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STRUCTURAL • ELASTOMERS • WEAR • COLOR
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Light-Weighting with Engineered Plastic Compounds

Karl Hoppe
Senior Product Development Engineer
RTP Company

- **Compounder** = We blend thermoplastic resins with fillers, additives, and modifiers
- **Specialty** = We create compounds custom engineered to your meet specifications
- **Independent** = We are unbiased in our selection and use of raw materials

Compounding Process

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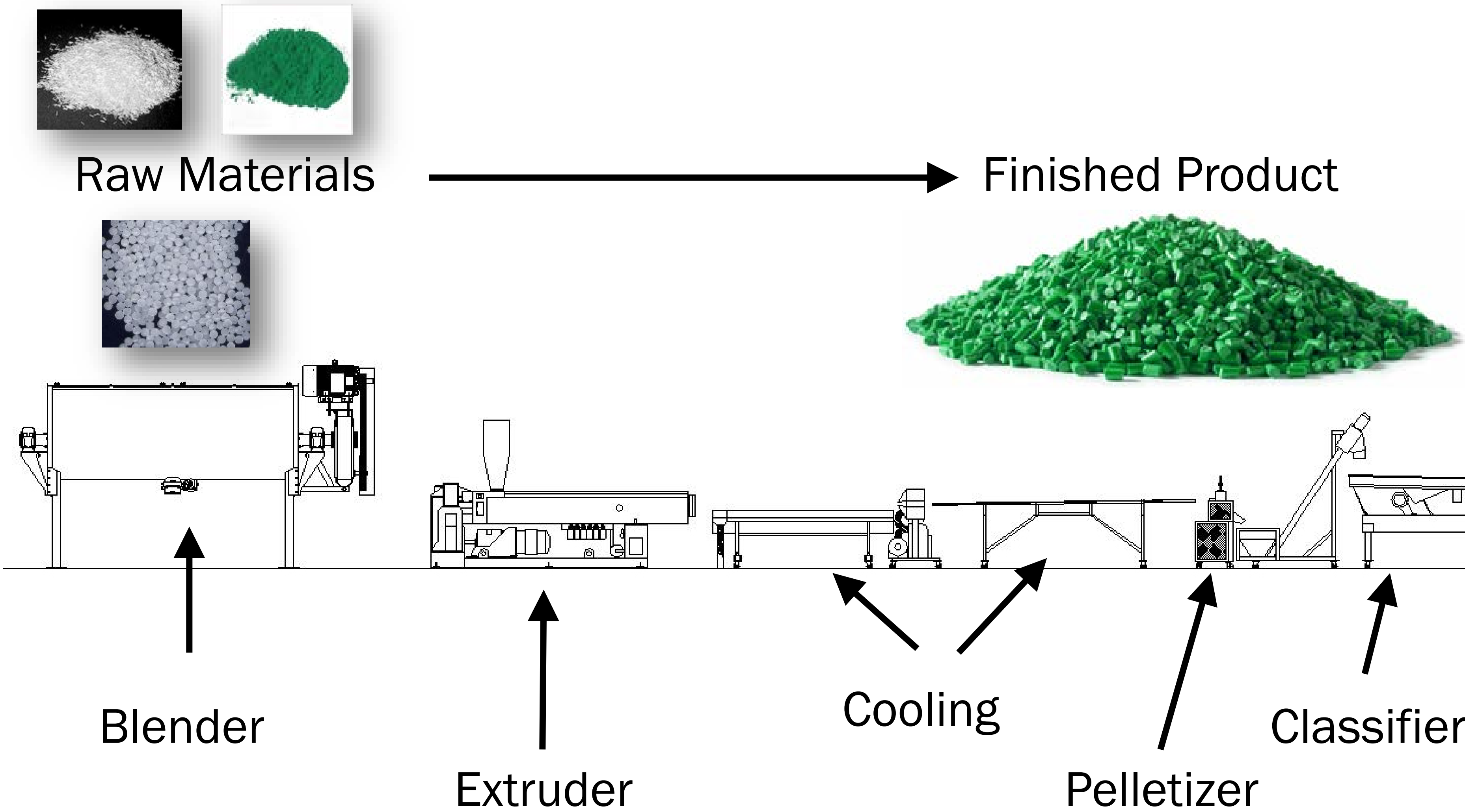

Agenda

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- **Lightweighting technologies**
  - Reinforced compounds
    - Glass fiber
    - Long glass fiber (VLF)
    - Carbon fiber
  - Hollow glass microspheres
  - Chemical foaming agents
- **Design considerations**
  - Resin selection
  - Fiber orientation effects

- Fuel economy and emissions regulations are driving mass reduction initiatives
- Reinforced plastics have a proven history of success in replacing traditional materials because of their excellent strength-to-weight performance
- RTP Company has the broad portfolio of products and support assistance needed for making material transitions

- **Short glass fiber**
  - Reinforcement theory
  - Resin selection
- **VLF (Very Long Fiber)**
- **Carbon fiber**

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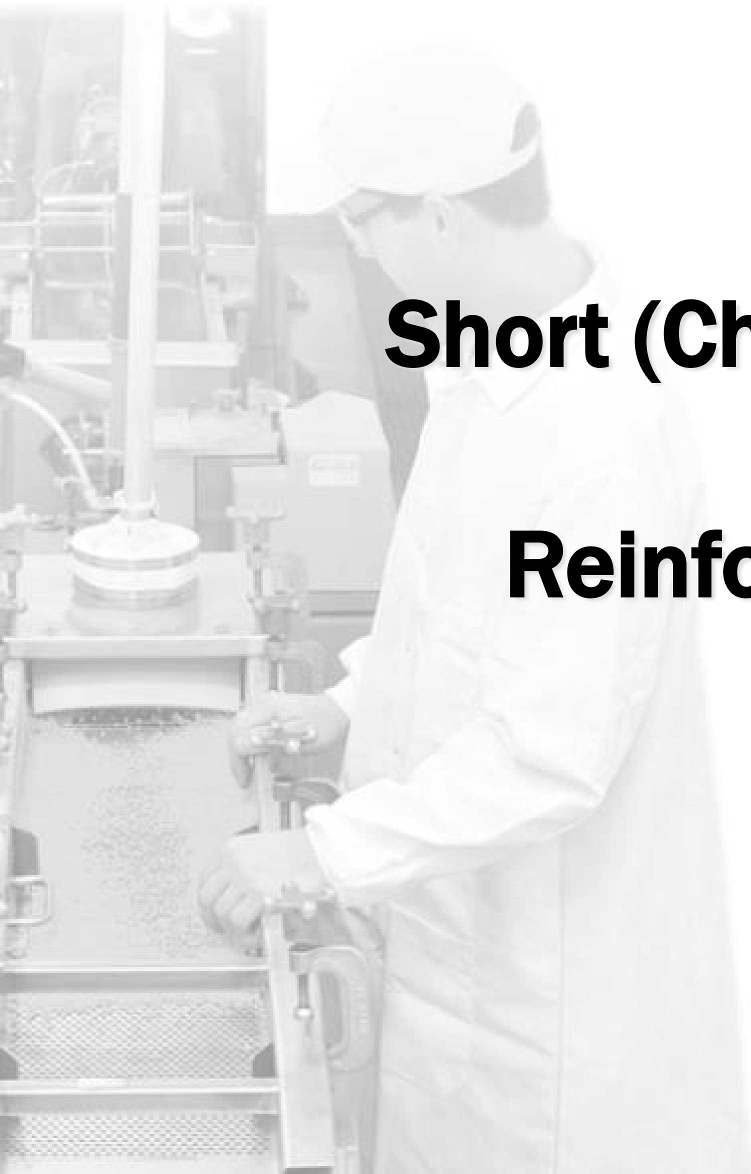


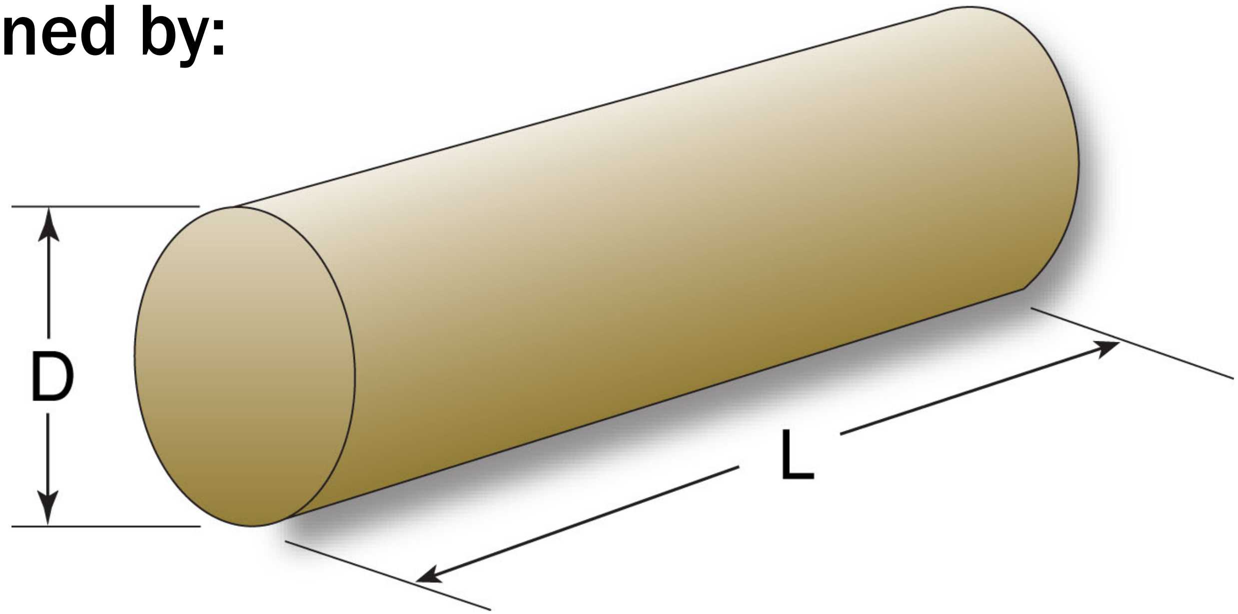
Short (Chopped) Glass Fiber
and
Reinforcement Theory

"As engineers who typically work with metal, we don't really know what plastics can do."

– Quote from RTP Company customer

Aspect Ratio

Property change determined by:



↑ Aspect Ratio ↑ Reinforcing

High Aspect Ratio - PP

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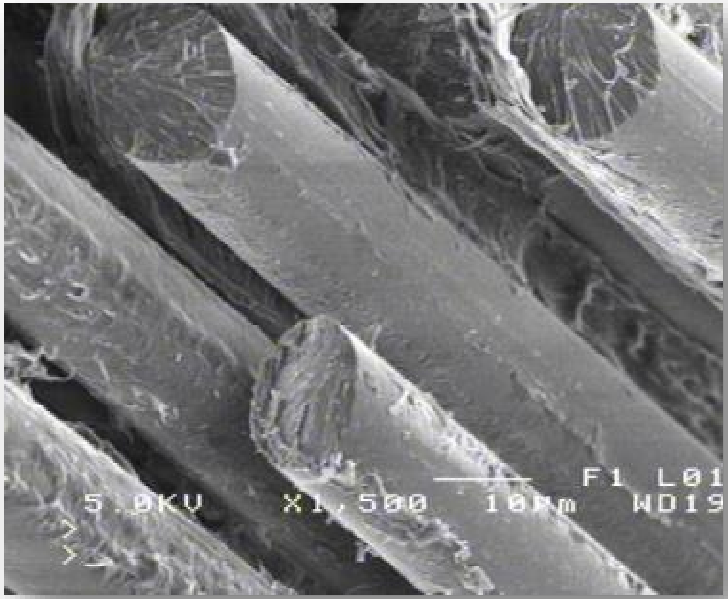

Fibers (Glass)
Aspect Ratio = 50-250

	PP	PP + 40% Glass Fiber
Specific Gravity	0.91	1.22
Tensile Strength	32 MPa	85 MPa
Notched Izod Impact	47 J/m	108 J/m
Flexural Modulus	1.5 GPa	6.9 GPa

