CREATIVE THERMOPLASTIC COMPOSITE MATERIALS FOR USE IN AUTOMOTIVE LOAD FLOORS

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Abstract

This paper offers a glimpse at emerging technology related to the application of composites in automotive structures. In a practical embodiment of this technology, composites comprised of thermoplastic polymers and fiberglass are married with a structural core and garnished with a decorative carpet to form an automotive load floor.

The exclusive polymer used throughout this particular load floor is polypropylene. Thus the composite structure is comprised entirely of polypropylene and fiberglass. Among the major advantages of this design are the following characteristics: structural integrity, low weight, excellent thermal stability, acoustic abatement, incorporation of recycled raw materials, and the opportunity for end-of-life component recycling.

Regarding processing of this load floor, additional key advantages exist such as: low cycle time, good formability, one-step part consolidation, high automation, and the low environmental impact associated with thermoplastic polymers.

Conceptually, products of this type promise to have a lasting impact on the environment through all phases of product life cycle. This is achieved at first by utilizing recycled raw materials going into the product. Next, offal from processing is recycled back into the materials stream. In addition, the system creates a product of a known common composition of materials which possesses a higher potential for recycling as a whole after the useful life of the vehicle.

Highlights of Thermoplastic Composite Load Floors

Automotive components are continually tasked to meet higher specifications at lower cost. During the past several years, both structural and interior components have incorporated more composite materials in order to achieve these market demands.

With the increasing functionality of today's vehicles and the tremendous crossover in vehicle markets, load floors are becoming both more common and more useful. The station wagons and mini-vans of two decades ago and the SUV's of the past decade have continued to spawn an increasing awareness and respect for accessible stowage space and vehicle flexibility. The consumer, it would appear, ascribes value to modularity of seats that fold flat and trunk areas that can support a great deal of cargo. Cargo areas are expected to provide innovative cargo management.

This market demand has required structural and load bearing floor surfaces with the following characteristics:

- Good flexural strength and modulus,
- High compressive strength,
- Low overall weight,
- System harmony with interior and attractive decorative finishes,
- Easy clean up,
- Tough surfaces with good abrasion resistance and UV stability,
- Excellent dimensional and thermal stability,
- Contours that maximize the available packaging space, and
- Acoustical absorption.

Load Floor Construction

In a conventional composite load floor and many other sandwich-type composite constructions, reinforcing sheets or “skins” are added to both sides of an internal core layer and bonded to create a lightweight structure. This functional backbone is then finished with a decorative layer, typically carpet or fabric. A structure of this fundamental design can be optimized to meet the basic load floor criteria listed in the paragraph above. A conceptual example of the load floor section view is illustrated in *Figure 1*. An illustration of an actual load floor composite is shown in *Figure 2*.

Combining these materials to form a consolidated sandwich exploits the individual strengths of each component. For example, pure polypropylene is relatively flexible and pure fiberglass is relatively formless, but when the two are intimately consolidated, the resulting composite exhibits compound mechanical properties which collectively are far superior to the component parts. The reinforcing skin created from PP and fiberglass possesses excellent flexural and tensile strength while remaining resilient, dimensionally stable, and robust under the high temperature and humidity environments typical of an automotive interior. One such commercially available reinforcing skin known as GComp^R is particularly well suited to applications such as these. GComp^R is manufactured by Georgia Composites, a wholly owned subsidiary of Eleison, Inc.

In a similar manner, when the skins are combined with a lightweight honeycomb core, the resulting sandwich composite has exceptional load bearing capability as well as transverse strength. Again, as is common among composites, the sandwich composite acting as a system exploits the individual strengths of its component parts. Some of these mechanical advantages are expounded in detail in the data shown in *Table 1*. Note that the flexural rigidity of a component is a measure of its flexural modulus for a given geometric cross section. In comparing this property, it becomes clear how the load floor composite as a whole exhibits excellent load bearing ability by optimizing the geometrical arrangement of its component parts. Please refer to *Chart 1*.

Table 2 demonstrates the primary characteristics of the various components of the composite as well as the finished composite itself. This Table is intended to demonstrate the fact that composites, when appropriately applied, are far superior than the sum of their parts.

