The Short Scoop on Long Fiber Thermoplastics (LFT)

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Plan

- Introduce fiber-reinforced materials
  - Contrast continuous vs discontinuous reinforcement
  - Establish the concept of critical fiber-length
- Define Long Fiber Thermoplastics (LFT) Composites
  - The promise (value attribute)
  - Locate LFT in the world of composites
- Approach to LFT Composites Design
  - Mechanical Properties (FEA)
  - Electrical Properties (CNT)
  - Mold Design (MFA)
- Summary
  - Cost to benefit ratio is high

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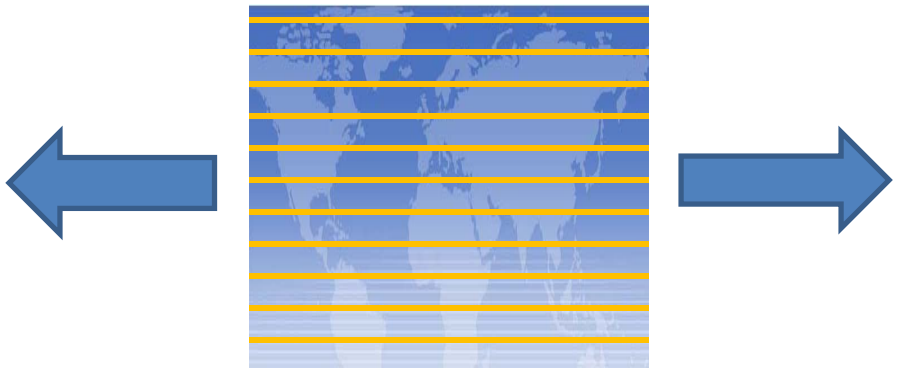
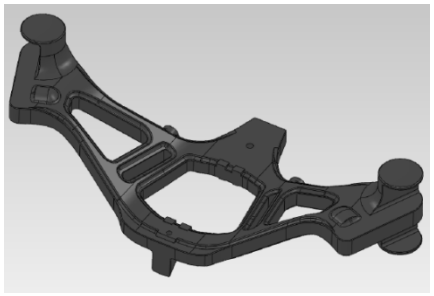
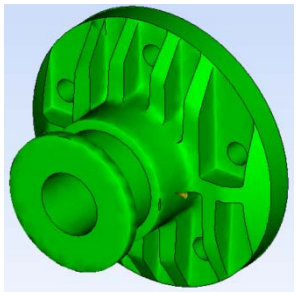
The challenge to fiber-reinforcement

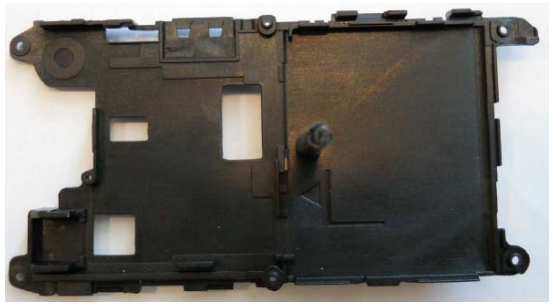
If only the world were square (rectilinear)!



Instead, we are confronted with these shapes:







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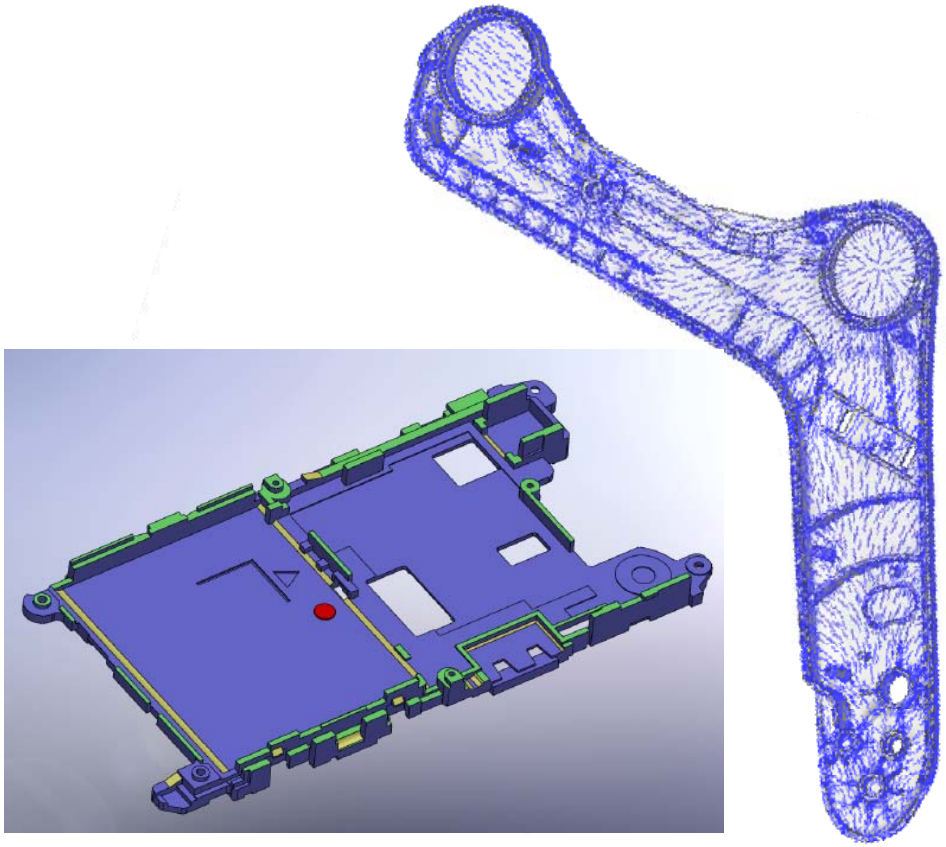
Chopped, or discontinuous fibers are a necessity for complex part shapes



- What fiber length?
- What fiber orientation?

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How do chopped fibers reinforce thermoplastics?

Reinforcing fibers pick up (support) the load through shear in the matrix

Based on composite theory, critical fiber length is given by:

$$L_{critical} = (\sigma_f * d_f)/(2*\zeta_m), \text{ where}$$

σ_f is tensile strength of fiber at failure

d_f is diameter of fiber

ζ_m is interfacial or matrix shear strength

The most effective fiber-loading occurs when the load direction is parallel to the fiber

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LFT Summary: Salient Processing Controls

- Fiber Length (Critical Fiber Length)
- Fiber Diameter (Finer Grain Size)
- Fiber Orientation (Parallel to Load Direction)
- Fiber-Matrix Adhesion (High Shear Strength)
- LFT Molding Process (Attrition in Barrel; Runner; Gate)

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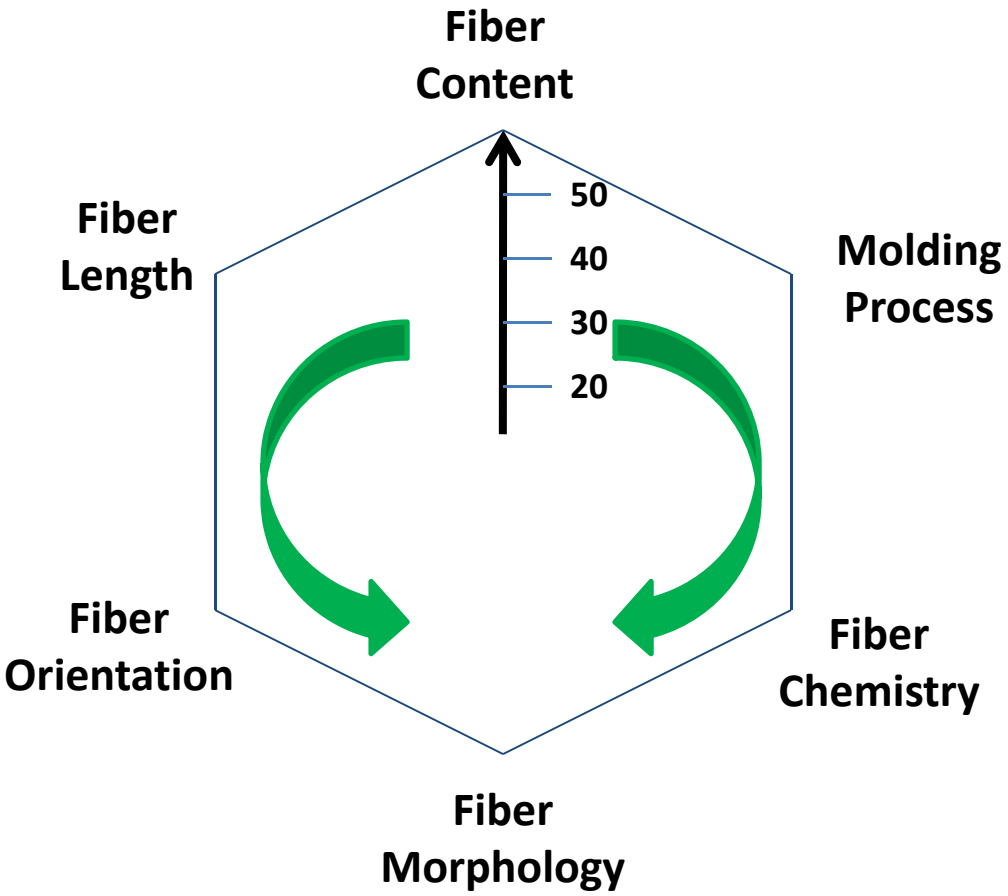
The winning approach to composite design