High Aspect Ratio – PA 6/6

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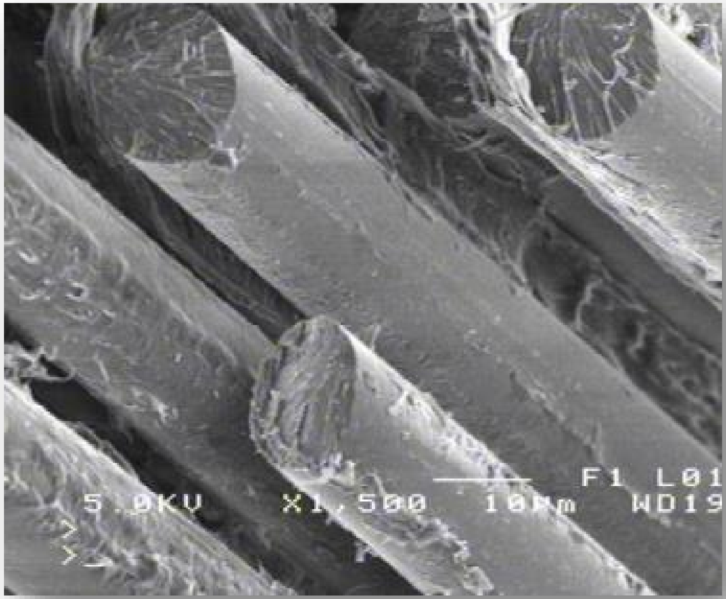

Fibers (Glass)
Aspect Ratio = 50-250

	PA 6/6	PA 6/6 + 30% Glass Fiber
Specific Gravity	1.14	1.42
Tensile Strength	85 MPa	186 MPa
Notched Izod Impact	50 J/m	120 J/m
Flexural Modulus	2.8 GPa	9.0 GPa

Bi-Directional Stress-Strain

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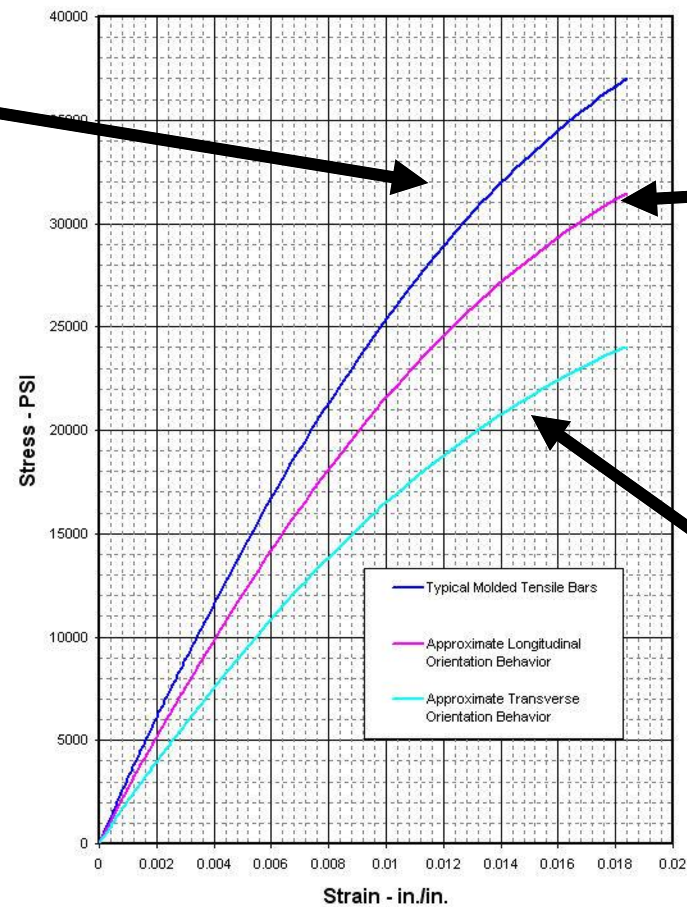
Tensile Bar Test Data



Approximate Longitudinal Behavior

Approximate Transverse Behavior

Orientation Effects

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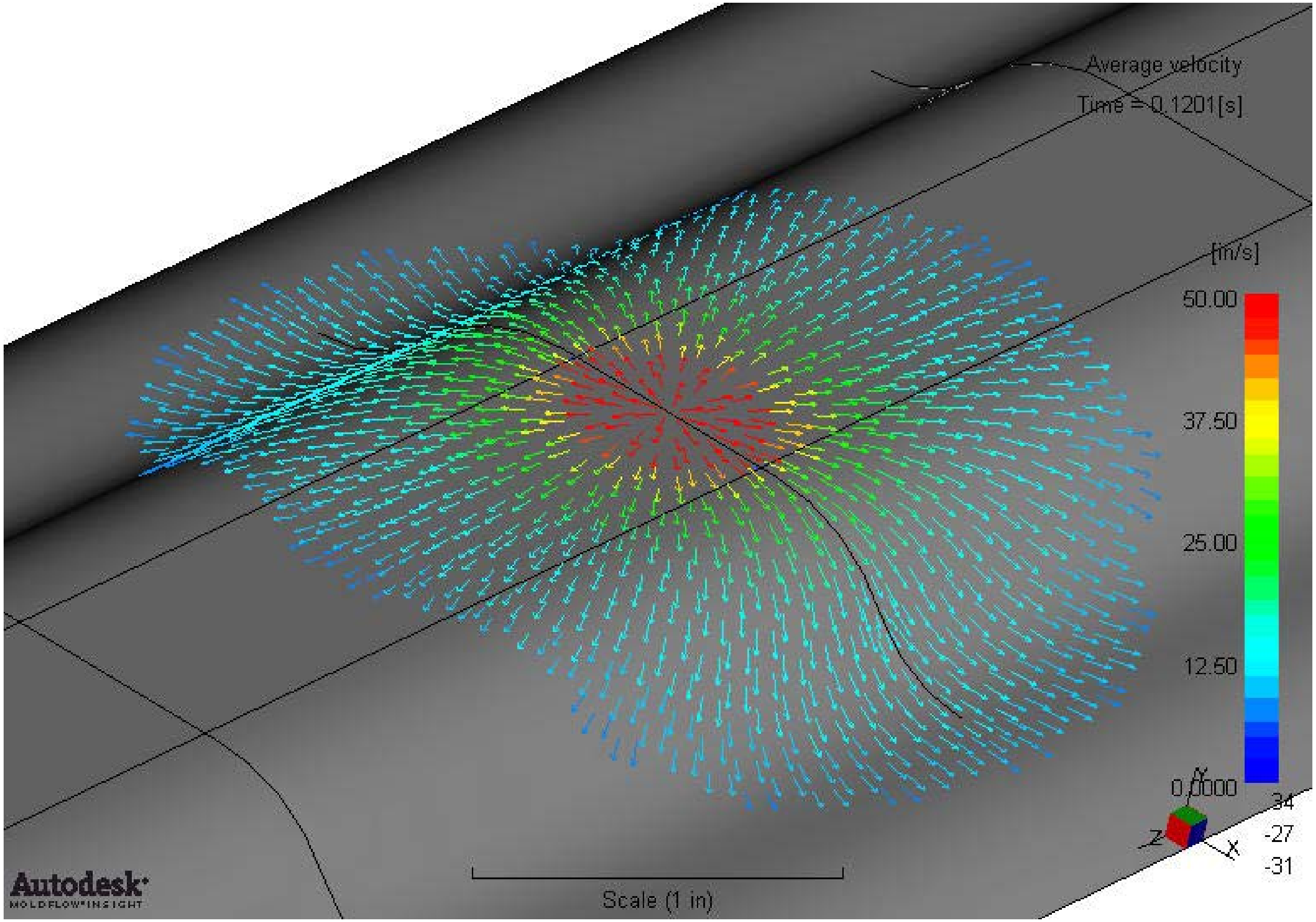

