vs. viewing angle

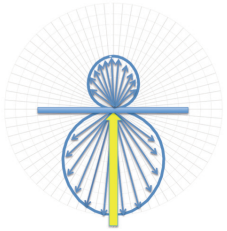




Emergence & Chromergence

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Features**
  - High contrast
  - Easily backlit
  - Tunable transmission
  - Neutral or tuned
  - Laser etch-able, paintable, printable
- **Common Uses**
  - Multi-shot graphics
  - Illuminated Indicators
  - Graphics with LED color correction
  - Paint and laser etched graphics in white and colors



Veil & Eclipse

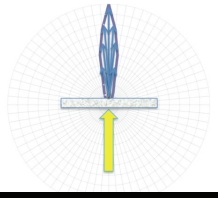
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

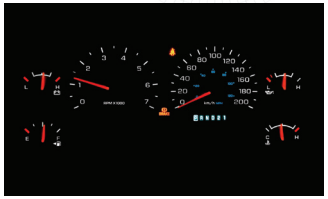
- **Features**
  - Wide angle diffuser
  - High transmission and efficiency
  - Laser etch-able, printable, paintable
  - Neutral transmission and/or color
- **Common Uses**
  - LED hotspot elimination
  - Hidden-until-lit graphics in color
  - LED color tuning diffusers
  - Substrate for surface decorated illuminated graphics

Pure

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Features**
  - Very high light transmission
  - Color tunable
  - Available in wide variety of scatter angles
  - from very narrow to wide angles
- **Common Uses**
  - Long light path light pipes
  - LED color correcting lenses
  - Point source softening elements
  - Complex light distribution covers





So how do we begin?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Data from LED bins used
- Actual LED on a PCB to be lighted at RTP
- Drawing with dimensions/thicknesses included
- OEM color and chromaticity specifications
- Painted clear chip if paint layer is involved
- Molded parts and data

RTP Company Typical Parameters

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Luminance tolerance of+/- 5 %
- Chroma tolerance of +/- 0.01 CIE 1931 x, y
- 1- 4mm specimen thickness
- Spectrophotometer for standard quality assurance needs
- Spectroradiometer for development and as needed QA

Typical button application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Daytime

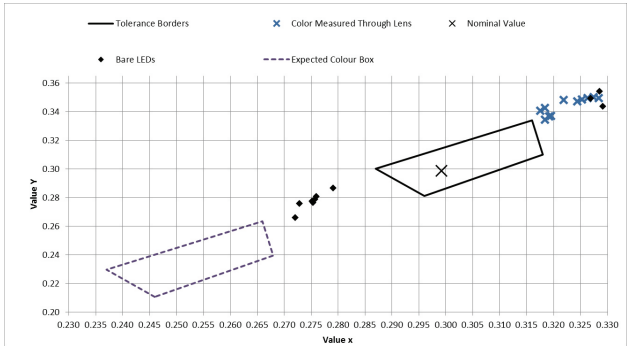
Reflected color of graphic Is determined by paint (or plastic) color.

Nighttime:

Back-lit color of graphic is determined by colors of light source, plastic, & paint.

Example: Color correction

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Our Resources

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Standard Products
  - Translucent White, Color Options, and 'clear or colorless'
  - Various levels of diffusion and optical performance
- OEM approvals on Lighting materials
- Specific Controls for manufacture and quality control
- Global Lighting Products Available
  - Local development with Global support
- Compounding Process for Lighting Materials
- Quality Assurance Controls for Lighting Materials

Challenges to overcome

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Missing or incomplete information
  - Changing targets
  - Lessons learned
- Limited access to light source
  - Light source is critical
  - PCB source is preferred
- Not enough data points
  - Often best to offer 2 or more samples for expediency
  - Sample plaques maybe used to define goals
- Distance of light path and part geometry

Communication is key

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

How do we share information?

- Luminance transmission
- Spectral transmission
- Most applications require reporting "Day and Night" performance
- X-Rite I7 Spectrophotometer
  - D65 SCI 10 degree, LAV
  - Black and white background defined thickness
- Minolta CS-2000
  - Preferred customer source
  - RTP source as alternative

Light Attenuating

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Block specific wavelengths
- Transmit at specific wavelengths
- Twilight sensors, remote controls

IR/NIR

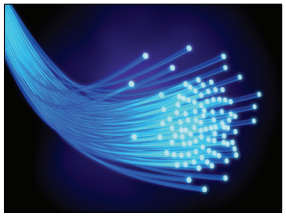
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Active 700 – 2500 nm range
- Transparent or opaque at specific wavelengths
- Combination of light controlling attributes
- Fiber optics
- Transmitters/receivers

NIR attenuation application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

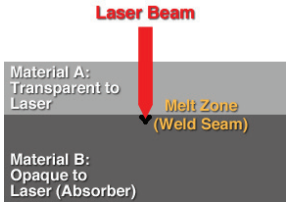
Market: Communications
Application: Fiber optic connector
Problem: Precise attenuation requirements
Solution: RTP Company pre-color NIR semi-trans black
Benefit: Precise attention at various target transmissions



Laser Welding

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

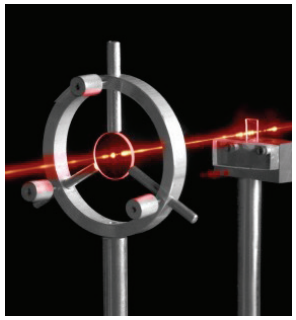
- **Method for joining thermoplastic parts by using the thermal power of laser to bond materials**
  - Useful when the parts being joined are delicate
  - High speed makes it valuable for bonding automotive plastic housings/sensors
  - Flexibility of the laser makes it ideal for complex shapes



Laser Welding of Thermoplastics

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

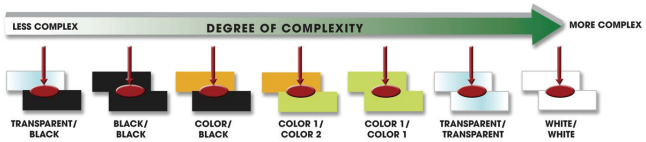
- **Advantages**
  - No contact with plastic part
  - Relatively high speed
  - Can weld complex parts
  - No flash is produced
  - High-precision joints can be produced
  - Gas-tight, hermetic seals are possible
  - Thermal distortion is minimal
  - Resins of different compositions can be joined
  - No consumables (adhesives, fasteners, etc.)



Laser Welding of Thermoplastics

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **The below chart indicates the degree of complexity for laser welding of various colors combinations**
- **RTP Company has experience with pigment/filler combinations, and loading levels, to support successful welding using both Diode and Nd:YAG lasers**



Laser welding application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Automotive
Application: Sensor housing
Problem: Cost efficient dependable bond in harsh environment
Solution: RTP Company structural Nylon 6:6 laser welding color
Benefit: Fast and consistent welding

Laser Marking

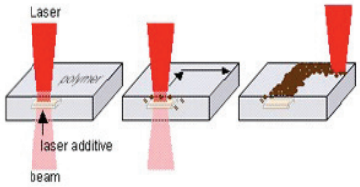
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Laser-marking can be achieved in conjunction with color and other additives
- Various commercial additives exist for FDA applications
- Unique colors achievable
- Dark or Light marks
  - Charring
  - Foaming

One Light – Two Marks

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Charring produces dark mark
- Foaming produces light mark



- Keypads, toys, medical, automotive
- FDA
- Combined with other technologies
- Unique colors achievable
- Dark or light marks

Laser Marking

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Different lasers can be used, but Nd:YAG (Neodymium doped Yttrium Aluminum Garnet is the best compromise of...
  - Speed
  - Flexibility
  - Marking quality
- For most applications

Laser Marking

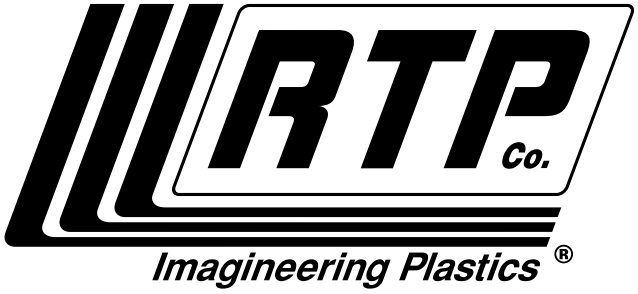
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Typical settings
  - Output power 20-25 amps
  - Pulse rate 5000-6000 Hz
  - Beam velocity 300-400 mm/s

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Questions?

Anna Kreofsky
akreofsky@rtpcompany.com
+1 507-474-5382



Plastic Design Principles for Structural Composites

Keith Scales
CAE Analyst
kscales@rtpcompany.com
(317) 473-2229

2:00 p.m.

STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

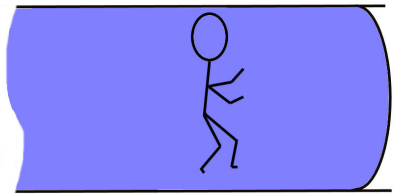
Plastic Design Principles for Structural Composites

Keith Scales
CAE Analyst

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Winan Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

ISO 9001

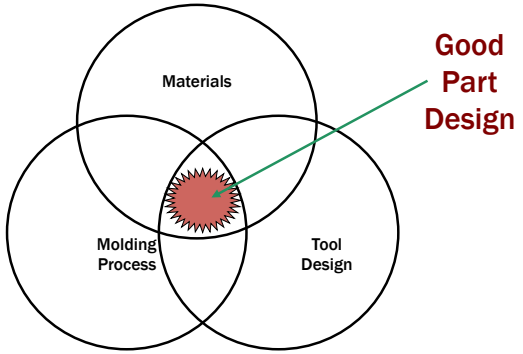
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Live in the Wall Section

Design for Injection Molding

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



What We Will Cover

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Material Issues/Concerns with Structural Composites
- Part Design Guidelines – Common Mistakes
- Warpage
- Structural Failures

Amorphous vs. Semi-Crystalline

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Random Structure	Ordered Structure
Broad Melting Point	Sharp Melting Point
Often Solvent Sensitive	Solvent Resistant
Impact Resistant	Fatigue Resistant
Low Shrink	High Shrink
Better Dimensional Stability	More Difficult Dimensional Control

Amorphous vs. Semi-Crystalline

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

ABS	Acetals
PC	Nylons
Polystyrene	Polyesters (PET, PBT)
Thermoplastic Urethanes	PP
PSU	PE
PEI	PEEK

Live in the Wall Section

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Many plastics are anisotropic

Plastics are non-Newtonian

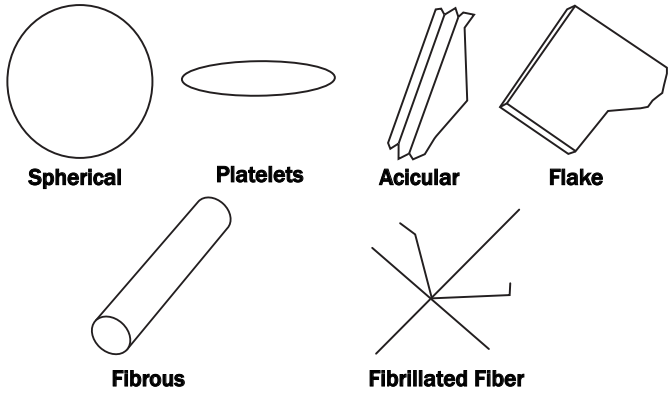
Isotropic vs. Anisotropic

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Isotropic: **Material properties (including shrink) are uniform in flow and cross-flow direction.**
- Anisotropic: **Material properties (including shrink) are not uniform in every direction.**

Filler & Reinforcement Geometry

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Filler/Reinforcement Classification

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Type	Geometry	Aspect Ratio	Classification
Glass Beads	Spherical	1	Filler
Clay	Platelet	1-3	Filler
Calcium Carbonate	Platelet	1-3	Filler
Talc	Platelet	2-5	Filler
Wollastonite	Acicular	5-20	Transition
Mica	Flake	30-50	Transition
Milled Glass	Fibrous	10-50	Transition
Glass Fiber	Fibrous	50+	Reinforcement
Carbon Fiber	Fibrous	50+	Reinforcement
Nickel Coated Carbon Fibers	Fibrous	50+	Reinforcement
Stainless Steel	Fibrous	50+	?
Aramid	Fibrillated Fiber	50+	Reinforcement

Properties Affected by Additives

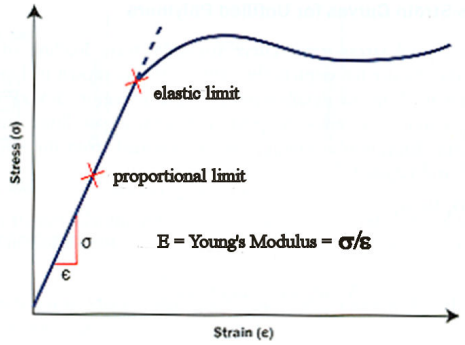
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Tensile Strength
Impact Strength

Specific Gravity
Viscosity
Thermal Conductivity
Specific Heat
Shrinkage

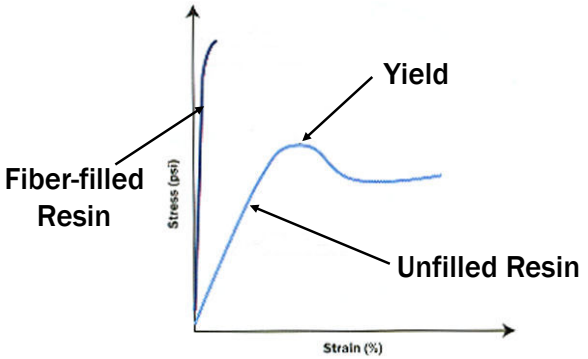
Stress-Strain of Polymers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Stress-Strain of Polymers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Stress-Strain of Polymers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

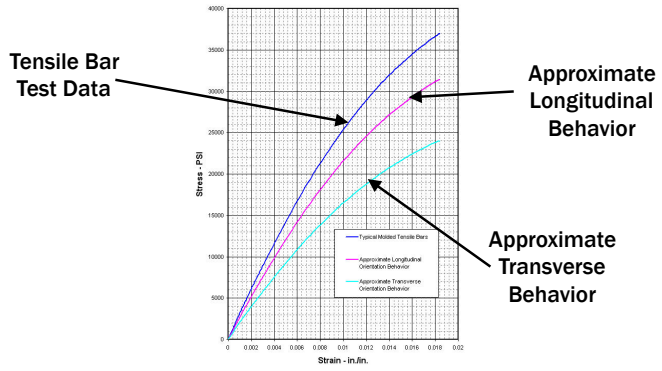
Dilemma:

Fiber filled materials are not isotropic

How do we account for this variation in mechanical properties during design?

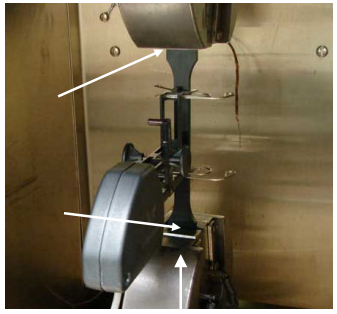
Bi-Directional Stress-Strain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Bi-Directional Stress-Strain

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



FEA of Filled Polymers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Recommendations:

When possible do analysis that considers fiber orientation – Moldflow followed by FEA

For FEA that doesn't use flow simulation inputs, use 60-80% of the modulus/strength to account for property variations

Viscosity of Polymers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Plastics are non-Newtonian

Viscosity varies not only with temperature but with shear rate

What is Shear Rate?

