Composite Prepregs Offering Improved Toughness, Impact and Consistency

Optimizing Racing Bike Performance: Weight vs Stiffness vs Safety

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Background and Thank You!
TenCate Advanced Composites – Investing for Growth

1972
- TenCate begin first thermoset prepregging.

1982
- First thermoplastic prepregs by TenCate Europe.
  In 1989, first thermoplastic aerospace usage.

1999
- TenCate acquires Bryte Technologies; changes name to TenCate Advanced Composites USA, Inc. (TCAC-USA).

2007
- TenCate acquires Phoenixx TPC for thermoplastic unitapes.

2008
- TenCate acquires YLA, Inc. & CCS Composites, LLC for space prepregs and compression molded parts.

2012
- TenCate acquires Composix, a leader in armor for military vehicles, aircraft and personnel.

2013
- TenCate acquires PMC/Baycomp for thermoplastics in industrial markets and AMBER Composites for tooling.
## Aerospace and Space Customers

| Boeing | Bell Helicopter | Airbus
A Textron Company | Cirrus Aircraft |
|--------|----------------|-----------------|-----------------|
| Space Systems Loral | Orbital | Lockheed Martin | AASC
Applied Aerospace Structures Corp. |
| General Atomics Aeronautical Systems | ATK | Northrop Grumman | MDA |
| Embraer | Raytheon | NASA | SpaceX |
Learning and Assumptions: Composites in Cycling Industry

- “Paint a picture” on topic “Weight vs Stiffness vs Safety” improvements
- Carbon fibers generally known and optimized for performance
  - Cycling industry generally knows strength vs stiffness options
  - Many current product gains are shape/design/fiber-orientation improvements; not simply “better” carbon fibers
- Resins and prepreg: strength/stiffness generally known and similar
  - Some higher temperature resins required, some tougher options offered
  - Many materials are common 250F/125C cure epoxy based
  - IM2C Prepreg “A” vs IM2C prepreg “B” = similar strength/stiffness
- Manual epoxy-based processes generally optimized for performance
  - Vs aerospace: much faster, improved consistency vs past, very complex shapes
  - Automation may improve
Assumptions of Composites in Cycling Industry (continued)

- Much composite knowledge based on empirical testing and experience
  - Same materials used in improved designs
  - Similar materials tested in similar processes; difficult to try new material in new process
- Few standard composite industry tests used to define cycling product performance
  - Testing = expensive
  - Material suppliers may offer limited data
  - Products with complex loading and shapes = less accurate predictions based on standard tensile, compression, etc.
Conclusions: Weight vs Stiffness vs Safety

- Weight/Stiffness/Strength *generally* optimized using current epoxy processes and available carbon fibers
- Higher performance resins may not offer drastic improvements in strength/stiffness and related weight
- Higher performance resins may offer toughness without sacrificing weight/strength/stiffness; which could improve safety
- “Toughness” is not always easy to define or compare between materials; especially in an industry with a large set of empirical knowledge
Composite Resin Toughness

- **Toughness**
  - Difficult and easy to define
  - Durability
    - “The ability of a material to absorb energy and plastically deform without fracturing. One definition of material toughness is the amount of energy per unit volume that a material can absorb before rupturing.”
  - Real life: dents/marks, cracks, remaining strength, crack propagation?
  - Related tests in aerospace
    - Fracture toughness (G1C, G2C, K1C…)
    - Compression after Impact
    - Open Hole Compression
    - Box drop test (aircraft interiors)

- **Resins/composites available with similar strength/stiffness but considerably higher CAI and FT values**
Definitions: Fracture Toughness

- ASTM D5528, D7905, others
- Crack initiated and loaded
- 3 modes, 2 common
  - G1C, G2C, G3C
- Difficult to make detailed result comparisons between test methods
Difficult to find comparisons of different materials online

Common 250F/120C cure epoxy composites:
- G1C: ~0-1 in-lb/in²; some over 2
- G2C: ~4-5 in-lb/in²

Newer 350F/175C cure epoxy composites with enhanced toughness:
- G1C: ~3 in-lb/in²
- G2C: ~9-10 in-lb/in²

PEEK thermoplastic composites – 725F/385C process temperature
- G1C: ~9-10 in-lb/in²
- G2C: ~18 in-lb/in²
Definitions: Compression After Impact

- ASTM D7137
- Typically quasi-isotropic lay-up
- Plate impacted for damage
- Plate compression tested to failure
- Results in stress units; not percentage drop
  - Fiber selection, matrix adhesion and impact resistance all play a role in comparison of results
Common 250F/120C cure epoxy composites:
- Basic – Under 20,000 psi (140 Mpa)
- Toughened – 20,000 - 30,000 psi (140-200 MPa)

Newer 350F/175C cure epoxy composites with enhanced toughness
- 30,000 – 40,000 psi (200-275 MPa)

PEEK thermoplastic composites – 725F/385C process temperature
- 50,000+ psi (345+ MPa)

PPS thermoplastic composites – 625F/330C process temperature (lower cost than PEEK)
- 40,000+ psi (275+ MPa)
C Scan Examples of Improved Epoxy/CF CAI Laminates

- Ultrasonic C scan of different toughened epoxy unidirectional plate with IM7 fibers
- Sound waves with shorter and longer reflection times through plate thickness defined by different color
C Scan Examples of Improved CAI Laminates

Mild CAI performance @ 1500 in-lb./in (low 20’s – mid 20’s ksi)

Moderate CAI performance @ 1500 in-lb./in (high 20’s – low 30’s)

Very Good CAI performance @ 1500 in-lb./in. (High 30’s – 40’s)
Some composite automation in production for years; examples:

- Fiber placement - Filament Winding
- Thermoplastic stamping
- Custom machines

Newer focus on thermoplastic composites

- Aerospace – generally higher material properties
- Automotive, energy, electronics
- Speed/cost/labor
- Materials and process consistency
- Added toughness
Consistency Improvements: Injection Overmolding

- Focus on thermoplastic composites
- Custom lay-up of composite
- Composite heated and formed
- Filled, injection molded material placed in areas
- Metal fittings can be included
- Fast cycle times, little manual labor
Other Automated Thermoplastic Processes

• **Welding**
  • Different processes
  • Can reduce reliance on surface prep, adhesive variation

• **Continuous Compression Molding**
  • “Endless” shapes that can be sliced
  • Additional fabrication options; welding, re-molding

• **Fiber placed preforms**
  • Greater consistency in lay-up location
  • Faster than in-situ processing
  • Combine with bladder molding, compression molding or other fast/automated processes
Many North American companies and universities investing in thermoplastics

More development history in Europe

Thermoplastic Composites Research Center in The Netherlands

TenCate also has lower temperature thermoplastic composites – generally lower cost but also lower strength/stiffness in some cases

Contact us

Growing dataset

Growing list of processors
More info?

- Visit our **website**
- Use our **Product Selector**
  - All typical property and processing datasheets
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[www.tencateadvancedcomposites.com](http://www.tencateadvancedcomposites.com)

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