Orientation Effects

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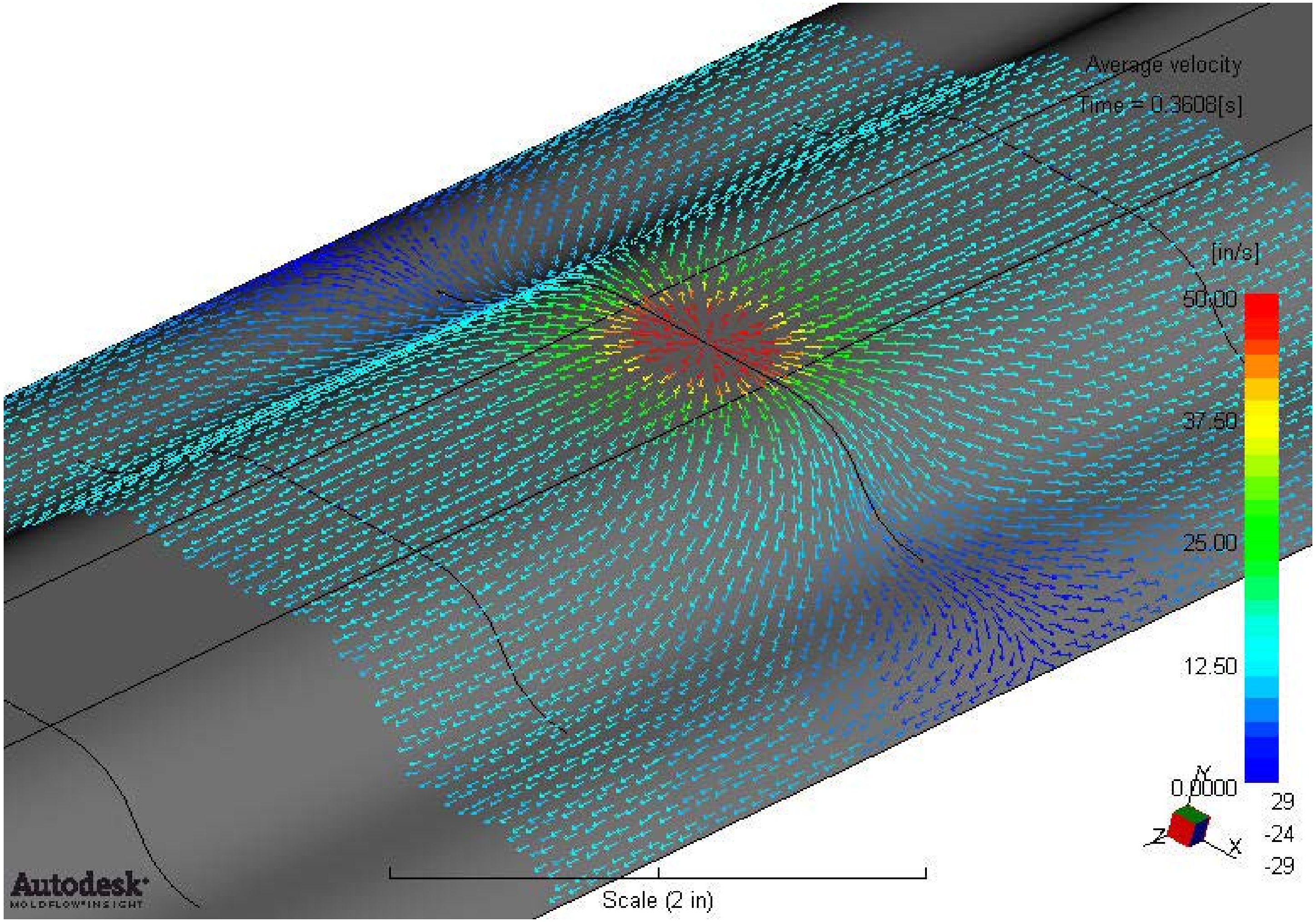
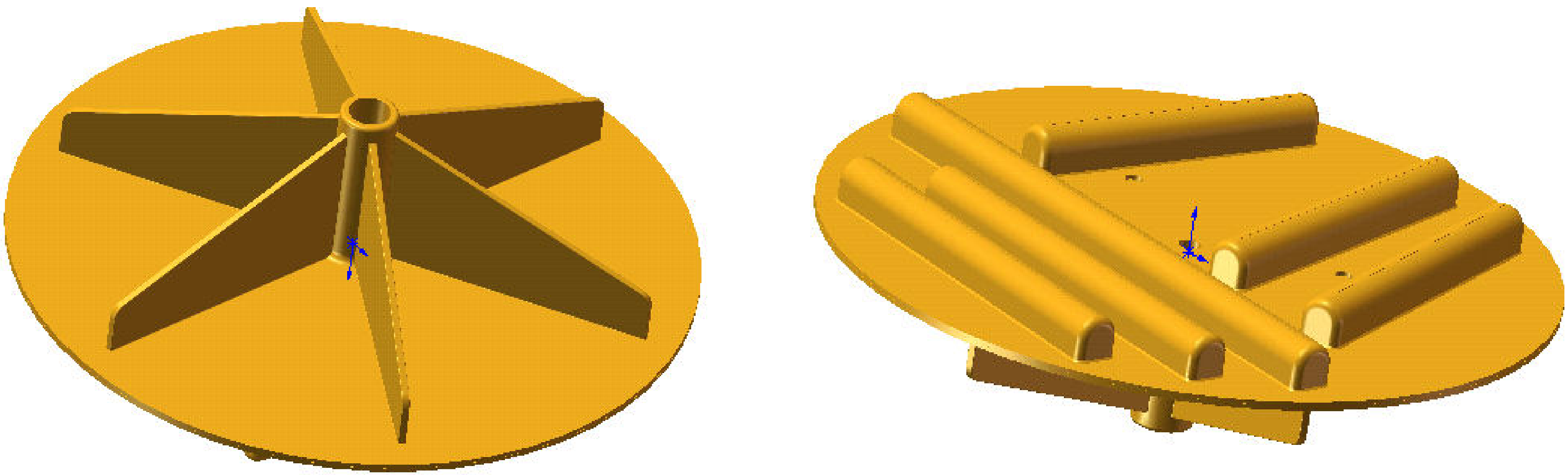
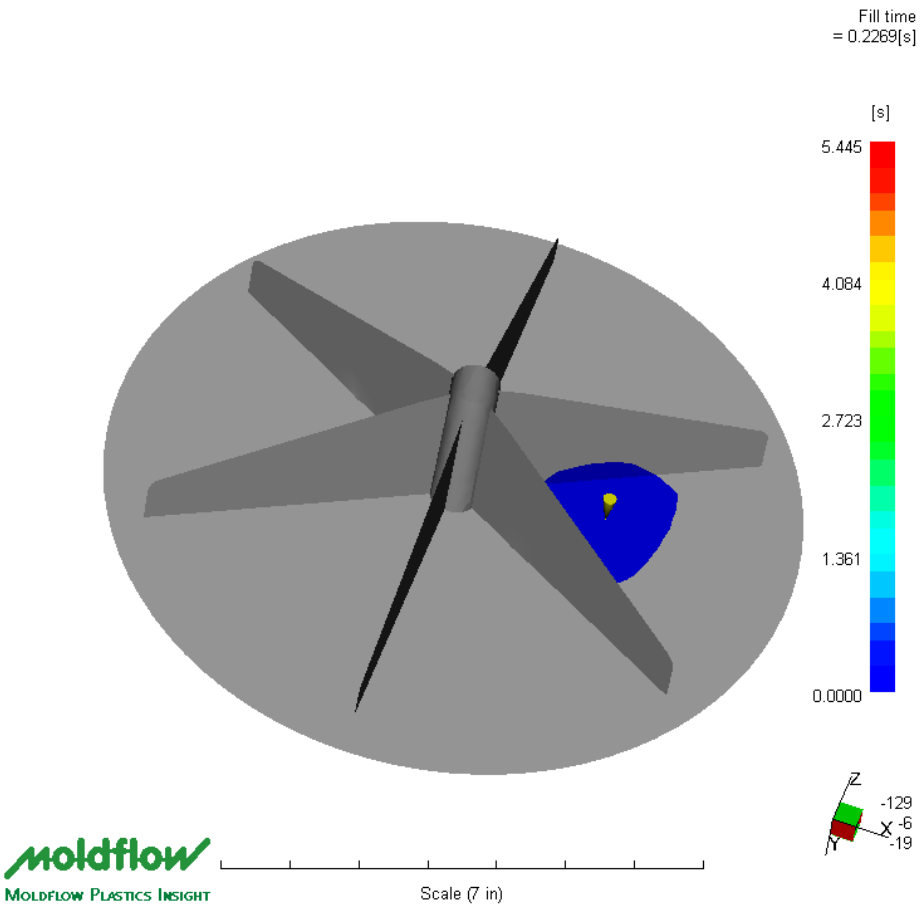
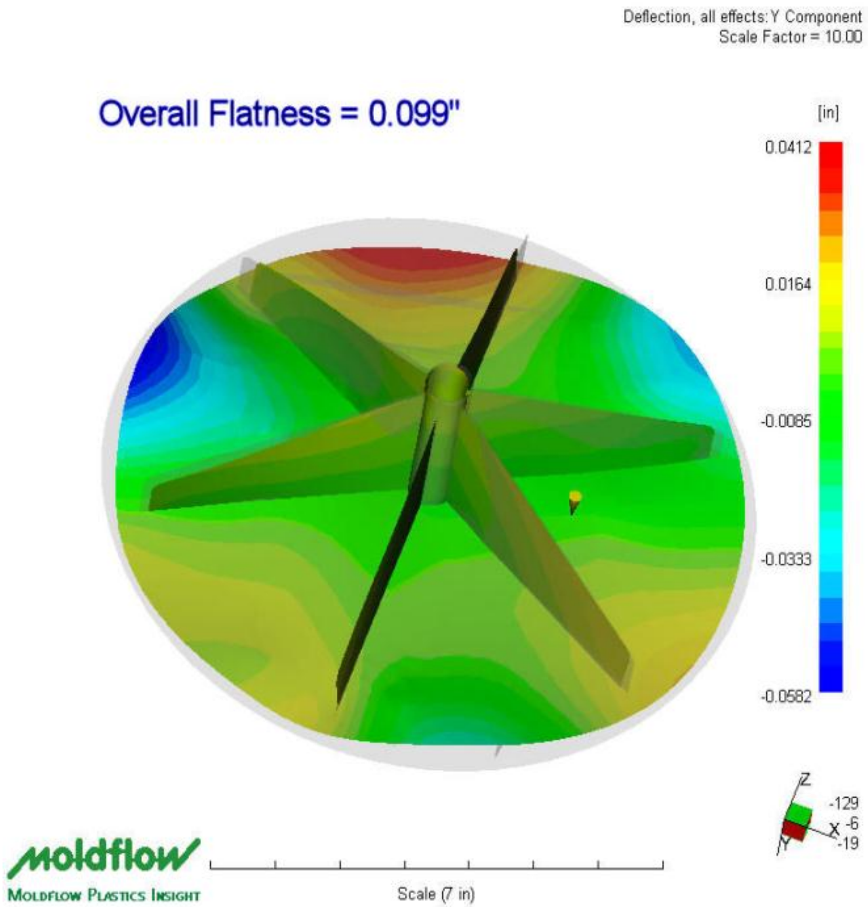


Coring Thick Walls



Coring Thick Walls





Coring Thick Walls

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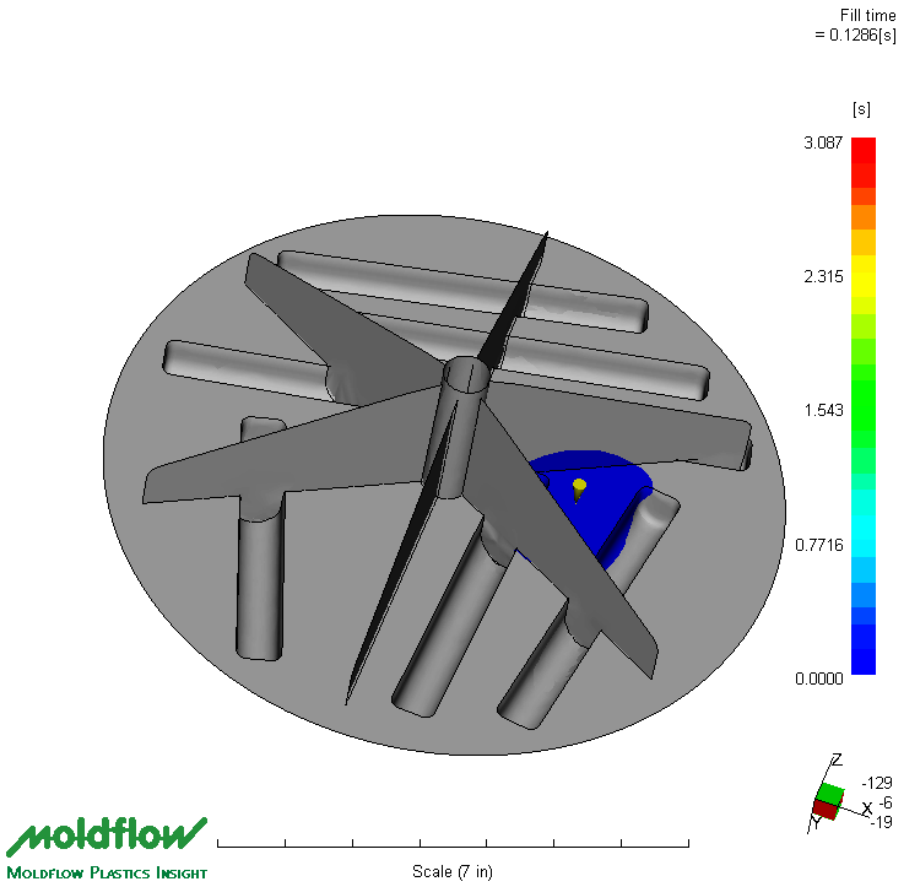

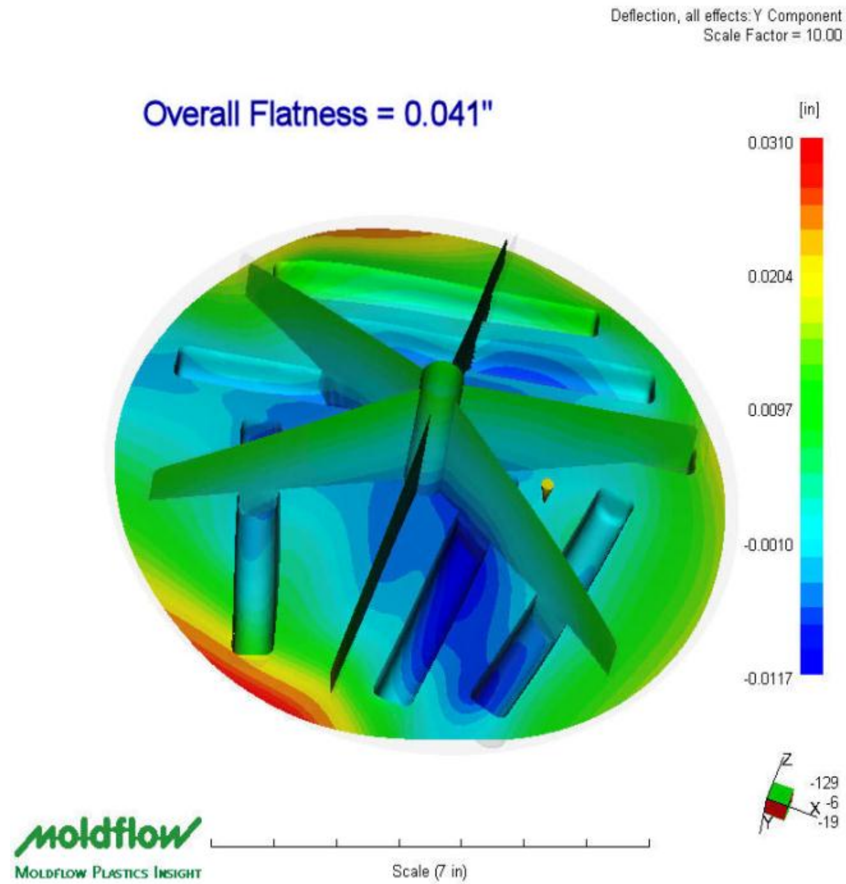

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On-Demand Recorded Webinars

CAE SIMULATION TOOLS FOR INJECTION MOLDING

Presented by Barb Matousek on May 15, 2012

Not all flow simulation analysis is the same. It's important to understand what you're getting and what it means. During this brief, yet detailed webinar Barb Matousek, CAE Analyst with custom compounder RTP Company, discusses the benefits and limitations of various analysis tools.

View Recorded Webinar

DESIGN PRINCIPLES FOR STRUCTURAL COMPOSITES

Presented by Bob Sherman on May 17, 2012

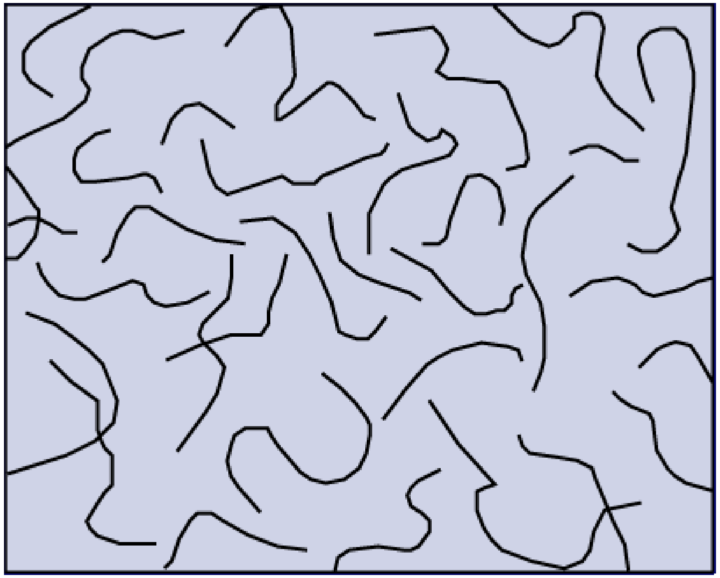
Fibrous reinforcements are used to enhance the mechanical properties of thermoplastics, but they also change the nature of these materials from isotropic to anisotropic. This significantly affects the materials molding characteristics and understanding this behavior is critical to successfully integrating them into your design. This webinar is a must see for anyone who designs parts or builds injection molds for applications that use filled or reinforced thermoplastic composites.

