Polyurethane Pultrusion Application Successes with Large Profiles

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About the Author:

Dustin L. Troutman received his BS in Civil Engineering Technology from the University of Pittsburgh located in Johnstown, Pennsylvania, in 1993. He currently holds the position of Director of Marketing and Product Development for Creative Pultrusions, Inc., (CPI) located in Alum Bank, PA. He has been instrumental in the development of major pultrusion products and product lines. He holds three patents related to pultrusion systems. He has been involved in sales, marketing and engineering for twelve years at CPI.

Abstract:

Polyurethane resin technology for pultrusion was first introduced in the late 1990's as an option that promoted elimination of continuous strand mat due to the exceptional strength and toughness of the resin matrix. All-roving reinforced pultrusions using low pressure injection or low volume wet out boxes were the initial focus for most pultruders pursuing this opportunity. With moderate effort and guidance of the raw material suppliers, success could be realized in fairly short order for small scale profiles. However, the challenges of reactive polyurethane processing of large heavy wall profiles of considerable complexity required considerably more development effort. This paper describes commercial successes at Creative Pultrusions with applications enabled by the superior performance of polyurethane composites.

Introduction

Pultruded composites are well known for their inherent strength, stiffness and corrosion resistance; however, every material has an Achilles heal. For pultruded composites, the Achilles heel is the in-plane and interlaminar shear strength coupled with low impact and abrasion performance. Add to that the issues with connections and before too long you realize that for many applications, traditional composites manufactured with polyester and vinyl ester based resins have limitations.

Creative Pultrusions, Inc., has spent the last five years overcoming such limitations with the introduction of pultrusion grade polyurethane resin systems. Creative has had great success with both the hybridized and pure two component polyurethane systems. The main obstacles early on in the program were manufacturing related. Specifically, the two component isocyanates and polyol systems required a special manufacturing discipline that had to be developed in order to make manufacturing practical.

Over the past five years Creative Pultrusions, Inc., has realized great success with the hybridized and two component polyurethane systems and we now manufacture over thirty-five profiles in production. The markets range from cooling towers and sheet piling to the traditional ladder rail market. This paper discusses some of the successes made possible with invent of advanced polyurethane pultrusion grade systems.

Material Attributes

The most important attribute that was discovered early on in the development of the polyurethane material properties was the drastic increase in mechanical properties. The common belief in the composite industry is that the reinforcement package dominates the material properties. The two component polyurethane system dispels this notion.

For example, Creative conducted numerous studies in order to classify the characteristics of the hybridized and two component polyurethane systems against the legacy polyester, vinyl ester and epoxy systems. As depicted below, in the comparison of the crosswise properties of a laminate pultruded with the same fiber architecture with matrixes consisting of iso-polyester, vinyl ester and the two component polyurethane systems, the properties are substantially higher as a result of the polyurethane matrix.

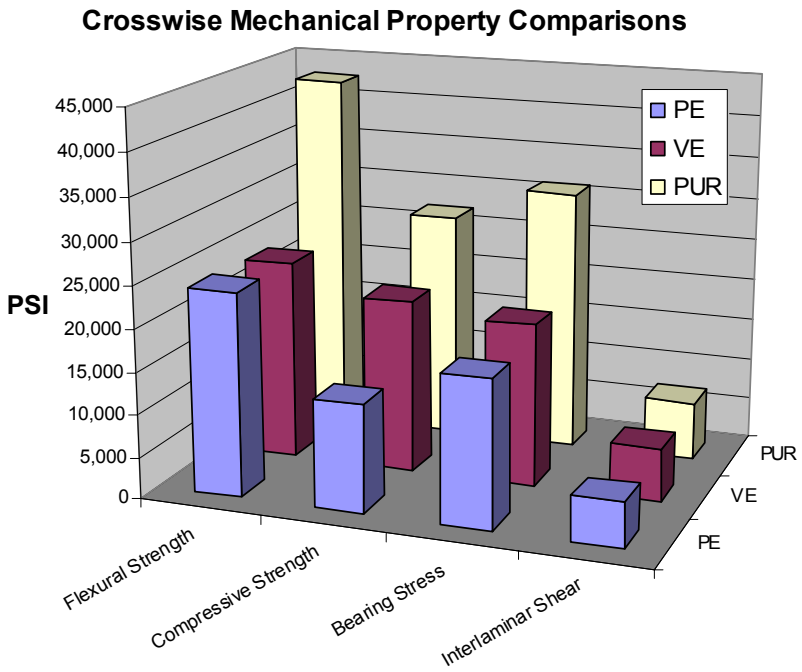

Figure 1.0 Crosswise mechanical property comparison

The chart below depicts a direct comparison of the two part polyurethane system against an iso-polyester manufactured with the same fiber architecture. The lengthwise mechanical properties more than doubled in all cases.

