Recycling Composite Boats

I set out to write about "What's New in FRP Recycling," but narrowed my focus to boats because: 1. In general, not much is "new" in FRP recycling; 2. boats are what I know and love; and 3. since boats are large, consumer-owned structures, they represent the greatest recycling challenge for the industry. Recycling is the big "Catch 22" issue that the composites industry faces. Composite boats are great investments precisely because of their durability. This creates two issues that boat manufacturers must overcome. First, in order to sell new boats, design evolution and features must be more attractive than what is on the used market. Second, we need to minimize shoreside abandonment and landfill waste resulting from hulls that are beyond their useful life. The first issue is a marketing conundrum and subject for another article. Now, what to do with composite boats that are beyond their useful life.

The issue of abandoned boats struck a personal note for me when I recently had the good fortune to spend a week on the beautiful island of Tortola in the British Virgin Islands. As with many Caribbean islands, a number of old fiberglass hulls littered the beaches and also were serving as "planters" further inshore. Islands are certainly microcosms of the greater landscape, albeit without certain infrastructure elements, such as large landfills. However, I've seen the same evidence of abandoned boats along the coasts and in inland lots around the U.S.

Addressing what happens to the products we build after consumers are done with them is not just an environmental issue. Sure, there's good public relations value by being out in front of the issue - just look at General Electric and BP. But there also may be good economic incentives. If recycled thermoset composite material can find it's way into new products, there is the potential for overall cost savings. Also consider that Europe has a more aggressive "cradle to grave" philosophy than the U.S., so as exchange rates are starting to favor export abroad, new markets may emerge if we can comply with international standards.

Waste Elimination

It almost goes without saying that the easiest and most cost-effective way to eliminate thermoset materials from the waste stream is to dispose of as little as possible during construction. Most shops employ these practices to improve the bottom line, but it's helpful to review the following waste elimination steps:

- Use kitted reinforcement and core products
- Avoid overspray
- Minimize flange cut-off widths
- Improve QA procedures to minimize part rejections
- Optimize structure to avoid "overbuilt" laminates
- Maximize part commonality between models
- Improve longevity of molds
- Institute effective waste disposal in compliance with environmental regulations

Recycled Content in New Construction

Thermoset composites can be recycled by two very different processes. Mechanical recycling involves grinding the waste products and then mixing it with virgin material for use in repair and new construction. Feedstock or chemical recycling converts waste product into raw material via a chemical or thermal process. Typical boat structures don't lend themselves to chemical recycling and thermal (pyrolysis) methods will be discussed later in this article. The process that has shown the most promise for adding recycled content to new boats is mechanical (grinding) recycling.

Recycling in Europe

The European Composites Industry Association (EuCIA) reports on its web site that "Landfill of composite waste will be forbidden by the end of 2004 by most EU Member states, and incineration will have limits imposed on the level of energy content." To address composites these impending recycling issues, the European Composites Recycling Company (ECRC) was formed by EuCIA. The ECRC is a group of suppliers and molders dedicated to "develop, introduce and implement standardized and financially acceptable Europe-wide waste management principles offering a recycling solution for the European composites industry as an answer to the challenging new European waste directives." The ECRC recognized the urgency to solving waste disposal problems for the industry, as the costs for disposal in some countries has gone up 250% since 2004. The ECRC is not a recycling company as we would recognize it but instead coordinates activities amongst various interested entities. They've established the "Green Label" for consumer products that "guarantees to OEM´s and final customers that for this specific part a working end-of-life solution is available."

Europeans have been seriously looking at recycling issues for over a decade. In the 1997 "Composites and Sandwich Structures" conference held in Stockholm, Sweden, there was an entire segment dedicated to recycling issues. Presentations focused on mechanical recycling and incineration. Energy recovery in cement kilns looked especially promising because the high temperature (2500° F) ensures complete combustion. For the most part, the mineral byproducts are useful for cement production. Several installations that recover energy from composites solid waste have been established in Northern Europe. For mechanically recycling, pilot programs looked to technology developed by Seawolf Industries in the U.S.