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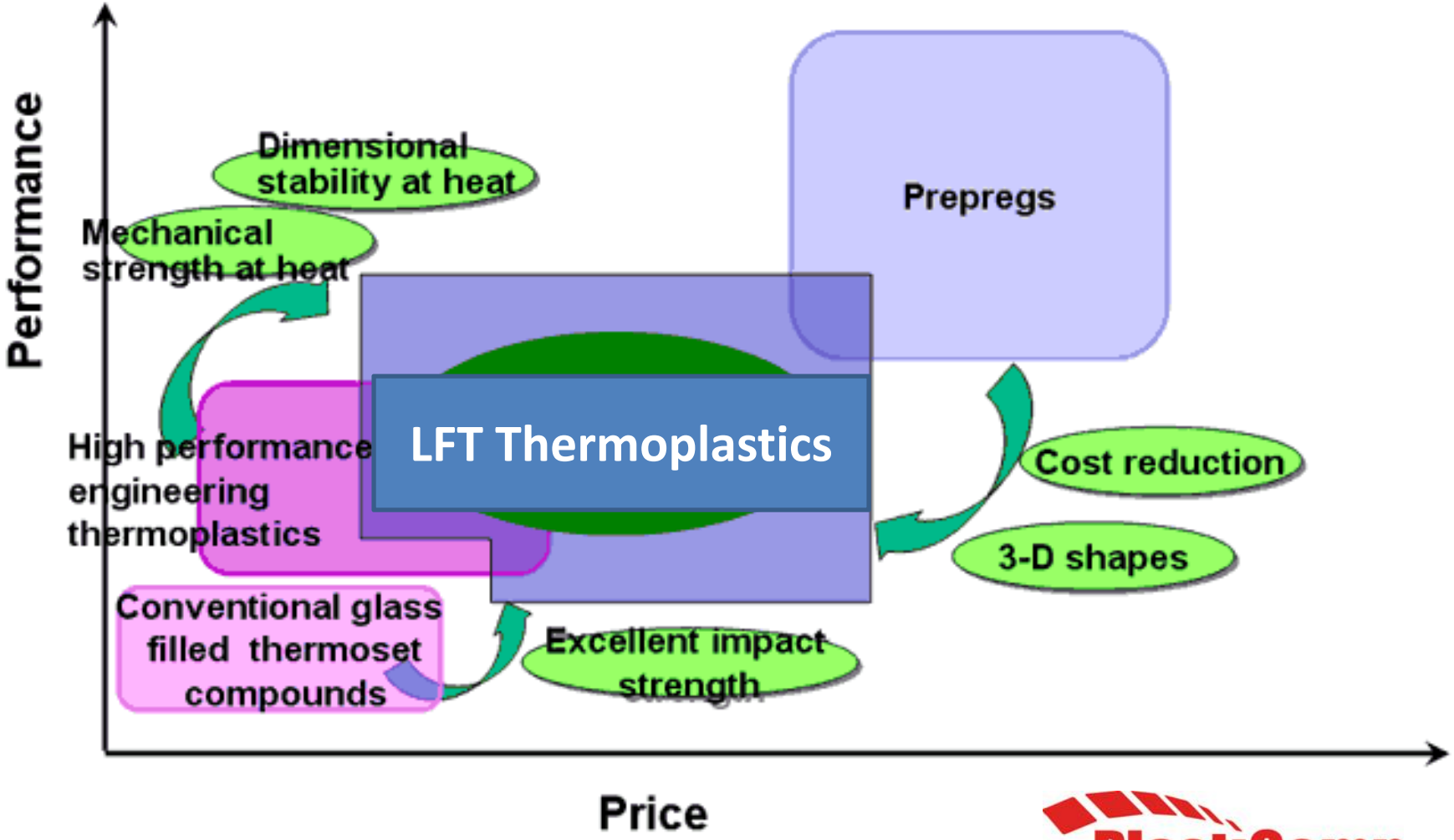
LFT Standing Amongst Composites



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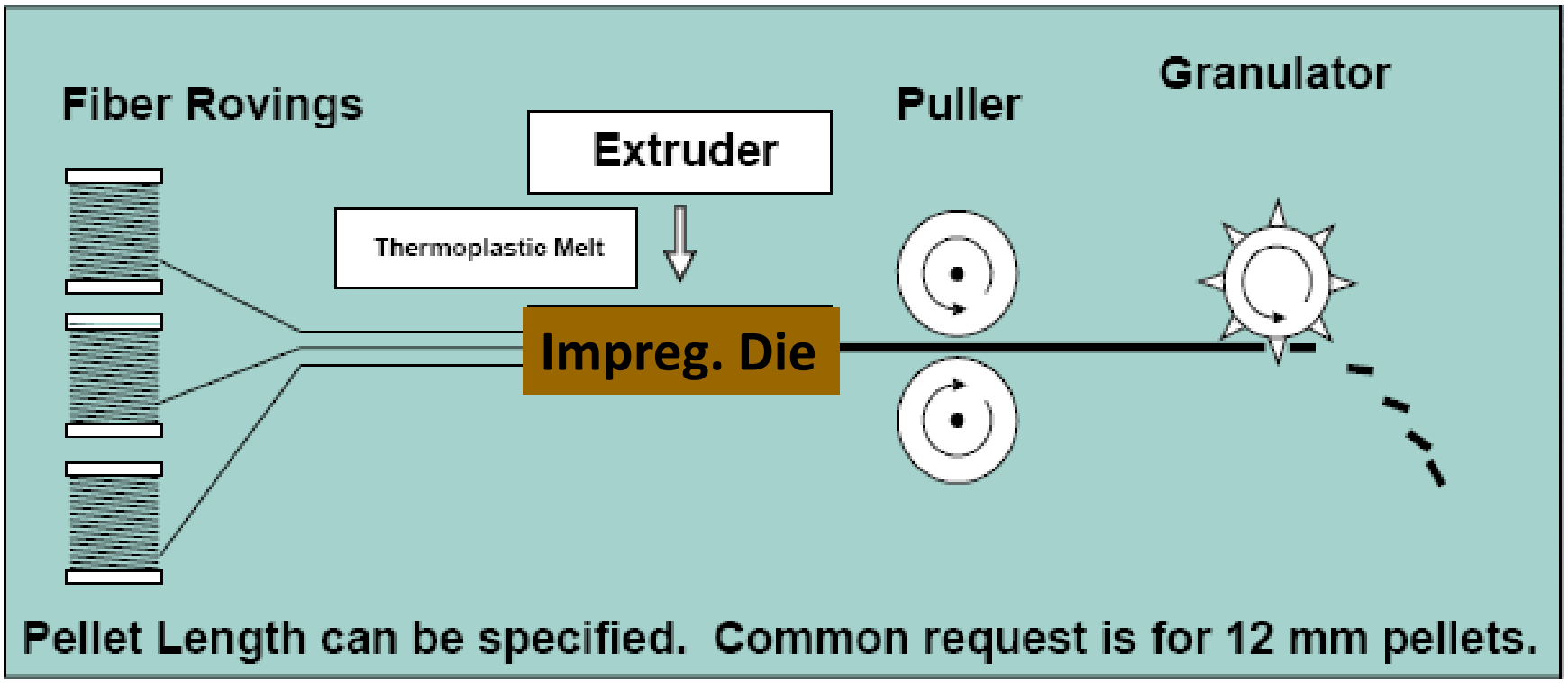
Complēt: Long Fiber Thermoplastics Pellets



