Strain Tunable Resin and Coating Technology for Next Generation Composites

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ABSTRACT

Leveraging Navy SBIR efforts, Structural Composites, Inc has invented a breakthrough coating and resin technology for composites. Our patent pending Co-Cure technology enables shop floor alteration of coating and resin properties, which can facilitate a range of performance enhancements to composite fabrications. This has the potential to impact the entire composites market, allowing for more cost effective optimized composite structures. We are working with industry leaders on both the technology development and deployment. These technology partners will become our early adopters and will have access to the technology. We are looking for key industry innovators in related emerging markets such as rail car, locomotive, wind energy, building construction, shelters and recreational vehicles.

Keywords: composites, advanced resins and coatings, lightweight, emerging markets, composites for transportation.

1 BACKGROUND

Composite technology has made tremendous advances over the past two decades. After much investment, we now understand how to better optimize the design, the material systems and the manufacturing process. This has resulted in many exciting applications for composites, in particular applications where traditional material technology has been dominant.

We all know the advantages of composites: lightweight, strong, tough, formable to complex shapes, durable and resistant to corrosion. In order to expand into new markets such as transportation, infrastructure and building construction, we face less of a performance gap but more of a price gap. Traditional approaches to composites can meet the performance requirements, however the high cost limits the application to those markets which value the advantage. New designs, materials and manufacturing approaches that reduce cost open new markets for composites.

The scale of these emerging markets should not be under-estimated. A Lucintel study presented at ACMA's Composites 2012 conference provides an indication as to the potential market size. The markets with the largest unachieved potential for composites are transportation and construction. The study indicates that the transportation market has achieved just 3.6% of its composite material market potential, and the construction market has achieved just 4% of its composite material market potential [1]. Even with this low level of market penetration, the dollar value of materials currently being used in each of these markets exceeds that of the entire 2.3 billion dollar aerospace composites material market. Just achieving a small segment of these potential emerging markets can transform the global composites industry by 10 to 100 fold from its current size.

Bridging the cost gap from traditional materials while maintaining the performance advantage for composites is the game changing technology that is needed to penetrate these emerging markets. In transportation, advances in composites will help make all powered vehicles lighter and more efficient. Weight reduction will also play an important role by helping other emerging technologies achieve commercial viability.

One major area of opportunity to improve composites is in advanced low cost coating and resin technology. Today's low cost resins and coatings limit the performance of our structures. The lowest cost resins are orthophthalic polyesters; the lower cost coatings are isophthalic polyester based gel coats. Both of these materials, while cost effective, suffer from relatively poor mechanical properties; in particular, low strain to failure and fracture toughness.

The recreational marine industry is a very cost sensitive industry for composites. Gel coat used as an in-mold coating is the industry standard. Gel coat is a filled resin system that has pigments, UV stabilizers, fillers and additives which enable it to be sprayed onto a mold and cure as thin film. Layers of composites (fibers and resin) are placed over the in-mold coating to create the part, in this case a boat hull or deck.

The consumer demands a high quality visual appearance from the gel coat. In boats it is commonly referred to as the automotive finish. Gel coat can deliver this finish, however its brittle nature, its location on high strain surfaces and the dominant flexural and shock loading experienced by boats commonly cause cracking of the coating. If you have ever owned a composite boat you have seen gel coat cracking.

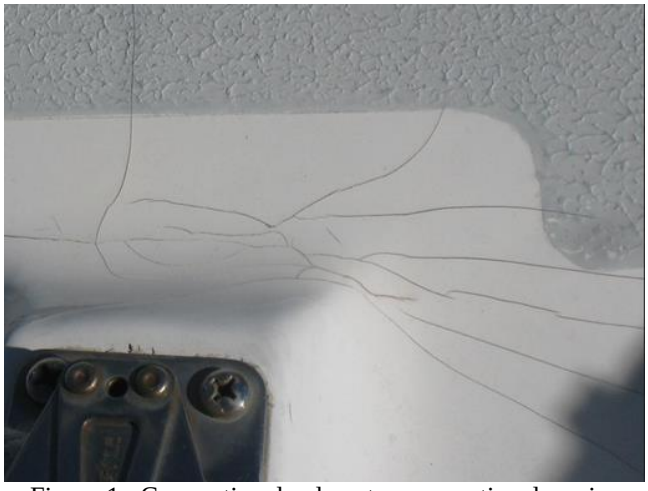

Figure 1: Conventional gel coat on recreational marine product.