Seawolf Design

Wolfgang Unger of Seawolf Design, Inc. (www.seawolfindustries.com) has been working on the challenge of thermoset composites recycling for over 15 years. He claims that by incorporating recycled trimmings with virgin material into new parts, raw material costs can be reduced 20% to 50%, while also reducing 80-100% of roll-out labor. The technology is based on the Seawolf Recycling and Dry Additive System, which can be used in spray-up, putties, casting, concrete reinforcement, RTM, pre-forms, compression molding, extrusion, pultrusion and rotation casting.

The Seawolf Recycling & Dry Additive System is a two part system designed to compliment each other or work separately. Part of the system is a machine called a Grinder/Muncher, shown in Figure 1. This machine is similar to a hammer-mill that is built to withstand abrasive fiberglass and maintain a low temperature. The low temperature operation is important to eliminate spontaneous ignition and maintain the integrity of fibers for viable and effective reuse. The other part of the system is an air-powered metering and transportation assembly attachment to a fiberglass spray gun, shown in Figure 2. This process enables the use of recycled FRP with preexisting spray-up machinery. Mr. Unger notes a recent upsurge in interest for his recycling equipment, especially in Brazil.

Molds for Thermoforming

Dr. Dru Wilson of Central Michigan University reported in 2003 about his study to use ground thermoset material to create prototype thermoforming molds.   He wanted to ascertain mold swelling, shrinking, heat resistance and overall quality of the thermoformed parts. His method of recovering fiberglass “powder” from a cured part was quite simple – he used a hand grinder with 36 grit sandpaper. The resulting powdered epoxy resin had a granular structure and the fiberglass rods had an average length of 70 μm, as seen in the electron microscope image shown in Figure 3.

70% by volume recycled filler material was mixed with epoxy resin to form the mold material. Polystyrene sheets 0.020 inches thick were heated for 10 seconds and thermoformed with vacuum. The parts showed good stability and were true to the mold shape. This study was done with relatively small molds in an academic environment, but that fact that 70% of the mold material was from easily-reclaimed waste was very encouraging.

Pyrolysis

The pyrolysis process is defined as the thermal degradation of the waste polymer component in the absence of oxygen. The polymer breaks down to produce oil/wax, gas, and a char product, leaving a solid friable residue. Pyrolysis has the advantage that potentially all of the products from the process can be used. Table 1 shows the product yield for a range of composite materials pyrolysed at 500°C. Pyrolysis breaks down the polymer chain to produce wax, oil and gas derived from the original plastic. The gas should have sufficient energy content to provide the energy requirements of the pyrolysis process plant. The gas composition produced is again dependent on the original plastic used in the composite. For oxygen-containing plastics such as polyester and phenolic resins, the main gases are carbon dioxide and carbon monoxide. For other plastics, higher concentrations of hydrogen and hydrocarbons, such as methane and ethane, are dominant. The wax and oil are given off as gases during pyrolysis but are condensed downstream.

The oil and wax have a high calorific value and can be burnt to provide energy or they can be used as a chemical source. The solid residue left behind after pyrolysis is a solid containing the glass fiber and filler, and a small amount of carbonaceous char derived from the plastic degradation.

Table 1. Product yield from the pyrolysis of various composite wastes in wt%.

Composite	Solid Residue	Oil/Wax	Gas
Polyester resin/$CaCO_3$/glass fibre	45.8	45.7	8.5
Phenolic resin/MgO,$CaCO_3$/ glass fibre	90.2	8.8	1.0
Epoxy resin/glass, carbon fibre	67.4	31.3	1.2
Polyester resin/silane bonder/glass fibre	30.0	59.4	10.6
Vinylester resin/glass fibre	83.4	15.0	1.6

One of the major and valuable constituents of composite plastic wastes is glass fiber. The problem for glass fiber recovery is to use process conditions that do not degrade the fiber strength, and the key parameter is the temperature. Above 800°C the fibers become very brittle and quickly lose strength. Pyrolysis has the advantage of low process temperatures of less than 500°C, which retains the strength and flexibility of the virgin glass fiber.