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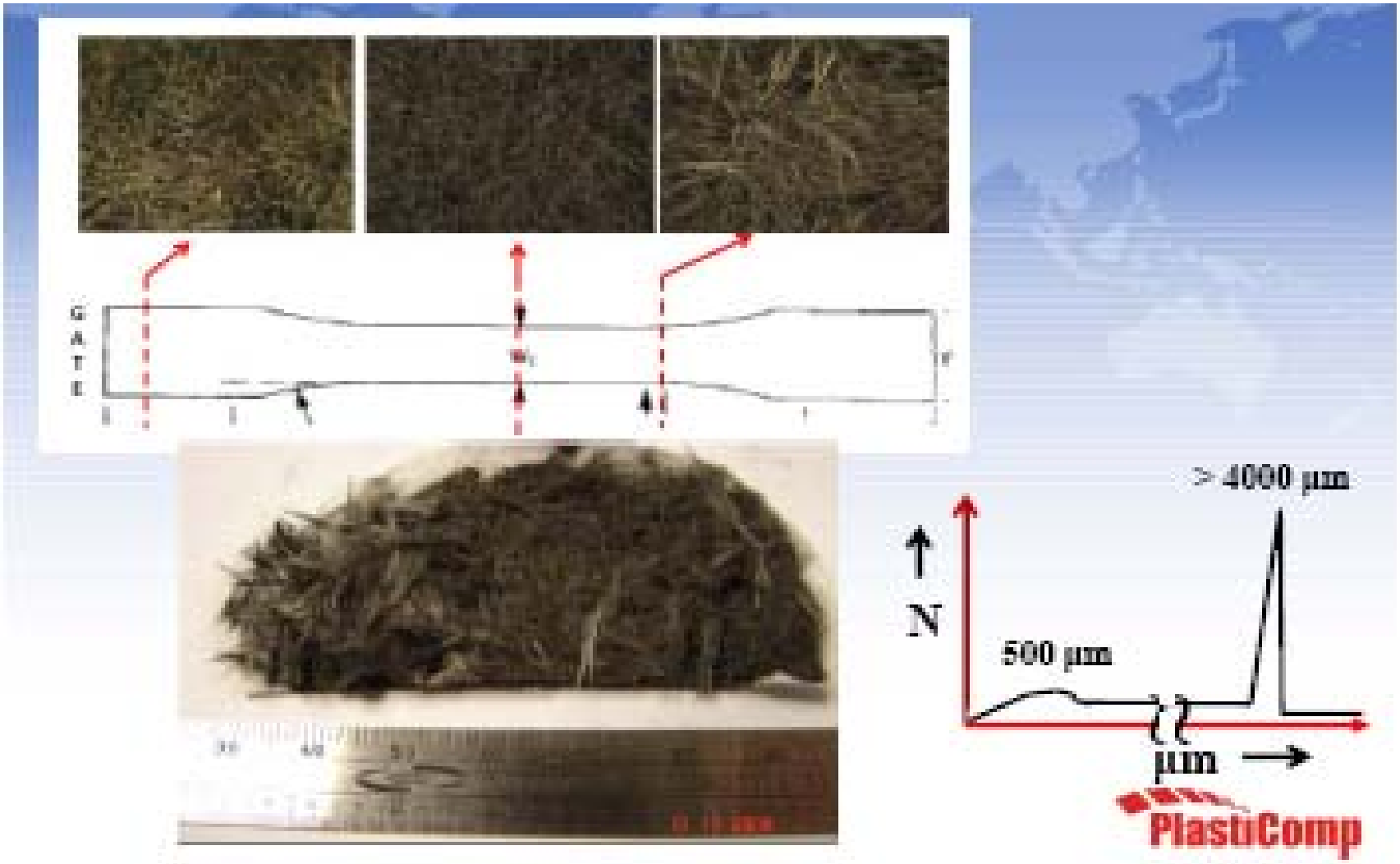
Molding Processes & Fiber Length



Fiber Lengths: Retention of part shape

The Long Fiber Advantage - Fiber Structure

- Stress is transferred to the fibers - the structural members of the composite

- Picture of long fibers after burning off the resin in an oven. Long fibers create a "skeletal structure" within the molded article that resist distortion and provide unmatched strength, toughness, and overall performance

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Fiber Length: Shape Retention

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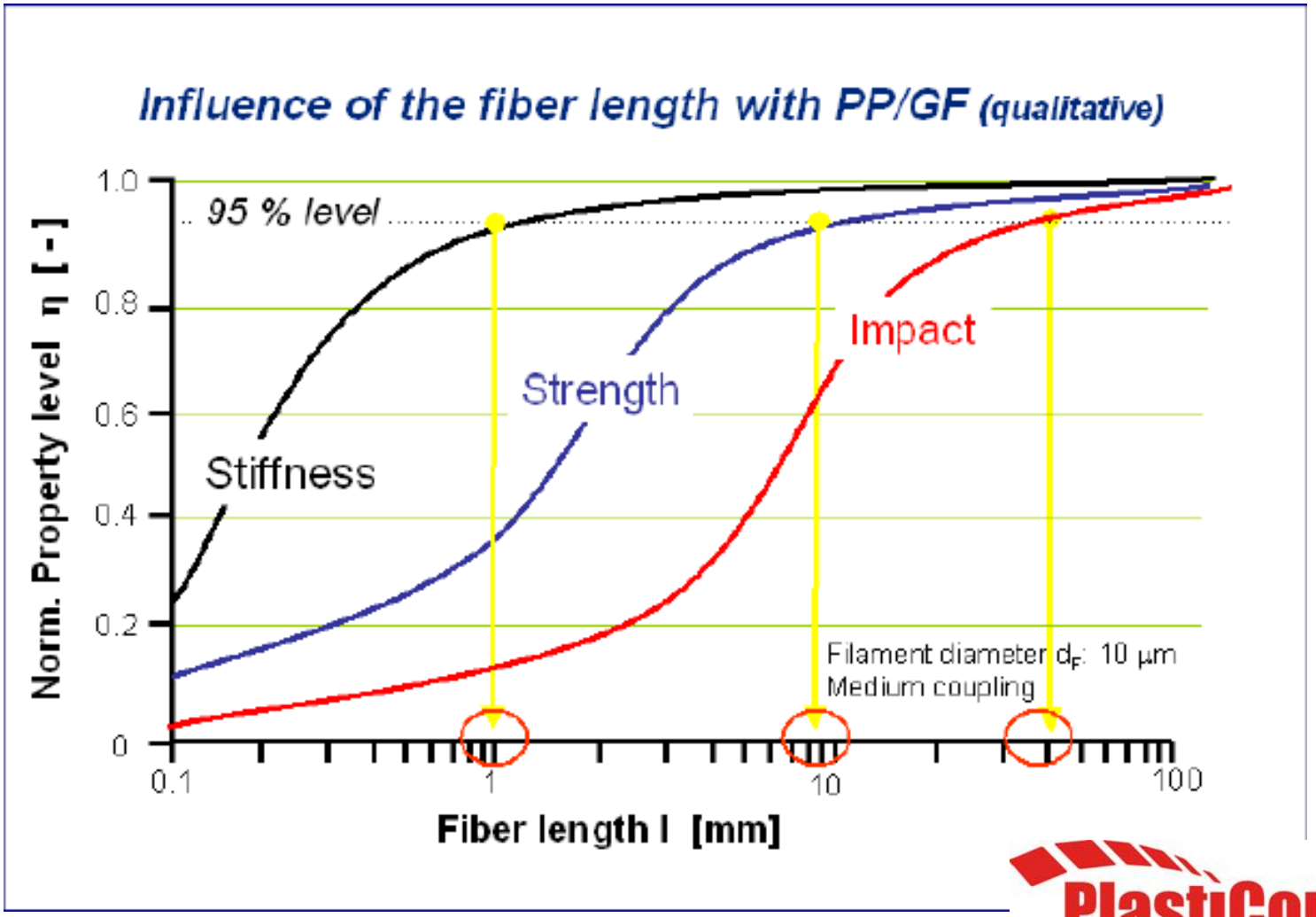
Fiber Length vs Properties