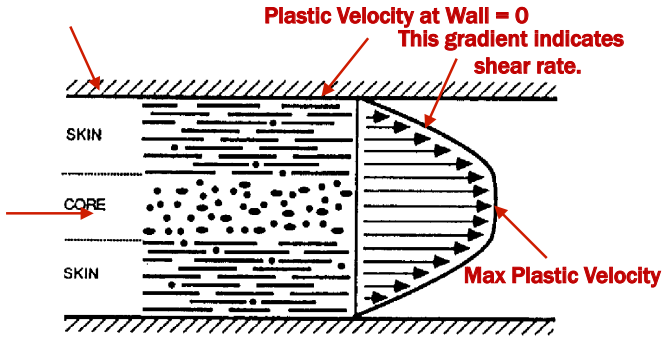
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Shear: Friction between moving plastic and the mold wall

Shear Rate: Velocity gradient in a flowing material

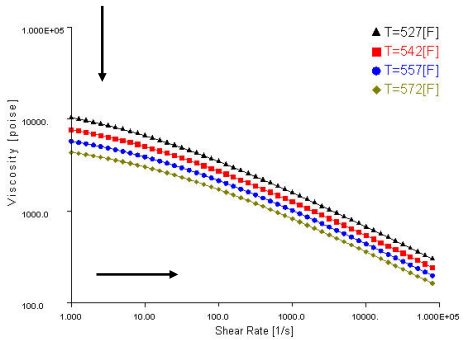
Injection Molding Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Viscosity of Polymers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Viscosity of Polymers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Important things that will affect viscosity:

Wall Thickness
Velocity
Temperature

Live in the Wall Section

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Many plastics are anisotropic

Plastics are non-Newtonian

What We Will Cover

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Material Issues/Concerns with Structural Composites
- Part Design Guidelines – Common Mistakes
- Warpage
- Structural Failures

Common Part Defects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Hesitation/Partialling
- Air/Gas Traps
- Weld Lines
- Warpage
- Sinks and Voids
- Structural Weakness or Failure

Common Part Defects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Hesitation/Partialling
- Air/Gas Traps
- Weld Lines
- Warpage
- Sinks and Voids
- Structural Weakness or Failure

Related to Fill Pattern

Common Part Defects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Hesitation/Partialling
- Air/Gas Traps
- Weld Lines
- Warpage
- Sinks and Voids
- Structural Weakness or Failure

Related to Fill Pattern, Cooling, and Packing

Common Part Defects

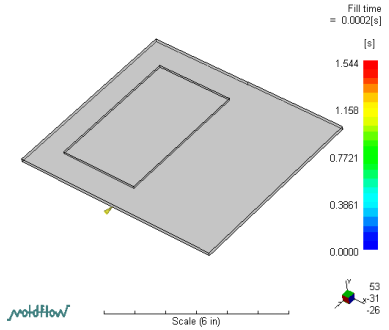
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Hesitation/Partialling
- Air/Gas Traps
- Weld Lines
- Warpage
- Sinks and Voids
- Structural Weakness or Failure

Related to Cooling and Wall Thickness

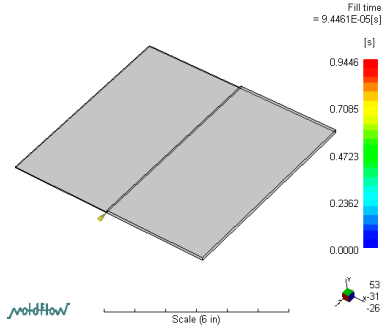
Hesitation/Racetracking

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



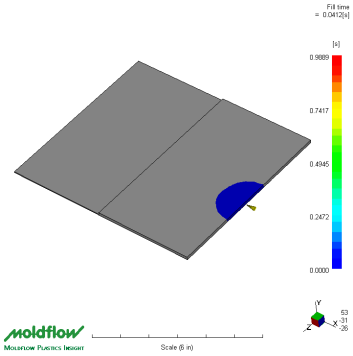
Hesitation/Gate Location

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



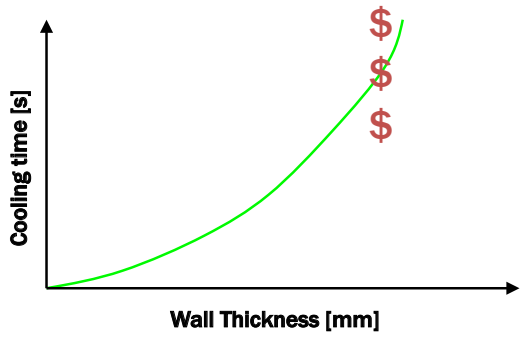
Hesitation/Gate Location

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



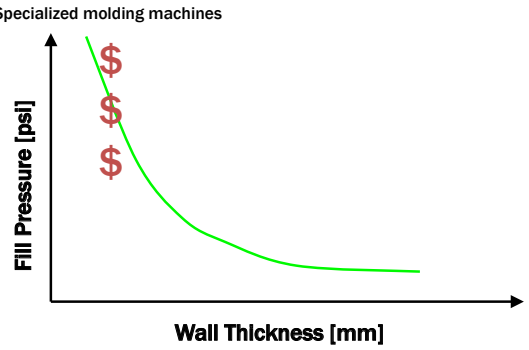
Effect of Wall Thickness

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



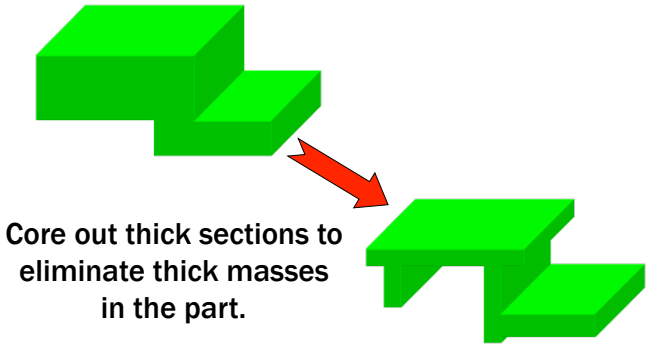
Effect of Wall Thickness

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Coring Out

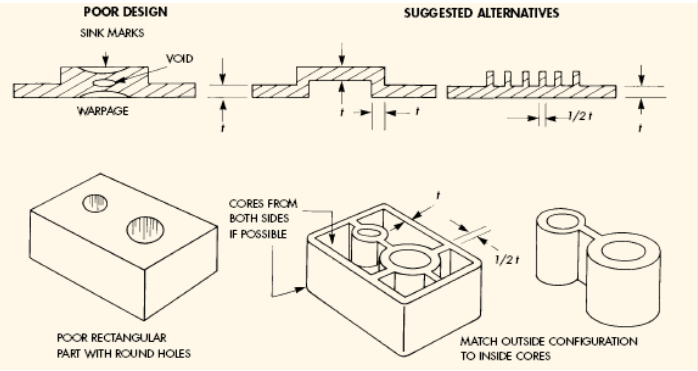
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Core out thick sections to eliminate thick masses in the part.

"Core Out" - Examples

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Part Design Guidelines

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Keep nominal wall less than 5mm (0.200")
- Avoid large variations in thickness
- Avoid abrupt changes in thickness
- Make thickness transitions gradual to avoid stress concentrations

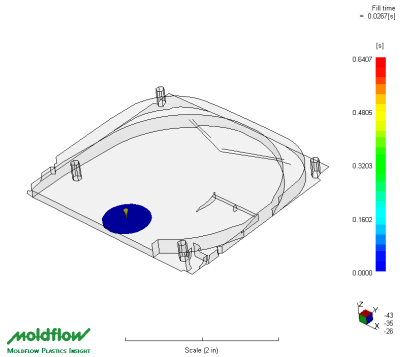
Part Design Guidelines

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Constant nominal wall simplifies fill pattern
- Constant nominal wall minimizes stresses and warp
- Avoid gating near areas with large variation

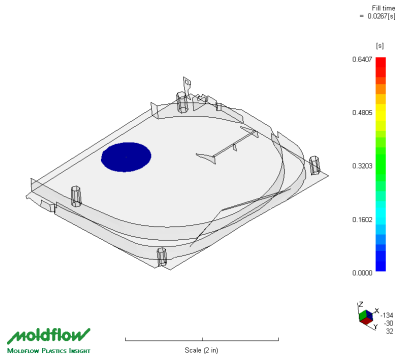
Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Sinks and Voids

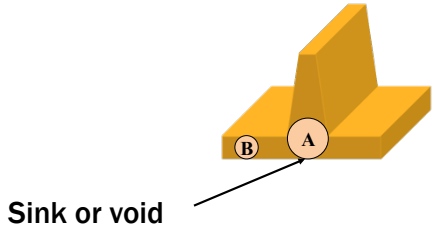
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Sinks and voids are both caused by wall sections that are too thick

Sinks are cosmetic flaws and voids can be structural weak points

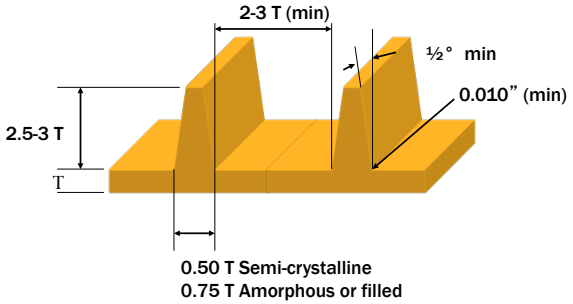
Sinks and Voids

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



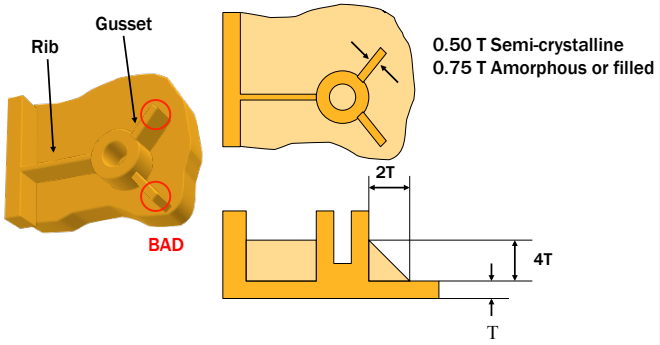
Recommended Rib Design

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



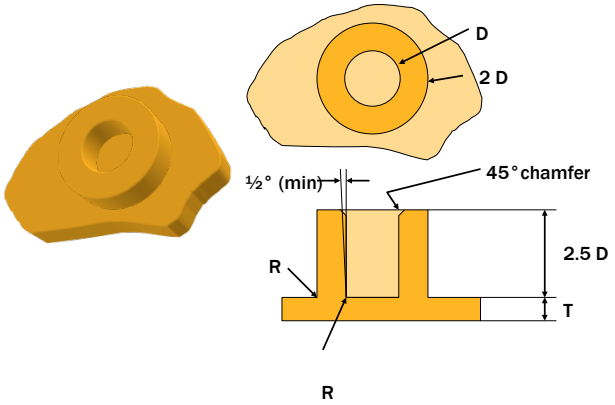
Recommended Gusset Design

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Recommended Boss Design

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



What We Will Cover

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Material Issues/Concerns with Structural Composites
- Part Design Guidelines – Common Mistakes
- Warpage
- Structural Failures

Warpage

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Shrinkage itself doesn't cause warp

Warp is caused by variations in shrinkage

Warpage

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Three Primary Causes

1. Non-uniform Cooling
2. Orientation Effects
3. Differential Area Shrinkage

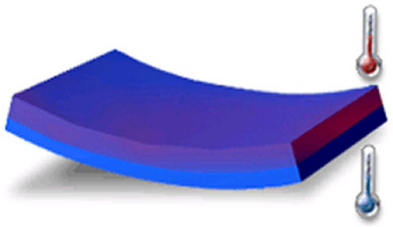
Non-Uniform Cooling

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

When the mold is hotter on one side than on the other side, the hotter side will take longer to cool so it will shrink more

Non-Uniform Cooling

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



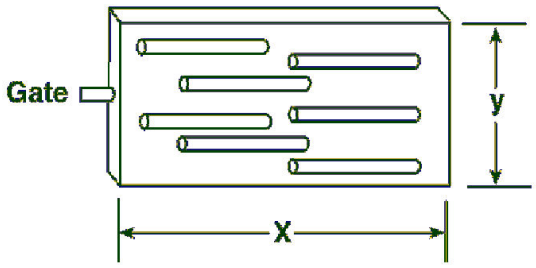
Orientation Effects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Some plastics shrink differently in the direction of flow than across flow

Orientation Effects

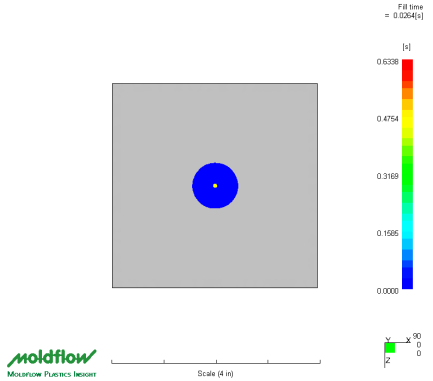
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Shrink Rate x ≠ Shrink Rate y → Warp

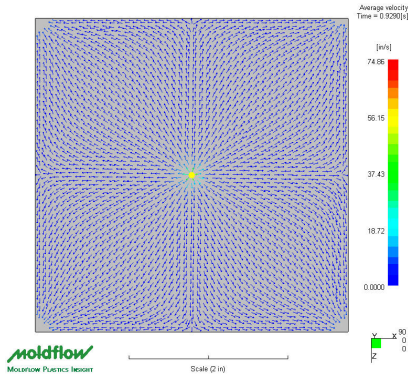
Orientation Effects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



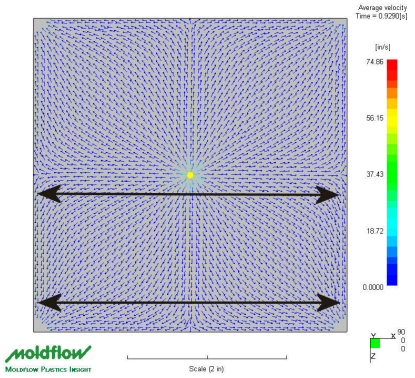
Orientation Effects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



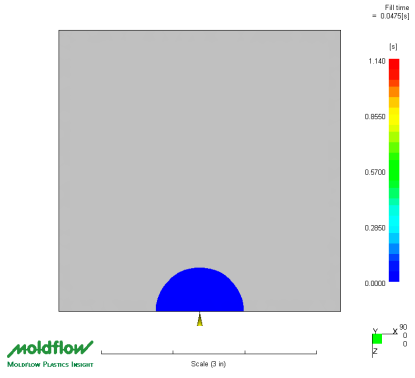
Orientation Effects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



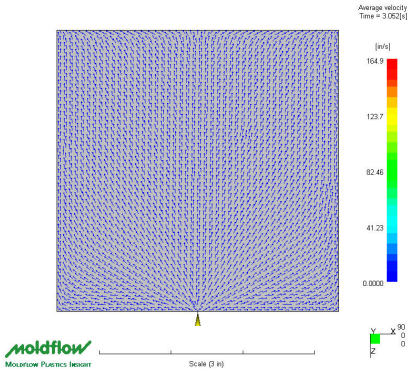
Orientation Effects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



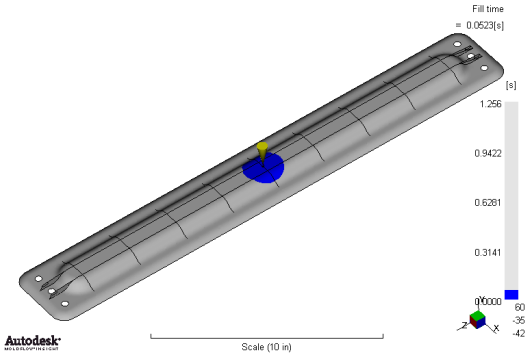
Orientation Effects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



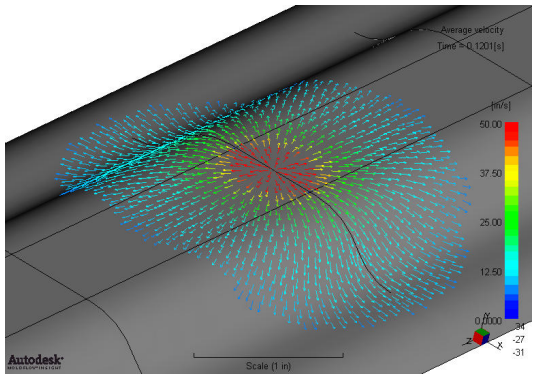
Orientation Effects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



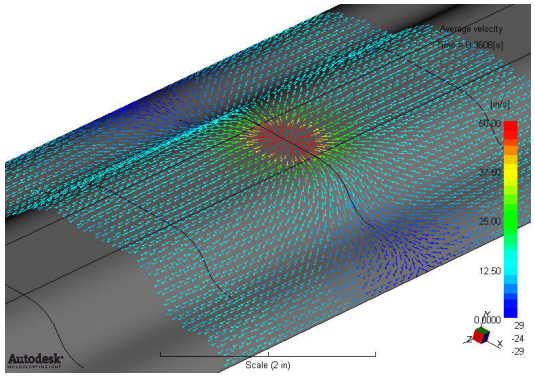
Orientation Effects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Orientation Effects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Orientation Effects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

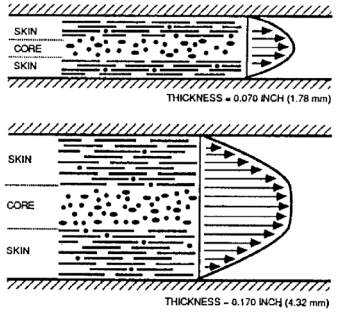
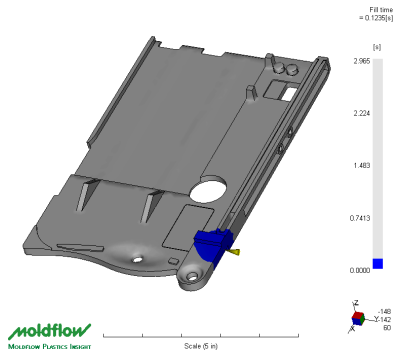


