COMPOSITES IN THE TRUCKING INDUSTRY

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Abstract

Over the years, the transportation industry has incorporated more and more composite materials into its vehicles. The automotive industry has used composites for exterior body panels, e.g. hoods, fascias, hatches and doors, as well as under the hood and structural reinforcements The truck industry followed by introducing composites for hoods, doors, roofs, bumpers and fairings. This paper will focus on the advancements made in composite materials, from hand-spray up open molded parts to the various improvements in sheet molding compounds to liquid molded resin materials. It will concentrate on parts used in the trucking industry and how quality, especially in cosmetic and surface properties, has improved over the years.

Background

Since the late 1950s and early 1960s, composites have played an important role in their incorporation into body panels for the transportation industry. Beginning with hand lay-up parts for the automotive industry, composite usage has expanded into the truck and industrial equipment segments and become a staple design medium for original equipment manufacturers (OEMs). This paper will look at the development, expansion and future opportunities of composites within the transportation market, specifically the truck industry.

Composites are defined as materials that are made up of two or more different types of materials that combine to form a singular substrate. The most common composite is one that occurs naturally, wood. Most composites are polymeric in nature, with glass, carbon, or other fibers used as reinforcing materials, commonly called fiber reinforced plastics (FRP). These are broken into thermosetting materials and thermoplastic materials, about which more will be stated later. There are also metal-matrix composites, whereby a metallic matrix, such as aluminum or titanium, can be reinforced with small metallic fibers or powder-like metallic fillers. Ceramic materials can also be reinforced as a composite. This paper will focus on FRP materials, which are the most commonly used in transportation applications.

Traditional Polymer Materials

As previously mentioned, FRP materials can come as thermosets or thermoplastics. Examples of thermosets are polyester-based resins that contain glass fibers for strength and may or may not contain fillers. Some processes that are common to this kind of composite are hand-spray-up (HSU), sheet molding compounds (SMC) and resin transfer molding (RTM). In thermoplastic composites, a polymer matrix with fibers, usually glass, is incorporated to add strength. An example here is glass mat thermoplastic (GMT), which is a glass-reinforced thermoplastic. Many other examples of this could be given, as many thermoplastic resins can be reinforced with one kind of fiber or another.

Most of the composite usage in the transportation industry is in the thermoset area and has evolved over the course of forty years. Composites began as smaller automotive body panels (e.g. fascias, quarter panels et al) and expanded to hoods, roofs, decks and doors. As composite usage grew, the size and application of this material did also. Smaller automotive panels became large truck and industrial equipment pieces. This was a slow transition but one that was very important to the composite industry insofar as becoming a viable material choice across many different applications and customers. Large hoods, roofs, extenders, and deflectors are some of the parts now used in truck and industrial applications.

Advantages of Composites

Composite usage is advantageous in several areas, which can explain its growth over the years. One big advantage, especially attractive to the truck industry, is its lower weight when compared to steel or aluminum. The density of FRP materials can be anywhere from 30% to 70% of commonly used metallic materials. Another big advantage is its inherent corrosion resistance. Plastic materials do not rust the way most metallic materials do and when exposed to the fluctuating conditions of the environment, as most trucks are, this can improve operation efficiency. Dent resistance is another advantage, also attractive to truck. Perhaps the biggest overall reason for choosing composites is the reduction in tool costs. Composite tooling may cost as little as 30% of steel equivalent and provides increased design flexibility. For truck body parts, that is quite important, as most pieces have extensive geometry and stiffness built into them. All this can explain the expanded use of composite materials in the truck industry.

