OPPORTUNITIES & DEVELOPMENT OF BIO-BASED MATERIALS FOR SMC (SHEET MOLDING COMPOUND)

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Abstract

Current and future changes in the automotive industry present an increased opportunity for thermosets. Bio-based materials in SMC present an opportunity to help automotive manufacturers in the US to meet the 2020 Freedom Car weight and 14.9 km/L (35 mpg) CAFÉ requirements as currently mandated by the federal government. Developments in the industrial bio-technology sector are also leading to knowledge to provide opportunities to use bio-based materials to provide solutions using SMC to lower costs and weight. The National Composite Center is leading collaborative efforts in the development of biobased resins, fillers, and reinforcements. The result of these collaborations in both biobased materials and the interface of nano technology are presented.

The opportunities exist for the development of biobased materials to produce a lighter weight SMC.

Background

To significantly reduce oil consumption, especially dependency on foreign sourced petroleum, the car manufacturers in America, principally Chrysler, Ford and GM, have been mandated by the Federal Government through President Bush's 2002 FreedomCar Initiative to reduce average passenger car weight by 50% by the year 2020. This initiative is currently overseen by the Department of Energy's Energy Efficiency and Renewable Energy (EERE) Office for FreedomCar and Vehicle Technologies (FCVT) and Automotive Lightweighting Materials (ALM).

Specifically, the 2020 FreedomCar goals for high volume production of automotive vehicles would, while maintaining same vehicle size, comfort, and safety standards compared with 2002 vehicles, have the following characteristics:

- Half the mass
- Are as affordable
- Have the same performance
- Are more recyclable (75% today, but with European aim of 95%)
- Are of equal or better quality and durability (1).

Although, according to the President's program, the new weight reducing FCVT technologies must be available for 2020 full scale automobile production, these new technologies actually need to be incorporated into the engineering designs for demonstration cars and light trucks by 2015. The automotive companies take this federal mandate very seriously and are quite concerned about reaching the established FreedomCar weight reduction targets. Accordingly, they have already implemented many weight saving or Automotive

Lightweighting (ALM) technologies such as the replacement of heavy steel structural components with more usage of lighter weight / stronger aluminum alloys, more exotic magnesium and titanium alloys and higher strength, but thinner gage steel materials. They have also transitioned to thinner, lighter weight glass for all car windows. In addition, they are already designing new vehicles with increasing amounts of plastics and lighter weight composite materials. What has become patently obvious to the automotive industry, is that weight reduction for all such vehicles, no matter what fuel or power system employed, will also lead to reductions in both energy consumption and harmful emissions (2).

Within the transportation segment, SMC/BMC comprises the second largest composite manufacturing process with about 340 million kg (750 million lbs.) shipping globally in 2004. In the U.S. in 2007, the transportation market was estimated to consume about 148 million kg. (325 million lbs.) of SMC/BMC materials. Ford Motor Co. uses more SMC annually than any other North American OEM, estimated at 68-91 million kg. (150-200M lbs.) annually. Yet despite continued demand for products, the North American SMC/BMC market can become flat due to challenges associated with developing new ideas and competition from other processes (3). There is some indication that the SMC of old is not the SMC of today. SMC is now a much more robust material and tailorable to customer needs (4).

OEM profit margins have suffered, and as a result, interest has been triggered in looking at replacement materials as well as alternative processes that could reduce costs. Four materials are under significant price pressure: palladium, aluminum, steel and plastics according to Design News (5). This publication points out 10 strategies that can be used to reduce exposure to high and unpredictable materials prices. One strategy is to substitute sheet molding compound (SMC) for flat rolled steel. The positive is that these composites are usually 25 to 35 percent lighter than steel parts and can be fabricated with low-cost tooling, and the negative is the process can be slow and the recycling track record is far inferior to steel.

Innovations in the SMC area have been made and consist of paint-free SMC’s, Eco-friendly SMC’s, improved quality control tests, and new manufacturing processes being investigated in Europe (6). Some of the problems of SMC formulations have been paint pops, high temperature resistance for E-coat application, and reduced cycle times for reduced cost. A Reinforced Plastics article points out that a consortium initiated by Dr. Hamid Kia was formed to reduce the effects of moisture and air that outgas from traditional SMC during the paint bake which creates paint pops or defects in parts being primed. Results obtained were improvements of the Class A paint finish of SMC exterior cladding during powder priming on the OEM assembly line (7).

