# Why SUPUR-TUF PolyUrethane (PUR) Pultrusions?

## FEATURES/BENEFITS

- Excellent Strength...Enhanced Performance Characteristics
- Superior Toughness...Increased Impact Strength
- Improved Damage Tolerance...Superior Fabrication Characteristics
- Optimized Properties...Lower Raw Material Cost, Lighter Weight
- Enhanced Compatibility... Superior Paintability and Adhesive Bonding
- VOC Free... No Residual Monomer,Reduced Composite Defects

Martin Marietta Composites realized the benefits of SUPUR-TUF polyurethane pultrusions. MMC utilizes the PUR pultrusions throughout their composite trailer

**Top Beam:**
Superior strength in a high impact zone.

**Sidewall Beam:**
No surface prep prior to bonding.

**Cross Rail Beam:**
Superior stiffness impact strength, flexural strength. No surface prep required.

**Pultruded Walking Floor:**
High impact zone and abrasion resistant.

**Top Rail:**
High impact and superior strength. No surface prep required to fabricate.

## WHY PUR RESIN?

Thermoset PUR pultrusions offer superior performance over typical polyester, vinyl ester and epoxy resin systems. The manufacturing process involves high pressure injection of a two part urethane resin system. The high pressure injection process allows for superior fiber “wet out” and reduced void content. The complete fiber wet out combined with the superior resin properties equates to structural performance previously unheard of in the structural composite industry.

## WHY ARE PUR COMPOSITES BETTER?

- Highest fiber volume fraction with glass, carbon or aramid fibers in all available fiber architectures.
- Excellent resin to fiber coupling.
- PUR resin delivers improved impact and transverse properties.
- Reduced composite defects (i.e., cracks, blisters, voids) (Figure 1 and Figure 2).
- Superior dielectric strength due to improved resin matrix integrity.

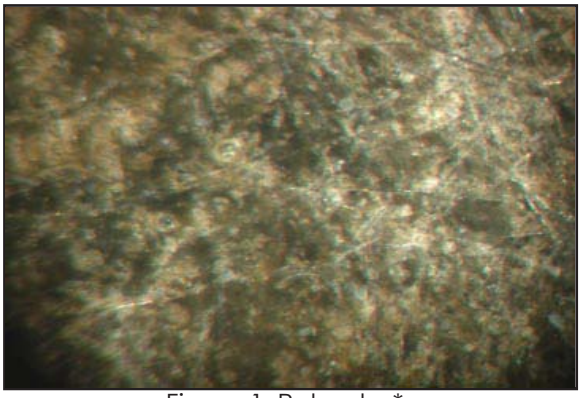


Figure 1. Polyester*

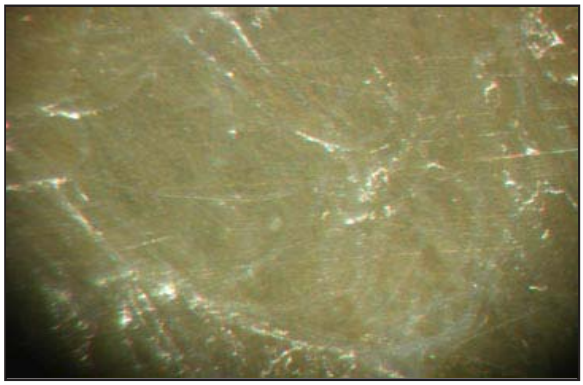
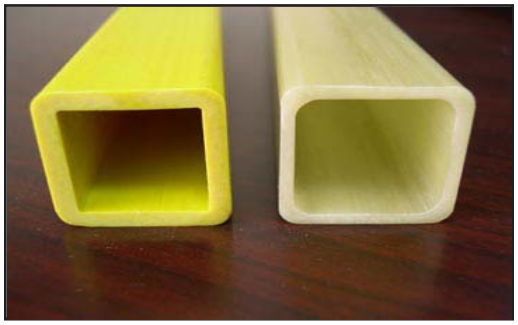


Figure 2. PUR*

*Composite Surface Integrity Viewed at 25X Magnification

## BENEFITS

- Lighter and more economical profiles can be manufactured due to the strength advantages.
- Reduced porosity.
- Low water absorption.
- Thermal conductivity is reduced with thinner wall sections.
- No fillers result in excellent RF Transparency properties.
- Reduced composite defects, higher full section strength.
- Superior fastening and fabrication results.
- Higher specific strength and stiffness.
- Available with low Flame, Smoke and Toxicity (FST) performance.