Evolution of FRP Composites

The evolution of composite usage was a slow and tedious process that evolved over time. Open molded composites were generally the first materials to achieve widespread usage in transportation applications. Hand spray-up (HSU) is the most common and is still used today. It incorporates spraying chopped roving into a single side, soft-shelled tool, generally epoxy or polyester in nature, using a polyester gelcoat to improve surface and minimize porosity. The roving has been run through a resin, generally unsaturated polyester and the fibers chopped to a length of one inch. There is no press required as the part cures in the tool, with or without baking or other means of heating. It is a very laborious process, as the spray-up material in the mold must be rolled out for shaping and thickness control and there is significant trimming that must be done post cure. Cure times vary with catalyst system chosen but are generally between 30 and 60 minutes. Since there is no pressure involved and a lot of manual labor, surface quality is somewhat lacking. Waviness is often seen on flatter surfaces due to the lack of pressure and the rolling out of the material. Shrinkage of both the tool and the substrate contributes to the lesser surface quality seen in HSU parts. Tool quality can also affect the surface quality and over time, the tool itself can become porous. Replacing tools generally must be done as the wear will impact part quality to the point of rejection to most OEM standards. Tool life varies but 1000 parts is a common figure used to estimate lifetime tool costs. Tool cost is relatively inexpensive, since it is soft tooling. However, multiple tools are generally needed to meet OEM demands. As an example, a truck hood that is from the HSU process may need 6-10 molds to meet a demand of 10,000 units per year. All this can make for an overall expensive program. Figure 1 provides a cost comparison.

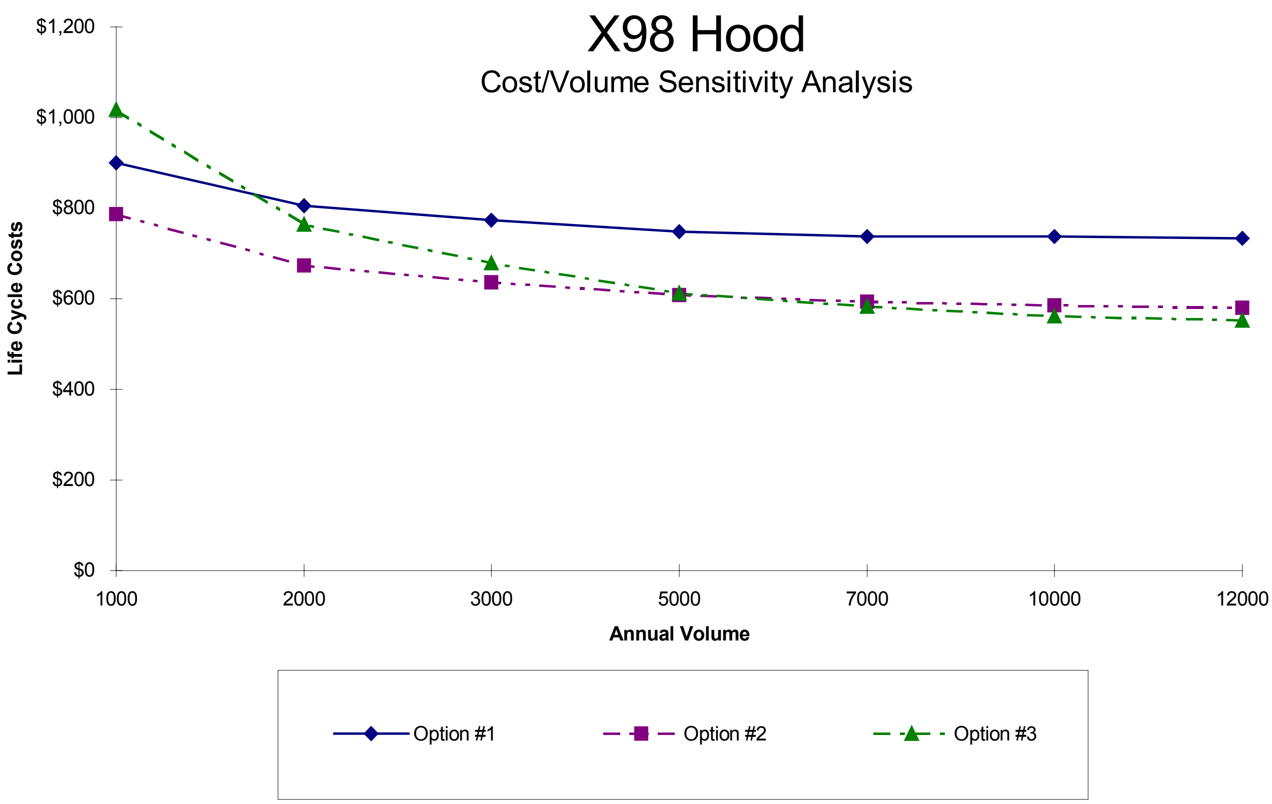
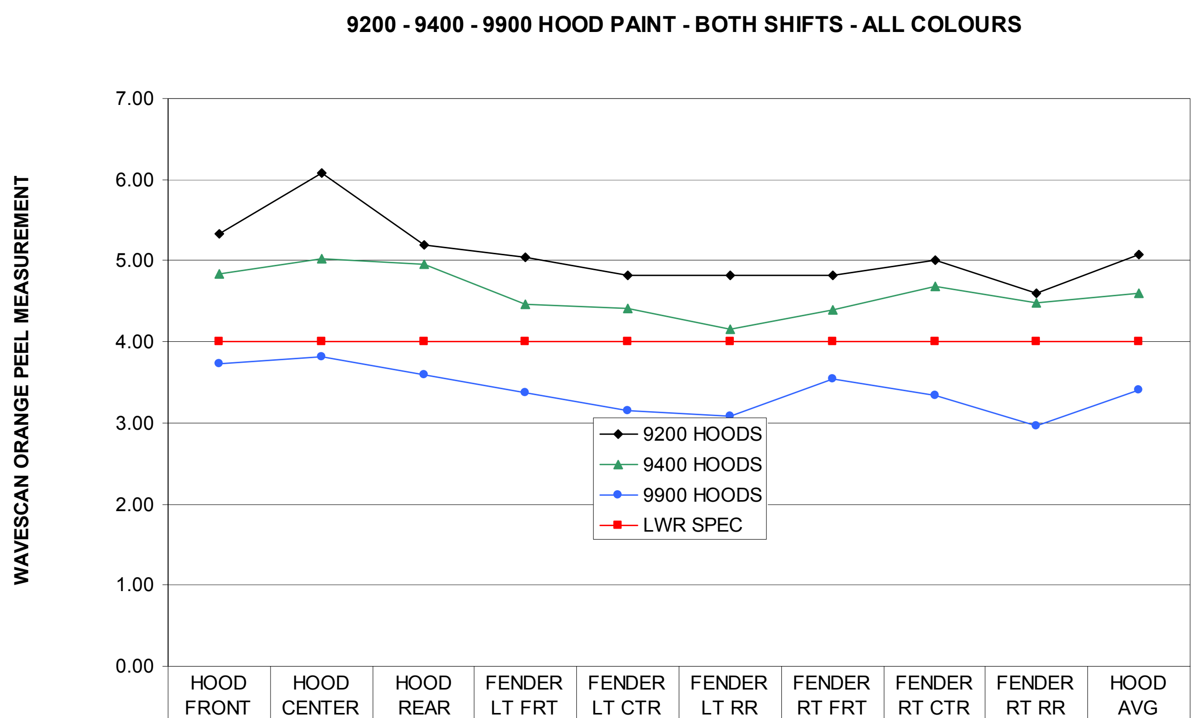