FIGURE 1 VELOCITY PROFILES AND THE RESULTING FIBER ORIENTATION

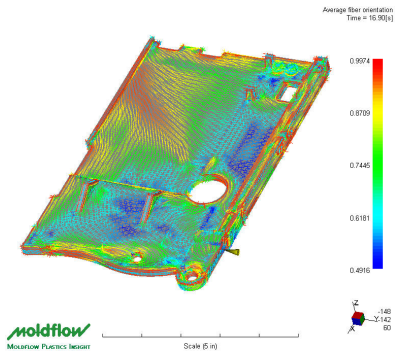
Orientation Effects Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



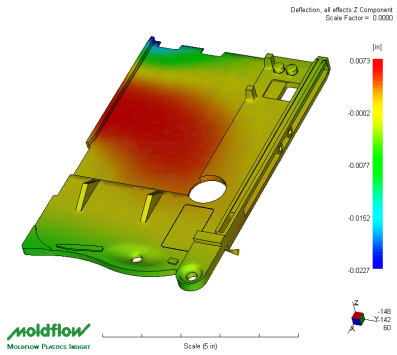
Orientation Effects Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Orientation Effects Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Example Conclusions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- The primary cause of the warp is orientation due to a non-uniform fill pattern
- A different gate location will not improve the fill pattern or improve orientation warp
- Reducing the warp will require either major part design changes or a material change

Design to Avoid Orientation Effects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Uniform wall thickness to allow simple fill pattern
- No major thin sections that could result in hesitation or racetracking

Reducing Orientation Effects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Gate for the most uniform flow
- Adjust molding conditions (often higher temps and faster injections will help)
- Adjust wall thickness
- Use more uniformly shrinking material (or sometimes a lower viscosity material)

Differential Area Shrinkage

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Variations in cooling rate result in variations in shrinkage
- Slower cooling results in higher crystallinity and more shrink
- Faster cooling results in less crystallinity and less shrink

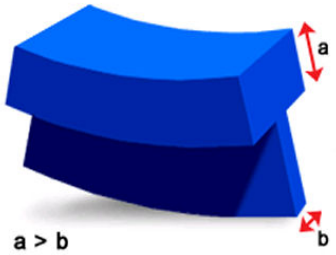
Differential Area Shrinkage

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Thick walls take longer to cool than thin walls resulting in non-uniform shrink
- More densely packed areas take longer to cool resulting in non-uniform shrink

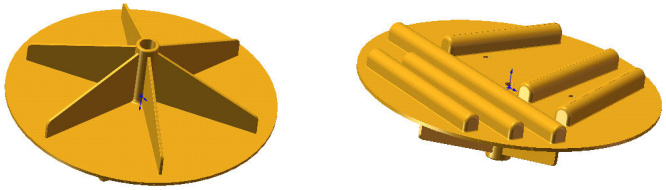
Differential Area Shrinkage

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



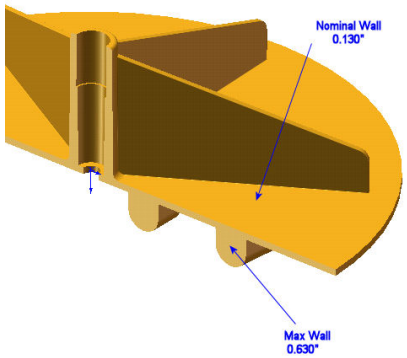
Differential Area Shrinkage Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



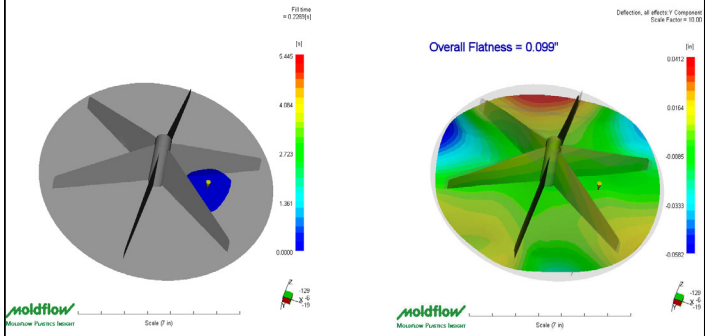
Differential Area Shrinkage Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



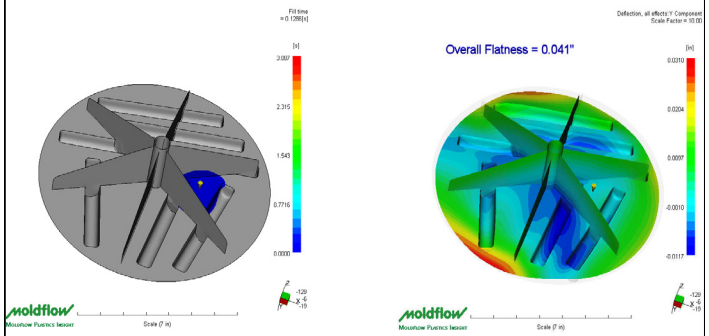
Differential Area Shrinkage Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



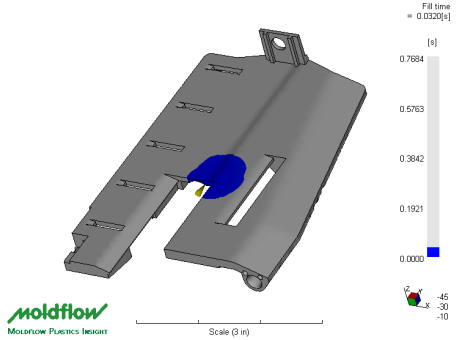
Differential Area Shrinkage Example

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



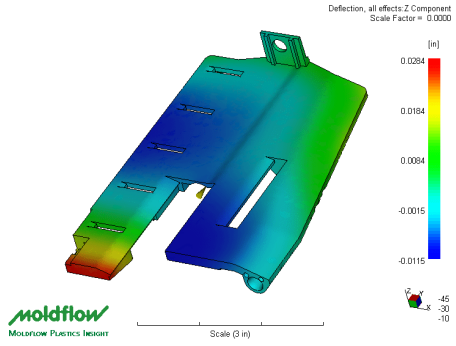
Original Gate Location – Fill Pattern

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



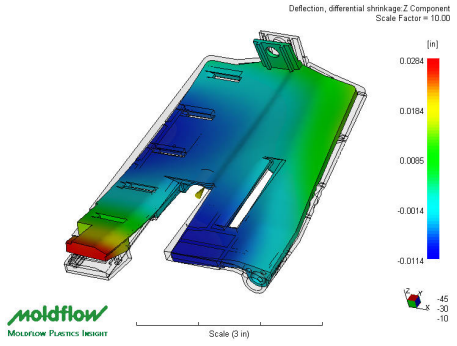
Original Gate Location - Warp

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



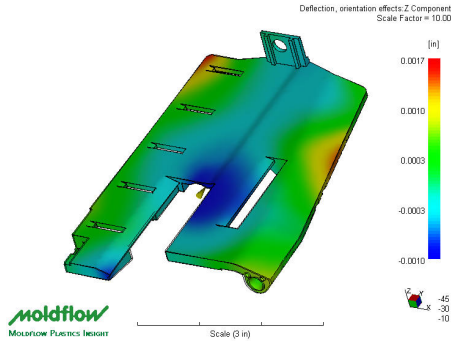
Warp Due to Differential Shrinkage

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Warp Due to Orientation Effects

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



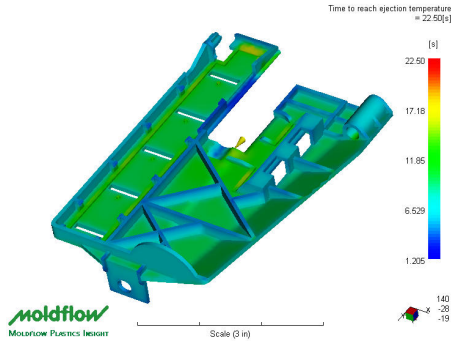
Conclusion

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

The primary cause of the warp is differential shrinkage

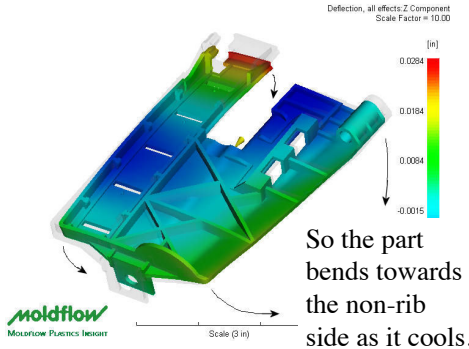
Explanation of Differential Shrinkage

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Explanation of Differential Shrinkage

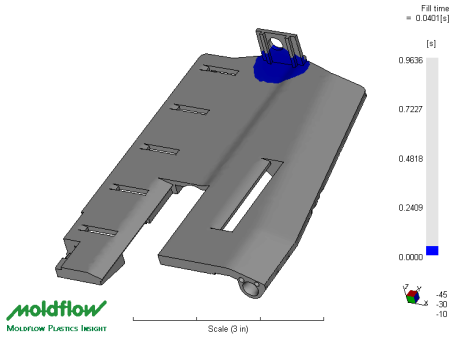
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



So the part bends towards the non-rib side as it cools.

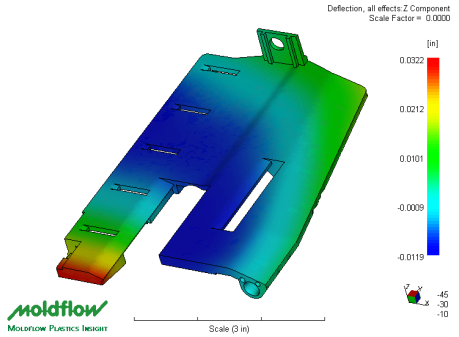
Opposite Gate Location – Fill Pattern

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Opposite Gate Location - Warp

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Conclusions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- The primary cause of the warp is differential shrinkage due to wall thickness variations
- A different gate location will improve the fill pattern but it will not improve differential shrinkage warp
- Wall thickness changes and packing pressure profiles may reduce warp

Part Design to Avoid Differential Shrinkage

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Uniform wall thickness to allow uniform cooling rate
- Balance thin ribs onto both sides of nominal wall

Reducing Differential Area Shrinkage

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Uniform wall thickness
- Lower shrink materials
- Adjust the wall thickness/rib structure
- Packing profile during molding
- Tooling inserts such as beryllium copper
- Move gate to allow packing of thick areas

What We Will Cover

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Material Issues/Concerns with Structural Composites
- Part Design Guidelines – Common Mistakes
- Warpage
- Structural Failures

Structural Weakness or Failures

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Mechanical failures happen when the loading of the part exceeds the capability of the material in a specific area

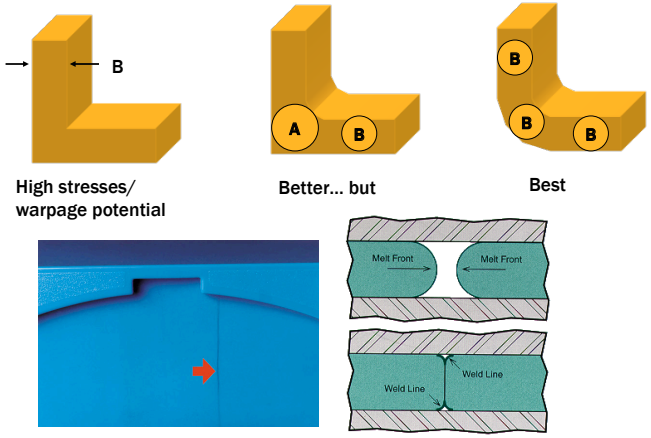
Common Structural Failures

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Stress concentrators (such a sharp edges or corners)
- Weld lines
- Poor fiber orientation
- Poor properties due to voids
- Wrong material

Common Structural Failures

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Design to Avoid Structural Failures

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Work with material supplier
- Radius corners and edges
- Thicker is not always better
- Gate to allow flow that orients fiber in the principal direction of the structural load

Other Structural Considerations

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Fatigue
- Creep
- Moisture, UV, temperature and other environmental concerns

Other Tooling Considerations

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Draft
- Surface Finish
- Undercuts
- Venting

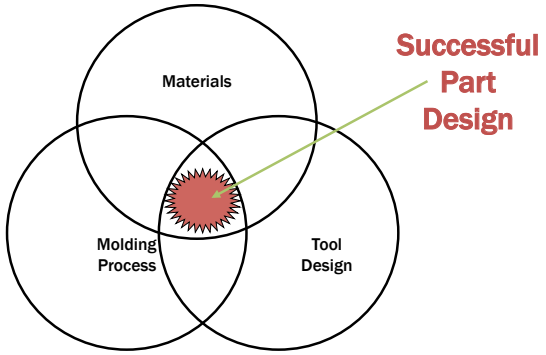
Summary

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Understand your material needs and understand the material
- Design parts with relatively uniform wall thickness
- Keep the fill pattern simple

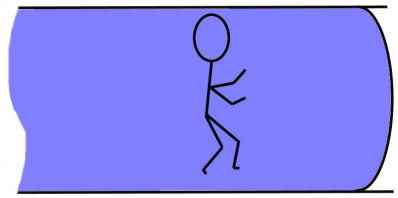
Design for Injection Molding

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

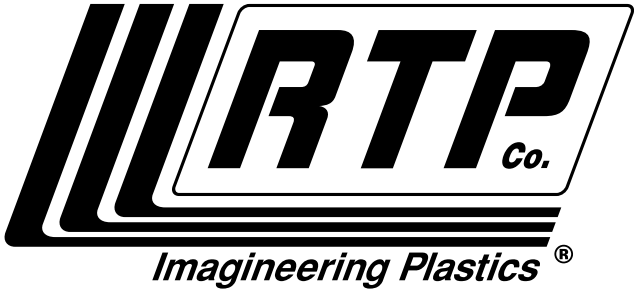
Live in the Wall Section!



STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

Questions?

Keith Scales
kscales@rtpcompany.com
(317) 473-2229



Fundamentals of Thermoplastic Wear and Friction

Ben Gerjets

Product Development Engineer
bgerjets@rtpcompany.com
(507) 474-5381

2:00 p.m.

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Fundamentals of Thermoplastic Wear and Friction

Ben Gerjets
Product Development Engineer

Wear Resistance

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Wear and Friction

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

"My application is wearing out!"

Fatigue?

Chemical Attack?

Abrasion?

Weather/UV Resistance?

Wear and Friction

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Be Specific!

- ***Wear*** – Sliding wear of thermoplastic compounds against a contact surface (steel, aluminum, other thermoplastics, etc.)
- ***Friction*** – Reducing/controlling the friction of this type of system above

Internally Lubricated Thermoplastics

Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

I. Definitions & Test Methods
II. Additive Technologies
III. Application Examples
IV. APWA Plus
V. Extreme Conditions

Definitions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Tribology

The Science of the mechanisms of friction, lubrication, and wear of interacting surfaces that are in relative motion

Tribologist, Tribological, Tribometer

Definitions Worksheet

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	Value	Typical Range
Wear		
Friction		

Definitions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Wear Recall: Sliding surfaces

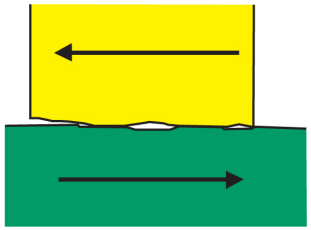
Loss of Material Over Time

Definitions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Adhesive Wear Mechanism

- The primary mechanism for thermoplastic wear
- Characterized by transfer of material from one part to the other caused by frictional heat

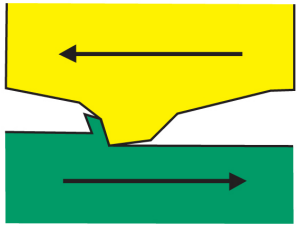


Definitions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Abrasive Wear Mechanism

- Caused by a hard material scraping or abrading away at a softer material
- Characterized by grooves cut or gouged into the surface
  - Three Body



Testing Wear Resistance

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Question: How do you simulate an application and test a material for **long-term** wear resistance?

Answer: Use **ASTM D-3702** wear test to quantify the amount of material a sample loses over time under specific conditions (pressure, speed, temperature)

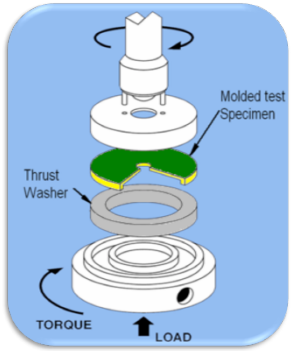
Wear Testing

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

ASTM D-3702 “Thrust Washer” Wear Test

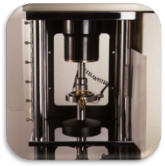
Rotating
Molded or machined sample

Stationary
Thrust washer
(steel, aluminum, plastic, etc.)