25% Weight Reduction
is Typical at Equivalent Strength

## SUPUR-TUF PHYSICAL PROPERTIES (cont'd)

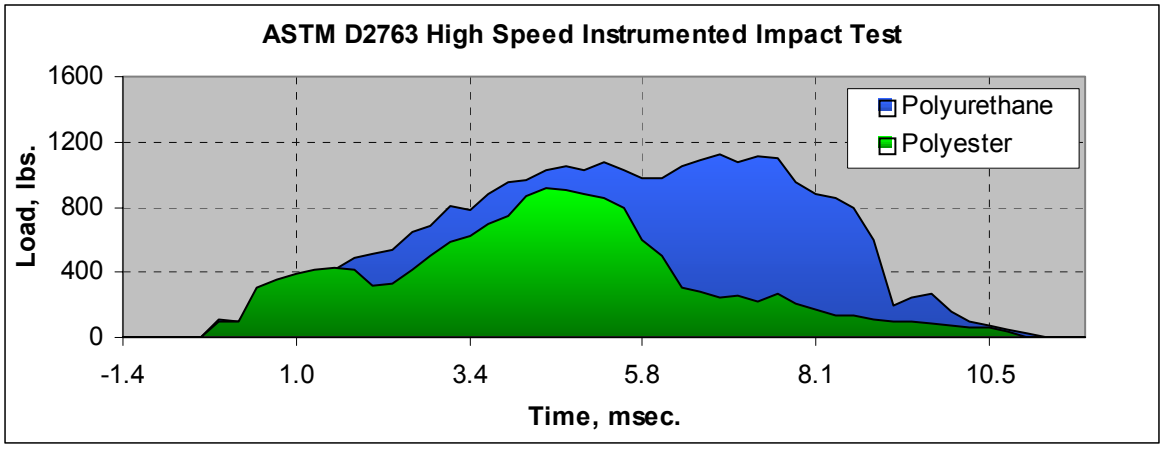



Figure 3.

## SUPUR-TUF PHYSICAL PROPERTIES

### Impact and Damage Tolerance

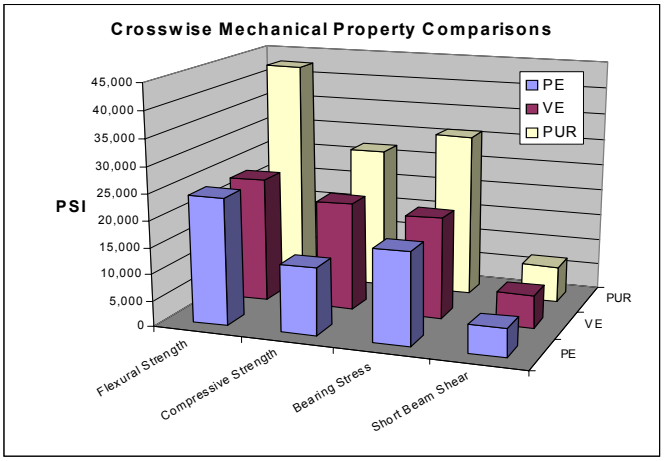
Impact property improvements can best be appreciated from high speed impact test results that show greater impact load capability and total energy absorption as indicated by test curve overlays (Figure 3). The proper combination of tough PUR and engineered fiber architectures yields superior impact performance in both low and high velocity impact events.

Applications that have high energy impact factors include:

- Sporting Goods
- Highway Products
- Ballistic/Disaster Mitigation Products

### Improved Transverse (Crosswise) Properties

Pultruded products can have a broad range of properties with different fiber compositions. A single table of mechanical coupon properties reflects the strength basis with equivalent fiber compositions, transverse properties highlight the resin contribution to composite strength. As can be seen, PUR is clearly superior in those properties that translate to high full section performance.