Separation of the glass fiber from the filler can be done using a drum carder machine, which gently separates the fibers from the friable char and filler matrix. The fibers can then be used as char-coated fibers to produce new composite plastic materials. Alternatively, the blackened glass fiber can be cleaned using low-temperature furnace oxidation to burn off the char to produce cleaned fiber.

The above description of composite material pyrolysis was provided by P. Williams of the University of Leeds as reported in ***Materials World*** in July 2003, where Professor Williams goes on to state "Test samples incorporating 25 wt% of the recovered glass fiber and 75 wt% virgin glass fiber were compared to a controlled sample containing 100 wt% virgin glass fiber. The results showed that up to 25 wt% of recycled fiber could successfully be incorporated into a new composite while still meeting manufacturer's specifications."

Wreck or Reef?

According to the USCG office of compliance, the Marine Pollution Act (MARPOL) does not regulate the disposal of fiberglass wrecks at sea. Although MARPOL (1) considers fiberglass as plastic because of the resin in it and (2) makes it illegal to dump plastic anywhere in the ocean, the disposal of fiberglass hulls at sea is not prohibited by this act because MARPOL applies only to "shipboard-generated garbage." Disposal of fiberglass wrecks at sea is permitted, as long as they do not float. Specifically, Title 40 CFR Sec 227.5 prohibits the dumping of "persistent inert synthetic...materials which may float or remain in suspension in the ocean in such a manner that they may interfere materially with fishing, navigation or other legitimate uses of the ocean."

According to the NY State Dept of Environmental Conservation and the NJ Department of Environmental Protection reef programs, fiberglass vessels are no longer accepted for their respective artificial reef programs because it was found that in the shallow reef program waters, wave action and currents broke up and moved the vessels about. Thus, fiberglass wrecks did not provide the stable environment necessary for an artificial reef and fiberglass debris ended up on the beaches. NYDEC's and NJDEP's suggestions to minimize these problems included disposal in deeper waters and disposal of the hull only, ballasted with concrete. [http://www.epa.gov/Region2/water/oceans/wrecks.htm]

Refurbishment

Our industry survives on new boat sales but in my article “Built to Last – The Lifespan of Fiberglass Boats” in the October 2006 issue, I showed numerous illustrations of boats lasting upwards of fifty years. If a hull is structurally serviceable, many owners and even those entering the market have a deep attachment to what may be considered a “classic” design. This is probably truer for sail than power boats. In my earlier article I noted that the outfitting, interior and machinery often wear out before the hull. “High-end” builders will often take in older yachts for refurbishment where hardware is re-bedded or replaced and systems can be upgraded. This same concept could work its way down to smaller boats where re-powering is most commonly needed. With power plants increasingly integrated with boat manufacturing, on a corporate basis, re-powering can be profitable. In theory, dealers would also be able to achieve more revenue from boats traded in. Based on warranty claims, builders will know what structural details may need attention. Unfortunately, the business model for such a program with smaller boats may not work with this country’s labor rates, unless very efficient refurbishing centers could be established

Conclusion

Three broad types of boat recycling have been discussed: mechanical (grinding); incineration and reuse. Presently, all these alternatives are not as economically viable as sending thermoset composite scrape to our nation’s landfills. However, as population demographics and environmental awareness in this country bring us closer to what is now the norm in Europe, alternative waste disposal methods will make sense both from an economic and public relations perspective. The consolidation of boatbuilders in this country amongst a few large, publicly-traded corporations makes it possible to address cradle-to-grave issues cost-effectively. Going “green” will appeal to stockholders as well as customers, who by definition are enjoying our waterways and clearly would rather not have to navigate amongst abandoned boats.