View Recorded Webinar

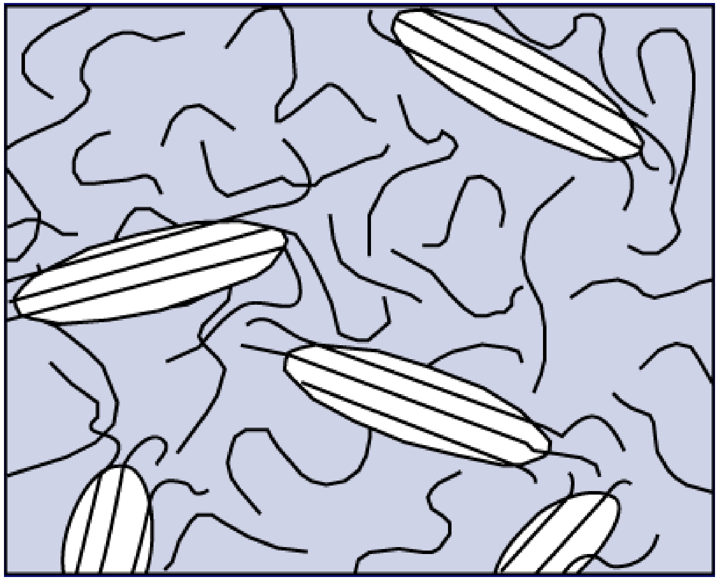
http://www.rtpcompany.com/webinars

Short (Chopped) Glass Fiber and Resin Selection

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



Amorphous



Semi-Crystalline

Morphology vs. Thermal

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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 Performance Increases

Commodity Engineered High Performance

Comparison at Temperature

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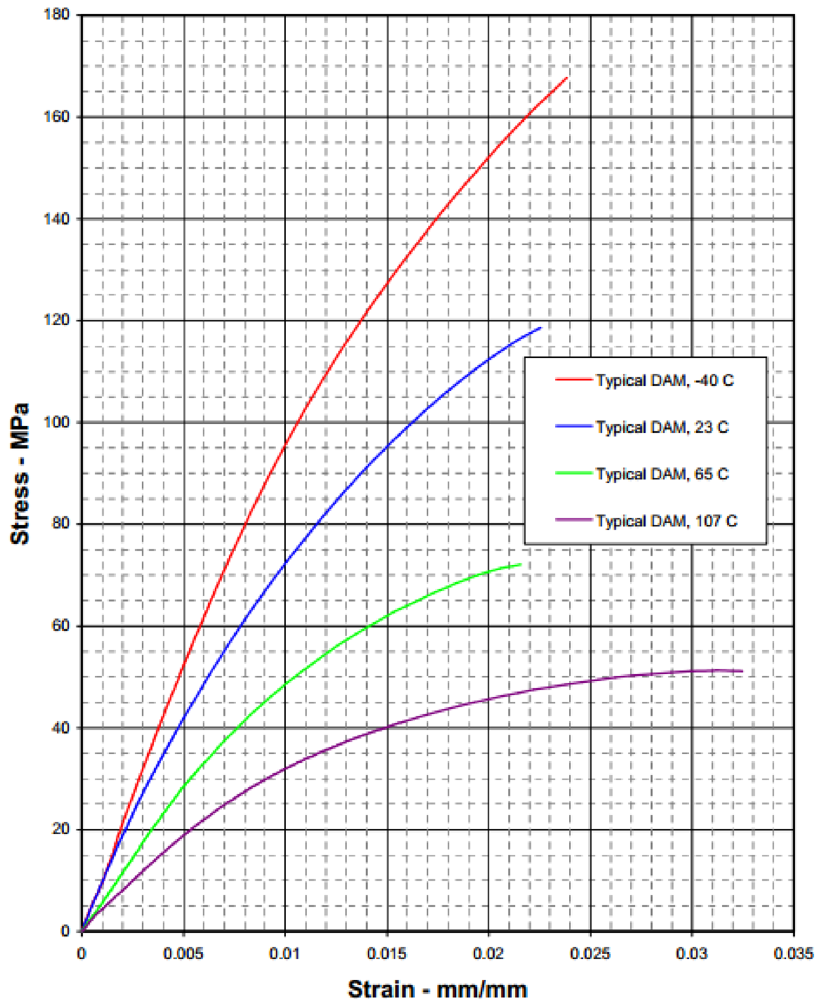
VLF 80107 CC Tensile Stress/Strain

(Molded Specimen Data)



Comparison at Temperature

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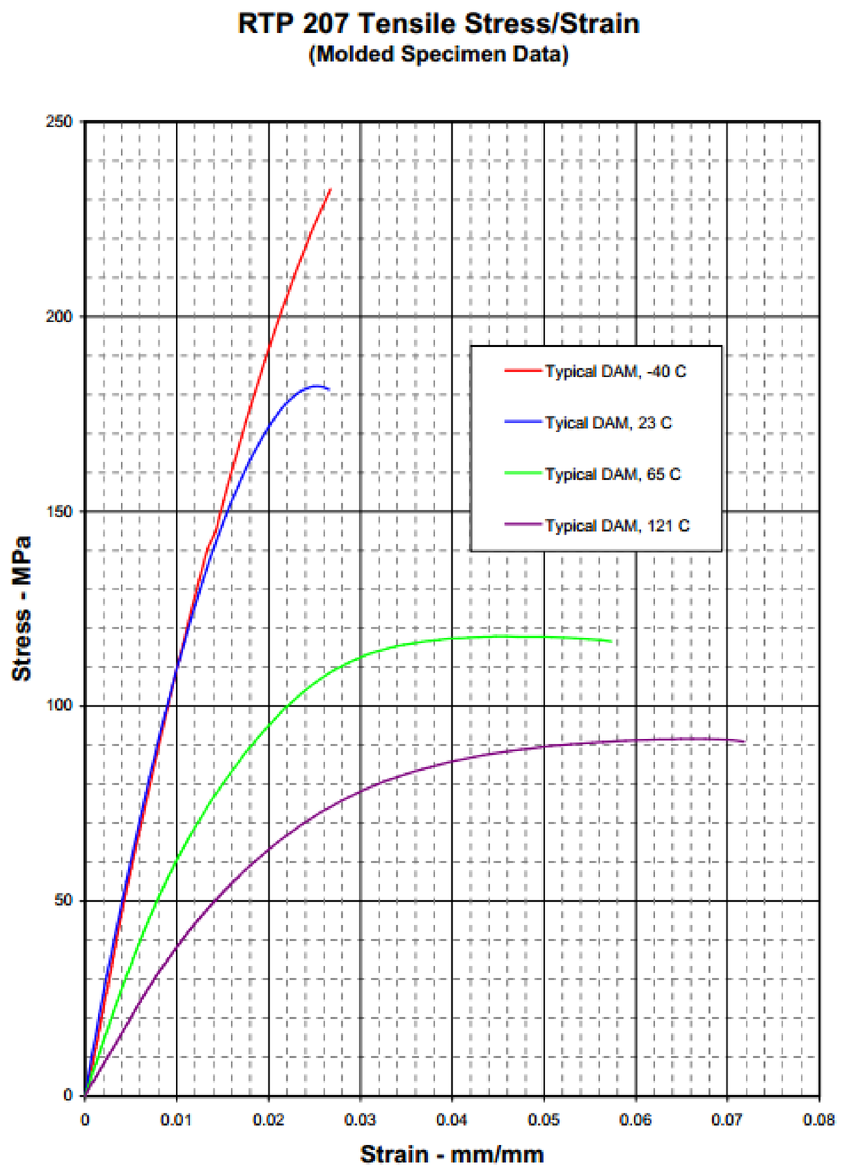
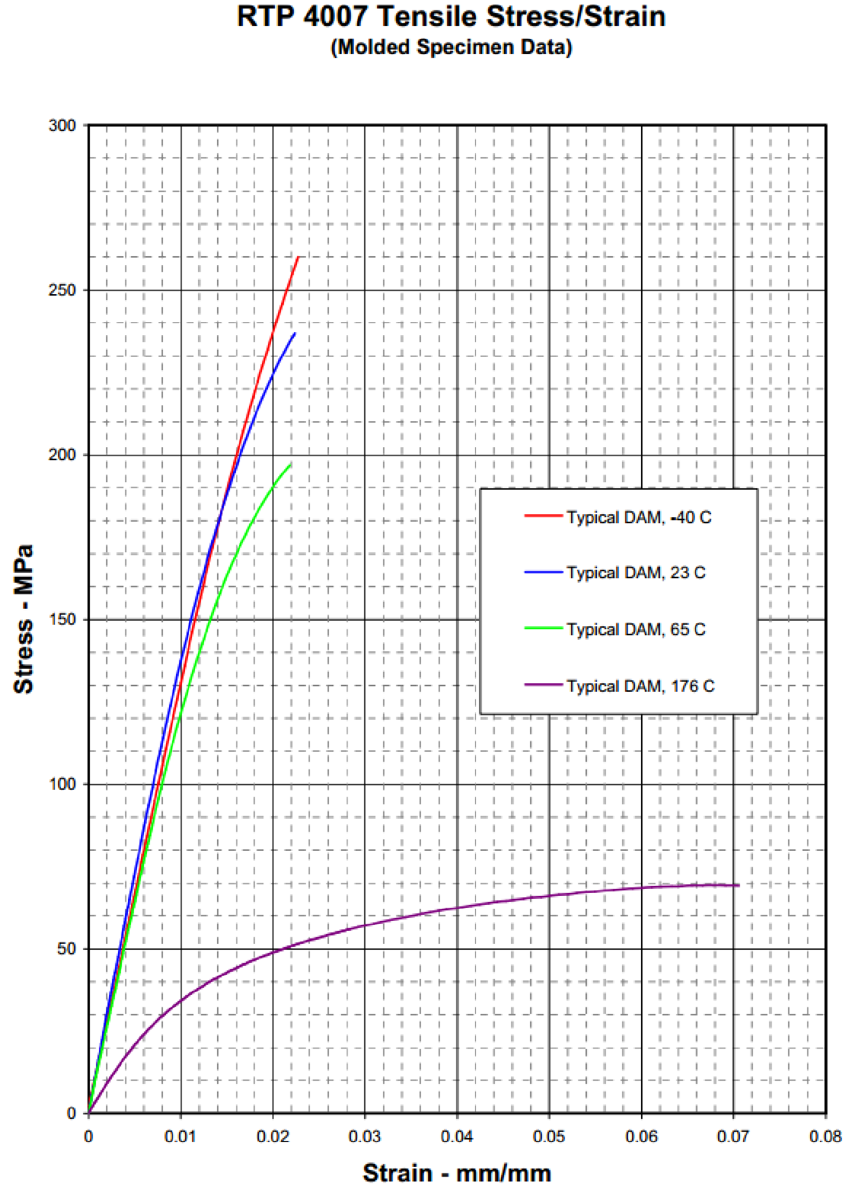


Comparison at Temperature

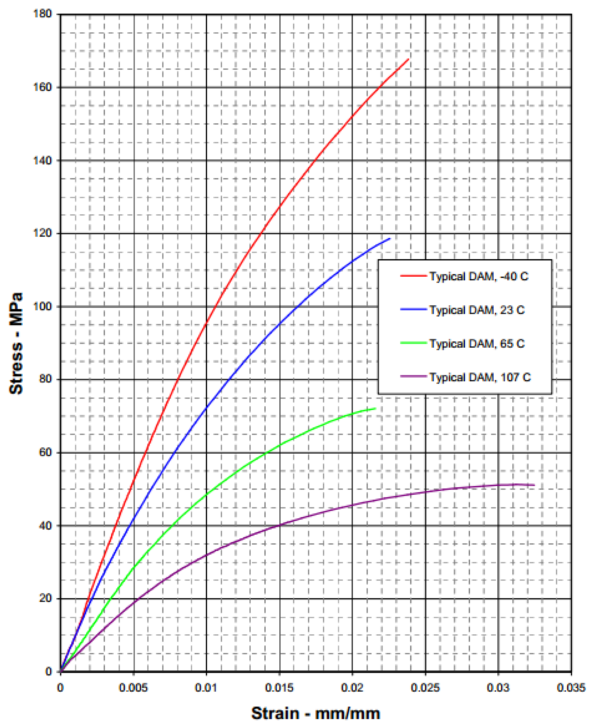
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