The competitive environment requires that innovation continues in the SMC industry to drive down costs, improve quality, and decrease weight.

Light Weight SMC Development

The main components of an SMC formulation are resin (25%), filler (50%), and fiberglass reinforcement (25%). The typical filler used in these formulations is calcium carbonate with a specific gravity of around 2.7. Fiberglass reinforcement has a specific gravity of 2.54, and the unsaturated polyester resins are around 1.0 specific gravity. Therefore, a typical SMC formulation has a specific gravity of 1.9. Various references are available that discuss this technology (8). Natural reinforcements have specific gravities that range from 1.2 to 1.5 or lower (9) which gives the potential for light weighting.

One approach to light weighting is to lower the calcium carbonate level. However, the calcium carbonate is a fraction of the cost of the resin and/or the filler, and the overall cost of the SMC compound is increased.

The use of materials from natural or renewable resources was introduced commercially into the SMC market in the early 2000's with an unsaturated polyester resin. The advantages of these resins were that they were more environmentally friendly and held the potential of offsetting the rising cost of petroleum based chemicals (10).

Natural materials have long been evaluated as reinforcements in resins (11). An evaluation of various natural materials used as reinforcements in SMC was made by Ford Motor Company (12), and researchers at Michigan State University also evaluated natural fibers as reinforcements in SMC (13).

Natural materials have also been evaluated or used as fillers in unsaturated polyester resins. These include corn cob flour, soybean meal and flour, rice husks (14), cotton seed hulls, and distillers dried grains (15). Typical of the findings of these studies is that treated materials have higher mechanical properties. Typical treatments are with sodium hydroxide (16). Similar alkaline treatments with other fibers in thermoplastics have shown similar results (17).

The goal of the development of these light weight SMC formulations is to demonstrate modifications of standard SMC formulations at commercial scale using nano and bio-based materials developed and proven using the development process shown in Figure 1.

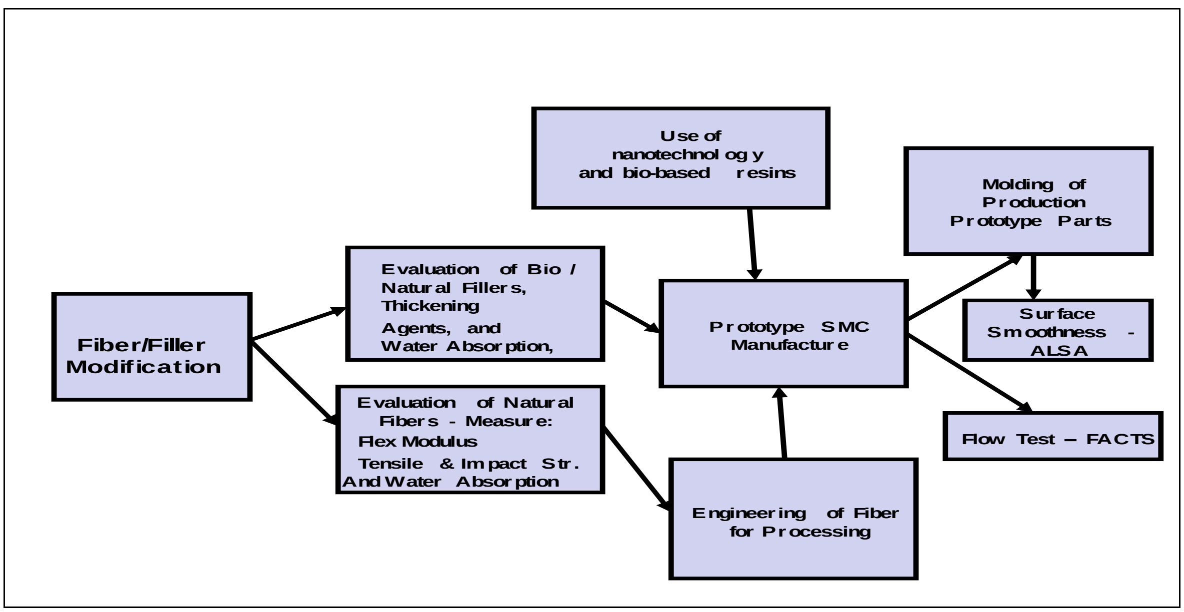

Figure 1: Natural Fiber/Filler Development Process for Light-Weight Bio-Based SMC Formulations

This process involves an initial evaluation of bio-based materials which will require modification to enhance the performance in SMC formulations. These initial evaluations consist of evaluating mechanical properties such as tensile and flexural strength and modulus, impact strength, and water absorption. Prototype manufacture allows for formulations to be tested for surface appearance (ALSA) and flow and cure profiles (FACTS).