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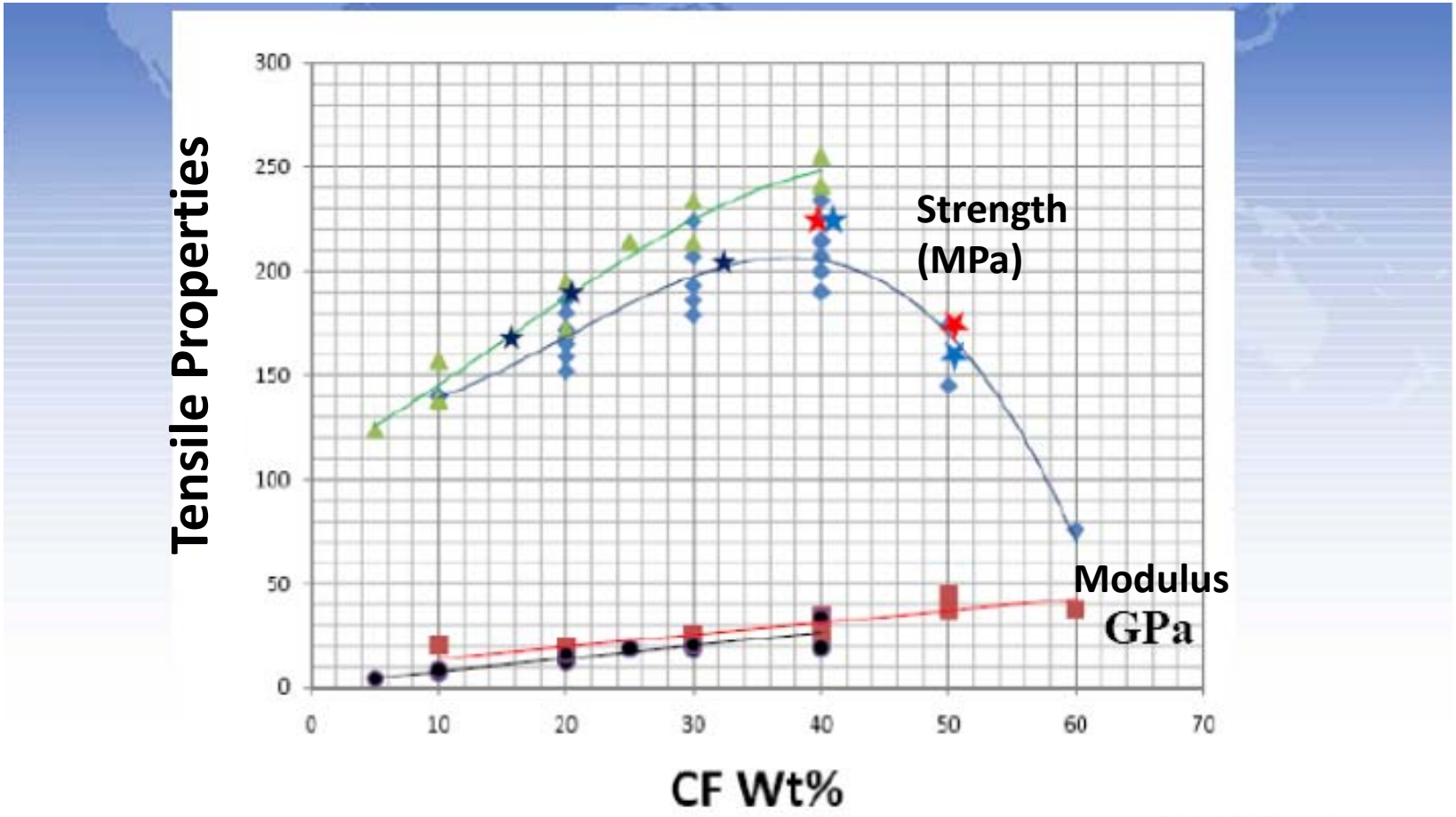
Microstructure: Role of fiber fractions



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Coherence in Matrices: High fiber content can lower composite strength due to matrix failure

Wf : 40%

Wf : 50%

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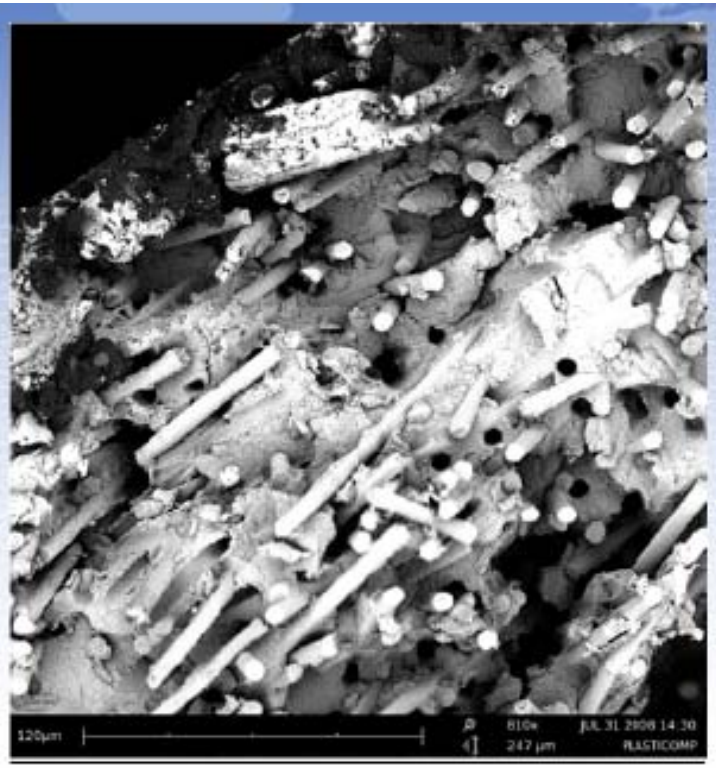
The Role of Fiber- Matrix Interface