ASTM D 3702 "Tribometer"

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Wear Testing

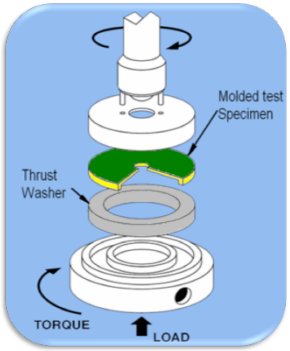
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

ASTM D-3702 "Thrust Washer" Wear Test

Adjustable:

- Counter-surface (thrust washer)
- Pressure
- Velocity
- Temperature

The best use of this test is to perform comparative screening of multiple candidate materials



Wear Factor (K)

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

$$K = W/(F \times V \times T)$$

K = Wear Factor: $(in^3\text{-}min/ft\text{-}lb\text{-}hr) \cdot 10^{-10}$ or $(mm^3/N\text{-}m) \cdot 10^{-8}$

W = Volume wear: in^3 or mm^3

F = Force: *lb or N*

V = Velocity: *ft/min or m/sec*

T = Elapsed time: *hr or sec*

100 Hour Test

Lower Value = Better Wear Resistance

Definitions Worksheet

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	Value	Typical Range
Wear	Wear Factor (K)	1 – 1000 *<75 Excellent*

ASTM D 3702 Notes

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **RTP Company has six thrust washer wear testing machines (Tribometers) in its wear lab**
- **Equipment is available to perform customer requested testing**
- **A test isn't always just a test**
  - Conditions matter!

Definitions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Standard conditions

- Steel thrust washer
- 40 psi · 50 ft/min
- Ambient temp
- 100 hour test

PV = (Pressure · Velocity)

Conditions often used together to characterize severity of a wear environment

2,000 = (40 psi · 50 ft/min)

Typical testing done at 2,000 to 10,000 PV

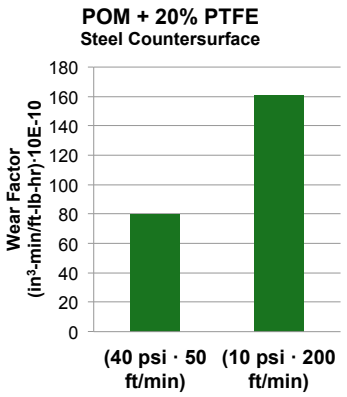
Wear Testing

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Wear data: typically shown at a specified PV**
  - Example: PV=2,000 (standard conditions)
    - 40 psi (P)
    - 50 ft./min(V)
- ***Question*: Does an equivalent PV always result in the same data?**
  - Consider PV=2,000 (nonstandard conditions)
    - 10 psi (P)
    - 200 ft./min (V)

Wear Testing

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Answer:

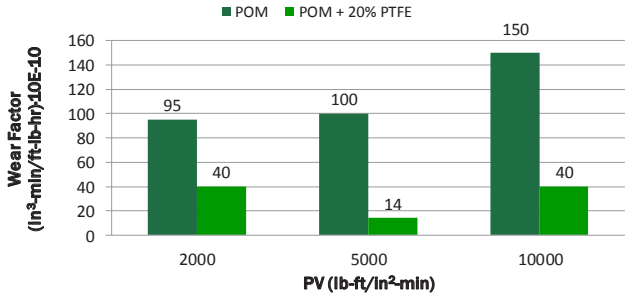
- No…Wear factor will change based on individual conditions.

- **Generalizations may be helpful, but not always equivalent.**

Wear Testing

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Wear factor generally increases with higher PV
(But not always!)



Wear per ASTM D 3702 against Steel

Definitions Worksheet

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

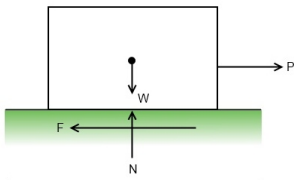
	Value	Typical Range
Wear	Wear Factor (K)	1 – 1000 *<75 Excellent*
Friction		

Definitions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Coefficient of Friction (μ)

- **Ratio of the force of friction between two bodies and the force pressing them together**



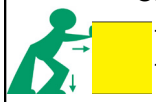
μ=F/N

Types of Sliding Friction

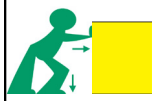
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Coefficient of Friction (μ)

- **Static coefficient of friction (μ_s) = Fx/Fy**
  - Fx = Force to *initiate* motion
  - Fy = Normal force holding surfaces together



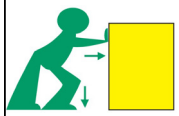
- **Dynamic coefficient of friction (μ_k) = Fx/Fy**
  - Fx = Force to *sustain* motion
  - Fy = Normal force holding surfaces together



Friction and Thermoplastics

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

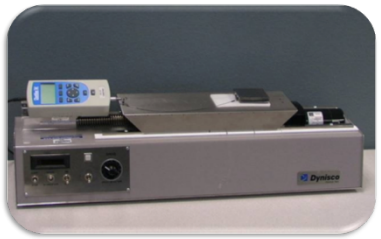
- In most non-plastic materials
  - $\mu_k < \mu_s$
- Thermoplastics are somewhat unique
  - $\mu_k > \mu_s$
- May cause "slip/stick"
- If $\mu_k >> \mu_s$ you may have squeaking



Friction Tests

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- ASTM D 1894 "sled test"
  - Coefficient of friction testing
  - Does not determine wear resistance
- Can show slip/stick



Definitions Worksheet

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	Value	Typical Range
Wear	Wear Factor (K)	1 – 1000 *<75 Excellent*
Friction	Coefficient of Friction (μ) -Static, Dynamic	0.05 – 0.9 *<0.2 Good*

Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

I. Definitions & Test Methods
II. **Traditional Additive Technologies**
III. **Application Examples**
IV. APWA Plus
V. Extreme Conditions

Traditional Additive Technologies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Additive Technologies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

PTFE – Polytetrafluoroethylene (5-20%)

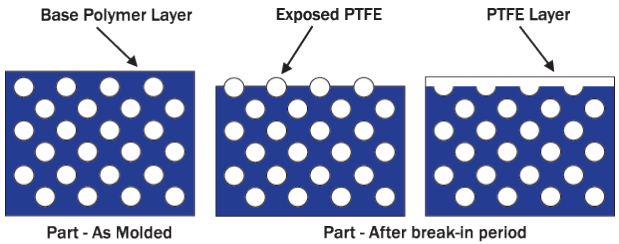
- Workhorse additive – solid white powder
- Homogeneously distributed throughout the polymer matrix
- Forms a lubricious layer at polymer surface – requires a "Break-in" period
- Compatible with nearly all thermoplastic resins

Limitations

- Fluorine content
- Die plate-out
- Relatively high loadings
- Becoming very expensive

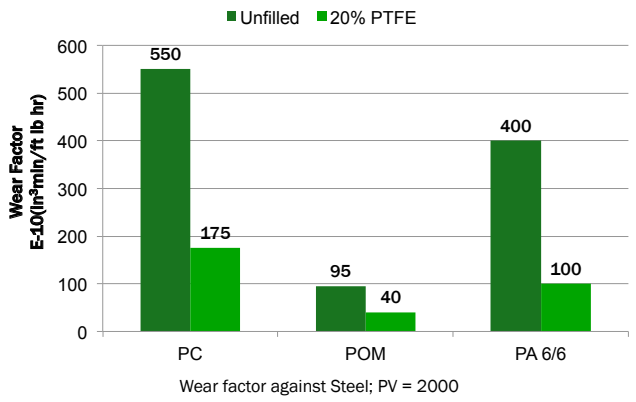
PTFE Wear Mechanism

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



PTFE Filled Compounds

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

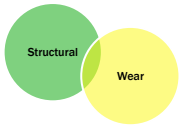


Business Machine Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Laser Printer Fuser Gears

- **Requirements**
  - Need for material with good wear resistance that can withstand high operating temperature
- **Solution**
  - Glass fiber reinforced and PTFE lubricated PPS



Additive Technologies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Additive Technologies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Silicone – Polydimethylsiloxane (1-3%)

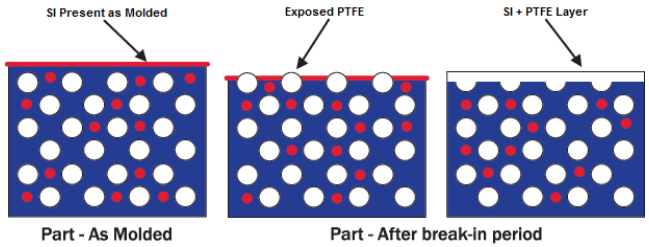
- Boundary lubricant which migrates to the surface over time
- Migration rate is viscosity dependent
- Excellent friction reducer
- Best in high speed/low load applications
- Used with PTFE to eliminate "Break-in" period

Limitations

- **Limited use in decorated parts**
  - Poor adhesion of paint or print inks
- **Bad for electrical applications**
  - Can foul contacts

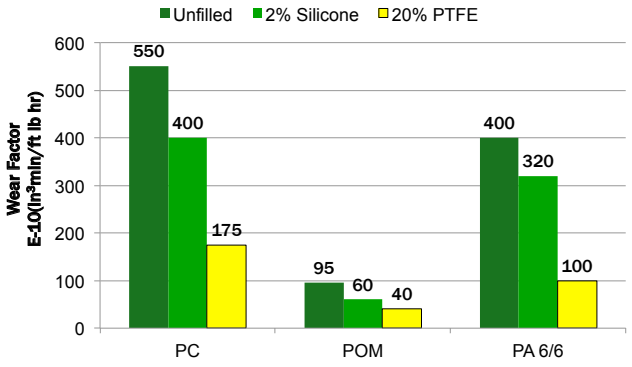
Additive Technologies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Wear Testing Results

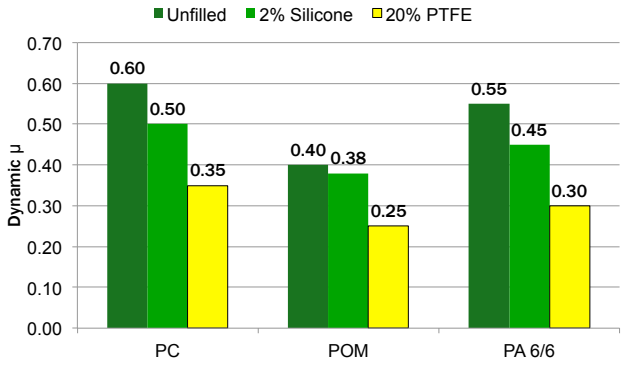
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Wear factor against Steel; PV = 2000

Friction Data

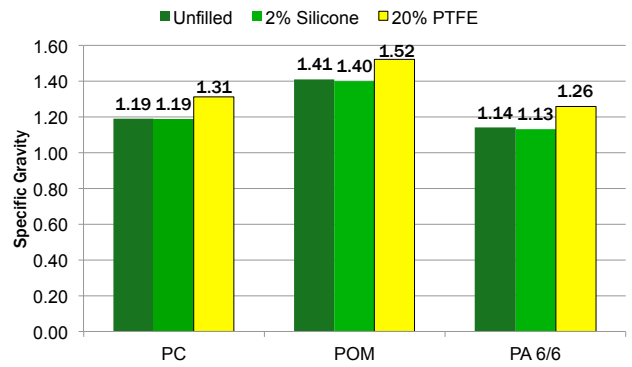
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Dynamic friction coefficient per ASTM D 3702 against Steel; PV = 2000

Specific Gravity Differences

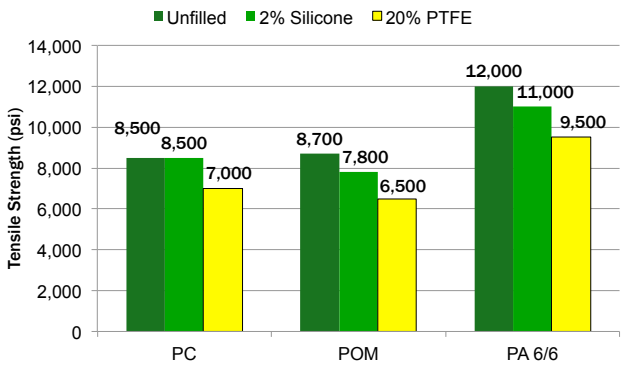
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Specific gravity per ASTM D 792

Tensile Strength Comparison

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Tensile strength per ASTM D 638

Physical Property Comparison

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	PC			PA 6/6			POM		
	Unfilled	PTFE (20%)	Silicone (2%)	Unfilled	PTFE (20%)	Silicone (2%)	Unfilled	PTFE (20%)	Silicone (2%)
Specific Gravity	1.19	1.31	1.19	1.14	1.26	1.13	1.41	1.52	1.40
Tensile Strength (psi)	8,500	7,000	8,500	12,000	9,500	11,000	8,700	6,500	7,800
Flexural Modulus (psi)	340,000	320,000	350,000	400,000	400,000	400,000	350,000	300,000	350,000
Notched Impact (ft-lb/in)	7.5	3.5	10.5	1.0	1.0	1.0	1.5	1.0	1.5

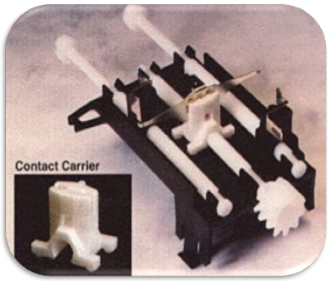
Values per ASTM test methods

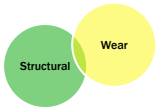
Industrial Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Garage Door Opener Limit Switch

- **Requirements**
  - Dimensional stability and good strength and stiffness
- **Solution**
  - Silicone lubricated PC





Medical Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Drug Delivery Pen Components

- **Requirements**
  - Good strength, dimensional stability and lubricity
- **Solution(s)**

PTFE or PTFE/ silicone lubricated PBT or POM

Fiber reinforced and PTFE or PTFE/ silicone lubricated PC or PBT

Additive Technologies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

PFPE

Graphite Powder

MoS_2

Fibers

Additive Technologies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

PFPE – Perfluoropolyether Oil (< 1%)

- Thermally stable up to PEEK processing temps
- Differentiates RTP Company from others
- Physical properties maintained
- Minimized die plate-out
- Synergy with PTFE
- Specific gravity benefits
- Improved fatigue resistance

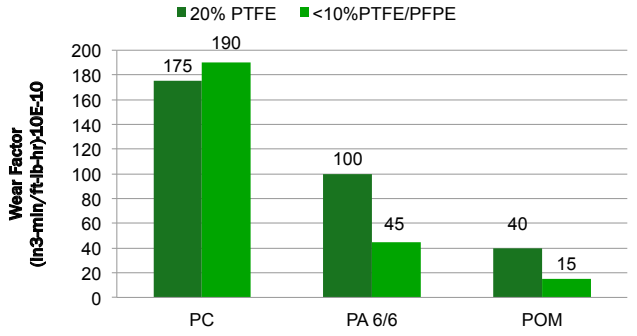
Limitations

- Limited effectiveness in amorphous resins
- Needs PTFE "kick" to deliver optimum friction reduction

Polymers and Additives

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

PFPE allows for a reduction in PTFE loadings



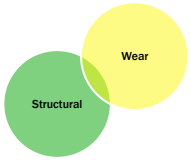
Wear per ASTM D 3702 against Steel, PV = 2000

Industrial Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Agricultural Pump

- **Requirements**
  - Chemical and Wear Resistance
- **Solution**
  - PFPE lubricated PP

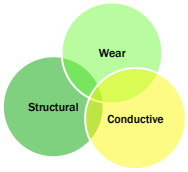


Industrial Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Universal Conveyor Roller

- **Requirements**
  - Strength, conductivity and wear resistance (must be silicone-free)
- **Solution**
  - Carbon fiber reinforced and PTFE/PFPE lubricated PPS



Additive Technologies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Additive Technologies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Graphite Powder (5-30%)

- Aqueous environments
- Excellent temperature resistance
- Black color

Molybdenum Disulfide - MoS_2 (1-5%)

- Nucleating agent in nylons: creates harder surface
- High affinity to metal:
  - Smoother mating metal surface = lower wear

Limitations

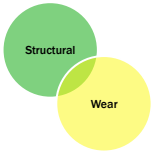
- Limited use
- Dark color limits colorability
- Sloughing type additives

Industrial Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Water Meter Valve

- **Requirements**
  - Dimensional stability, potable water contact - NSF listed
- **Solution**
  - Graphite lubricated PS and SAN



Additive Technologies

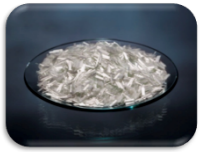
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Fibers and Wear Resistance

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Reinforcing Fibers

Glass Fiber



- Improved bearing capabilities/wear resistance
- Very abrasive

Carbon Fiber

- Higher bearing capabilities
- Excellent thermal resistance
- Conductive
- Less abrasive

Aramid Fiber

- Little strength improvement
- Very gentle to mating surface

Fibers and Wear Resistance

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Fibers protect the polymer, but may be abrasive against the mating material

Glass

Carbon

Aramid

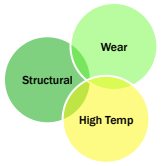
Aluminum Contact Surface

Business Machine Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Copier Bushings

- **Requirements**
  - High HDT and good wear resistance
- **Solution**
  - Aramid fiber reinforced and PTFE lubricated PPA



Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

I. Definitions & Test Methods

II. Traditional Additive Technologies

III. Application Examples

IV. APWA Plus

V. Extreme Conditions

APWA PLUS

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

APWA PLUS: **A**ll **P**olymeric **W**ear **A**lloy Technology

APWA PLUS Definition

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

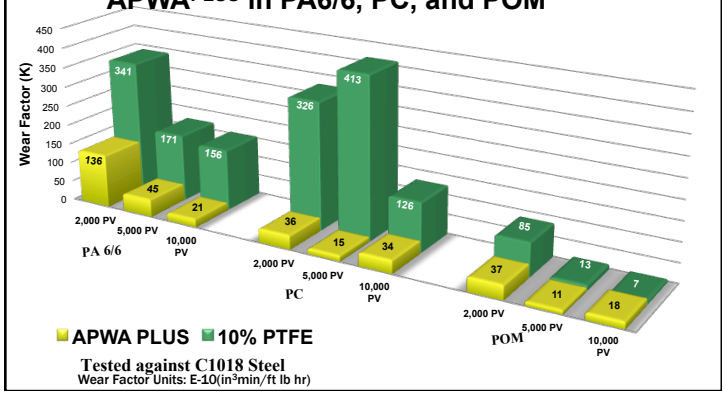
A Unique Polymer Alloy Technology Offering:

- Improved wear and friction performance
  - Especially effective in plastic vs. plastic wear
- Safe/easy handling (halogen-free >> RoHS)
- Good retention of base resin physical properties
- Lower specific gravity than PTFE
- Reduction/Elimination of plate-out associated with PTFE
- Colorable
- FDA Food Contact Compliant

Testing Results

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Wear Performance of 10% PTFE and APWA PLUS in PA6/6, PC, and POM



Tested against C1018 Steel
Wear Factor Units: E-10(in³min/ft lb hr)

Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

I. Definitions & Test Methods
II. Traditional Additive Technologies
III. Application Examples
IV. APWA Plus
V. **Extreme Conditions**

Extreme Conditions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

What happens when your application has a PV higher than 10,000?