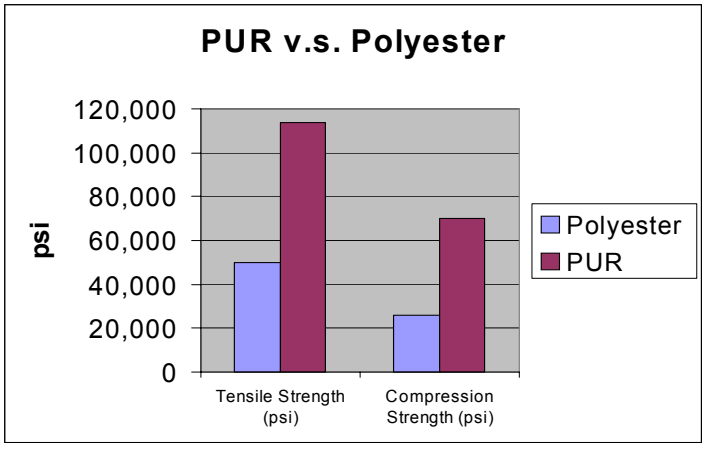


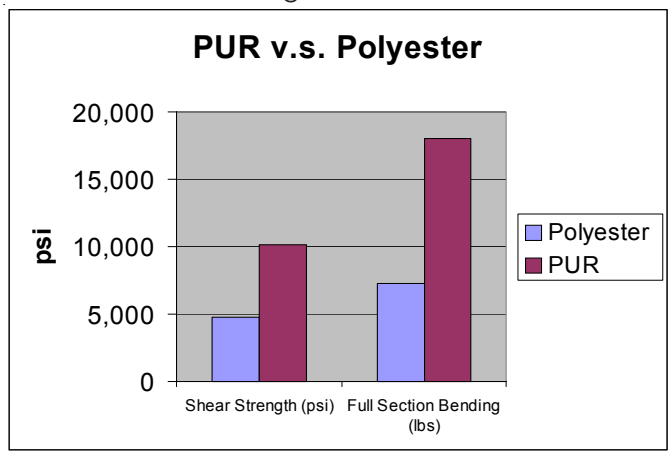

*PE = Polyester Resin  VE = Vinyl Ester Resin*
*PU = Polyurethane Resin*

## FULL SECTION MECHANICAL PERFORMANCE (cont'd)

A test involving the manufacturing of a 4 x 6 rectangular tube demonstrated the superior properties of urethane pultrusions over traditional resin systems (Figure 3). For example, the 4 x 6 tube was processed utilizing a standard polyester resin and the superior urethane system with the same fiber architecture and volume fractions. Coupon and full section evaluations were performed on the specimen. In general, the urethane section revealed an average coupon value of 54% above the polyester profile. The full section test, which consisted of a three-point bend, demonstrated an impressive 60% strength advantage.

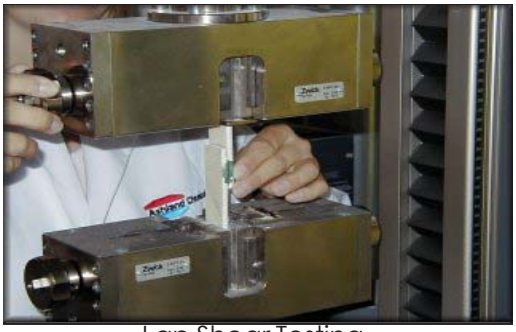
Figure 3. Full Section Test



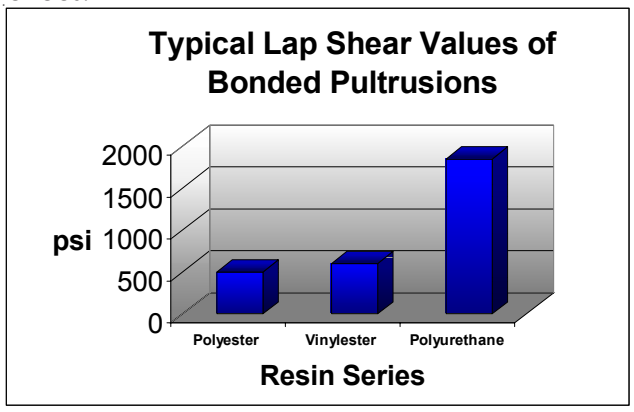




## URETHANE ADHESIVES

- Perfect match for PUR pultrusions.
- No surface preparation required.
- Laboratory adhesive trials, on dust free specimens, demonstrate a 370% increase in bond performance when compared to traditional pultrusions.
- Reduced bonding labor costs!
- Minimal dust, which creates a healthier work environment.
- Superior connection performance.
- Reduced fabrication rework and tooling cost.
- Increased revenues!