Figure 1: Lifecycle cost analysis

Introduction of presses to aid in part formation and surface quality were then incorporated. Cold molding and resin transfer molding (RTM) are processes whereby a press is used to help mechanically shape parts and thereby remove some of the labor involved in part formation. Soft tools are still used to keep tooling costs down. Cold molding involves mixing resin, filler and catalyst and pouring into the mold. Filler addition makes this material lower in cost. RTM involves laying glass into the cavity of the mold, closing and injecting resin into the tool and impregnating the glass mat. It is referred to as “cold molding” because the molds are heated but to temperatures that are around 200°F, below that of other closed molding operations. Both processes are an improvement over open molding for surface and part quality. Tool life is generally expanded to approximately 10,000 parts but still can be porous. It is still a laborious process due to the glass trimming needed, especially in cold molding. Lower volume, non-show surface parts still employ these processes today.

The most employed composite process for large body panels is SMC. This is a process where resin, filler and glass are compounded (with other additives) and made into a thin sheet that is maturated and molded in a heated, matched metal molds (usually steel) under pressure, around 1000 psi at approximately 300°F. Qualitatively, this is the best process among those referenced because of the nature of the tooling and pressures used to form the part. The graph below shows a comparison of orange peel for SMC (9200 and 9400 hoods) and HSU (9900 hoods) at an OEM paint facility.



	HOOD FRONT	HOOD CENTER	HOOD REAR	FENDER LT FRT	FENDER LT CTR	FENDER LT RR	FENDER RT FRT	FENDER RT CTR	FENDER RT RR	HOOD AVG
9200 HOODS	5.33	6.09	5.19	5.04	4.82	4.82	4.82	5.00	4.59	5.08
9400 HOODS	4.84	5.02	4.95	4.46	4.41	4.16	4.39	4.69	4.48	4.60
9900 HOODS	3.72	3.82	3.60	3.37	3.16	3.08	3.54	3.33	2.97	3.40
LWR SPEC	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00

MEASUREMENT LOCATION

Figure 2: SMC vs. HSU orange peel comparison

It is also the least laborious although deflashing and finessing are certainly a part of part preparation. In-mold coating (IMC) can be used to seal porosity and provide conductivity for electrostatic paint application. SMCs come in many formulations, depending on the application desired. There are structural grades that are usually a vinyl ester resin containing glass up to 50% by weight. Pigmentable formulations, general purpose, Class A and other formulations are available. There are some newer developments in SMC that will be discussed later in this paper. The following photos are of Loria® scans for a general purpose SMC (2802) and Class A (2801).

