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
The challenge to fiber-reinforcement

*If only the world were square (rectilinear)!*

Instead, we are confronted with these shapes:
Chopped, or discontinuous fibers are a necessity for complex part shapes

- What fiber length?
- What fiber orientation?
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:

$$L_{critical} = \frac{\sigma_f \cdot d_f}{2 \cdot \zeta_m},$$

where

- $\sigma_f$ is tensile strength of fiber at failure
- $d_f$ is diameter of fiber
- $\zeta_m$ is interfacial or matrix shear strength

The most effective fiber-loading occurs when the load direction is parallel to the fiber.
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)
The winning approach to composite design
LFT Standing Amongst Composites

- Dimensional stability at heat
- Mechanical strength at heat
- High performance engineering thermoplastics
- Cost reduction
- 3-D shapes
- Excellent impact strength
- Conventional glass filled thermoset compounds
- LFT Thermoplastics

Price

Performance
**Complēt:** Long Fiber Thermoplastics Pellets

Pellet Length can be specified. Common request is for 12 mm pellets.
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
Fiber Length: Shape Retention
Fiber Length vs Properties

Influence of the fiber length with PP/GF (qualitative)

- Strength
- Stiffness
- Impact

Norm. Property level \( n [-] \)

Fiber length \( l \) [mm]

Filament diameter \( d_F \): 10 \( \mu \)m
Medium coupling

95% level
Microstructure: Role of fiber fractions

![Graph showing tensile properties versus CF Wt%]

- **Strength (MPa)**
- **Modulus (GPa)**

**Tensile Properties**

- Strength
- Modulus

**CF Wt%**

0 10 20 30 40 50 60 70
Coherence in Matrices: High fiber content can lower composite strength due to matrix failure.
The Role of Fiber-Matrix Interface

Poor Fiber-Matrix Adhesion

Good Fiber-Matrix Adhesion
SEM Micrographs showing good fiber-matrix adhesion
Failure Mechanisms: Voids Coalescence
Injection vs Injection Compression
**FEA:** Interplay between fiber orientation and stresses

Stresses are in the shown direction
Mold Flow Analyses: Unusual location of gate to achieve fiber orientation
Preferred Fiber Orientation

Fibers are oriented in the stress direction
EMI Shielding Test Results

Shielding Effectiveness

* Sectional Thickness  * Fiber Content

![Graph showing shielding effectiveness vs frequency for different wt% sections and fiber contents.](image-url)
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
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..
Molded Parts: A Collage
PlastiComp, LLC

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

Business Model

PlastiComp

- Complêt®
- Pushtrusion™
- R&D
- Molding
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.