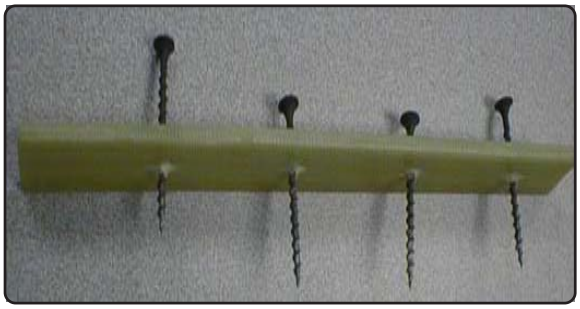
Lap Shear Testing
(Courtesy of Ashland Chemicals)

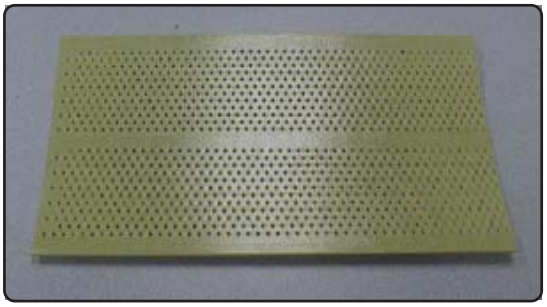



*Note: Adhesive trials performed on the PLIOGRIP 8000 Series.

## FABRICATION BENEFITS

Tougher composites means fewer fabrication related defects. Reduced cracking, splitting delamination when drilling, punching and milling make SUPUR-TUF composites a better choice when fabrication is part of final product manufacturing procedures.





All roving parts do not split when fasteners are installed. This gives PUR Superior Machinability.

## BOTTOM LINE - COST EFFECTIVE SUPUR-TUF COMPOSITES!

While PUR resin is more expensive than polyester and on par with vinyl ester resins, composite profiles designed with SUPUR-TUF deliver the superior performance of this tough material and can be supplied at equal or marginally higher cost than polyester. A strength optimized cost effective solution can be reached that enables the end user to realize superior performance with total satisfaction.

## FIRE PERFORMANCE

The following chart depicts the fire performance of Creative Pultrusions, Inc.'s (CPI) standard PUR (SUPUR-TUF)pultrusions.

**Fire Reaction Properties of Polyurethane Composites**

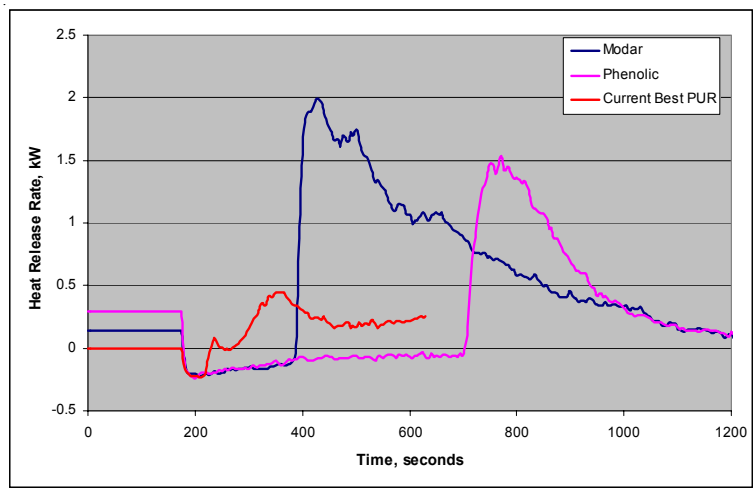
| Fire Safety | Test Description | Units | Polyurethane Triax/roving | Polyurethane All Roving |
|---|---|---|---|---|
| Limiting Oxygen Index (LOI) | D2863-97 | % O2 | 36 | 47 |
| Horizontal Burning | D635 | - - - | Self-Extinguishing | Self-Extinguishing |
| Optical Smoke Density (Flaming) | E662 | Ds, 4 min. | 20 | 101 |
| Optical Smoke Density (Flaming) | E662 | Dmax | 190 | 342 |
| Optical Smoke Density (Non-Flaming) | E662 | Ds, 4 min. | 12 | 1 |
| Optical Smoke Density (Non-Flaming) | E662 | Dmax | 212 | 240 |
| Flame Resistance (Ignition) | D229-96 | sec | 71 | 64 |
| Flame Resistance (Burning) | D229-96 | sec | 372 | 375 |