Poor Fiber-Matrix Adhesion

Good Fiber-Matrix Adhesion

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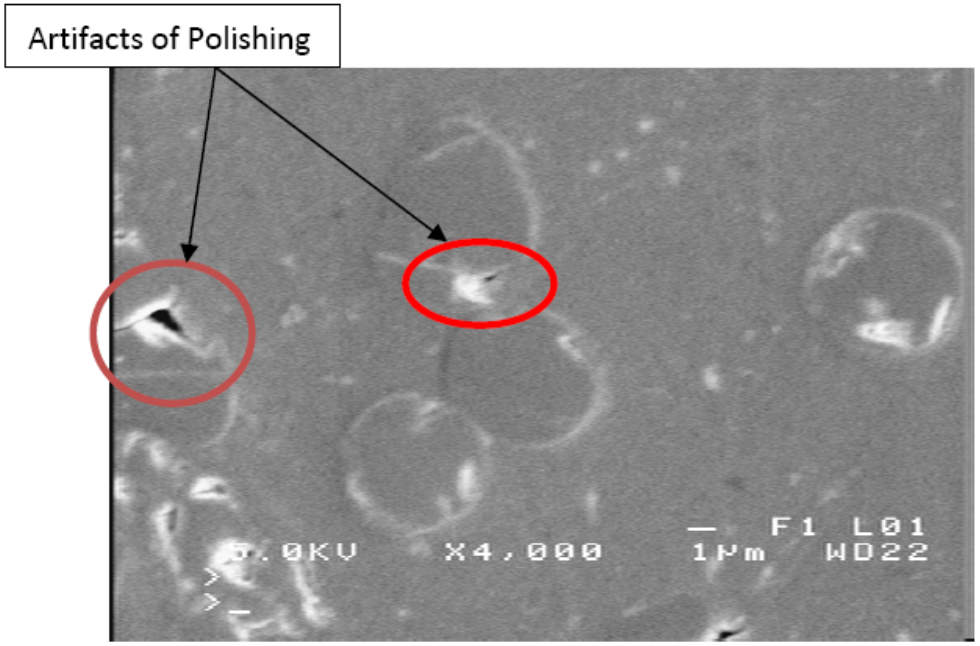
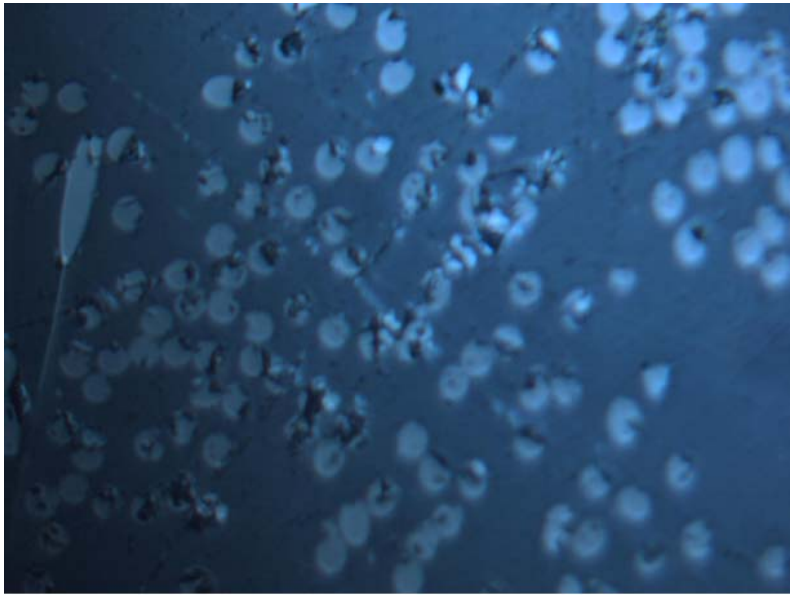
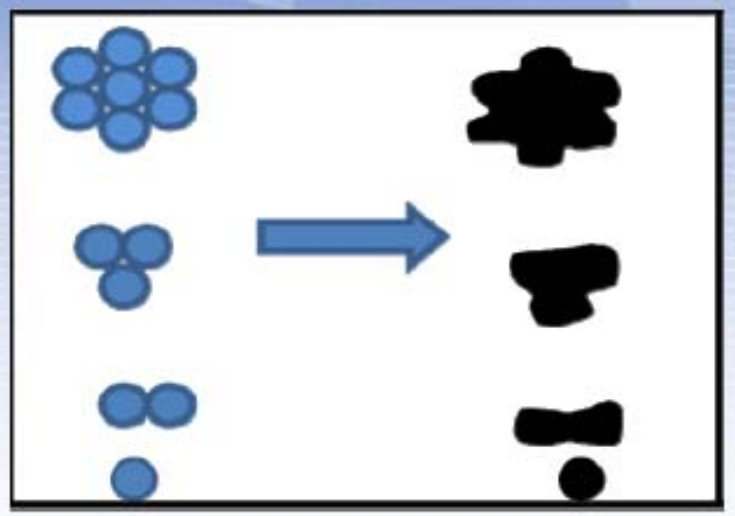
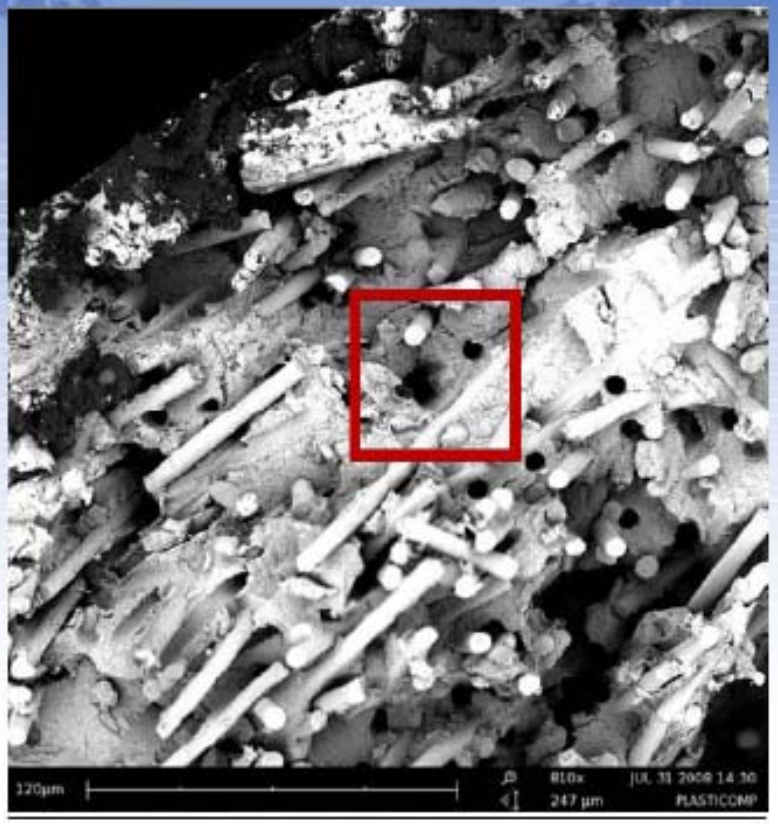
SEM Micrographs showing good fiber-matrix adhesion





Failure Mechanisms: Voids Coalescence





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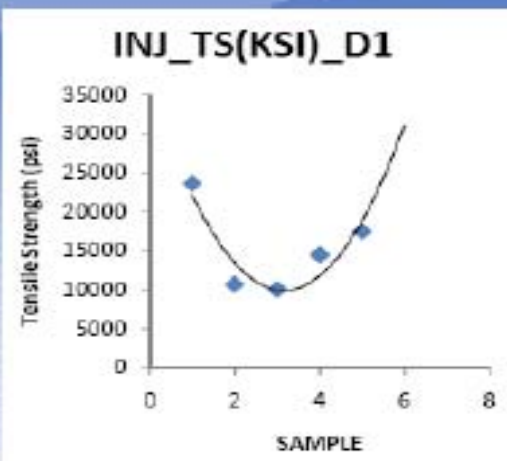
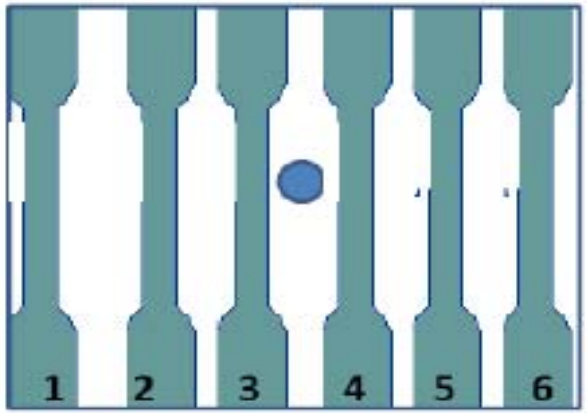
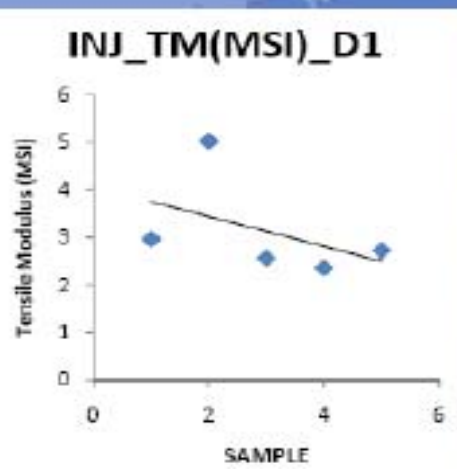
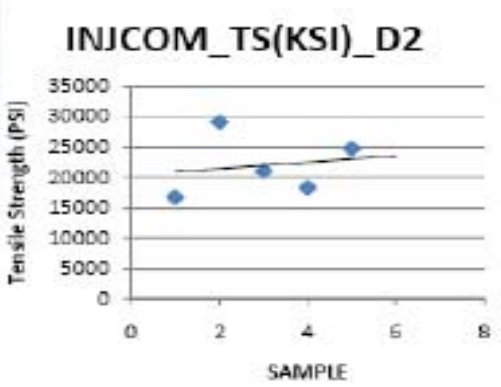
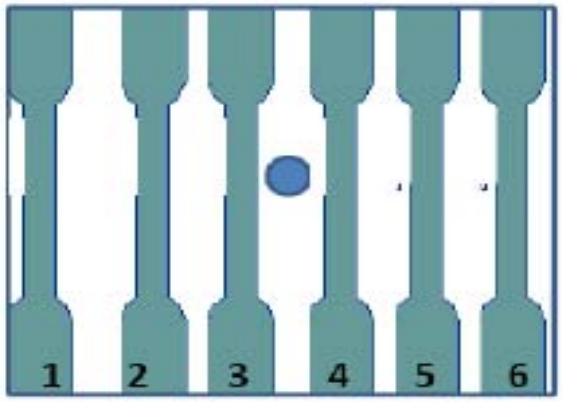
Injection vs Injection Compression