High Temperature
High Loads (500+ psi)
High Speeds
Chemical Resistance

Excellent Mechanical Properties
Injection Molded Parts

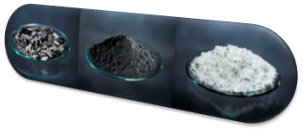
100 ft/min tests	*200 ft/min tests*
10,000 PV: 100 psi	*10,000 PV: 50 psi*
25,000 PV: 250 psi	*25,000 PV: 125 psi*
50,000 PV: 500 psi	*50,000 PV: 250 psi*

Additive Synergies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

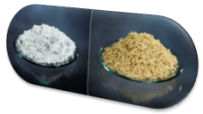
10/10/10 – Carbon Fiber/Graphite Powder/PTFE

- Typical additive package for high load bearing/high temp. applications



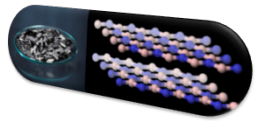
Aramid Fiber/PTFE

- Excellent wear package that is gentle on the mating surface



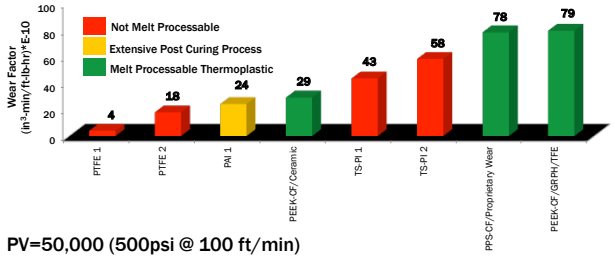
Carbon Fiber/Ceramic Additive

- Non-PTFE solution, good for very demanding conditions



Ultra-Wear Data (Room temp.)

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



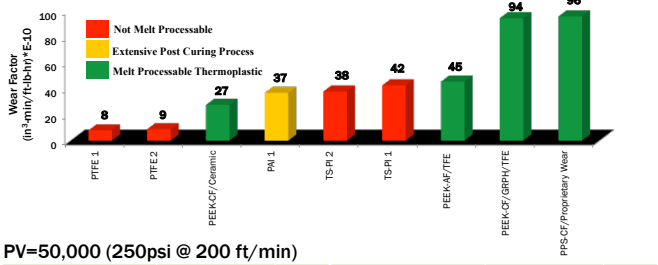
PV=50,000 (500psi @ 100 ft/min)

Compound	Wear Factor (in³-min/ft-lb-hr)*E-10	Dynamic μ	Compound	Wear Factor (in³-min/ft-lb-hr)*E-10	Dynamic μ
PTFE 1	4	0.15	PPS-CF/TFE	134	0.26
PTFE 2	18	0.16	PPS-AF/TFE	Wear Limit	NA
PAI 1	24	0.12	PPS-GF/TFE	Wear Limit	NA
PEEK-CF/Ceramic	29	0.06	PEEK-CF/TFE	Wear Limit	NA
TS-PI 1	43	0.14	PEEK-CF/AF/TFE	Wear Limit	NA
TS-PI 2	58	0.15	PEEK-CF/GRPH/TFE/PFPE	Wear Limit	NA
PPS-CF/Proprietary Wear	78	0.24	PEEK-CF/PFPE	Wear Limit	NA
PEEK-CF/GRPH/TFE	79	0.16	PPA-CF/TFE	Wear Limit	NA
PAI 2	105	0.18	PPA-CF/Proprietary Wear	Wear Limit	NA
PEEK-AF/TFE	119	0.18	PPA-CF/AF/TFE/SI	Wear Limit	NA
PEEK-CF/GRPH/TFE (CGP)	133	0.23	PA 46 - TFE	Wear Limit	NA

Wear per ASTM D-3702 against Steel

Ultra-Wear Data (Room temp.)

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



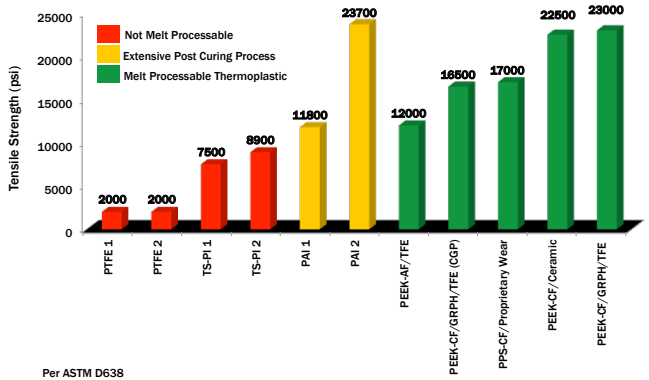
PV=50,000 (250psi @ 200 ft/min)

Compound	Wear Factor (in³-min/ft-lb-hr)*E-10	Dynamic μ	Compound	Wear Factor (in³-min/ft-lb-hr)*E-10	Dynamic μ
PTFE 1	8	0.21	PEEK-CF/PFPE	202	0.24
PTFE 2	9	0.25	PAI 2	262	0.23
PEEK-CF/Ceramic	27	0.07	PEEK-CF/GRPH/TFE/PFPE	337	0.26
PAI 1	37	0.12	PPS-AF/TFE	Wear Limit	NA
TS-PI 2	38	0.11	PPS-GF/TFE	Wear Limit	NA
TS-PI 1	42	0.13	PEEK-CF/TFE	Wear Limit	NA
PEEK-AF/TFE	45	0.15	PEEK-CF/AF/TFE	Wear Limit	NA
PEEK-CF/GRPH/TFE	94	0.18	PPA-CF/TFE	Wear Limit	NA
PPS-CF/Proprietary Wear	96	0.19	PPA-CF/Proprietary Wear	Wear Limit	NA
PPS-CF/TFE	127	0.19	PPA-CF/AF/TFE/SI	Wear Limit	NA
PEEK-CF/GRPH/TFE (CGP)	194	0.23	PA 46 - TFE	Wear Limit	NA

Wear per ASTM D-3702 against Steel

Tensile Strength

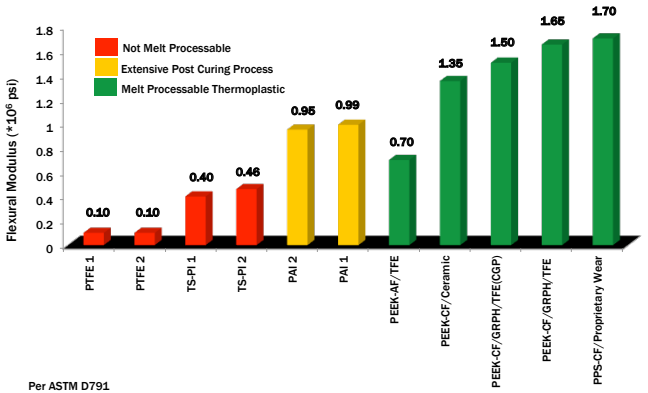
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Per ASTM D638

Flexural Modulus

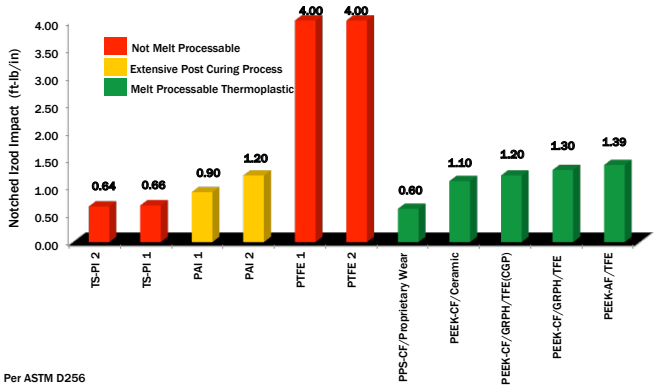
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Per ASTM D791

Notched Izod Impact

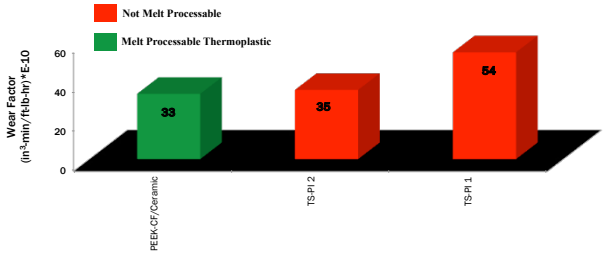
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Per ASTM D256

Ultra-Wear Data (Elevated temp.)

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

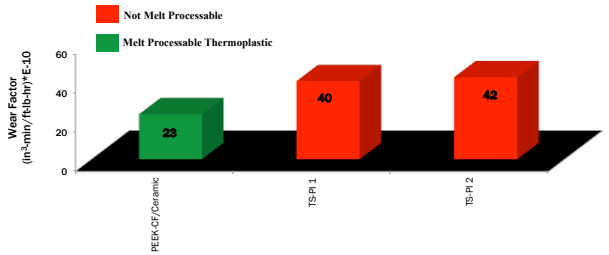


Disc Material	Wear Factor (in³-min/ft-lb-hr)*E-10	Dynamic μ
PEEK-CF/Ceramic	33	0.06
TS-PI 2	35	0.07
TS-PI 1	54	0.10
PTFE 1	Wear Limit	NA
PAI 1	Wear Limit	NA
PPS-CF/Proprietary Wear	Wear Limit	NA

Wear per ASTM D-3702 against Steel at **400°F; PV = 75,000**

Ultra-Wear Data (Elevated temp.)

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Disc Material	Wear Factor (in^3-min/ft-lb-hr)*E-10	Dynamic μ
PEEK-CF/Ceramic	23	0.05
TS-PI 1	40	0.10
TS-PI 2	42	0.07
PTFE 1	Wear Limit	NA
PAI 1	Wear Limit	NA
PPS-CF/Proprietary Wear	Wear Limit	NA

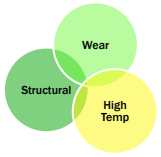
Wear per ASTM D-3702 against Steel at **400°F; PV = 100,000**

Automotive Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

AC Compressor Scroll Seal

- **Requirements**
  - High temperature, chemical and wear resistance
- **Solution**
  - Carbon fiber reinforced and PTFE/Graphite lubricated PEEK

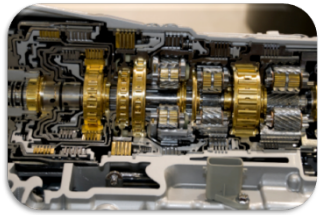


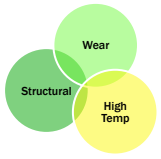
Automotive Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Transmission Seal Rings/ Thrust Washers

- **Requirements**
  - Ability to survive extremely high PV conditions with external lubrication
- **Solution**
  - Carbon fiber reinforced, internally lubricated PEEK

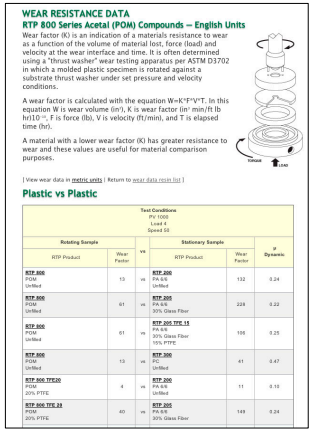




Additional Information

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Wear Factor (K) and friction coefficient (μ_K) for common tribological compounds** www.rtpcompany.com/info/wear
- **Additional webinars on wear and friction** web.rtpcompany.com/info/webinars/



WEAR RESISTANCE DATA
RTP 800 Series Acetal (POM) Compounds – English Units

Wear factor (K) is an indication of a materials resistance to wear as a function of the volume of material lost, force (load) and velocity at the wear interface and time. It is often determined using a "thrust washer" wear testing apparatus per ASTM D3702 in which a molded plastic specimen is rotated against a substrate thrust washer under set pressure and velocity conditions.

A wear factor is calculated with the equation $W=K*P*V*T$. In this equation W is wear volume (in^3), K is wear factor (in^3 min/ft lb hr)(10^{-10}), F is force (lb), V is velocity (ft/min), and T is elapsed time (hr).

A material with a lower wear factor (K) has greater resistance to wear and these values are useful for material comparison purposes.

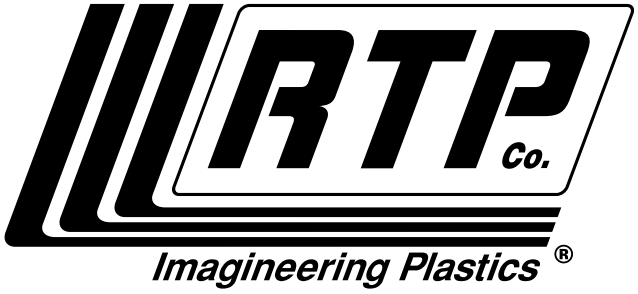
[View wear data in metric units | Return to wear data resin list]

Plastic vs Plastic

Test Conditions
PV 1000
Load 10
Speed 50

Rotating Sample		vs	Stationary Sample		μ Dynamic
RTP Product	Wear Factor		RTP Product	Wear Factor	
RTP 800 POM Unfilled	13	vs	RTP 300 PA 6/6 Unfilled	132	0.24
RTP 800 POM Unfilled	61	vs	RTP 305 PA 6/6 30% Glass Fiber	224	0.22
RTP 800 POM Unfilled	61	vs	RTP 305 TFE 15 PA 6/6 30% Glass Fiber 15% PTFE	106	0.25
RTP 800 POM Unfilled	13	vs	RTP 300 PC Unfilled	41	0.47
RTP 800 TFE20 POM 20% PTFE	4	vs	RTP 300 PA 6/6 Unfilled	11	0.10
RTP 800 TFE 20 POM 20% PTFE	40	vs	RTP 305 PA 6/6 30% Glass Fiber	149	0.24


THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT
Thank you for your attention.
Questions?
Ben Gerjets
bgerjets@rtpcompany.com
(507) 474-5381



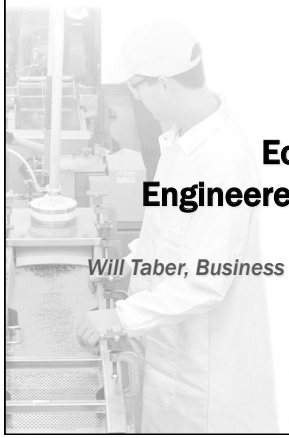
Eco-Friendly, Engineered Plastic Solutions

Will Taber

Business Manager-Emerging Technologies
wtaber@rtpcompany.com
(816) 591-7181

3:00 p.m.