Recreational boat manufacturers indicate about 50% of all warranty claims are centered around the gel coat. In essence, today's composite products that use in-mold gel coat are designed around the gel coat, as this material will fail prior to structural failure of the fiber reinforced laminate.

A cost effective, tougher gel coat that provides a high quality cosmetic finish would be a major asset to the industry. It would allow thinner laminates, resulting in weight savings and cost savings. In the emerging transportation markets (trailer, rail, bus, etc.) this can help bridge the price gap and improve performance helping drive economic viability.

Today's performance resins are epoxy, vinyl ester and polyurethane. These resins can provide far superior performance over the low cost polyester resins. The next performance step above polyester resin is vinyl ester resin, at prices that can be double or more over the polyester. Today's advanced resins improve performance but increase the price gap.

In performance applications such as naval structures or theme park rides, vinyl ester or expoy resins are the standard. These applications are far less price sensitive than the commercial transportation, civil infrastructure and construction markets. A low cost resin that can provide the toughness and ease of process as the current advanced resins will help bridge the price gap for emerging markets.

Structural Composites has been at the forefront of this effort leveraging government funding and low cost technology from the marine industry. This has led to several breakthroughs that are reducing the price gap and increasing performance for composites in these emerging markets. This paper details one aspect of the technology, an innovative co-cure resin and coating technology that not only has the potential to bridge the price gap but has the potential to change composites as we know them today.

2 CO-CURE TECHNOLOGY

Leveraging Navy SBIR efforts, Structural Composites Inc has invented a breakthrough coating and resin technology for composites. Our patent pending Co-Cure technology enables shop floor alteration of coating and resin properties which will facilitate a range of performance enhancements to composite fabrications. This significant accomplishment has the potential to impact the entire composites market, allowing for more cost effective optimized composite structures.

Current state of the art is for fabricators to purchase a fully formulated resin or coating system. The co-cure technology enables resin or coating formulation at the fabricator site at the resin gun head/dispensing equipment, thus the coating and resin properties can be formulated on the fly and applied to the part. This development opens a spectrum of opportunities for both existing and emerging markets.

The invention pertains to coatings and structural layers commonly used to fabricate molded products, and in particular to co-cured systems having improved adhesion, toughness, flexibility, and structural performance.

One facet of the invention concerns gel coats comprised of specially formulated co-cured urethane and vinyl ester, epoxy, or unsaturated polyester components. The gel coats have improved toughness and flexibility compared with conventional gel coats, they adhere well to structural layers, and they can be used in a traditional in-mold process. Laboratory testing has shown that these improved gel coats allow laminates that can withstand 25% greater allowable stress and have a superior bond, in particular for difficult applications such as continuous submergence.

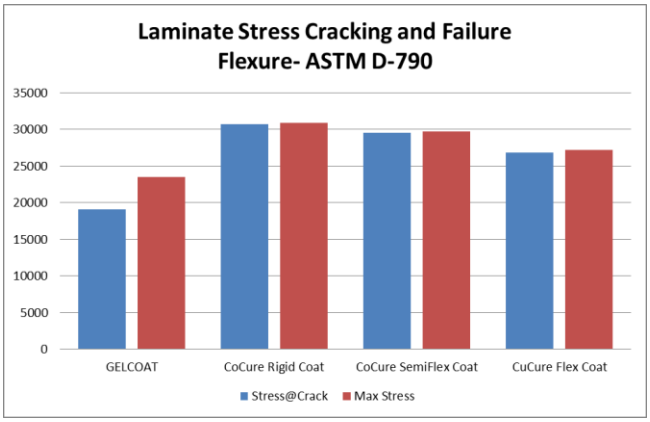

Figure 2: Comparison of laminate stress cracking and failures in flexure for conventional gel coat and Co-Cure coating configurations.