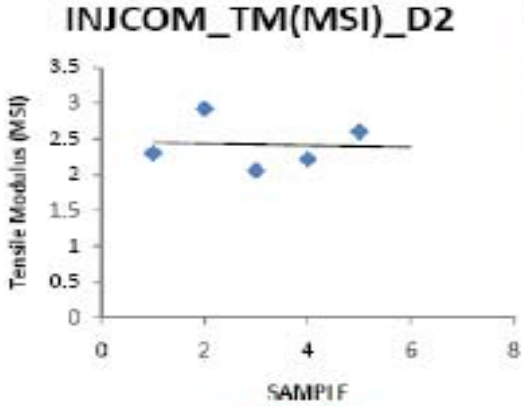












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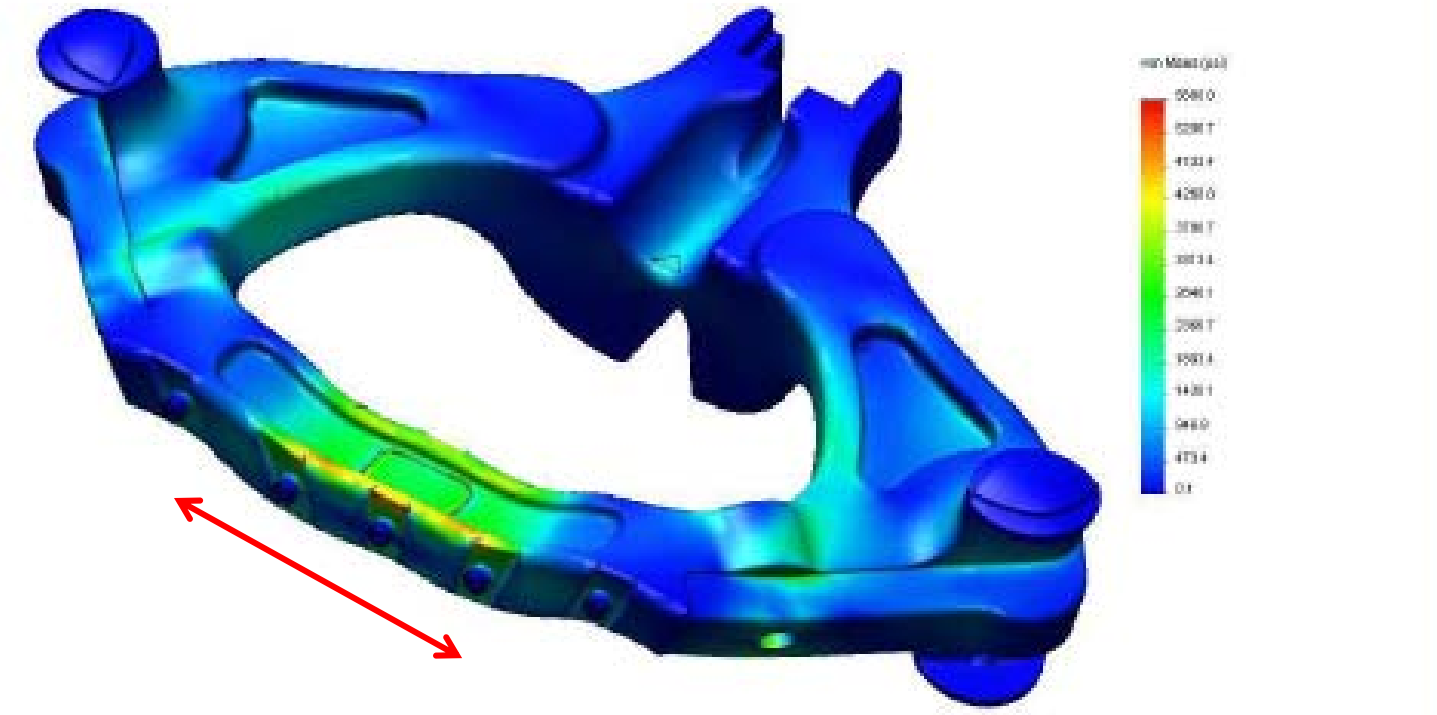
FEA: Interplay between fiber orientation and stresses



Stresses are in the shown direction

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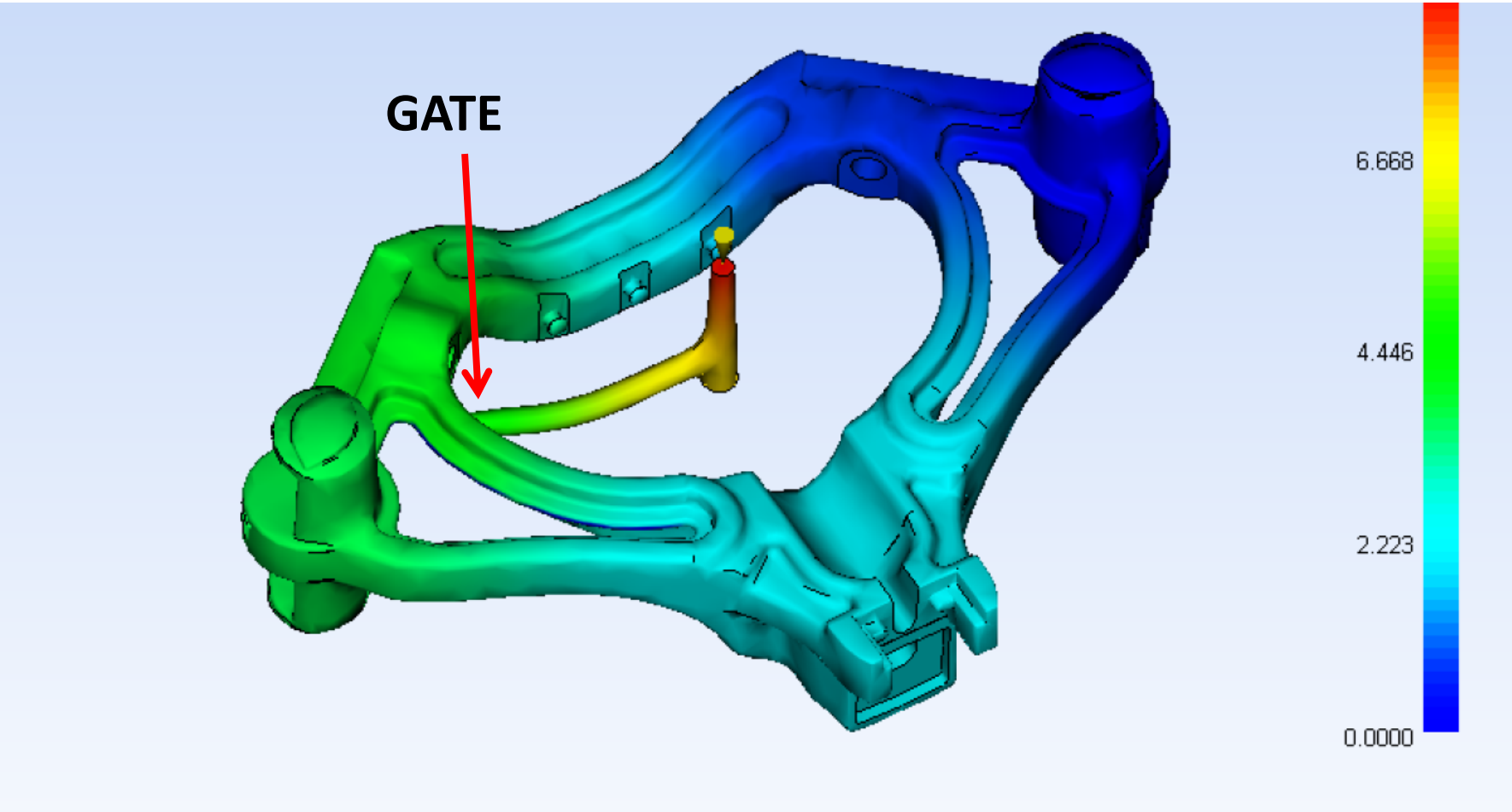
Mold Flow Analyses: Unusual location of gate to achieve fiber orientation