The equipment needed to evaluate these bio-based materials was obtained through the State of Ohio through the Third Frontier Project. The National Composite Center (18) was awarded a Wright Capital Grant in 2006 for the scale-up of a SMC line which would work with nano materials (and bio-based approaches) to reduce the mass of sheet molding compound (19). The goal of the project is to demonstrate at scale modifications to a standard SMC which would enable molders in the State of Ohio to be competitive with the SMC process in automotive, heavy duty truck, agricultural, and recreational products.

A 0.9 million kg. (two million pounds) per year SMC line has been purchased and refurbished and is installed at the Dayton Campus for Advanced Materials Technologies, This site was selected in cooperation with the City of Dayton, Ohio to help re-establish Dayton's West side as a new location for advanced materials manufacturing. Equipment that was also installed in this facility for evaluating flow and cure (FACTS) and surface smoothness for Class A body panel applications (ALSA).

FACTS (Flow Analysis Cure Time System) is a unique method to analyze the gel time, cure time, and flow characteristic of an SMC during the compression molding process. It utilizes a dielectric cure sensor in the center of the spiral flow mold to determine gel and cure times. The mold has a 15.2 x 15.2 cm. (6 x 6 inch) center load area and a 5.1 cm (2 inch) wide channel that flows form the load area and circles the load area yielding a channel that is 122 cm. (48 inches) long. By varying the molding pressure and using the data collected by the sensors you can tell how a SMC material cures and flows.

ALSA (Advanced Laser Surface Analyzer) is an advancement of the LORIA created by Ashland, Inc. in the 1980's. It works by projecting a straight laser line onto an SMC part or panel at an angle of about 34 degrees. A projector screen is positioned so the reflected line is visible. That line deviates from straight by any waviness in the part or panel. The image on the screen is captured by a video camera, digitized into a computer, and has a polynomial regress analysis performed on the data. Any deviation from the best fit is accumulated and used to generate an Index. A series of 21 lines 25.4 cm. (10 inches) wide, spaced 12.7 cm (0.5 inches) apart are used to analyze a 25.4 x 25.4 cm. (10 x 10 inch) area. Results of the 21 lines are averaged and multiplied by a calibration factor to give an Index that reflects surface smoothness.

An evaluation of nano technology in composites indicates that they offer improvements of various mechanical properties, including tensile strength, modulus, barrier, and heat distortion temperature. However, they were proven to be more difficult to manufacture than they were first expected. Also, the cost would be the main obstacle for replacing convention composites with nanocomposites in the automobile industry (20). It remains to be seen if selective use of nano technology will lead to significant use in SMC applications.

Summary and Next Steps

For the SMC process to be cost competitive, reduction of mass in the SMC panel must be made. This can either be done by improving physical properties to allow for thinner cross sections and/or a reduction in specific gravity of the SMC compound. Replacing the higher specific gravity reinforcements and/or fillers are a way to reduce the specific gravity while maintaining or improving the costs.

Based on collaborative efforts with industry partners through project grant funds, state government grants such as the Third Frontier Project, and federal grants such as the National Science Foundation SBIR/STTR program, this project to develop bio-based materials for lower weight SMC compounds is currently underway.

Feedback from grant proposals would indicate that the following areas must be addressed:

1. Demonstration that bio-fillers will permit significant substitution for calcium carbonate, particularly at an affordable cost.
2. Address the issues of styrene emissions, recycling, and surface quality including paint defects in the development of these materials.
3. Determine whether the fragmented nature of the SMC industry and its orientation toward proprietary formulations will result in centrally-developed technologies to be readily implemented.
4. Lastly, and more importantly, determine if there is commitment from the auto industry – a major "customer" with stringent requirements to support these programs in order for SMC to have a positive impact on the viability of the industry. Can the commercial goals be met?

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