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT



Eco-Friendly, Engineered Plastic Solutions

Will Taber, Business Manager–Emerging Technologies

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554
TELEPHONE:

U.S.A.	SOUTH AMERICA	MEXICO	EUROPE	SINGAPORE	CHINA
+1 507-454-6900	+55 11 4193-8772	+52 81 8134-0403	+33 380-253-000	+65 6863-6580	+86 512-6283-8383

ISO 9001

Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- RTP Company
- What are Eco Solutions?
- What is green?
- Bioplastic compounds
- Recycle content compounds
- Cellulose Fiber Reinforced PP
- Future development work
- Economics
- Summary

Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- RTP Company
- What are Eco Solutions?
- What is green?
- Bioplastic compounds
- Recycle content compounds
- Cellulose Fiber Reinforced PP
- Future development work
- Economics
- Summary

Profile

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- RTP Company is an <u>independent</u>, privately owned custom compounder.
- Global manufacturing and engineering support
- Worldwide sales representation/distribution
- Established in 1982
- 1000+ employees
- $400+ million annual sales

Custom Solutions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

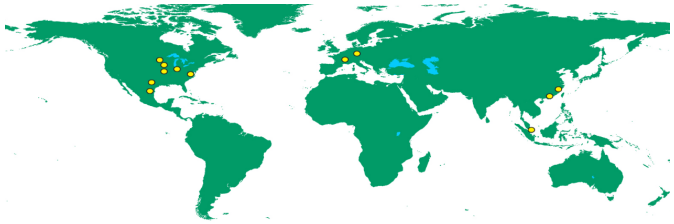
- **High-tech specialty compounder**
  - 60+ engineering resins
  - 100+ modifiers
- **Annual production**
  - 6000+ commercial products
  - 1750+ new products each year

The image cannot be displayed. Your computer may not have enough memory to open the image, or the image may have been corrupted. Restart your computer, and then open the file again. If the red x still appears, you may have to delete the image and then insert it again.

Your GLOBAL Compounder

OF CUSTOM ENGINEERED THERMOPLASTICS

Global Manufacturing



United States • Mexico • France • Germany • China • Singapore

Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- RTP Company
- **What are Eco Solutions?**
- What is green?
- Bioplastic compounds
- Recycle content compounds
- Cellulose Fiber Reinforced PP
- Future development work
- Economics
- Summary

Eco Solutions "Green" Compounds

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Our Eco Solutions portfolio consists of compounds that utilize

- Renewable or biobased content
- Recycled content
- Halogen-free additives
- Natural fibers
- Combinations of bioplastic, recycled, halogen-free, natural fiber

Eco Solutions Compounds

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Bioplastic Compounds

- **Polylactic Acid:** Impact Modifed, Glass Reinforced, Alloys
- **Biobased PE:** Mineral filled, Glass Reinforced
- **Biobased Nylon:** Glass Reinforced, Flame Retardant

Recycled Content Compounds

- PP, Nylon, PC, PET
- Glass Reinforced, Flame Retardant, Mineral, Wear Additives
- Pre- and Post- Consumer Recycled

Natural Fibers

- **Cellulose PP:** Homopolymer, Copolymer, Glass, Combinations, Recycled Content
- **Diced Wood, Recycled Fibers**

Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- RTP Company
- What are Eco Solutions?
- **What is green?**
- Bioplastic compounds
- Recycle content compounds
- Cellulose Fiber Reinforced PP
- Future development work
- Economics
- Summary

Eco Solutions "Green" Compounds

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

What does "green" mean?

- Depends on industry, products, and capabilities
- Infers that a product is more environmentally friendly
  - Examples: less energy consumed, less CO_2 produced, made from a renewable resource etc…
- Eco Solutions are our products (capabilities) we can utilize to help your customers produce a "green" product

"Green" Products

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Lots of people say they want 'em…
- Lots of companies say they make 'em…
- How are you going to prove that?

"Green" Products

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Product certifications provide credibility**
  - USDA BioPreferred, EPEAT (US)
  - Vincotte, C2C (Europe)
  - Japan BioPlastics Association (Japan)
  - BIFMA (Business and Institutional Furniture Mfg. Assoc.)
  - All of the above value and or certify recycle content, biobased content or both
- **Certifications provide proof a product meets a set of "green" criteria**

Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- RTP Company
- What are Eco Solutions?
- What is green?
- **Bioplastic compounds**
- Recycle content compounds
- Cellulose Fiber Reinforced PP
- Future development work
- Economics
- Summary

RTP Company Eco Solutions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Bioplastic Compounds

- **Definitions**
- **Types**
- **Strategy**
- **Product portfolio**
- **Applications**
- **Information**
- **Limits of use**

Bioplastics – Defined

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Bioplastics** are a form of plastics derived from renewable (annually) biomass sources such as corn, wheat, sugar cane, and sugar beets rather than traditional plastics derived from petroleum
- Some, but not all, bioplastics are designed to biodegrade.

Economics, availability, and performance has placed an emphasis on

Polylactic Acid (PLA)

Biobased versus Biodegradable

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Biobased

- PLA
- Nylon (11, 6/10)
- PTT
- PHA
- PE
- PBS
- Thermoplastic starch

Biodegradable

- PLA (via industrial composting)*
- PBS
- PHA (via "backyard" composting)
- Thermoplastic starch

* Not biodegradable in household waste sanitary landfill

How Do We Report Biocontent?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Renewable resource content (weight%)
  - Tells how much of the compound by weight is a renewable or biobased plastic (ie 30% PLA and 70% PC)
- Biobased carbon content
  - Per ASTM D 6866 – Distinguishes "new" carbon vs "old"
  - Reports renewable carbon content as a % of total carbon content
  - Does not consider product weight
  - Does not measure biodegradability
  - Does not take into account non-organic (carbon) elements such as oxygen, hydrogen or silicon (glass)
  - Can provide different results vs weight%

Where Does RTP Fit?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Base Resins	• PLA, Nylon 11, Nylon 6/10, PTT, PE.
Semi-durable and durable applications	• Office furniture, appliance, consumer electronics, niche "green" electronics in controlled environments.
Custom Compounds	• Structural, impact modified, mineral, FR, conductive, wear, recycled content.
Current Focus PLA	• Good economics, good supply, easy to modify, advancements in compounding and polymerization.

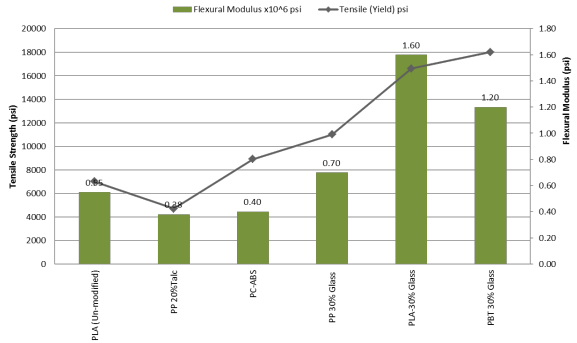
PLA Compound Portfolio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Glass reinforced
- Impact modified – Performance (high HDT)
- Impact modified – Translucent
- Impact modified – Opaque
- Impact modified – FDA compliant
- Alloys

Glass Reinforced PLA

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Glass Reinforced PLA Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Consumer

Application: Scissors Handle

Problem: Biobased material to replace glass reinforced PP

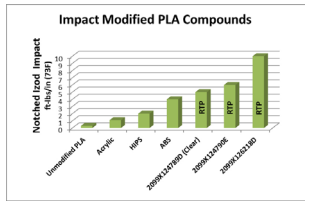
Solution: RTP 2000 Series 30% glass reinforced PLA

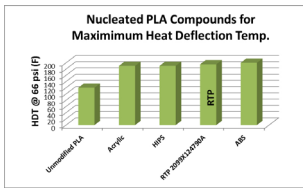
Benefit: Superior strength and stiffness vs 30% glass PP. Nucleated for improved cycle time. 68% renewable resource content

Impact Modified PLA

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Nucleated
- Mineral reinforced
- FDA compliant ingredients
- Opaque or translucent
- Colorable and glossy
- Injection or extrusion
- Balance cost, properties, biocontent





Impact Modified PLA Portfolio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Extensive portfolio can be modified to meet specific economic and performance targets

RTP PRODUCT	RENEWABLE CONTENT	NOTCHED IZOD ASTM D 256	TENSILE STRENGTH ASTM D 638	FLEXURAL MODULUS ASTM D 790	HDT @ 66 psi (455 kPa) ASTM D 648
RTP 2099 X 124790 A Medium Impact, Fast Cycle, High HDT, 10% Talc	78%	1.8 ft-lbs/in - 96 J/m	7,000 psi - 48 MPa	0.60 psi x 10^6 - 4,137 MPa	195 °F - 90 °C
RTP 2099 X 124790 B High Impact, Fast Cycle, High HDT, 10% Talc	68%	3.5 ft-lbs/in - 187 J/m	5,900 psi - 38 MPa	0.50 psi x 10^6 - 3,448 MPa	160 °F - 71 °C
RTP 2099 X 124790 C Medium Impact, Standard Cycle, 10% Talc	78%	1.5 ft-lbs/in - 80 J/m	6,500 psi - 45 MPa	0.60 psi x 10^6 - 4,137 MPa	180 °F - 82 °C
RTP 2099 X 124790 D High Impact, Standard Cycle, 10% Talc	68%	3.4 ft-lbs/in - J/m	5,200 psi - 36 MPa	0.50 psi x 10^6 - 3,448 MPa	150 °F - 65 °C
RTP 2099 X 124790 E High Impact, Fast Cycle, 10% Calcium Carbonate	73%	6.0 ft-lbs/in - 182 J/m	5,700 psi - 39 MPa	0.45 psi x 10^6 - 3,103 MPa	145 °F - 63 °C
RTP 2099 X 124790 F Medium Impact, Fast Cycle, 30% Calcium Carbonate	53%	1.5 ft-lbs/in - 80 J/m	4,600 psi - 32 MPa	0.60 psi x 10^6 - 4,137 MPa	165 °F - 74 °C
RTP 2099 X 124789 A Impact Modified, Lower Cost, Clear	94%	0.5 ft-lbs/in - 27 J/m	9,000 psi - 62 MPa	0.49 psi x 10^6 - 3,379 MPa	124 °F - 51 °C
RTP 2099 X 124789 B Impact Modified, Clear	89%	0.9 ft-lbs/in - 48 J/m	8,000 psi - 55 MPa	0.44 psi x 10^6 - 3,034 MPa	124 °F - 51 °C
RTP 2099 X 124789 C Medium Impact, Clear	84%	1.5 ft-lbs/in - 80 J/m	7,000 psi - 48 MPa	0.41 psi x 10^6 - 2,827 MPa	124 °F - 51 °C
RTP 2099 X 124789 D High Impact, Clear	79%	5.0 ft-lbs/in - 267 J/m	6,000 psi - 41 MPa	0.37 psi x 10^6 - 2,551 MPa	124 °F - 51 °C
RTP 2099 X 126211 Z Impact Modified, FDA Compliant, Clear	89%	0.8 ft-lbs/in - 43 J/m	6,700 psi - 46 MPa	0.44 psi x 10^6 - 3,034 MPa	124 °F - 51 °C
RTP 2099 X 126218 A Impact Modified, Lower Cost, Opaque	94%	0.6 ft-lbs/in - 32 J/m	8,500 psi - 59 MPa	0.47 psi x 10^6 - 3,241 MPa	124 °F - 51 °C
RTP 2099 X 126218 B Medium Impact, Opaque	89%	1.0 ft-lbs/in - 53 J/m	7,300 psi - 50 MPa	0.44 psi x 10^6 - 3,034 MPa	124 °F - 51 °C
RTP 2099 X 126218 C High Impact, Opaque	84%	3.5 ft-lbs/in - 187 J/m	6,400 psi - 44 MPa	0.39 psi x 10^6 - 2,689 MPa	124 °F - 51 °C
RTP 2099 X 126218 D Super High Impact, Opaque	79%	10.0 ft-lbs/in - 534 J/m	5,500 psi - 38 MPa	0.35 psi x 10^6 - 2,413 MPa	124 °F - 51 °C
RTP 2099 X 126217 Z Super High Impact, FDA Compliant, Opaque	79%	12.0 ft-lbs/in - 641 J/m	5,700 psi - 39 MPa	0.36 psi x 10^6 - 2,482 MPa	124 °F - 51 °C

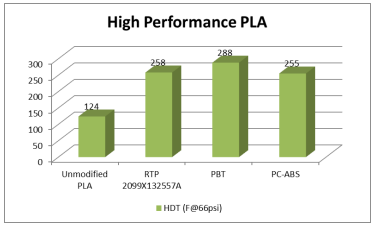
Glass fiber reinforced compounds and thermoplastic alloys using PLA are also available from RTP Company

High Performance PLA

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Increased rate and degree of crystallization yields:

- **Reduced cycle time**
- **Higher HDT with lower cost nucleators**
- **Improved hydrolysis resistance?**



***2099X132557A:**
standard impact mineral reinforced

Impact Modified PLA Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Sporting Goods
Application: Bicycle Helmet
Problem: High biobased content. Good durability, gloss and color. Option to paint.
Solution: RTP 2000 Series Impact Modified PLA
Benefit: 79% renewable content, excellent balance of strength and toughness. Good flow for thin walls. Glossy and colorable

Impact Modified PLA Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Sporting Goods
Application: Promotional Divot Tool
Problem: High biobased content. Good durability, gloss and color
Solution: RTP 2000 Series Impact Modified PLA
Benefit: 84% renewable content, excellent balance of strength and toughness. Good flow for thin walls. Glossy and colorable

PLA Alloys

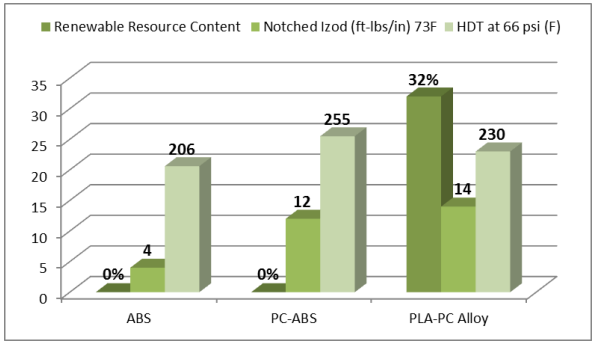
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **PLA/PC**
- **PLA/PC (recycled PC)**
- **PLA/PC FR (non-hal V-0)**
- **PLA/PC FR (non-hal V-0, recycled PC)**
- **PLA/PMMA (clear and impact opaque)**
- **PLA/PE**

PLA/PC Alloys

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- PLA-PC Alloys Balance Renewable Content With High Impact Strength and Heat Deflection Temperature



PLA/PC Alloy Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Consumer Electronics

Application: Portable Electronics Housing

Problem: Biobased content with good balance of stiffness, impact and heat deflection temperature. Moldable in existing tooling

Solution: RTP 2000 Series PLA/PC Alloy

Benefit: 32% renewable resource content. 14 ft-lbs/in notched izod with a 240°F (115°C) HDT. Processed in existing tooling with added benefit of being overmoldable with soft touch elastomer

PLA Compounds Limits of Use

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Suitable for applications requiring:**
  - High impact and stiffness
  - High gloss and colorability
  - FDA compliant ingredients
  - Products with renewable/sustainable resource content
  - Moldability in existing tools
  - Use in a controlled environment, ie: home, office

PLA Compounds Limits of Use

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Not suitable for applications requiring:**
  - Extended exposure to high heat and humidity. Consult with R&D to determine limits for your particular application
  - Applications requiring biodegradability in landfill at ambient temps

New PLA Products

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- High gravity
- Permanently anti-static
- PLA/acrylic sheet compound
- Improved FR PLA/PC
- Recycle content

PLA Compounds – Information

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Updated bio-compounds innovation bulletin
- Glass reinforced bulletin
- Impact modified bulletin
- USDA product listings
- Processing guide
- Regrind studies
- Sample plaques
- Product data sheets

USDA CERTIFIED BIOBASED PRODUCT
PRODUCT 99%

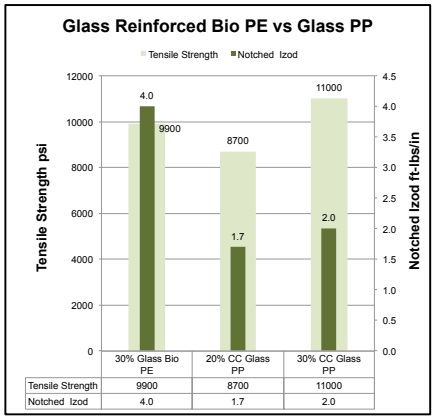
Biobased PE Compounds

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Advantages
  - Biobased
  - Recyclable
  - Compostion..same as Petroleum PE
  - Properties, and processing
  - Cost relative to other biobased plastics
- Disadvantages
  - Some unknowns in supply
  - Compostability

Biobased PE Compounds

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- RTP Company
- What are Eco Solutions?
- What is green?
- Bioplastic compounds
- Recycle content compounds
- Cellulose fiber reinforced PP
- Future development work
- Economics
- Summary

RTP Company Eco Solutions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Recycled Content Compounds

- RTP Company Strategy
- Source Certification
- Portfolio
- Considerations

Recycled Content Strategy

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Provide a means for customers to “green” their product via recycle content
- FTC guidelines – type/amount, substantiation
- Utilize pre- and post-consumer:
  - PP, Nylon6, Nylon 6/6, PC, PET
- Pursue “one off” opportunities as presented
- RTP Company is a compounder who can utilize recycled content to add value…. not a recycler

Recycled Content – FTC Guidelines

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Type and Amount

Product Data Sheet & General Processing Conditions

RTP 199 X 126273
Polypropylene (PP)
40% Talc Filled
60% Post Consumer Recycled Content

PROPERTIES & AVERAGE VALUES OF INJECTION MOLDED SPECIMENS

PERMANENCE	English	SI Metric	ASTM TEST
Primary Additive	40 %	40 %	
Specific Gravity	1.23	1.23	D 792
MECHANICAL			
Impact Strength, Izod			
notched 1/8 in (3.2 mm) section	0.8 ft-lbs/in	43 J/m	D 256
unnotched 1/8 in (3.2 mm) section	7.0 ft-lbs/in	374 J/m	D 4812
Tensile Strength	4200 psi	29 MPa	D 638
Tensile Elongation	> 10.0 %	> 10.0 %	D 638
Tensile Modulus	0.70 x 10^6 psi	4826 MPa	D 638
Flexural Strength	7500 psi	52 MPa	D 790
Flexural Modulus	0.55 x 10^6 psi	3792 MPa	D 790
PROPERTY NOTES			

Data herein is typical and not to be construed as specifications.
Unless otherwise specified, all data listed is for natural or black colored materials. Pigments can affect properties.