Results based on .250 inch thick samples tested at SGS U.S. Testing Company

PUR composites have also been developed with enchanced low Flame, Smoke and Toxicity (FST) properties for use in transportation applications including train, rail, marine, military and aircraft. High strength and stiffness, with superior damage tolerance and low FST properties delivers the complete package to weight sensitive applications. Heavy char formation during a fire event allows for composite strength retention during fire suppression efforts. Low smoke density and toxicity are achievable due to the low organic resin content and the unique fire barrier package developed for SUPUR-TUF LOW FST grade material.

Surface Flammability Test per IMO Part 5

## FIRE PERFORMANCE (cont'd)




Heat release curves during the Surface Flammability test show the very low heat release (area under the curve) achieved with the SUPUR-TUF LOW FST grade pultrusion as compared to the popular fire retardant composite alternatives. Given the higher strength, toughness and long term durability of polyurethane, a new option now exists for fire hazard areas in marine and naval applications. Full compliance to IMO or other standards often may require certification and on-site audit.

Not only does SUPUR-TUF Low FST comfortably pass surface flammability tests, the smoke and toxicity results indicate a substantially reduced smoke and toxicity hazard to allow for egree and fire supression.

| Test Specification for IMO Part 5 Surface Flammability | Bulkhead, Wall & Ceiling Linings | SUPUR-TUF LOW FST |
|---|---|---|
| Critical Flux at Ext. (CFE) | ≥20.0 kW/m² | 33.9 |
| Heat for Sustained Burning ($Q_{sb}$) | ≥1.5 MJ/m² | 2.60 |
| Total HR ($Q_t$) | ≤0.7 MJ | 0.09 |
| Peak HRR ($q_p$) | ≤4.0 kW | 0.50 |
| **Smoke Generation per ASTM E662** | | |
| Specific Optical Density, Flaming Mode | <200 | 183 |
| Specific Optical Density, Non-Flaming | <200 | 225 |
| **Toxicity Per ASTM E662 via FTIR** | | |
| Carbon Monoxide, ppm max. | <1000 | 342 |
| Hydrogen Cyanide, ppm max. | <30 | 11 |
| Hydrogen Chloride, ppm max. | <30 | 0 |

## ENVIRONMENTAL PROPERTIES

### Elevated Temperature Performance

On par with quality polyesters with a $T_g$ of 105°C, use of SUPUR-TUF should be considered based on load and operating temperatures. As for all composites, strength and stiffness decrease moderately as the $T_g$ is approached. Consult Creative Pultrusions, Inc. Engineering Department for further guidance.

### Creep and Fatigue Performance

Creep and Fatigue Tests were performed on the PUR pultrusions. The PUR pultrusions were compared to Polyester resin based pultrusions. In both cases the results demonstrated that the PUR and Polyester based pultrusions perform similar.

### Chemical and Corrosion Resistance

PUR resins perform very well in acid, alkali and salt spray environments. A Chemical Compatibility Guide for liquid and vapor exposures is available upon request.

### Weathering

Based on aromatic isocyanate chemistry, PUR resins have a tendency to change color with extended UV exposure. As with polyesters and vinyl esters, some surface resin degradation may occur with exposure time and a protective synthetic veil can be incorporated for protection against glass "fiber bloom". Post weathering tests show little mechanical property degradation due to weathering exposure of PUR samples. For best results in applications where color stability is important, as with polyesters a weathering coating application is recommended. Unlike polyesters, styrene-free PURresins exhibit fewer painting defects and superior paint adhesion.