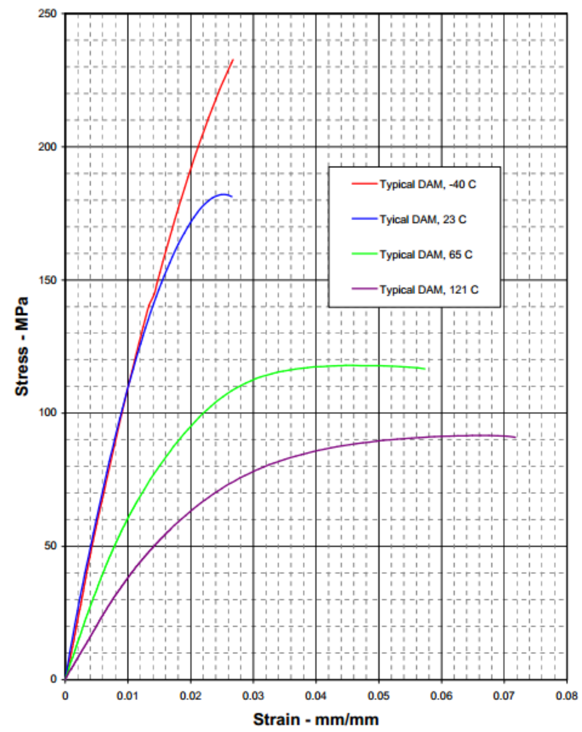
Comparison at Temperature

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

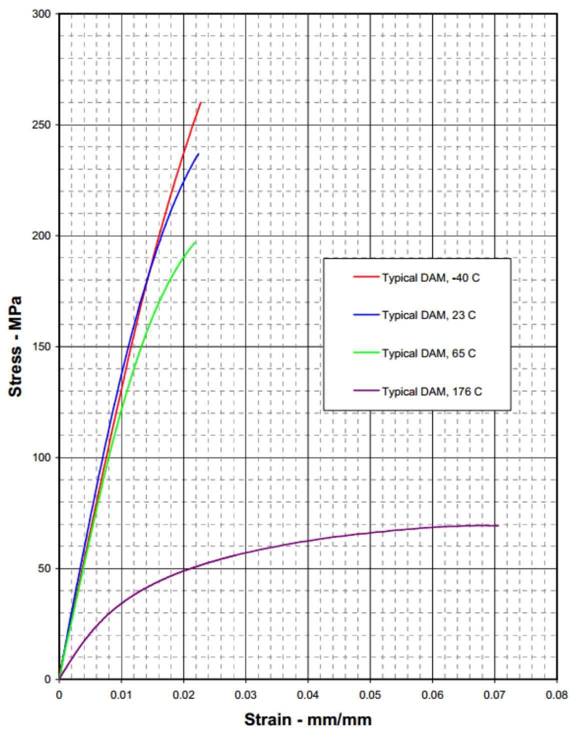
VLF 80107 CC Tensile Stress/Strain
(Molded Specimen Data)



RTP 207 Tensile Stress/Strain
(Molded Specimen Data)



RTP 4007 Tensile Stress/Strain
(Molded Specimen Data)



Morphology vs. Thermal

Amorphous	Thermal Performance Increases	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)

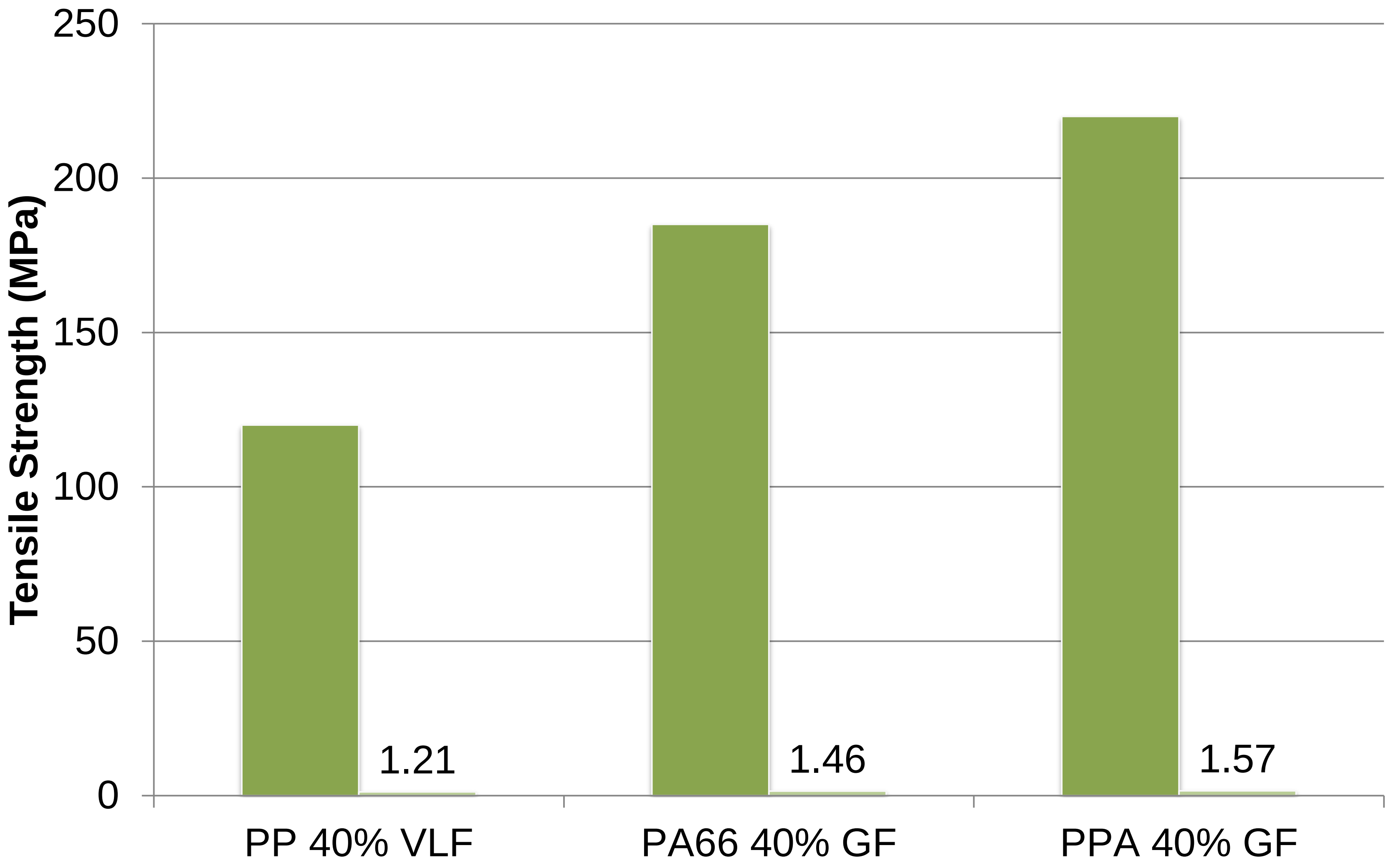
Commodity Engineered High Performance

Morphology vs. Cost

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)

Cost Increases ↑

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


Tensile Strength (MPa)
250
200
150
100
50
0
1.21
1.46
1.57
PP 40% VLF
PA66 40% GF
PPA 40% GF

VLF (Very Long Fiber) Reinforced Thermoplastics

Strength/Impact Advantage

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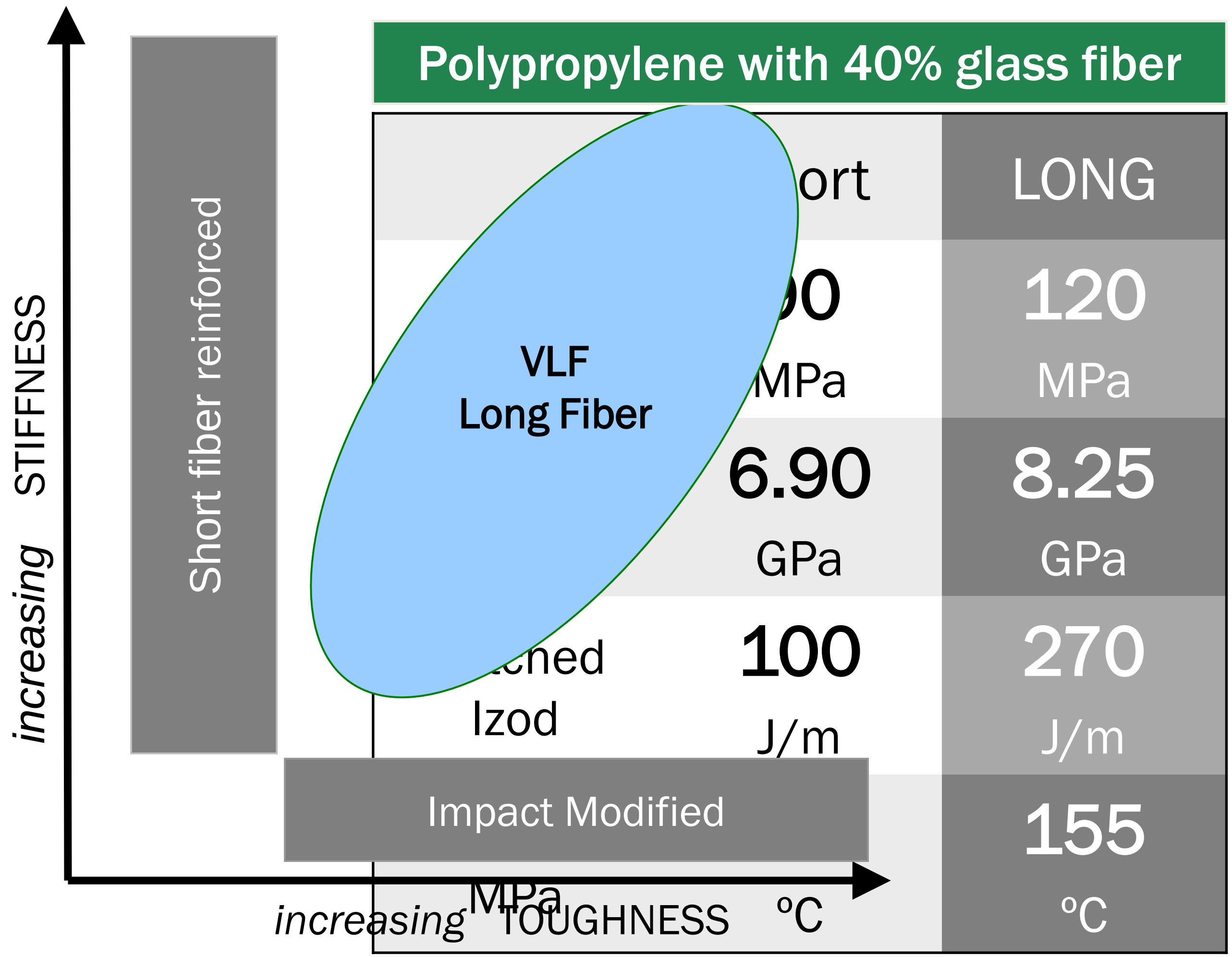