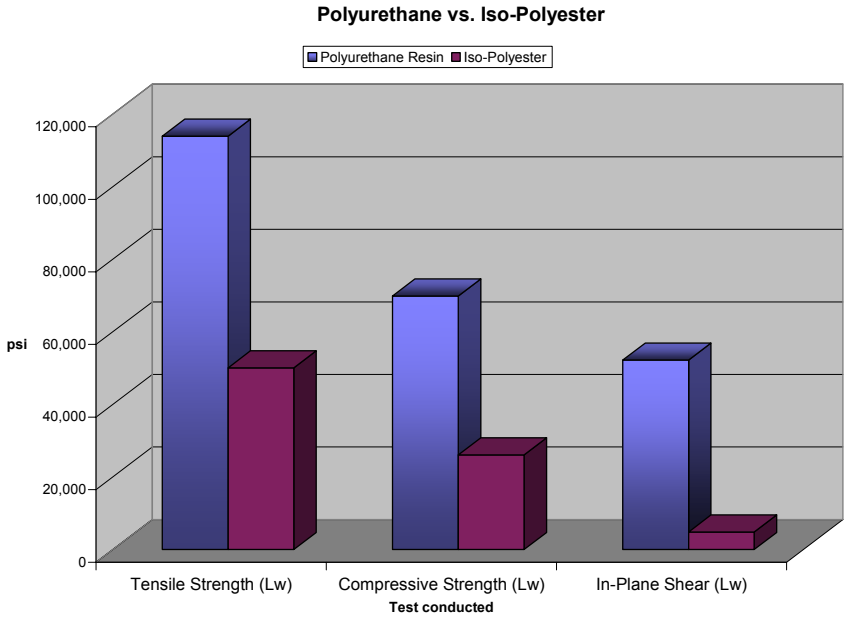

Figure 2.0 Lengthwise mechanical properties

The information provided thus far deals strictly with coupon level experimentation. The same strength phenomena that occurred at the coupon level were duplicated by pultruding a 6”x4” rectangular tube in both an iso-polyester and a two component polyurethane system. The tube was tested in a full section bend test both at a long span and at a short span in order to determine the shear and compression stress at failure. In both test cases, the two component polyurethane system out performed the polyester tube. In fact, the full section bending strength was increased by a factor of 2.46 times.

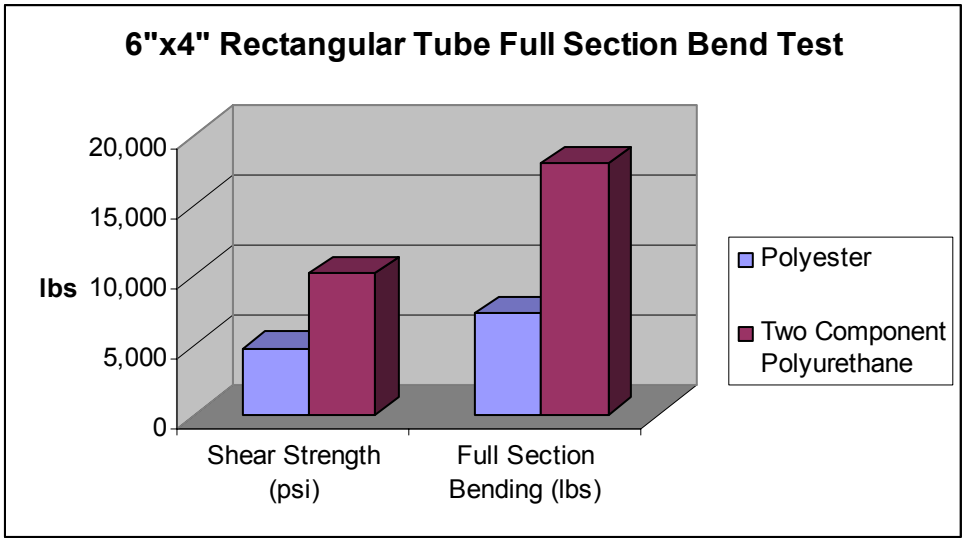

Figure 3.0 Full section bending strength graph

Figure 4.0 Full section bend test

Breaking Barriers to Markets
The material characteristics described in the previous paragraphs combined with many more positive attributes including impact resistance, abrasion resistance and low flame smoke and toxicity have allowed Creative Pultrusions, Inc., to penetrate markets and improve upon products in existing markets.

A prime example of a product that required the discipline of process technology, material characterization and impact engineering, is the SuperRail™ composite guardrail. Creative developed the SuperRail™ through a Small Business Innovative Research (SBIR) program that was sponsored by the Federal Highway Administration. The project involved developing an all-composite guardrail rail system began with extensive engineering and computer simulation on a polyester resin/e-glass reinforced multicellular profile design. After several years and several crash tests it was evident that a better resin technology was required to make this product a success. It was about this time that Creative developed the manufacturing technology to manufacture products with a two component polyurethane system. The direct inject technology allowed Creative to go back to the drawing board and redesign the guardrail around the polyurethane material properties. The result was an NCHRP 350 compliant guardrail that is now approved for use by the FHWA.