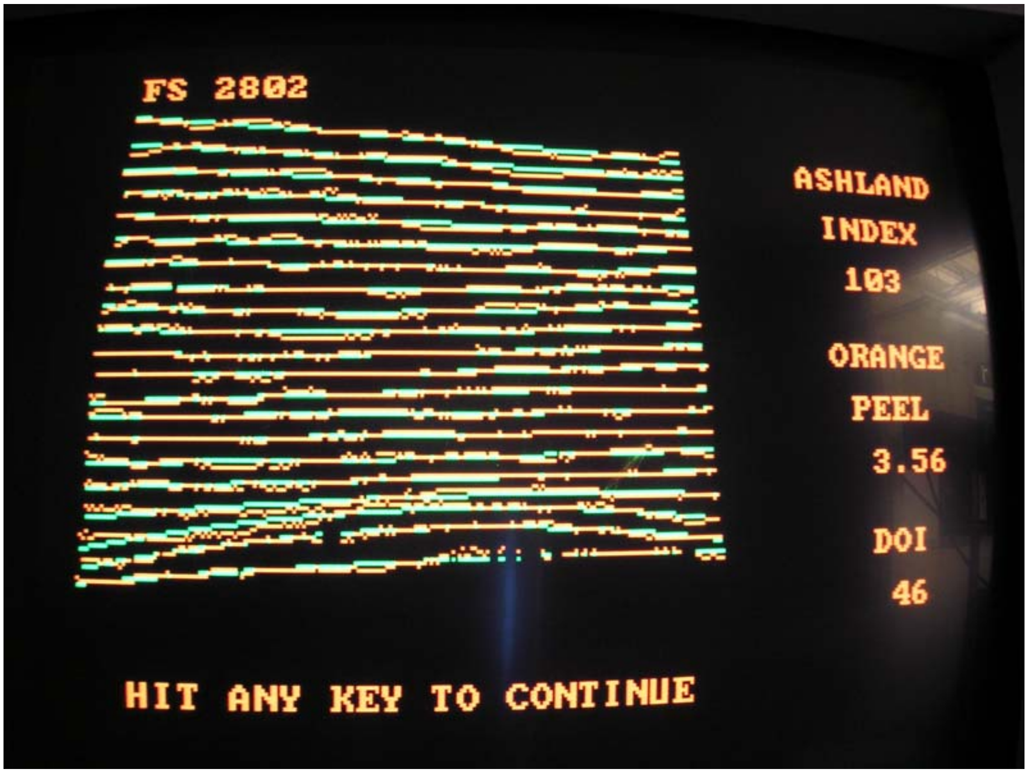


Figure 3: Loria® general-purpose SMC surface waviness test results

Figure 4: Loria® class-A SMC surface waviness test results

Quality Issues with FRPs

The main qualitative issue with FRPs is porosity that forms on the surface and usually impacts the paint performance on body panels. This stems from the fact that there are two or more ingredients that do not want to blend together and when forced into a single material, trap air within the composite and is released in the molding process. In SMC for example, the glass, filler and resin are not typically materials that want to blend together. Much work has been done over the years within the FRP processes to address this issue. This includes the FRP substrates themselves (some of which will be detailed later), coatings (such as IMC and primers), tool design and paint process to alleviate the surface and edge porosity that is common to these materials. Closed molding, particularly in SMC has shown the most favorable results. Incorporation of vacuum molding, improvements in tool design, such as flanges on edges to force any edge effects to a non-show surface, and press leveling and speed control (for closing and opening) have improved part quality over the years, but chronic porosity is still an ongoing battle for the industry as the basic premise of air incorporation into the raw material is still a basic fact of life.

There have been some improvements made in the area of soft shell tooling and RTM. Vacuum assisted molding, known as VARTM or VRIM, have incorporated the use of vacuum to help eliminate trapped air within the substrate and provide the pressure to form the part. This eliminated the need for large presses and reduces the wear on the tools. Resin is infused behind the vacuum as opposed to being introduced prior to a vacuum being pulled, as in RTM. As most of the truck industry has moved away from open molding and soft shell tooling, the discussion of improvements in FRP will be centered on SMC and newer materials.

New FRP Material Developments

SMC development seemed to stagnate in the 1980s and early 1990s. One development that occurred in the mid-90s was low pressure SMC (LPMC). This improvement assisted with the molding of larger truck parts that often were too large to accommodate the presses and yield the 1000 psi molding pressure needed. These formulations allowed one to reduce typical molding pressures to the range of 100-300 psi, thus enabling these large parts to run at 4000 tons and achieve optimum pressure on the part. The drawback to this system was that it was more expensive, in that a slightly more expensive resin was used and some filler, the least costly ingredient, was removed. Also, if IMC were used, pressures would most likely need to be raised to at least 500 psi to coat the part.

Another formulation that the truck industry has taken notice of is low density SMC. For large over the road haulers, weight reduction is a much sought after trait that can help with fuel economy or increase the load carried by the hauler. Typical SMC filler, calcium carbonate, contributes heavily to the specific gravity of SMC, typically 1.90 g/cc. Incorporation of clay fillers can reduce the gravity to 1.60-1.65 and glass beads can bring it down to 1.30-1.40. Again, cost increases due to replacing the lowest priced ingredient. With the glass beads, surface quality is sacrificed, as well as some physical properties (5-10% reduction over standard). The challenge for the SMC industry has been to get the specific gravity down to a point where it reduces enough weight to help offset the inherent cost difference versus a typical SMC formulation.

Currently, resin companies, filler suppliers and molders are working to get the benefit of a true lower density, around 1.50 g/cc and maintain surface without sacrificing physical properties. Nanocomposites seem to show the most promise of achieving all of the aforementioned in a way that is not too cost prohibitive. While a production formulation does not currently exist, the development work being done shows promise and could provide the industry with one of its better technological breakthroughs in recent years.

Recently, the industry has come up with a system designed to reduce the edge popping so commonly seen on painted body panels. The concept is to make the edges more flexible so as to better resist small surface breakage that is one of the underlying causes of edge popping. Since the edges tend to be resin rich, the resin was formulated to be tougher than standard without being so flexible as to not retain rigidity necessary for the application. These toughened systems were formulated with edge performance in mind and maintaining or improving surface quality. Both the automotive and truck industry have introduced this type of material on body panels within the last couple of years. The reduction in edge effects allows the molders to do less in-house repairs and ensure edge quality while giving the OEM better first time yield, increasing their throughput and reducing rejects.