PA 6/6 – 40 Glass Fiber%

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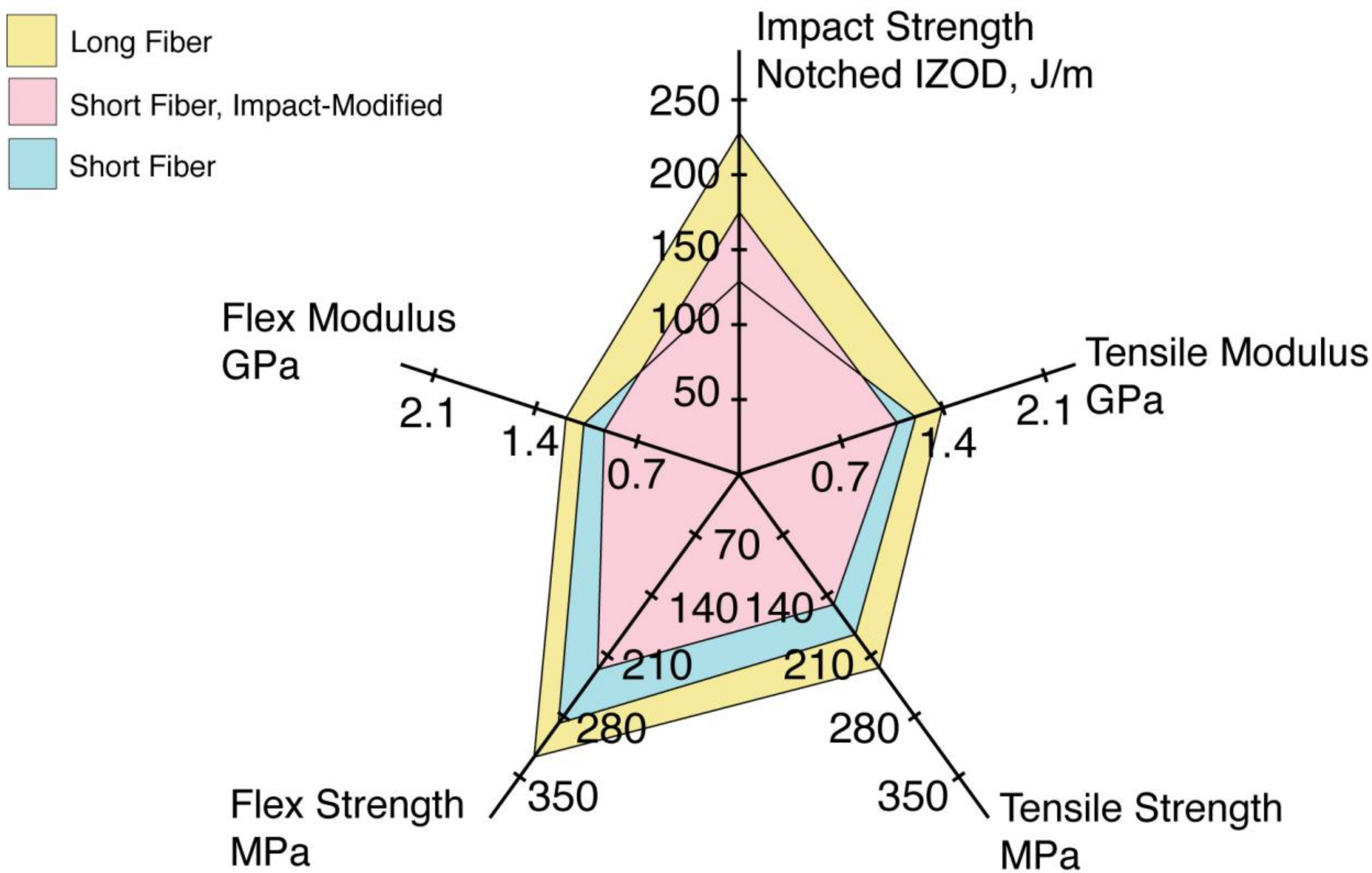

PA 66 + 60% VLF
Seat Belt Tensioner Housings

Drop Impact Test

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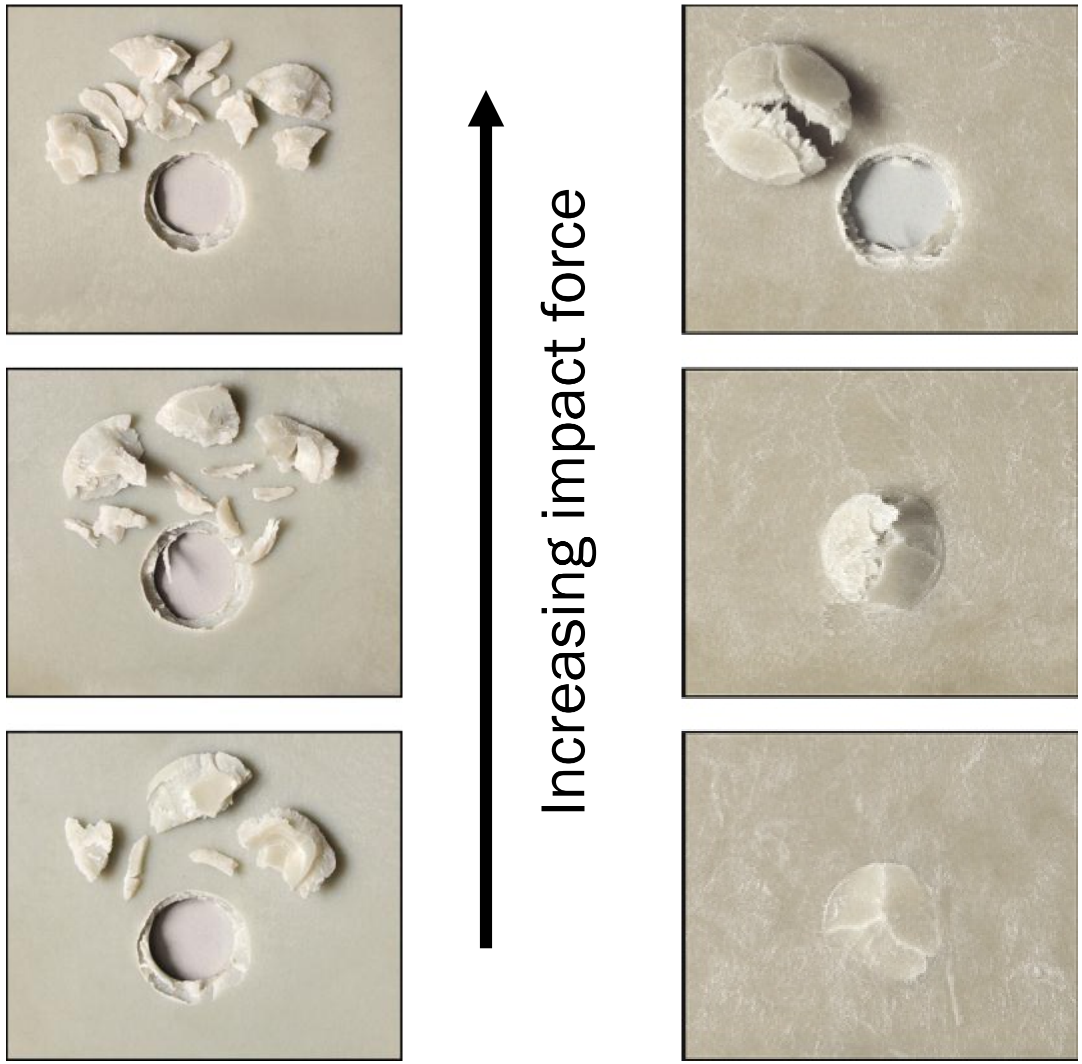
Short Fiber PA



VLF PA

PA 6/6 vs. VLF PP

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	30% Short Glass Polyamide 6/6		40% Long Glass PP
	(Dry as Molded)	(50% RH)	
Tensile Strength	186 MPa	124 MPa	120 MPa
Flexural Modulus	9.0 GPa	6.2 GPa	8.25 GPa
Izod Impact	120 J/m	135 J/m	270 J/m
Specific Gravity	1.38		1.21
HDT @ 1.8 MPa	250 ºC		155 ºC

Application: Auto Shifter Base

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End User: Honda, GM, Toyota

Material: VLF Polypropylene

Benefits of choosing VLF PP vs. short glass PA
• Cost reduction • Weight reduction • Designed for the environment – more commonly recycled

PBT vs. VLF PP

	PBT + 30% SGF	PP + 40% LGF
Specific Gravity	1.53	1.21
Tensile Strength	124 MPa	120 MPa
Flexural Modulus	8.3 GPa	8.25 GPa
Notched Impact	96 J/m	270 J/m
HDT @ 1.8 MPa	213 °C	155 °C

PPA vs. VLF PA6/6

	PPA + 40% SGF	PA66 + 40% LGF
Specific Gravity	1.55	1.46
Tensile Strength	221 MPa	228 MPa
Flexural Modulus	13.4 GPa	11.7 GPa
Notched Impact	107 J/m	320 J/m
HDT @ 1.8 MPa	279 ºC	254 ºC

Metal Replacement Objectives

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

Instantaneous Properties at 23 ° C

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

VLF PA6/6 vs. ZAMAK 3

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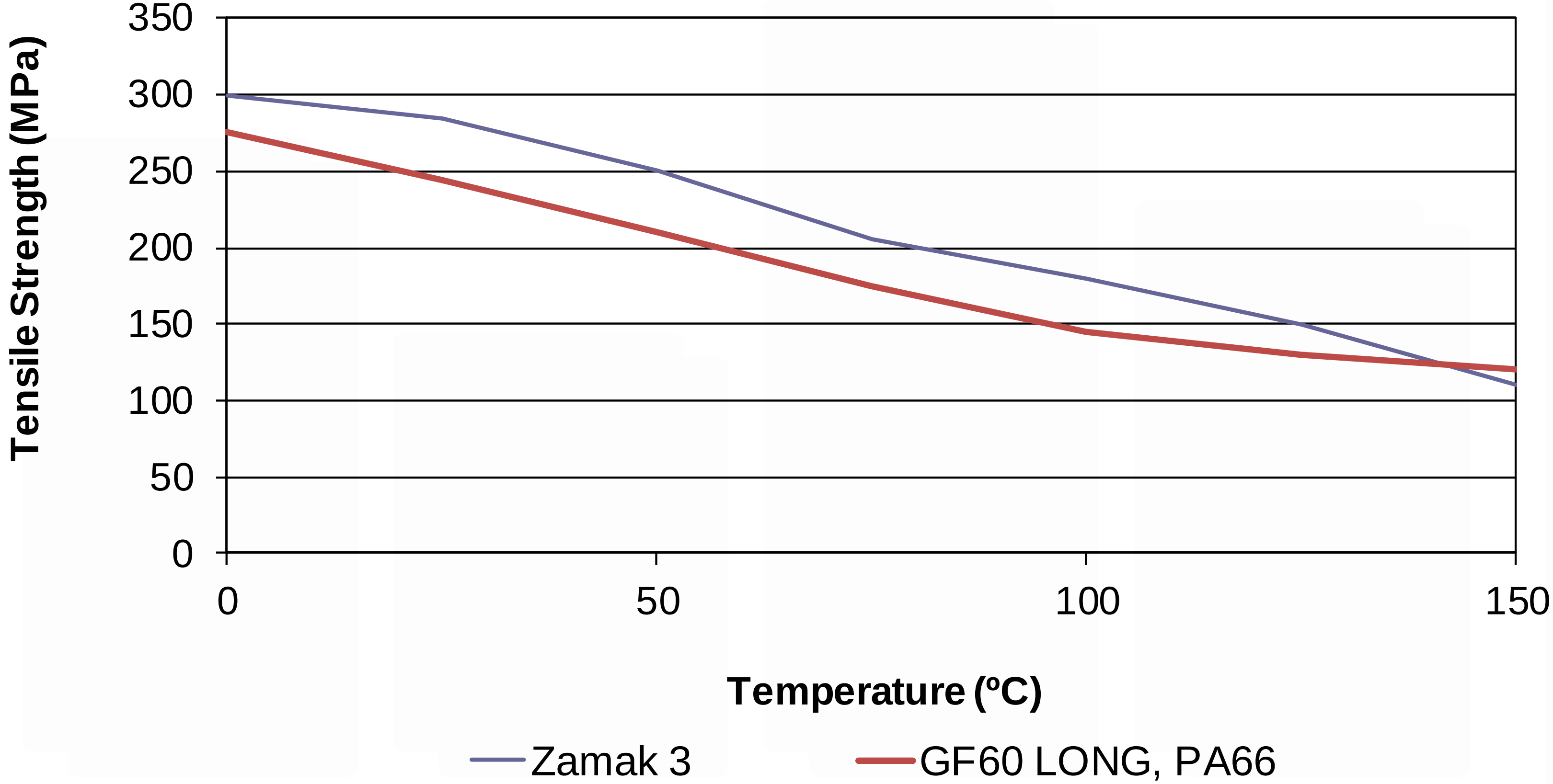

Carbon Fiber

Carbon Fiber

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

Fiber Comparison – PA 6/6

	PA 6/6 60% VLF (Long Fiber)	PA 6/6 35% Carbon Fiber
Flexural Modulus	19.3 GPa	19.0 GPa
Tensile Strength	275 MPa	244 MPa
Tensile Elongation	2%	2%
Specific Gravity	1.71	1.29

Fiber Comparison – PPS

	PPS 40% Glass	PPS 20% Carbon
Flexural Modulus	15.1 GPa	15.8 GPa
Tensile Strength	169 MPa	172 MPa
Tensile Elongation	1.5%	1%
Specific Gravity	1.68	1.40

