Low-Cost Resin Technology for the Rapid Manufacture of High-Performance Fiber Reinforced Composites

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trimer

Project ID: mat216

PROJECT OVERVIEW

Barriers and Technical Targets

- Lack of cost-effective systems and designs, including tooling and high-volume processing
- Joining technologies for carbon fiber composites to each other or within a multi-material system are inadequate
- The ability to bond the fiber to the resin is inadequate to take full advantage of the inherent properties of the fiber, USDRIVE Materials Technical Team Roadmap October 2017, section 6

USDRIVE Materials Technical Team Roadmap, 2017

Timeline

- Project Start: 8/24/2020
- Project End: 8/23/2020
- Percent Complete: 37.5%

Partners

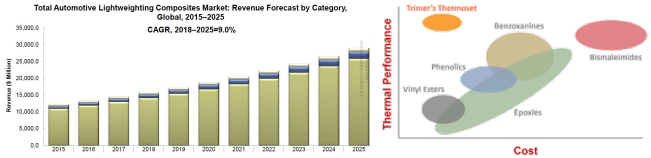
- Project Lead: Trimer Technologies, LLC
- IACMI-SuRF
- TPI Composites

Budget

- Total Project Funding:$1,150,000

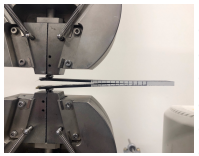
OPPORTUNITY

- Carbon fiber composites provide 50-70% weight savings over steel
- New materials with both rapid cure and significantly improved mechanical properties are required
- Trimer's resin has shown <1-minute cycle times
- Trimer could achieve the DOE's 2050 goal for cycle time under 1 min

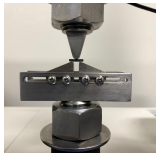


APPROACH

Trimer's Thermoset Resin



- Low viscosity for rapid infusion
- Rapid Cure - as fast as 30 sec at 140ºC
- High strength, stiffness and toughness
- Non-flammable
- High glass transition temperature
- Low-cost high-performance



Material Property	Trimer Technologies' RTM Resin	Dow Voraforce 5300	Huntsman Araldite LY 3585 / Aradur 3475	AOC VIPEL FO10 BIS-A VE	Reichhold DION IMPACT 9102-75
Polymer Type/Chemistry	-	Epoxy	Epoxy	Vinyl Ester	Vinyl Ester
Glass Transition, Tg Dry ºC	375	120	110	130	99
Tensile Strength (MPa)	105	68	77.5	88	79.2
Tensile Modulus (GPa)	4.0	2.8	2.8	3.2	2.9
Tensile Strain to Failure, %	4.0	7	9	6.2	4.5
Compressive Strength (MPa)	149	-	-	121	108.9
Flexural Strength (MPa)	140	-	-	153	144
Fracture Toughness, K1c (MPa/m$^{1/2}$)	1.03	1.22	0.85	0.6	-
Viscosity (cP at 23 ºC)	200	500	1,000	3,200	170

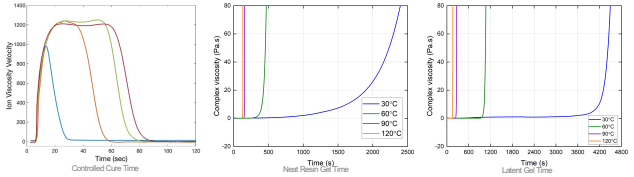
TECHNICAL PROGRESS

Resin Transfer Molding

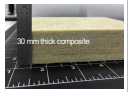
- HP-RTM injects liquid resin at high pressure into a closed mold which is heated to cure the resin
  - Resin injected at pressures around 100 Bar (~1,500 PSI)
- Viscosity dictates infusion time and can lead to deformation of the weave, known as fiber wash if too high
- Rapid cure required to enable low cycle time and high part count
- Used for complex and high-performance parts with continuous fibers
- Performance can greatly exceed sheet molding compound (SMC)

Images from BMW

Reaction Kinetics



- Trimer developed chemistry that allows for tailoring the cure time and expands the gel time important for molding large parts
- Trimer demonstrated curing of 30 mm thick composites in under 120sec
- Cycle time can be more than 5 times faster than state of the art resins
- Cure rate is unprecedented and enabled by low exotherm
- Resin and fiberglass preform were added to the mold cold and therefore cure time could be further reduced