Alternative fibers are also an ongoing effort within the composite industry, both with SMC and other materials. Carbon fiber is the biggest type being pursued, as it has become big in the aerospace and aeronautical arena. Carbon's advantages are that it has a lower specific gravity versus glass and can achieve equivalent or superior strength at equivalent or reduced loading. Its major detriment is its significant cost increase over glass. With this in mind, several truck companies have teamed up with the Department of Energy, looking at means of incorporating carbon fiber materials into vehicles that reduce weight and increase fuel efficiency. At the same time, this could increase the usage of carbon fibers and thus bring the price down to a level that would justify its use in the truck industry.

Another material that has found its way into the truck market is dicyclopentadiene (DCPD). While the application of DCPD, trade names Metton®, Telene® and Cymatech®, has not been as a composite, it is a thermosetting material that can be reinforced or filled and become a composite. DCPD has been used as an impact-modifying agent in standard open and closed molded polyester resins, namely isophthalic and orthophthalic acid based systems. DCPD offers superior impact resistance while maintaining physical properties that compare to many HSU, cold molded and engineering thermoplastic systems. Applications within the truck industry employ the neat system, which allows for a homogeneous material that flows well and needs very little preparation prior to painting and installation. Surface quality is quite good, as the lack of filler and glass give a flat surface.

While the emphasis here has been on thermosetting materials, thermoplastic composites have made inroads into the transportation industry. Glass reinforced polypropylene and polycarbonate have been incorporated into parts such as interior trim pieces, battery box covers, engine covers and other non-appearance parts. Superior surface parts are currently not available but as thermoplastic materials evolve, the use of these materials will only expand, as they offer lighter weights and opportunity for reuse that thermosets currently do not.

Challenges for the Composites Industry

This brings up the challenges faced by the composite industry, particularly in thermosetting materials such as SMC. Edge and surface quality remains a topic that OEMs maintain must be solved. Materials such as the toughened system, along with developments in the coating arenas show promise that this issue is being addressed with some degree of success. Technology must further evolve, as the combination of resin, glass and filler is still a recipe to incorporate air causing the detrimental effects the industry has been referring to.

Cost is another area in which composites have suffered. Resin prices have continued to trend upward as well as glass reinforcements. Carbon fiber introduction is continually slowed by the cost impact of its use. Technology usually comes at a price but just maintaining current materials is having a negative impact as to cost. The industry needs to address the processing issues associated with these materials as a means to offset the continuing rise in raw material costs.

The biggest obstacle faced by the composites industry as it relates to the transportation industry is the issue of recyclability. Thermosetting materials are generally considered to be non-recyclable as they cross-link rather than chain extend, as thermoplastics do. The truck industry has been and will be mandating that more content in vehicles be considered recyclable and this will limit the use of SMC and similar materials unless something is done. About a decade ago, there was an attempt to reclaim scrap SMC parts, shred them, pyrolize them and use them as filler in future formulations. The endeavor failed, as all it did was raise the cost of the SMC, when using the reclaimed filler material, as once again the least costly ingredient, calcium carbonate, was replaced with a more expensive option. There are attempts being made now to revisit this option.

Composite materials can expand in non-appearance applications, such as under the hood and structural parts. There are heat resistant materials available in the composite library that can resist the increasing temperatures that will come from the new generation of truck engines. Carbon fiber application can reduce weight and give improved structural properties that could result in new composite materials used for tie rods, frames, floors et al that currently is not be considered. Composite usage may have to rethink the types of applications they wish to be considered for in future programs in order to maintain a presence in the transportation industry.

Summary

To summarize, composite usage has grown and expanded from its early days. Strides have been made in the materials, tooling and processing that make composites such as SMC and other FRP more attractive than 20-25 years ago. At the same time, the industry leveled off somewhat whereby they risked their competitive advantage over metals and thermoplastics due to the perceived lack of progress in the technology arena. Today, the FRP industry is at a crossroads. Some new technology, like tougher systems and nanocomposite formulas, can open up some new opportunities for the industry while at the same time, obstacles such as porosity and recyclability threaten to further reduce composite usage and do significant harm to the industry. How the material suppliers and molders, working with the OEMs, address these issues and come up with viable, cost competitive solutions, will determine the direction composite usage takes in the years ahead.