For more information on recycling activity in Europe, contact Taco Rison at Structural Composites Europe bv, taco@structuralcomposites.eu

Figure 1. 16-inch Grinder/Muncher from Seawolf Industries (photo courtesy of Seawolf Industries)

Figure 2. Chopper Gun with Attached Recycling Equipment (photo courtesy of Seawolf Industries)

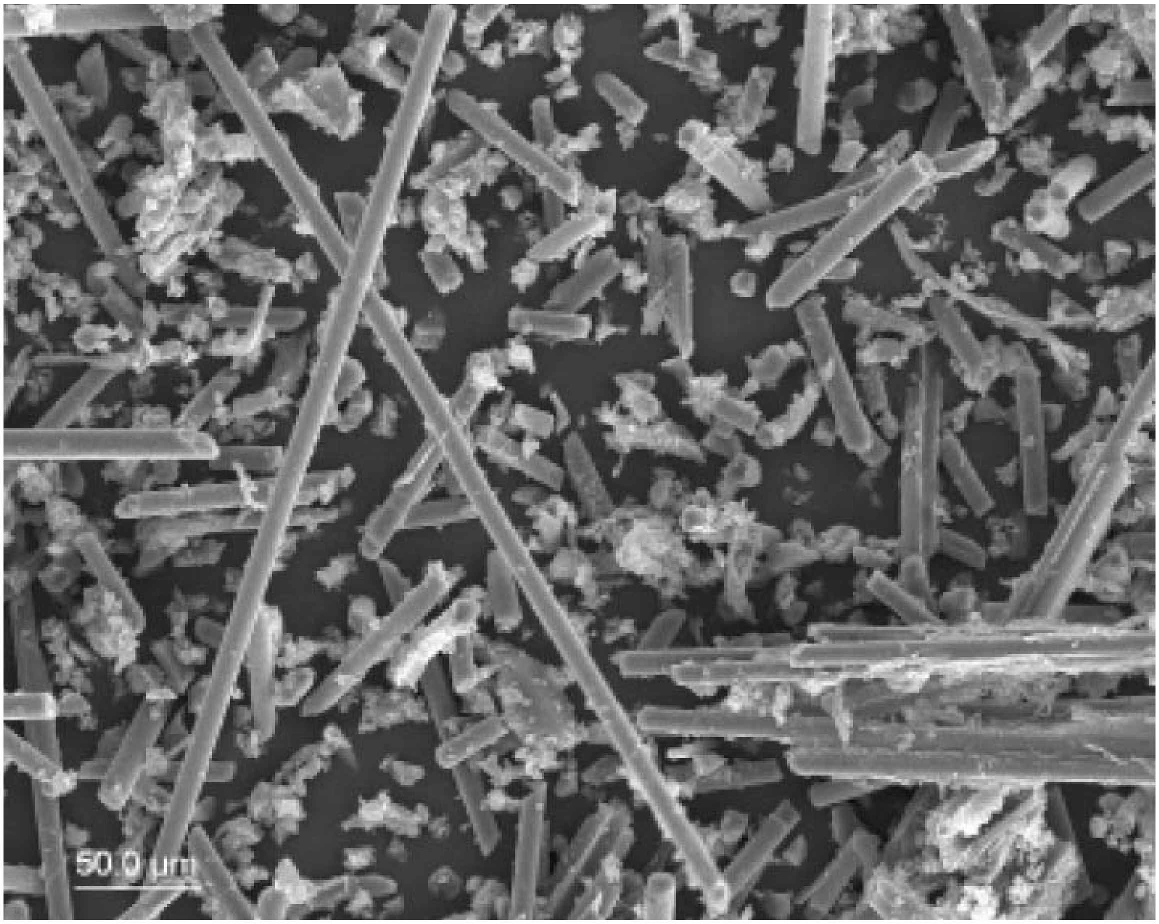

Figure 3 A sample of the Recycled Fiberglass Composite Powder as Examined under an Electron Microscope. (photo furnished by Central Michigan University's Electron Microscopy Facility, Journal of Industrial Technology, www.nait.org).

Figure 4. Waste Composite Scrape Suitable for Mechanical Recycling (photo courtesy of Seawolf Industries)