Recycled - Source Certification

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

UL Environment™
YOUR PARTNER IN SUSTAINABILITY

UL Environment Inc.
333 Pfingsten Road, Northbrook, IL 60062-2096 USA
T.: 888.4UL Green (888.485.4733) / F.: 360.817.6263
W.: ulenvironment.com

February 11, 2010

[redacted]

Our Reference: 09CA50720

Subject: Validation of environmental claims for recycled content in Greentron and Greenlon

[redacted]

All testing, auditing and analysis work associated with the product listed above under Project number 09CA50720 has been completed. Please refer to the following page for all environmental claims that were validated and the methods used for validation.

Please be informed that in some cases, UL Environment Inc. did not select the samples. Auditing conducted to validate environmental claims was performed on a sample of available documentation, products and materials.

Recycled Content - Considerations

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Supply and pricing is dynamic
- Can be difficult to verify source
- Post Consumer is more highly valued than Pre Consumer but generally more variable in properties and higher levels of contamination
- Post Consumer compounds limited to black
- Consider tradeoffs between recycle content and performance…RTP can help to overcome limitations!
- Opportunity for cost parity with complex compounds and provide a "green" angle… ie impact modified, FR, wear, conductive.

Recycled Content Product Portfolio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Post-consumer content
- Limited to black
- Can provide lot COA with type and amount of recycle
- Directed at applications where PCR recycle content is key
- Not necessarily lowest cost
- Limited feedstock availability in Europe/ Asia

Post-Consumer Recycle Content Compounds

PP	Nomenclature
20% cc glass	RTP 199X128064 B Black
40% cc glass	RTP 199X128064 D Black
20% talc	RTP 199X128065 B Black
40% talc	RTP 199X128065 D Black
non-halogenated V0	RTP 199X128515 Black
30% glass non-halogenated V0	RTP 199X128508 Black
Nylon 6	
20% glass	RTP 299AX128066 B Black
30% glass	RTP 299AX128066 C Black
Impact modified	RTP 299AX128067 A Black
Nylon 6/6	
20% glass	RTP 299X128068 B Black
30% glass	RTP 299X128068 C Black
Impact modified	RTP 299X128069 A Black
PC	
10% glass	RTP 399X127989 A Black
20% glass	RTP 399X128070 B Black
PET	
30% glass	RTP 1199X126220 A Black
45% glass	RTP 1199X128071 A Black
25% glass 15% mineral	RTP 1199X126220 C Black
20% glass 15% mineral	RTP 1199X126220 B Black

Recycled Content Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Sports and Recreation
Application: Kayak Paddle
Problem: Very high strength and rigidity with good surface finish
Solution: RTP 200 A Series carbon fiber reinforced compound
Benefit: Excellent balance of properties and surface finish while utilizing recycled carbon fiber content

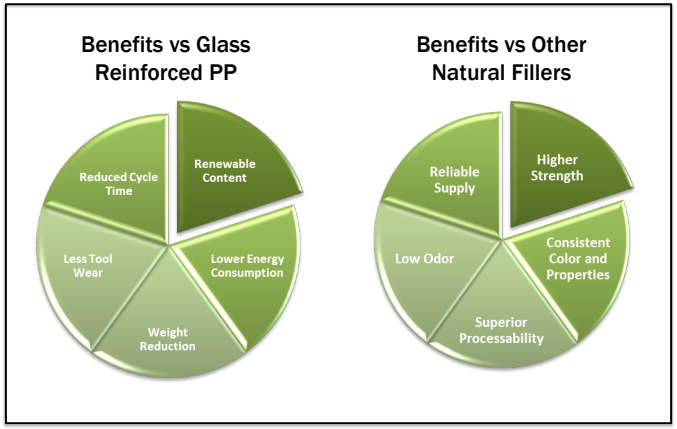
Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **RTP Company**
- What are Eco Solutions?
- What is green?
- Bioplastic compounds
- Recycle content compounds
- **Cellulose fiber reinforced PP**
- Future development work
- Economics
- Summary

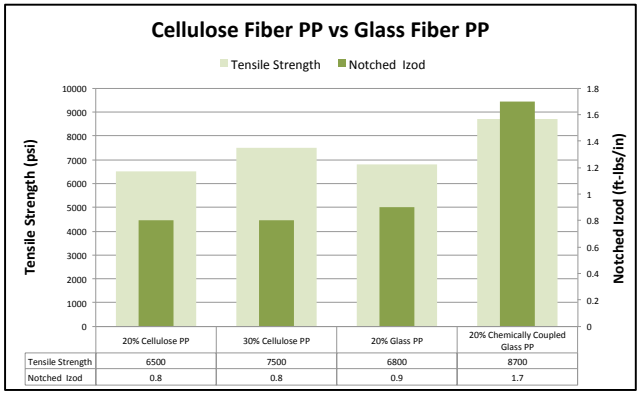
Cellulose Fiber Reinforced PP

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



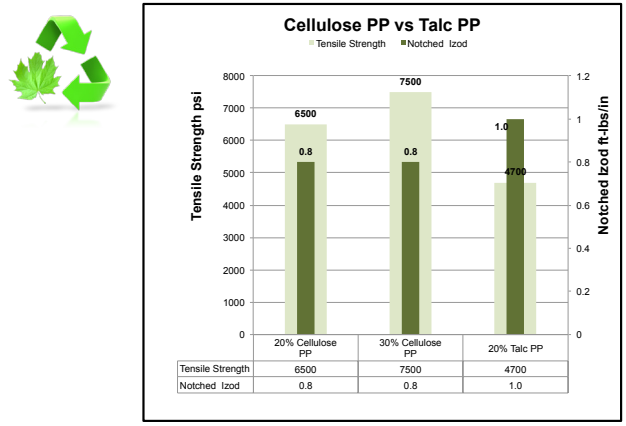
Cellulose Fiber Reinforced PP

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Cellulose Fiber Reinforced PP

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Cellulose Fiber PP Compounds

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Base Resin**
  - Homopolymer (standard and high flow)
  - Copolymer
  - Recycle content
- **Fiber**
  - Cellulose (5% - 40%)
  - Cellulose + glass
- **Other**
  - Color (precolor or concentrate)
  - Elastomer overmold

Cellulose Fiber PP Compounds

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

** View technical data sheets: www.rtpcompany.com/info/data/bioplastics*

PRODUCT NUMBER	DESCRIPTION
RTP 199 X 124797 A	20% Cellulose, Standard flow PP homopolymer
RTP 199 X 124797 B	30% Cellulose, Standard flow PP homopolymer
RTP 199 X 132495 A	20% Cellulose, High flow PP homopolymer
RTP 199 X 132495 B	30% Cellulose, High flow PP homopolymer
RTP 199 X 130883 A	10% Glass, 20% Cellulose, PP homopolymer
RTP 199 X 130883 B	10% Glass, 30% Cellulose, PP homopolymer
RTP 199 X 132474 A	20% Cellulose, High-impact PP copolymer
RTP 199 X 132474 B	30% Cellulose, High-impact PP copolymer
RTP 199 X 125445 A	20% Cellulose, Post-consumer recycled PP
RTP 199 X 125445 B	30% Cellulose, Post-consumer recycled PP

** Custom formulations available to meet your application requirements.*

Solutions For:

Material Handling

Furniture

Automotive

Appliance

Sporting Goods

Lawn & Garden

Cellulose Fiber PP Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Furniture

Application: Chair

Problem: Produce an eco-friendly product with that has mechanical properties similar to 20% glass reinforced PP that can be molded via gas assist

Solution: RTP 100 Series 30% Cellulose fiber reinforced Homopolymer PP

Benefit: Superior properties and processing versus wood flour PP with equivalent stiffness to glass reinforced PP and good colorability. Molded via gas-assist with improved cycle time versus glass PP

Cellulose Fiber PP Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Lawn and Garden

Application: Weeding Tool

Problem: Produce an eco-friendly product with that has good mechanical properties and “natural” look

Solution: RTP 100 Series Cellulose fiber reinforced PP

Benefit: Superior properties and processing versus wood flour PP with good colorability

Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- RTP Company
- What are Eco Solutions?
- What is green?
- Bioplastic compounds
- Recycle content compounds
- Cellulose Fiber Reinforced PP
- **Future development work**
- Economics
- Summary

Development Work

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Higher HDT (crystallinity) PLA**
- **Lower cost nucleators**
- **Improved stabilization of PLA**
- **Biobased olefin compounds**
- **PCR feedstreams**
- **Lower cost FR PLA/PC**

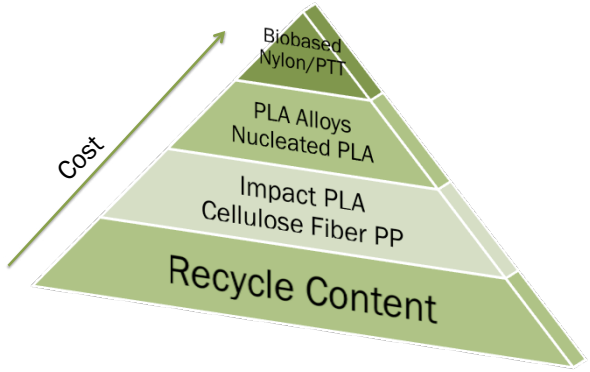
Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- RTP Company
- What are Eco Solutions?
- What is green?
- Bioplastic compounds
- Recycle content compounds
- Natural fibers
- Future development work
- **Economics**
- Summary

Eco-Friendly Compound Economics

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

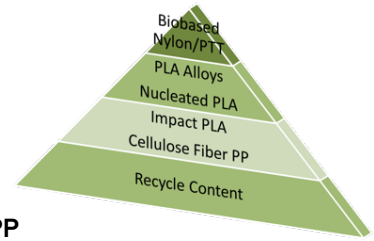


Economic Fits

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Yes:

- Recycle content
- PLA compounds
  - (antistatic, lubricated, precolor)
- BIO PE compounds
- Cellulose PP vs Glass PP



No:

- Commodity PP, HIPS, ABS

Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- RTP Company
- What are Eco Solutions?
- What is green?
- Bioplastic compounds
- Recycle content compounds
- Cellulose fiber reinforced PP
- Future development work
- Economics
- Summary

Summary

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- The "green" movement is approaching a "tipping point"
  - Knowledge of "green" products and benefit
  - Technical feasibility
  - Economic viability
  - Visibility via first movers

Summary

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- RTP Company has many hard to replicate assets that can be used to achieve your "green" initiatives
  - Formulation and compounding knowledge
  - Key supply relationships
  - Worldwide mfg., tech service, and R&D
  - An entrepreneurial spirit
  - How can we help you meet your sustainability objectives?

Questions & Contact Info

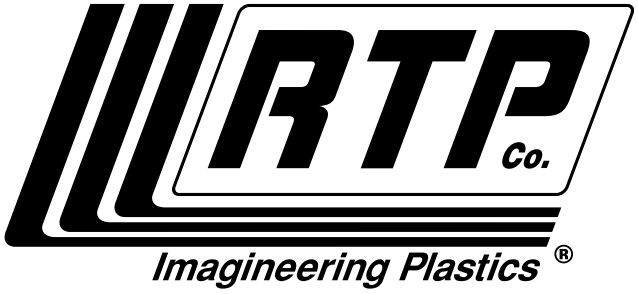
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Questions?

Will Taber, Business Manager–Emerging Technologies
wtaber@rtpcompany.com, (816) 591-7181

Dr. Chuck Orr, Sr. R&D Engineer
corr@rtpcompany.com, (507) 474-5371

www.rtpcompany.com



Flame Retardants and the Evolving Regulatory Landscape

Jesse Dulek

Product Development Engineer

jdulek@rtpcompany.com

(507) 474-5502

3:00 p.m.

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Flame Retardants and the Evolving Regulatory Landscape

Jesse Dulek
Product Development Engineer
Flame Retardant Products

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

Overview

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Background/Overview
- Thermoplastic Flammability
  - Flame Retardant Additive Chemistries and Mechanisms
- Regulatory Landscape
- Testing Standards
- FR Products meet End Applications

Flame Retardant (FR) Materials

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Definition

Materials that do not ignite readily or propagate flames under small to moderate fire exposures

- Materials are combustible
- Fire retardants reduce the intensity and spread of fire
- Reduces smoke and toxic by-products of combustion.

Fire Triangle

Goals of Flame Retardant Compounds

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Increase Resistance to Ignition
- Reduce Rate of Flame Spread
- Reduce Rate of Heat Release
- Reduce Smoke Emission

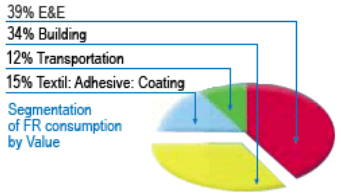
End Goal

- Meet FR Specifications
- Make the World a Safer Place!

Markets for FR Thermoplastics

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Electrical Parts
- Electronic Enclosures
- Wire and Cable
- Appliances
- Transportation
- Building and Construction



THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Flammability of Thermoplastics

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • + 1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

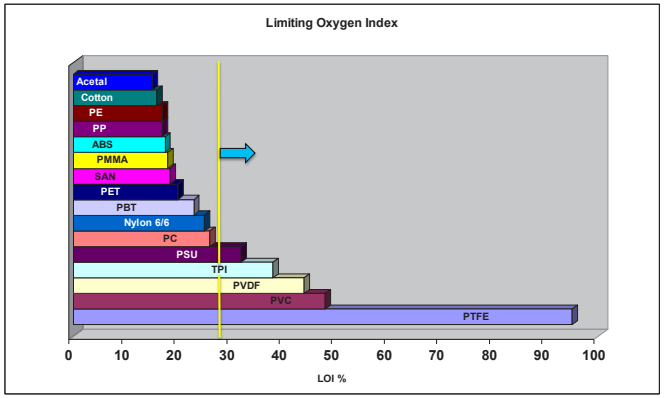
Thermoplastic Resin Flammability

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Flammable	Inherently Flame Resistant
• Polyolefins • Nylons • Polycarbonate • Polyesters • Styrenics • TPE'S	• Polysulfones • Polyphenylene Sulfide • Polyetheretherketone • Polyetherimide • Flouropolymers

Challenges of Flame Retarding Plastics

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Flame Retardant Additives and Mechanisms

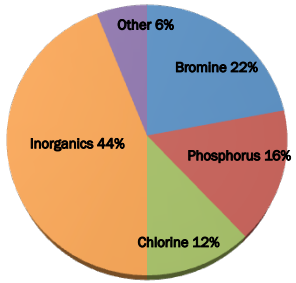
RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

Common Types of FR Additives

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Halogenated FR's**
  - Brominated
  - Chlorinated
- **Halogen Free FR's**
  - Metal hydroxides
  - Phosphorous Based
  - Melamine Based

Flame Retardant Additive Usage, 2011



Halogenated FR Mechanism

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Halogenated technology inhibits the chemical reaction in the gas/vapor phase
- Various molecules that efficiently get large amounts of free radicals to the gas phase

Additive Type	Polymeric Type
• Higher Halogen Content • Lower Loadings • High Thermal Stability	• Melt Blendable • Less effect on physical properties • Enhanced Flow

Halogenated flame retardants are compatible in most resin systems with the exception of Acetal

Non Halogen Mechanisms

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Phosphorous	Hydrated Minerals	Melamine Cyanurate
• Various forms • Contributes to the condensed phase char formation	• Produce water during combustion process, dilute flammable vapors • Insulative char formation	• Endothermic decomposition • Physical removal of flame from surface

Resin Systems		
Polyolefins, Polyamides, Polyesters, Polycarbonate and alloys	Polyolefins, Polyamides	Polyamides, used as a synergist for other Phosphorous technologies

Halogen vs. Halogen Free

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Past

Halogenated	Halogen Free
• Lower Cost	• Limited Availability
• Better Processing	• Low Smoke
• Better Efficiency	• Lower Toxicity
• Better Physical Properties	• Less Corrosive
	• Lower Specific Gravity
	• Niche Product

Halogen vs. Halogen Free

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Past		Present
Halogenated	Halogen Free	Halogen Free
• Lower Cost	• Limited availability	• Evolving Economics
• Better Processing	• Low Smoke	• Improved Processability
• Better Efficiency	• Lower Toxicity	• Wide Variety of Products
• Better Physical Properties	• Less Corrosive	• Low Smoke
	• Lower Specific Gravity	• Lower Toxicity
	• Niche Product	• Less Corrosive
		• Lower Specific Gravity

Choosing a FR System

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

How do we decide which FR mechanism to use?