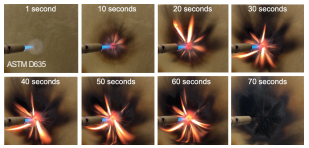


Composite Mechanical Properties

Property	Trimer Rapid	Crestapol 1250
0º Tensile Strength, GPa (ASTM D3039)	1.04	1.03
0º Tensile Modulus, GPa (ASTM D3039)	44.2	46.45
0º Compression Strength, MPa (ASTM D6641)	966.0	568.7
0º Compression Modulus, GPa (ASTM D6641)	47.2	43.9
90º Tensile Strength, MPa (ASTM D3039)	36.4	19.5
90º Tensile Modulus, GPa (ASTM D3039)	14.3	14.9
90º Compression Strength, MPa (ASTM D6641)	184.3	99.5
90º Compression Modulus, GPa (ASTM D6641)	31.0	12.9
In-Plane Shear Strength, MPa (ASTM D3518)	64.7	57.77
In-Plane Shear Modulus, GPa (ASTM D3518)	3.4	2.66
Mode I Fracture Toughness, J/m², (ASTM D5528)*	437	809
Mode I Fracture Toughness, J/m², (ASTM D7905)†	1,510	1,640
Translaminar Fracture Toughness, MPa•m$^{1/2}$ (ASTM E1922)	60.64	51.87

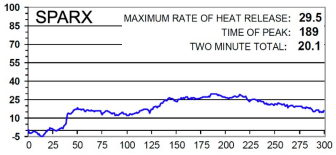
- Trimer's RAPID was compared to another fast-curing system and showed superior performance
- The axial compressive strength of Trimer's resin was 70% higher than the competing resin and the transverse loading showed an 85.2% increase
- RAPID performed extremely well in both Mode I and Mode II fracture toughness when compared to Hexcel 8552, a toughened aerospace resin

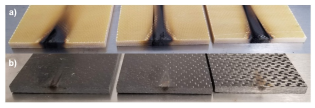
Fire Resistance



60 second burn time

- Trimer tested the neat polymer for horizontal flame spread (ASTM D635) and passed the horizontal burning test after 30 sec exposure to flame
- The polymer was subjected to a 60 sec burn under more intense flux than the ASTM
- Fiberglass panels were tested through OSU heat release at Test Corp using FAA certified equipment
  - Results showed a peak heat release rate of 29.5 kW/m2

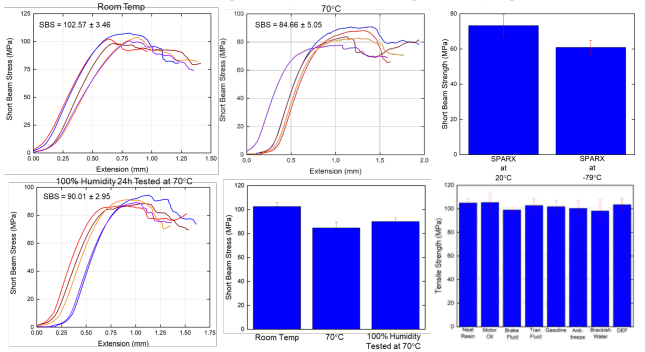




TECHNICAL PROGRESS

Environmental Testing

- Trimer tested short beam samples prepared by VARTM that were heated to 70° C and incubated at 100% humidity at 70° C for 24 hours
- There was a slight decrease in the performance under these conditions
- Short beam samples were also cooled to -79° C and likewise showed a slight reduction in performance
- Common automotive fluids show no statistically significant impact on resin properties
- These results suggest the fatigue performance of Trimer composites would not drop significantly under harsh environmental conditions
- Room temperature fatigue testing has been completed with OEM partners and has showed similar or improved performance when compared to epoxies
- Further environmental testing will be performed throughout the program



FUTURE RESEARCH

- Trimer has demonstrated the capability to achieve molded continuous fiber composites in under 60 seconds, a critical lightweighting goal
- Commercialization of Trimer's resin requires extensive process development and material testing necessitating further work
- Internal mold release (IMR) agents must be further tested to enable continuous HP-RTM manufacturing
- Resin adoption in high volume automotive manufacturing requires scale up of the manufacturing process
- Component level testing will be required for the commercialization of Trimer's resin in production automotive components therefore requiring close partnerships with OEMs
- Any proposed future work is subject to change based on funding levels.

SUMMARY

- Carbon fiber composites provide 50-70% weight savings over steel providing a critical technology to enable lightweighting in vehicles
- Trimer Technologies has developed a revolutionary low viscosity thermosetting resin which can enable rapid cure and achieves excellent mechanical properties
  - Mechanical properties greatly exceed state of the art automotive resins
- Polymer exhibit very high glass transition temperature (up to 235º C) which can enable body in white structures
- Trimer has demonstrated composite panel can be molded in under 45 sec
  - Cycle time exceeds the DOE's 2050 goal for cycle time under 1 min
- We have developed cure technology to reduce the reaction rate allowing extended molding times for larger structures
- Testing has shown the resin to be non-flammable and offers FST performance exceeding the needs of the automotive industry