Carbon Fiber – Highest Stiffness

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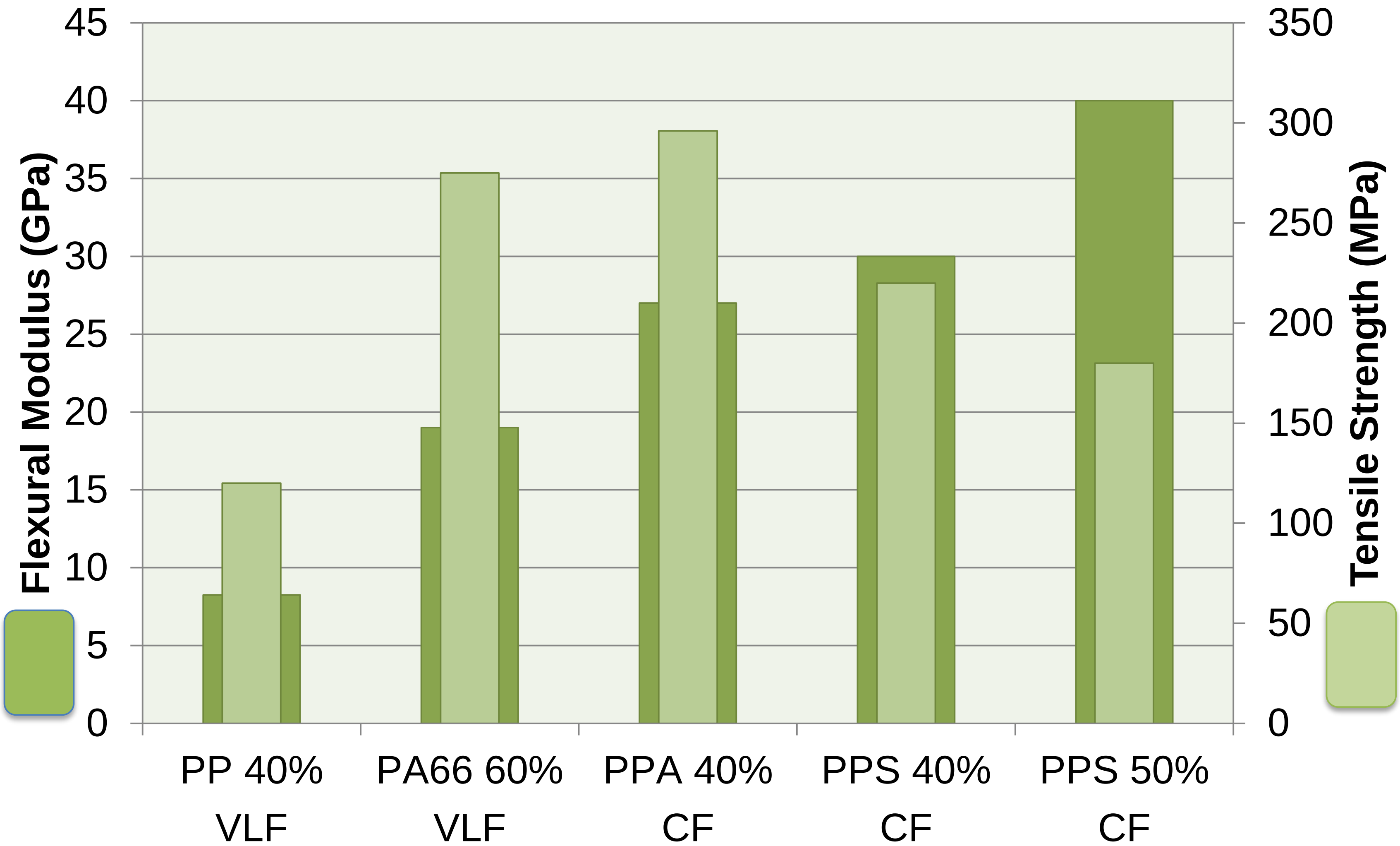

Carbon Fiber – Highest Strength

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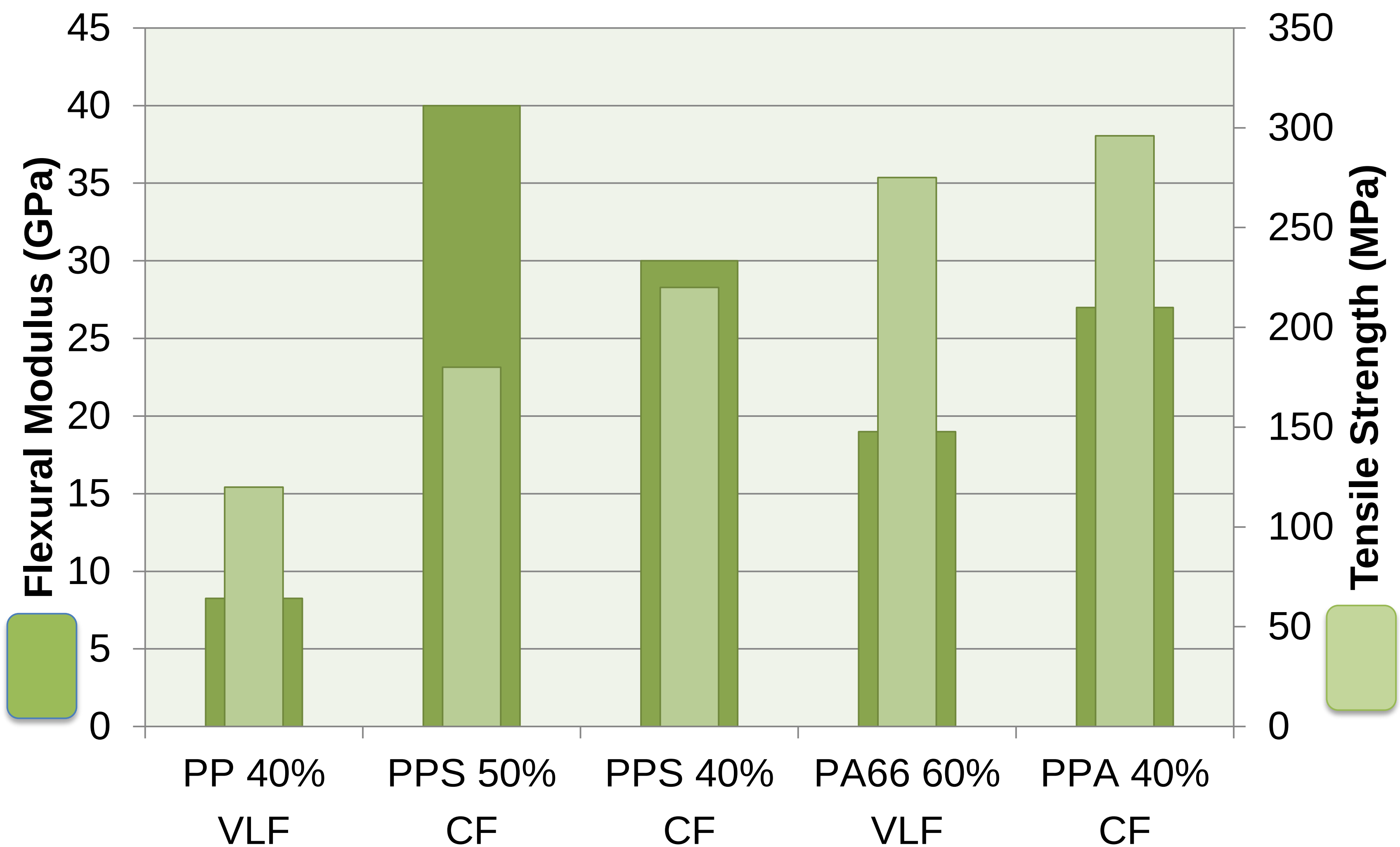

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Carbon Fiber - Polypropylene

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	PP 40% GF	PP 40% VLF	PP 30% CF*
Tensile Strength	85 MPa	120 MPa	105 MPa
Flexural Modulus	6.9 GPa	8.25 GPa	11.4 GPa
Notched Izod Impact	108 J/m	270 J/m	110 J/m
Specific Gravity	1.21	1.21	1.06

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On-Demand Recorded Webinars

INCREASING MECHANICAL PERFORMANCE OF PLASTICS

Presented by Karl Hoppe on October 11, 2011

Modified and reinforced plastics provide increased mechanical performance and allow plastics to be used to solve the unique and challenging material requirements of today's leading product development efforts. See how structural compounds could be the key to your next successful application.

View Recorded Webinar

VERY LONG FIBER COMPOSITES

Presented by Karl Hoppe on November 15, 2011

Does the idea of replacing metal parts with light-weight and easy to fabricate reinforced plastics seem appealing but you are not sure how to get started? The impressive performance benefits of "stiff and tough" very long fiber reinforced composites will be explained.

View Recorded Webinar

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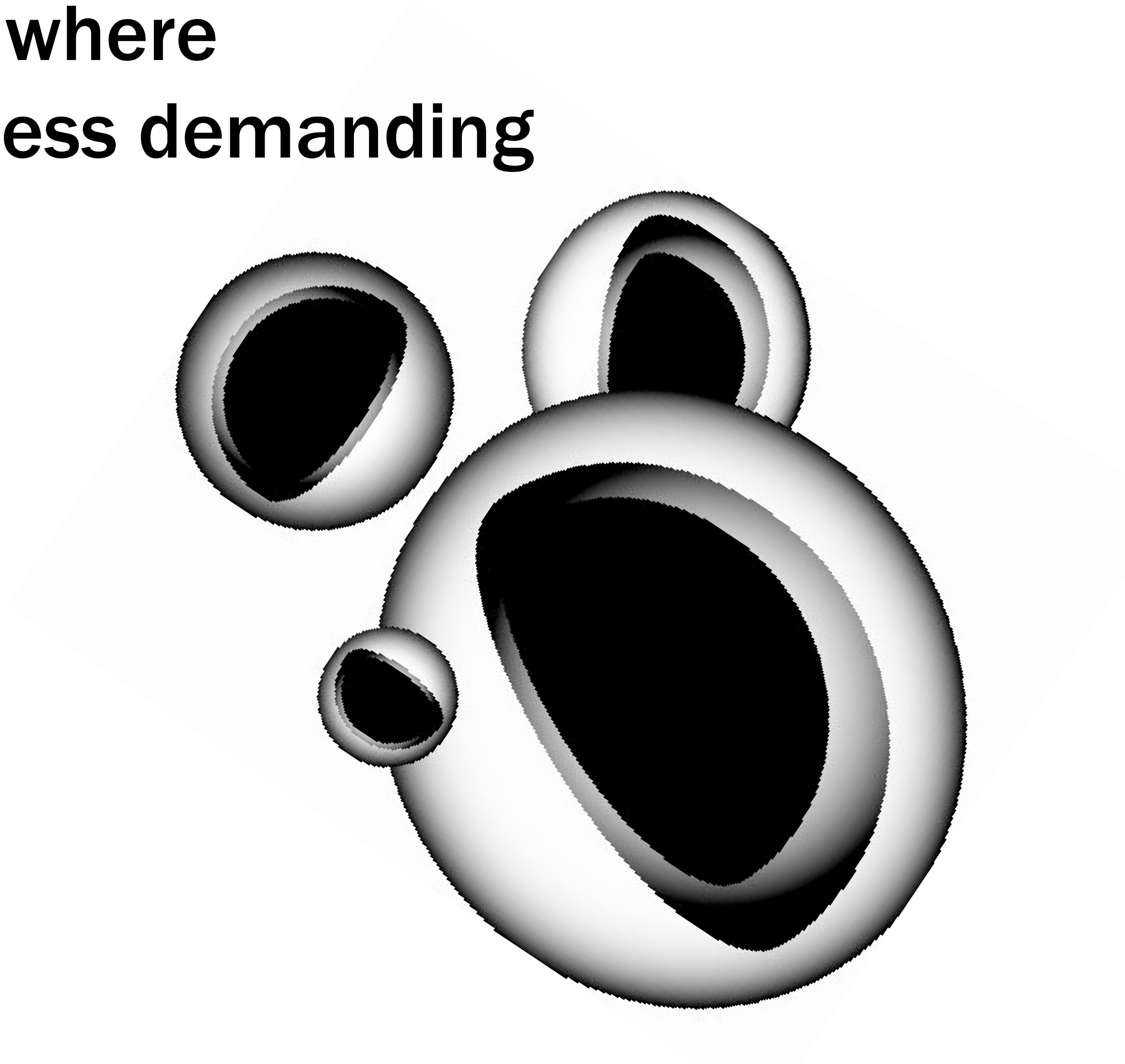
- Lightweighting where properties are less demanding