- **Resins System**
- **FR Specification**
- **Part Function**
- **Fillers/Additives**
- **Regulatory Concerns**
  - Halogen, RoHS, etc

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Regulatory Landscape

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

RoHS Directive

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Restriction of Hazardous Substances (RoHS)**
  - EU Directive in effect as of July 2006
- **Banned Substances**
  - Lead (Pb)
  - Mercury (Hg)
  - Cadmium (Cd)
  - Hexavalent Chromium (CrVI)
  - Polybrominated Biphenyls (PBB) and Polybrominated Diphenyl Ethers (PBDE)
- **Flame Retardants and Pigments**

Does not need to be Halogen Free!

Impact of RoHS

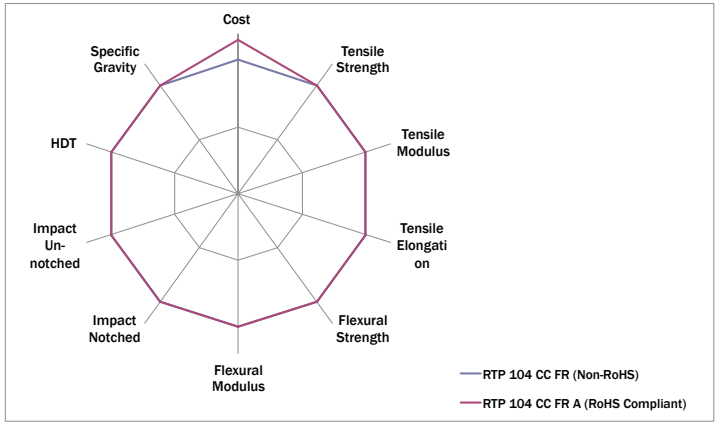
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

How does RoHS compliance affect material selection?

- **Drop in replacements available**
- **Identical Properties**
  - Physical, Flow, Heat Resistance, Processability
- **Cost Premium**

25% GF Polypropylene

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Evolution of Halogen Free Technologies

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **More “self-policing”/customer driven bans**
- **New FR standards**
- **Green Movement**
- **More Effective FR Chemicals**
- **More Economical FR Chemicals**
- **Increased Performance**
- **Competition in the Market**

Halogen Restrictions

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **OEM Driven Ban on Halogenated Chemicals**
  - HP, DELL, IBM etc.
- **Eco Labels**
  - Blue Angel, White Swan, Ecolabel etc.

Impact of Halogen Free

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Resin Limitations**
- **Physical Properties**
  - Strength/Impact
  - Flow
  - Heat Resistance
  - Resin Dependent
- **Flammability**
- **Cost**
- **Reduction in Specific Gravity**

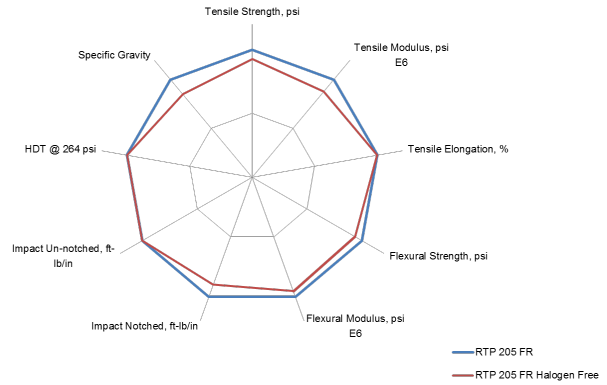
30% GF Nylon 6/6

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Mechanical Properties	RTP 205 FR	RTP 205 FR Halogen Free
Tensile Strength, psi	21000	19500
Tensile Modulus, psi E6	1.65	1.45
Tensile Elongation, %	2-4%	2-4%
Flexural Strength, psi	33000	31500
Flexural Modulus, psi E6	1.55	1.45
Impact Notched, ft-lb/in	2	1.8
Impact Un-notched, ft-lb/in	16	16
HDT @ 264 psi	470	470
Specific Gravity	1.66	1.41
Flammability	V-0 @ 1/32	V-0 @ 1/32

Property Comparison

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Test Standards

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

Industry and Market Driven

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Electrical and Electronics (E&E)

– Appliance, Connectors, housings, etc.

- **UL 94**
  - V, 5V, HB
- **UL 746**
  - HAI, HWI, CTI

Flame Tests In-Depth

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Lets look closer at…

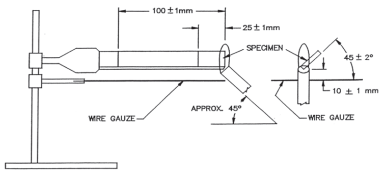
UL94

- **Horizontal Burn (HB)**
- **Vertical Burn (V-0, V-1, V-2)**

UL94 HB

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Horizontal burning test for HB classification



Classification Criterion

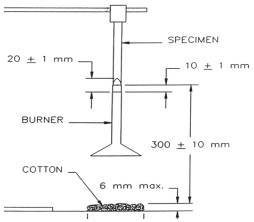
3.0 mm to 13.0 mm thickness	*< 3.0 mm thickness*
– slower than 40 mm/minute or…	*– slower than 75 mm/minute or…*
– combustion ceases prematurely	*– combustion ceases prematurely*

*** In general most thermoplastics meet this criteria***

UL94 VB

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Classification Criteria	V-0	V-1	V-2
Number of bar specimens	5	5	5
Maximum flame time per specimen per flame application, sec	10	30	30
Maximum total flame time 5 specimens, 2 ignitions, sec	50	250	250
Specimen drips, ignites cotton	No	No	Yes
Maximum afterglow time per specimen, sec	30	60	60
Burn to holding clamp	NO	NO	NO



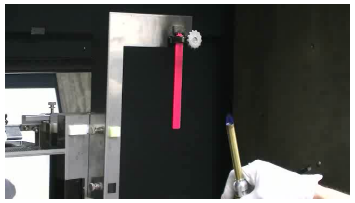
Thickness dependent ratings

UL94 Vertical Burn Demo

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Flame Retardant – V-0

Non- Flame Retardant – No Rating



Aerospace

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

FAR 25.853

- **F**lammability:
  - 15-Second Horizontal Burn
  - 12-Second Vertical Burn
  - 60-Second Vertical Burn
- **S**moke Density:
  - Ds@4min <200
  - ABD0031 or BSS 7238 or ASTM E-662
- **O**hio **S**tate **U**niversity Heat Release:
  - Calorimetry Test Measures Peak and Total Heat Release
  - <100/100, <65/65, & <55/55 are common

OEM Driven Requirements

- **T**oxic Gas Emission:
  - Varies by OEM
  - ABD0031 or BSS 7239

Requirements vary by part size and location

Building/Industrial

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Requirements focus on:**
  - Low Smoke, Heat Release, Burn Rate, Flame Spread
- **Various standard that apply:**
  - UL2043, UL723/ASTM E84, ASTM E1354, NFPA 701, FM 4996, CAL TB133
- **Applications**
  - Wall coverings, Furniture, Plenum, Pallets, Storage systems, Roofing, Floor coverings, Ventilation

FR Products meet End Applications

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- LED Lens
- Outdoor Connector
- Overhead Speaker Unit
- Consumer Electronic Cover

FR Meets Transparency

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Consumer
Application: LED Lens Cover
Problem: UL 94 V-0, High Light Transmission, UV, Light Diffusion, RoHS Compliance
Solution: PC – Transparent, Flame retardant, Specialty pigment package
Benefit: Provided ample diffusion of high powered LED lights with a proprietary pigment technology while achieving the required flame performance

FR Meets Outdoors /UV

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Consumer
Application: Marine Connector
Problem: Strength/Impact, UV Resistance, Specialty color, UL94 V-0, F1
Solution: PC/PBT – Glass reinforced, UV stabilized, Flame retardant
Benefit: Product was able to pass the required drop impact testing and stringent UL outdoor and flammability ratings

FR Breaks Through the Ceiling

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: Industrial
Application: Speaker Unit
Problem: Plenum location, UL 2043, UL94 5VA, Rigidity
Solution: Polypropylene – Glass fiber reinforced, Halogen free flame retardant
Benefit: Provided structural requirements needed for function and stringent UL flame resistance

FR Joins the Green Movement

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Market: E&E

Application: Wireless Access Point

Problem: Bio-Content requirements, Impact resistance, UL94 V-0, Green FR solution

Solution: PLA Alloy – Flame retardant, Impact modified

Benefit: Bio based material that meets demanding heat requirements, provides good dimensional stability and complies with the regulatory flame requirements

RECAP

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Designing for an FR application

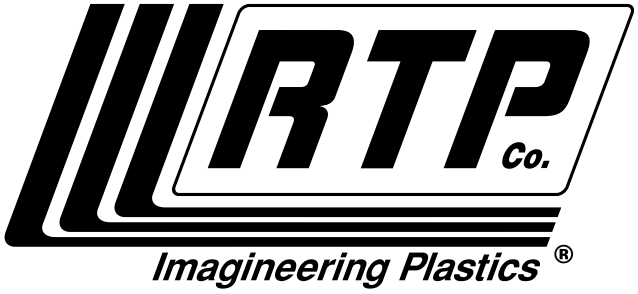
- **Regulatory Landscape**
  - RoHS, Halogen Restrictions
- **Specifications**
  - UL94, FAR, ASTM, etc.
- **Part Function**
  - Performance Requirements, Application Environment, etc.
- **Economics**
  - Price is a Property

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Questions?

Jesse Dulek
jdulek@rtpcompany.com
(507) 474-5502

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383



A Practical Guide to the Process of Selecting Materials

Karl Hoppe
Senior Product Development Engineer
khoppe@rtpcompany.com
(507) 474-5367

4:00 p.m.

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Practical Guide to Plastics Selection

Karl Hoppe
Senior Product Development Engineer

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
websites: www.rtpcompany.com • email: rtp@rtpcompany.com • Winman Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383

ISO 9001

Fear Not!

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Purpose of this presentation:

- Remove the mystery
- Help you understand our language

Overview of the Process

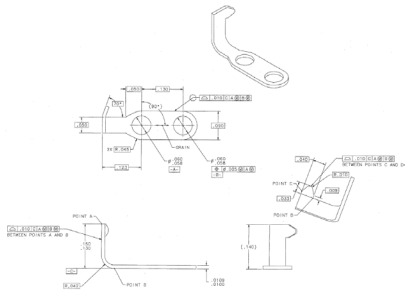
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- What does it do?
  - ***Part Qualification***
- Where does it live?
- Manufacturing process
- Other technical requirements
- Understanding history
- Economics

What does it do?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- How does the part function?
- Understand the assembly



Mystery part

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

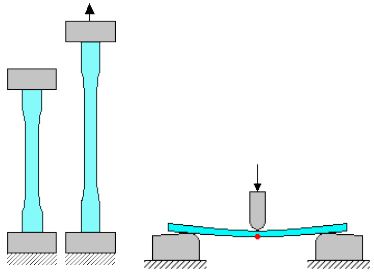
What does it do?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

What does it do?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

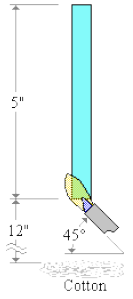
- **Define known mechanical property requirements**
  - Strength
  - Stiffness
- **Electrical**
  - Insulative
  - Antistatic
  - Conductive

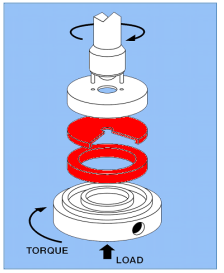


What does it do?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Flame Retardance**
  - Connectors
  - Electronics
- **Wear Resistance**
  - Gears
  - Bearings
  - Bushings
  - Seals

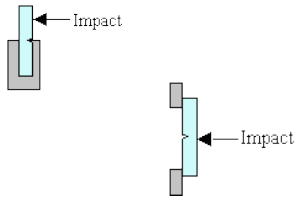




What does it do?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

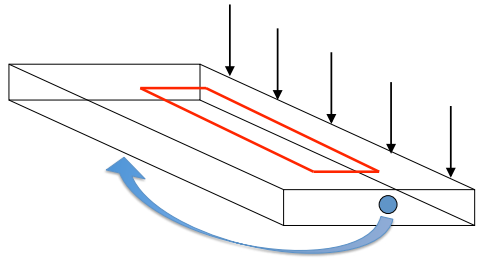
- **Impact resistance**
  - Izod impact
  - Charpy impact
  - Falling dart
  - Drop tests
- **Anisotropic properties**
  - Semicrystalline materials
  - Fiber reinforced materials



What does it do?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **How will material be qualified?**
- **Part vs. specimen testing**
- **Example: RTP 102 CC (15% GF PP)**



Suggestions for testing

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Make it realistic**
- **Test the part**
- **Make it repeatable**

Where will it live?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Environment**
- **What does it need to survive?**
  - Chemical Resistance
  - UV
  - Temperature
  - Humidity

Chemical Resistance

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

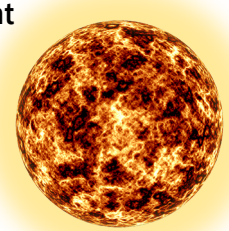
- Supplier information is often general
- Real data best for comparison
- Data on specimens doesn't guarantee success
- Data on specimens doesn't guarantee failure

Narrow down the options

UV

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Every UV situation is different
- Define failure criteria
  - Color
  - Stress cracking
  - Material degradation



No guarantees on time

Temperature

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Temperature for:

- Storage
- Normal use
- Temperature spikes

Temperature needs to be related to TIME

Humidity

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Important to understand for hygroscopic materials
- Examples:
  - Nylons change properties
  - Polyesters may degrade

Manufacturing Process

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Production process**
  - Molding, extrusion
- **Tolerances**
  - How flat/how tight?
- **Secondary Operations**
  - Welding, fastening



Other Technical Requirements

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Regulatory/Agency Compliance**

FDA NSF RoHS USP Class VI UL Ex

Other Technical Requirements

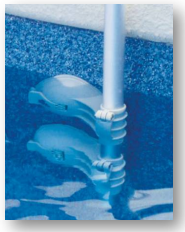
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Surface aesthetics**
  - External parts
  - Hidden parts
- **Color**
  - For ID
  - For Marketing

Understanding History

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- **Understand project status**
  - New application
  - Existing application (non-thermoplastic)
    - Why change?
    - Does tool exist?

Economics

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Price is a property
- Look at the system cost

Material Cost
\+ Manufacturing Cost
\+ Operational Advantages
= System Cost

Case Study

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Description: We are looking at an explosion proof wireless antenna cover. The cover must withstand operating temp range of -20ºC to 75ºC (-5º F to 170º F); good chemical and impact resistance
- Requirements: Currently, all our instrument covers are aluminum die cast for ex-proof application

Requirements

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Explosion-Proof
  - Impact resistance
- -20ºC to 75ºC (-5º F to 170º F)
- Good chemical resistance
- Good impact resistance
- Currently aluminum die-cast

Long glass (VLF) Rigid Polyurethane

Refined Information

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Does it need to be flame retardant?
  - YES
- Define “explosion-proof”
  - Resists catastrophic static discharge
  - “ATEX”

PermaStat® Plus Nylon 6 + FR

Summary

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- ***No Fear***
- Plan out ***part qualification***
- Compound technologies = ***SCIENCE***
- Applying technology = ***ART***

THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR
CONDUCTIVE • COLOR • FLAME RETARDANT

Thank you for attending today's Workshop!

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Winan Corporation • +1 320-259-2554
TELEPHONE:
U.S.A. +1 507-454-6900 | SOUTH AMERICA +55 11 4193-8772 | MEXICO +52 81 8134-0403 | EUROPE +33 380-253-000 | SINGAPORE +65 6863-6580 | CHINA +86 512-6283-8383