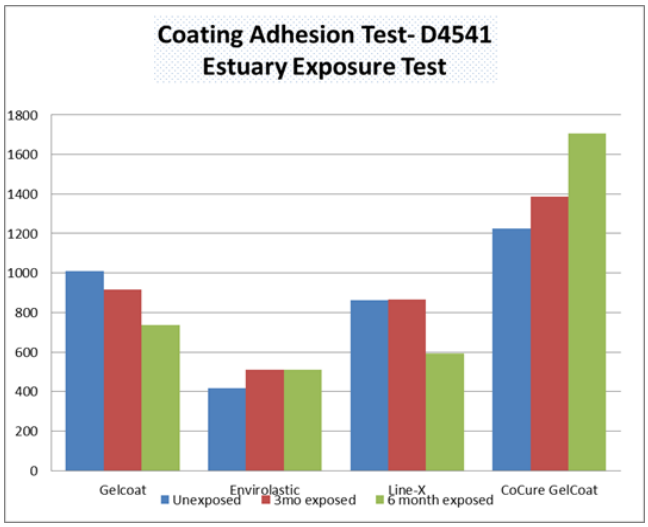

Figure 3: Coating adhesion test results comparison for estuary exposure of coatings.

Another facet of the invention concerns an elastomeric coating comprised of specifically formulated co-cured urethane and vinyl ester, epoxy, or unsaturated polyester components. The elastomeric coatings are flexible and tough, they adhere well to structural layers, and unlike conventional urethane coatings they can be used in a traditional in-mold process. Our Co-Cure technology combined with advanced new fibers enables a new generation of ultra-tough composites that can better withstand shock and impact and are more resistant to damage.

The ability to radically alter resin properties in real-time on the factory floor creates many exciting new opportunities for composites. Co-Cure has tremendous potential for producing lighter, more structurally efficient composite structures such as wind blades, underwater turbines, boats, aircraft, and ground transportation vehicles at more affordable (cost neutral) pricing.

Co-Cure based on low cost unsaturated polyester resin and moderate cost polyurethane chemistry is of particular interest as it has the potential to bridge both the price gap and the performance gap which prohibit broader use of composites in many segments of transportation. Another aspect of this market segment is the need for scalability as it embodies a broad range of production volumes. Co-Cure provides the ability to tune the resin cure cycle to meet the various and diverse needs of this broad emerging market.

Previous work has focused on hybrid resin systems, such as Amoco's Xycon Resin (1990s), where single property systems were formulated at the resin manufacturer and compounded. Co-Cure's ability to alter resin properties on the factory floor, on-the-fly, literally at the resin gun head, is distinctive. Importantly, Co-Cure also eliminates issues of the greatly reduced shelf life which have plagued formulated hybrid resin systems.

Our goal is to develop and refine the technology and deploy it to the composites industry with the aid of leading industry partners. We believe the technology has broad global application, as it can improve today's composites and can help open doors for new emerging markets for composites.

3 CURRENT STATE OF THE TECHNOLOGY

Working with a major global supplier, we are currently refining and optimizing the Co-Cure technology in preparation for market deployment. The technology has been applied to several prototypes in cost sensitive emerging markets.

Figure 4: Co-Cure coating as a wear surface for a prototype produce box truck.

It is anticipated that a military version of gel coat replacement will be available and fielded in 2014. Production volumes scaled for this market are targeted to begin in 2015.

Figure 5: SBIR Phase III 11M low cost lightweight shock mitigating prototype combatant craft hull in fabrication.

In parallel with this, experimentation is underway to develop a gel coat replacement that will meet the cosmetic requirements for consumer goods such as boats, RVs trailers and buses. Trials are in progress and prototype products are being produced or in planning.

In addition to the coating technology the team is working on a complementary low cost co-cure resin system to help bridge the price gap for transportation, infrastructure and construction. Our goal is to develop a high performance resin at 30-40% lower cost than current low cost performance resins. The significance of this invention will be market opportunities for composites that in past studies have not been financially viable.

We are working with industry leaders on both the technology development and deployment. These technology partners will become our early adopters and will have access to the technology.

We are looking for key industry innovators in related emerging markets, including rail car, locomotive, wind energy, building construction, shelters and recreational vehicles.

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