Hollow Glass Spheres

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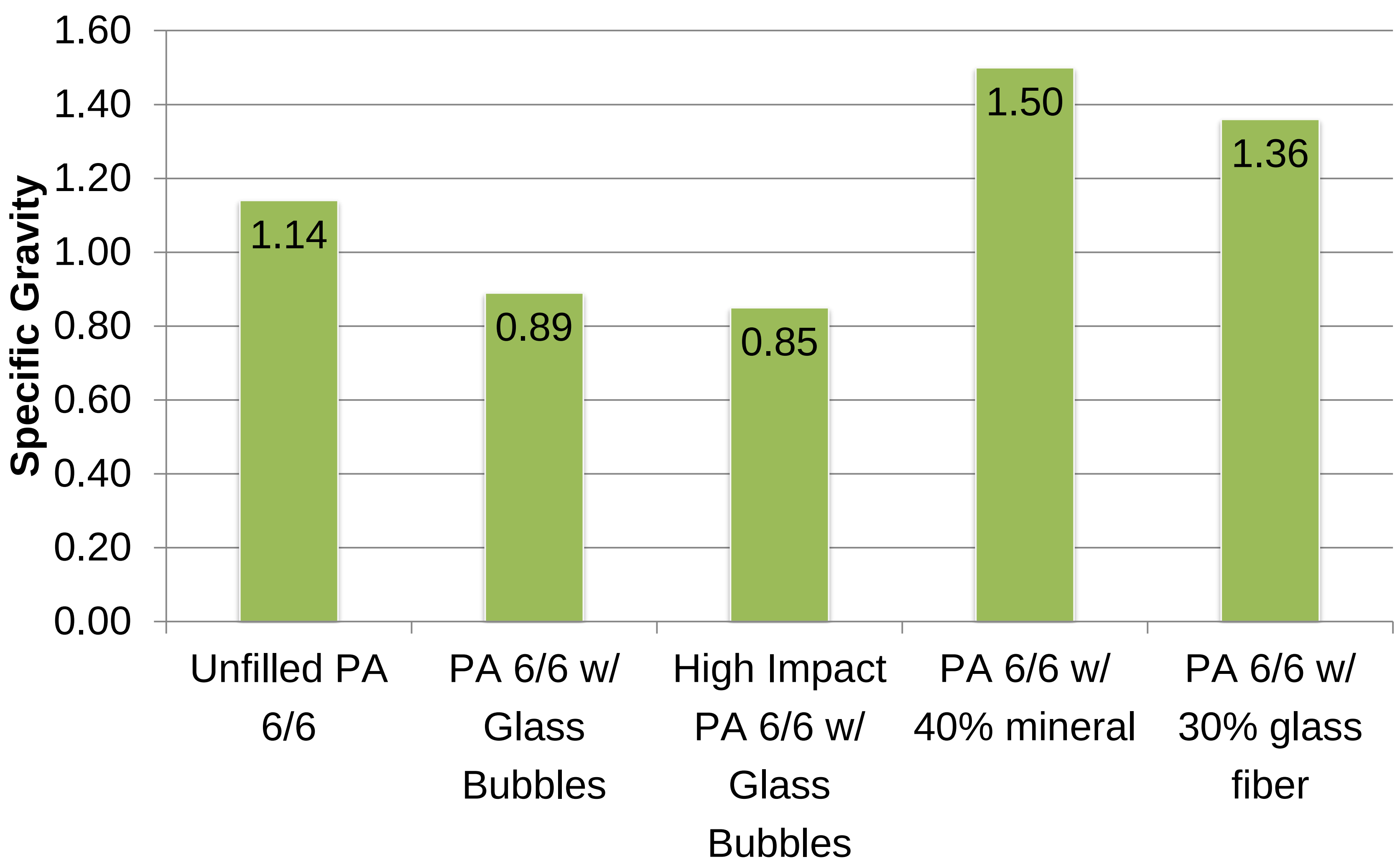

Hollow Glass Spheres

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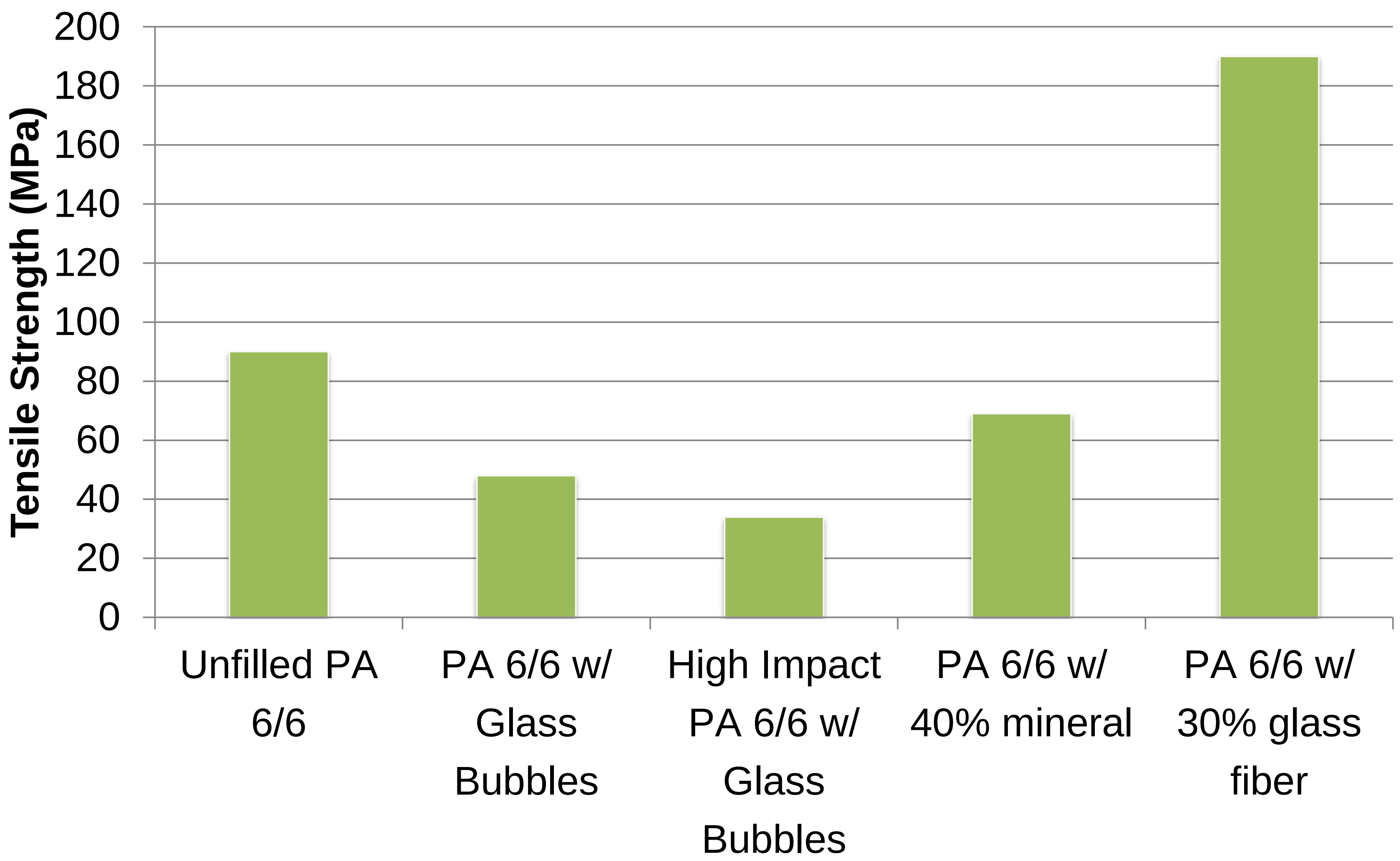

Hollow Glass Spheres

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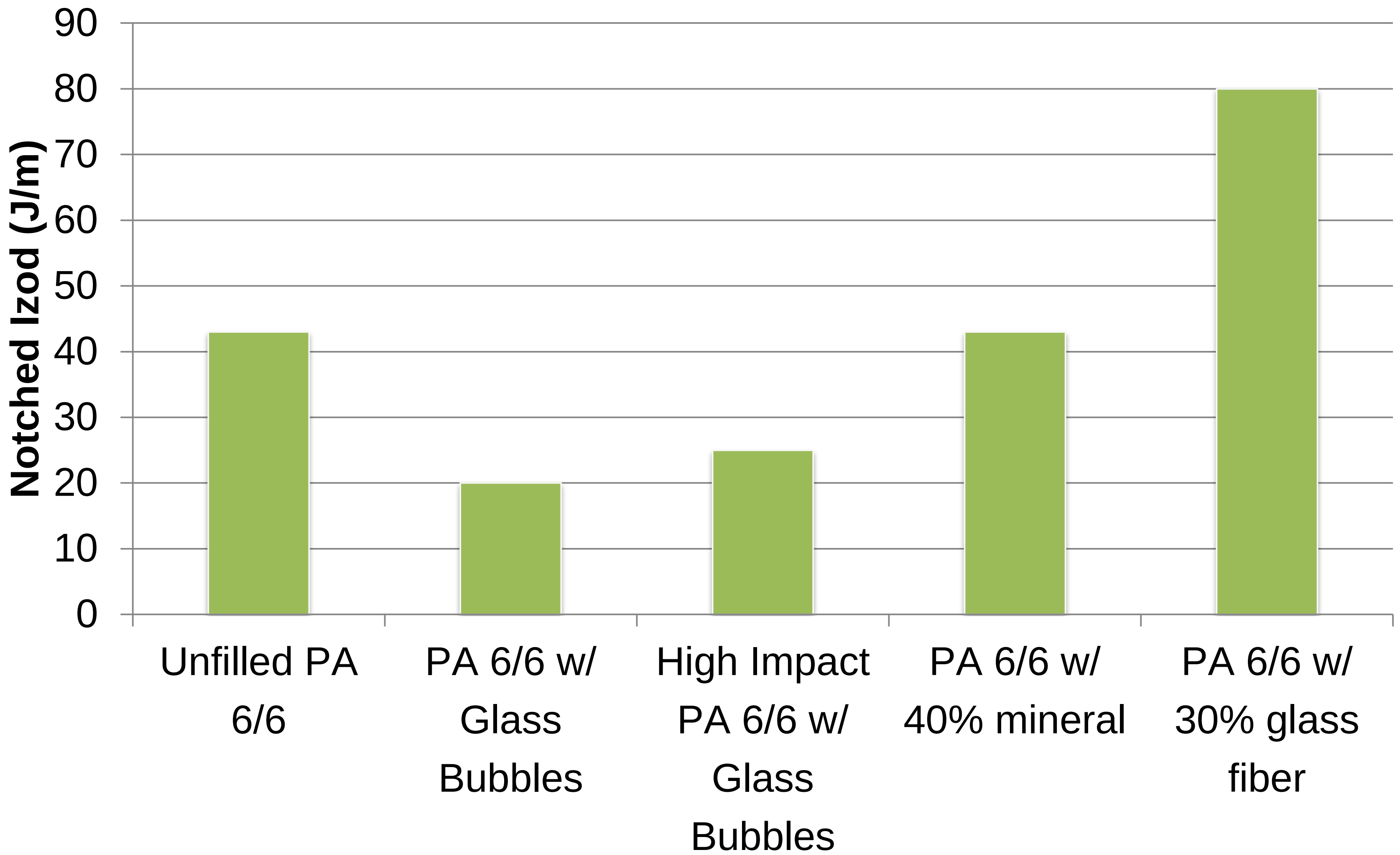

Chemical Foaming Agents

- Achieve up to 20% density reduction
- Added as masterbatch
- Loading levels of 2-5% for foaming
- Two types:
  - Exothermic
  - Endothermic

Exothermic

- "Exothermic" = generate heat during decomposition
- Release Nitrogen gas (N_2)
- Base color is somewhat yellow

Endothermic

- “Endothermic” = removes heat during decomposition
- Produces CO_2
- Mostly colorless

Selecting Chemical Foaming Agents

- **Activation temperature**
- **Compatibility of masterbatch carrier**
- **Tweak based on other requirements:**
  - Cell structure
  - Surface finish
  - Color

Summary

- **Reinforced thermoplastics**
  - Used in place of other materials for many years
- **VLF (Long Fiber) thermoplastics**
  - Wider range of applications with stiffness/toughness combination
- **Carbon fiber**
  - Best combination of weight reduction and properties, but at a premium
- **Hollow glass spheres, chemical foaming agents**
  - Reduced density where mechanical performance is less critical

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- Conductive
- Flame Retardant
- Structural
- Wear Resistant

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