Figure 5.0 ¾ Ton Pickup traveling at 62 Mph; Impact angle 25°

The SuperRail™ composite guardrail reduces the occupancy hazard by decreasing the deceleration rate during impact. Another major performance criteria is the ability to redirect the vehicle at a trajectory parallel to the rail. Traditional steel rail systems have the tendency to redirect traffic into the parallel and opposing lanes of traffic.

The product sales and marketing will begin with the entry into niche markets where corrosion is a large problem. An example is the replacement of steel rail, due to corrosion, along coastal highway systems.

Cooling Towers
A view into the cooling tower market demonstrates a prime example of a material evolution into a new market. Specifically, up until the last 10 years the cooling tower market was dominated by redwood and concrete. The transition of fiberglass reinforced plastics (FRP) into the cooling tower market has occurred resulting in 70% of all new cooling tower structures being manufactured out of pultruded profiles.

The evolution continues with the introduction of polyurethane beams into the cooling tower market. Specifically, pultruded polyurethane double webbed I-sections are being utilized as fill support beams in tower structures. The urethane matrix allowed Creative to design an ultra thin, lightweight, high modulus, extremely tough profile. The robust lightweight beam exhibits a flexural capacity of 60,000 psi and a Modulus of Elasticity of 5.5E6 psi.

Figure 6.0 Polyurethane Fill Support Beam

Sheet Piling
In the mid nineties Creative introduced a composite sheet pile section into the marine market. After initial feedback from the field, Creative chose to further develop the composite sheet pile section into a full-blown system. The SuperLoc™ composite sheet pile system has been further enhanced with the use of the two component polyurethane system.

Specifically, two cosmetic caps were developed and manufactured with the polyurethane matrix. The polyurethane matrix was chosen due to the high abrasion resistance and extreme impact strength. We knew that the application required a shape that would be able to take the abrasion abuse of weed eaters the impact from lawnmowers and the wear and tear from ice and waves. The result was a thinned walled channel section that caps the sheets forming a robust aesthetically pleasing closeout.

Figure 7.0 Superloc™ Sheetpile system with the polyurethane cap

The immediate market consisted of the residential homes and homeowner associations and small commercial marinas. After a few years Creative introduced a polyurethane sheet pile section for retaining walls heights of approximately 15' and under. The market required a more robust impact resistant sheet capable of being driven into very firm soils. The result of was a highly optimized hat section known as the Series 1610 Polyurethane sheet piling.

Figure 8.0 Superloc™ 1610

The 1610 measures 10" in depth and over 24" wide and has a moment capacity of 46,000 ft-lbs/ft of wall. The polyurethane matrix helped to strengthen the very important

interlock system. The enhanced interlaminar shear strength allows the connection to transfer the transverse tensile load from sheet to sheet during the three-way or diaphragm bending that occurs with the high exposures. The heavy-duty sheet piling is earning a position in the commercial market as the price of steel continues to increase and contractors realize the labor savings associated with light weight FRP sheet.

Power poles/Cross arms

Creative has partnered with Powertrusion in order to market a product line that focuses on the utility industry. Specifically, the products consist of distribution class poles and cross arms. The poles are manufactured with a hybridized polyurethane, while the heavy duty arms are manufactured with a two component polyurethane system.

The urethane resins allow profiles that were originally manufactured in polyester based resins, to satisfy higher classifications of both the arms and the poles. For example, an arm that was designed and tested to satisfy the requirements of a heavy tangent in a polyester system, was manufactured and tested with a polyurethane matrix and the result was an arm that was twice as strong that can satisfy the requirements of a tangent or heavy dead end.

Figure 9.0 Powertrusion Pole and Arms

Composite poles have been adopted as part of the IEEE/NESC 2007 code. The ASCE 111, Reliability Based Design of Utility Pole Structures document permits composite poles to be treated like steel poles as a result of the low coefficient of variation between pole breaks. The engineering community is realizing the true benefits of polyurethane pultrusions. The composite poles and arms continue to erode the wood, steel and concrete pole market. A niche market has been created and there is not doubt that the niche will continue to grow until composite poles and arms are commonplace.

The Future Looks Bright

The future of polyurethane matrix composites looks very bright, the material attributes continue to be realized and capitalized upon. The SupurTuff™ polyurethane pultrusions are offering solutions that the legacy polyester and vinyl ester systems were not capable of providing. I predict that within the next five years, polyurethane pultrusions will be as common as polyester based pultrusions. In fact, we may see the day when polyester resins go the way of the buggy whip.