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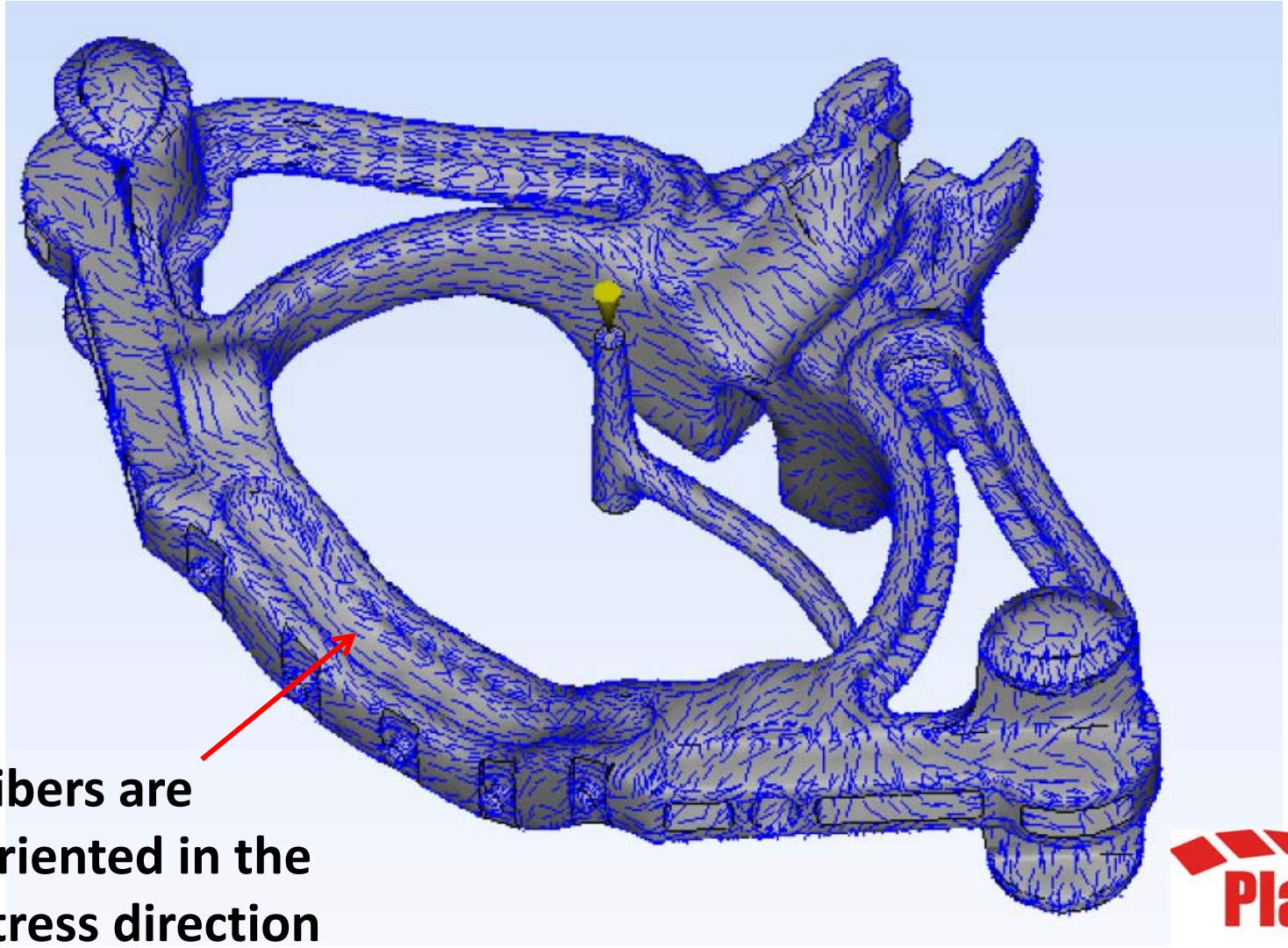
Preferred Fiber Orientation



Fibers are oriented in the stress direction

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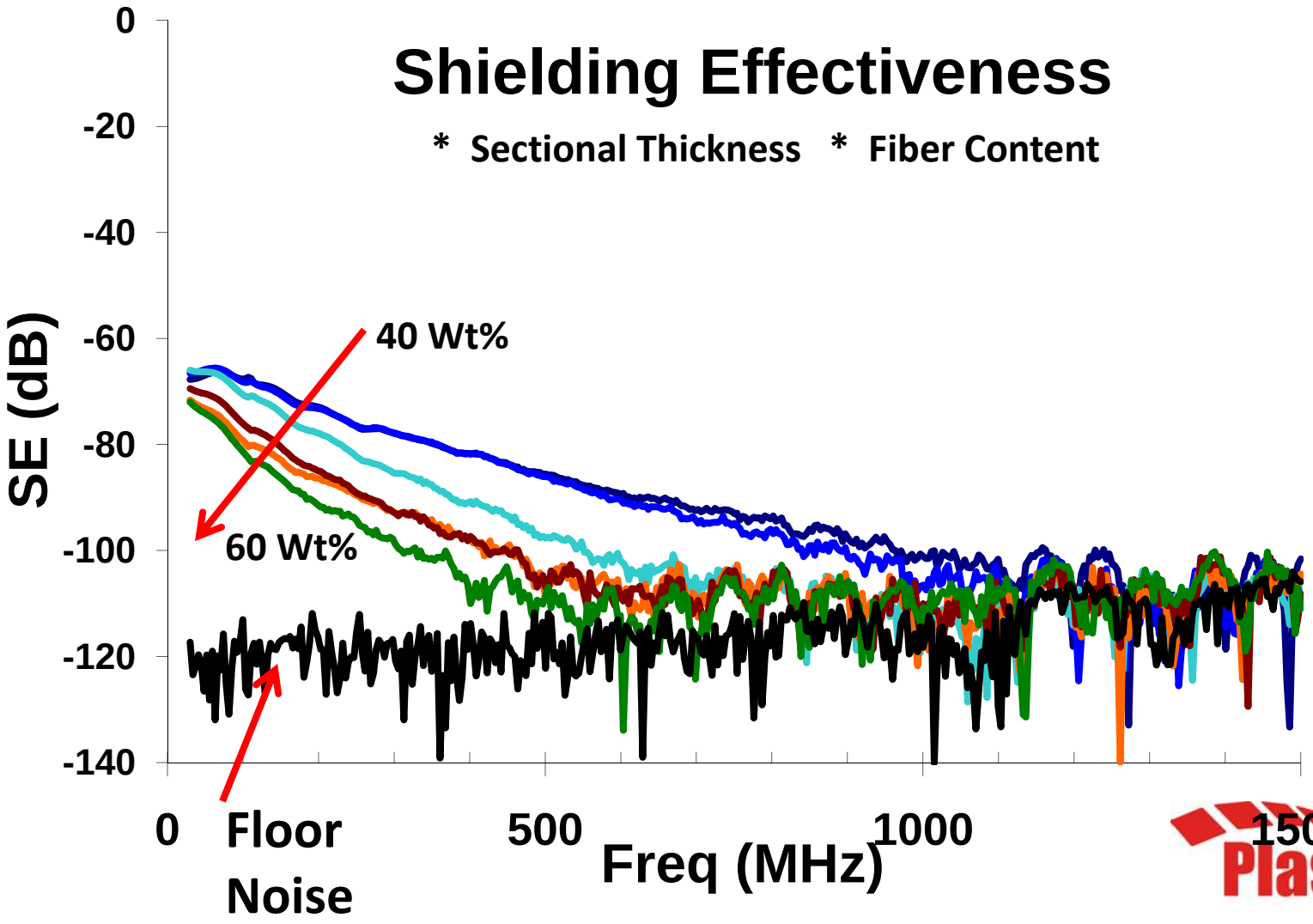
EMI Shielding Test Results



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Summary: Working with LFT

- Tailor fiber-content to the strength and stiffness requirements
- Tailor fiber-orientation in the direction of the critical stresses
- Tailor the melt-flow in the mold so that:
  - Achieve desired fiber-orientation
  - Weld-lines are moved to areas of low stress
- Employ a low-shear molding process, with generously-sized runners and gates
- Utilize FEA and MFA analyses to design & test “on paper” before cutting steel

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Summary: Process Economics

- LFT composites are true 3D structures, with fibers in all three dimensions, as opposed to continuous fiber lay-ups, or layered structures. These discontinuous –fiber composites can achieve 90% of theoretical properties of fiber-reinforcement
- In stark contrast to hand lay-ups, LFT composite manufacturing has cycle times of the order of minutes. Their manufacturing lends itself to automation and high quality assurance
- Because LFT composites preserve the aspect ratios of the reinforcing element, they are far superior to the conventional short-fiber composites. In turn, fiber orientations can be tailored
- A distinct advantage over short-fiber reinforcement is the exemplary toughness (impact strength) of LFT composites
- LFT composites are ideally suited for metal replacement. The weight savings possible from such material substitutions make them energy efficient, especially in the transportation industry.
- Their recyclability is advantageous in terms of Life Cycle Analyses (LCA). The increasing use of bio-resins also makes them candidates for green or sustainable materials of construction..

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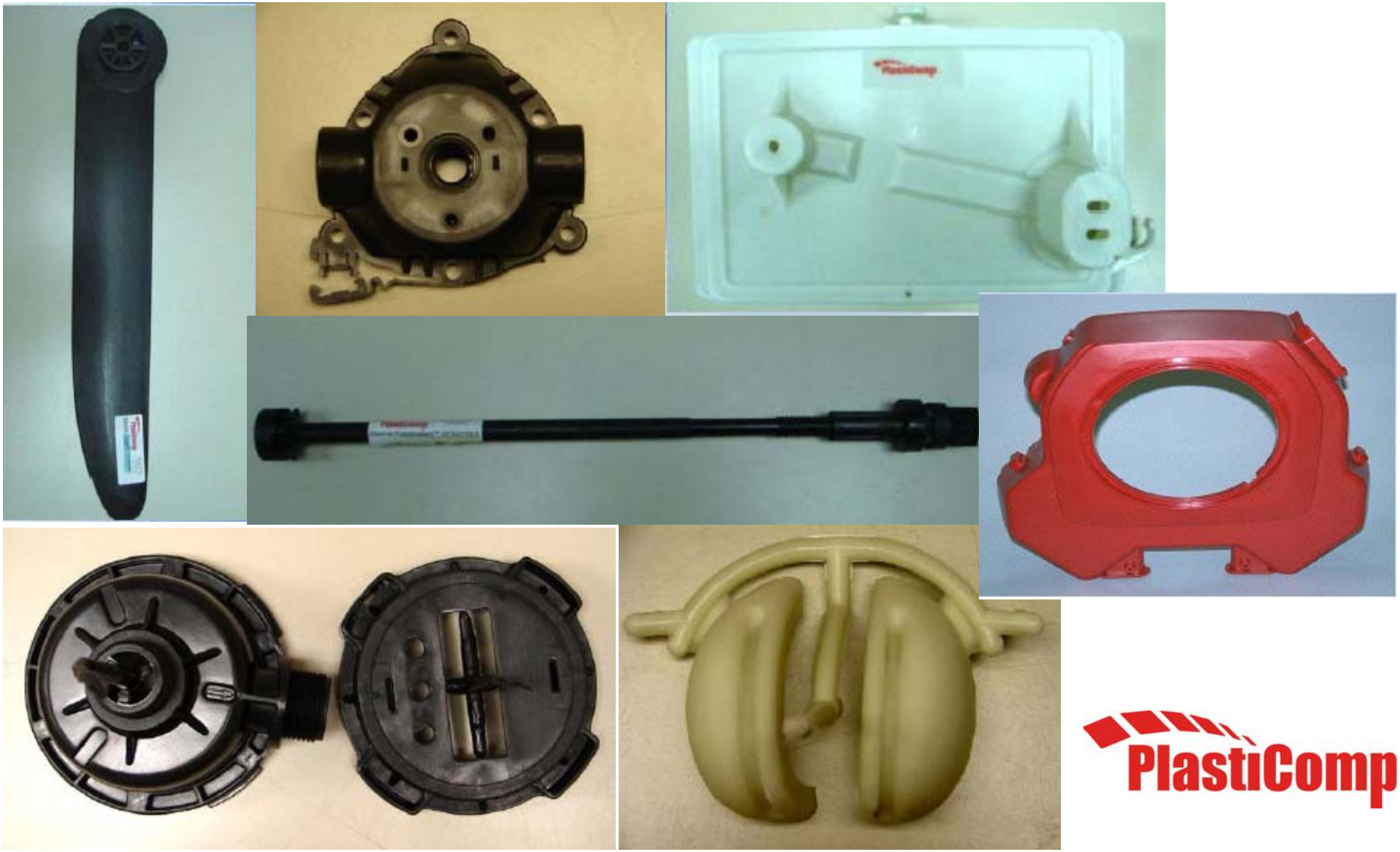
Molded Parts: A Collage



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PlastiComp, LLC

- **Formed May, 2003 (Winona, MN, USA)**
- **Commercial activities started in 2006**

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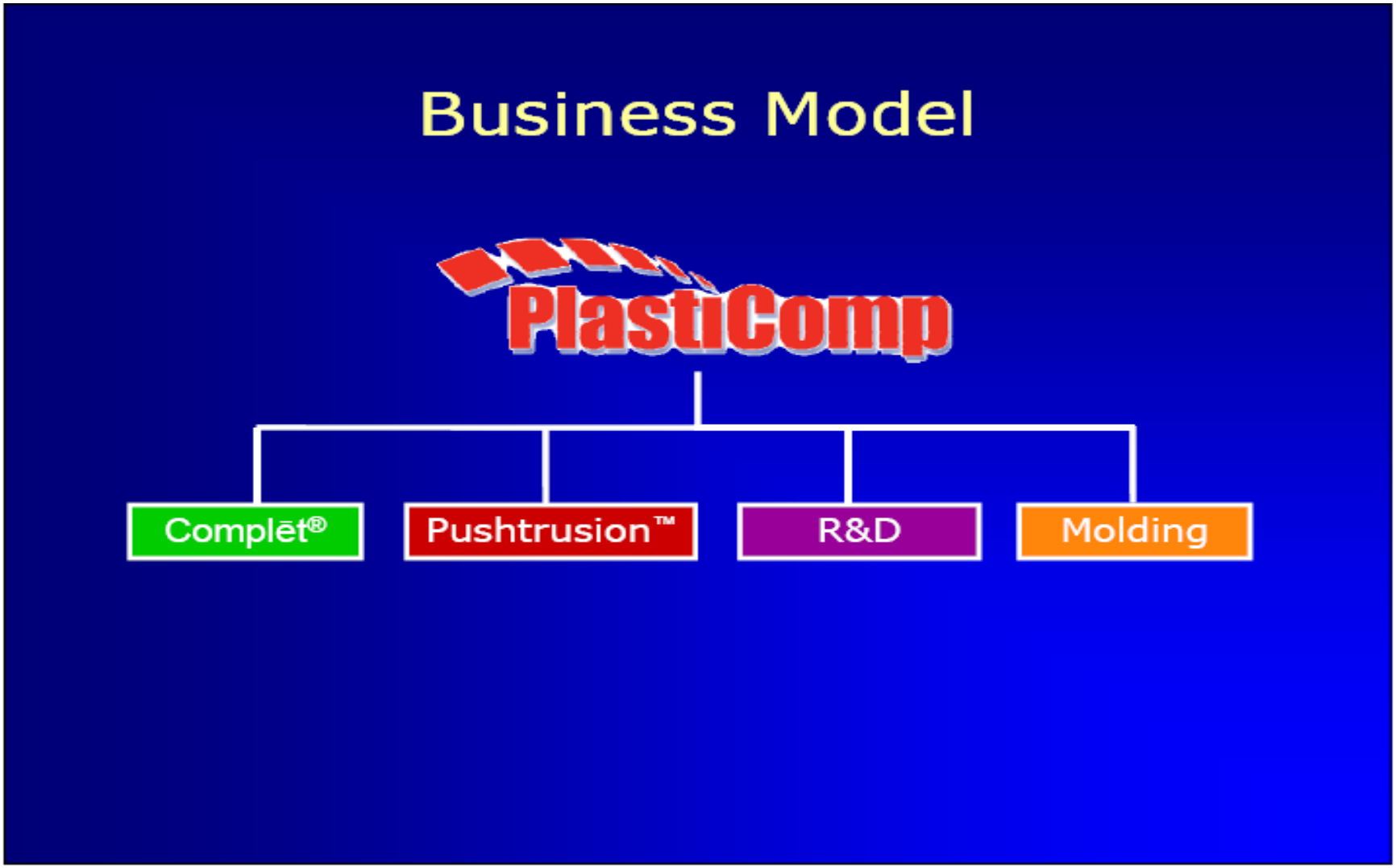
Business Units



Creed

Vision

To Deliver Industry Leading and World Class LFT Technology and Innovation!

President & CEO
Steve Bowen

Mission

To Forge a Partner-based global enterprise bringing transformative technology to market.

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Living Up to PlastiComp Vision

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