Functional Features of an Automotive Load Floor

On a particular thermoplastic composite load floor recently prepared for production in a popular 2005 MY vehicle, a concerted effort was made by the OEM and suppliers to develop an extremely practical cargo system. Integrated below the decorative primary load bearing floor surface are compartments for jumper cables, various tools and vehicle accessories, jack stowage, and other miscellaneous items that are desirable to store out of view and out of the way. This particular load floor exhibiting these features can be seen in *Figures 3 and 4*.

Not only does this particular design offer compartmentalized and out-of-view stowage, it also provides a new type of stowage area for materials that may be dirty, wet, or otherwise ill-suited for storage in a typical carpeted trunk space. The internal compartment underneath the large rectangular load floor has a tough polymer lining which can hold wet umbrellas and muddy boots, and yet be covered to make use of the primary trunk. Later, this compartment could be emptied of its dirty contents and easily cleaned. This feature has been integrated by Venture Industries and is illustrated in *Figure 5*.

The key challenge in developing more versatile stowage areas is to be able to maintain all the expected properties of a rigid floor deck, yet create accessible areas below. This dictates lightweight and easy to use closure panels. This applies whether the load floor substrate is designed to cover storage areas, spare tires, folding rear seats and even if the substrate acts as a shelf unit to support speakers or to conceal a hatchback trunk. It is exciting to see developing automotive applications which demand much greater functionality and whose specifications can be increasingly met by intelligent designs employing today's thermoplastic composite structures.

Manufacturing a Composite Load Floor

The processing of composite thermoplastic honeycomb load floor assemblies offers several advantages over alloy or thermoset processes. Traditional load floors require a great deal of secondary operations and hand finishing. The use of thermoplastics with the same polymer allows higher part consolidation, automation, and process integration.

In the highly competitive auto industry part consolidation is a key factor in meeting system design specifications while reducing cost. An example of this is formed hinges, shown in *Figure 6*. Forming living hinges is facilitated by the use of thermoplastic composites. Living hinges have a proven life cycle. This example alone reduces inventory cost, labor cost, and reduces operator errors, while increasing dimensional tolerances and system reliability.

Composite thermoplastics combined with automated work cells produce a product that is fully formed, trimmed and covered with a decorative skin. This is pivotal to produce parts capable of meeting the greater utility requirements and increasing quality standards. All of the requirements are met while competing against traditional load floor substrates on the pricing front.

Integrating carpet into the molding process reduces labor cost by eliminating hand-wrapping operations. Traditional "Things Gone Wrong" or "TGW" issues such as exposed glue, wrinkles, poor edge wrap, and adhesion failures are virtually eliminated.

Composite thermoplastics have unique properties that allow complex forming and provide non-uniform wall sections that would either not be possible in solid wall thermoplastics or thermosets, or would negatively impact cycle time. Please refer to *Figure 2.*

Thermoset vs. Thermoplastic Technology

In the same way that steel structures have been replaced in the past with thermoset plastic constructions, certain automotive components are trending from thermosets to thermoplastics and from pure plastics to those combined with reinforcements which multiply mechanical properties and dimensional and thermal stability.

Single-use cross-linking plastic components and composites based upon them have offered key advantages over more expensive or difficult to form materials like steel or aluminum. Some applications of thermosets include urethane or epoxy based structures in automotive bumper beams, door trim, package trays, sunshades, headliners, and seat backs. Traditionally, these components have very good mechanical properties, excellent thermal stability, they form well in molding complicated structures and are generally economical.

Drawbacks of this technology can include unforgiving processing envelopes, shelf-life issues, and adverse environmental impacts. With capable processes, thermosets can be efficiently controlled during manufacturing; however, little can be done today to address the adverse effects some thermoset chemicals have on the environment. Thermosets can have a negative environmental impact during their production and the composite structures that employ them can be difficult to recycle. The advantages gained from cross-linked structures such as good mechanical properties or thermal stability come at a costly environmental price. Once two chemicals of a thermoset combine or once one chemical is cured (usually by UV or heat), by their very nature they will not separate or permit re-forming into a different shape by any means. This, we know, is both their strength and their weakness.

Recycling Thermoplastic Composites

Thermoplastic composite technology offers the possibility of resolving some of the negative environmental impacts normally associated with automotive composite products. Because thermoplastics themselves can be recycled from virgin polymers, the raw materials that comprise thermoplastic composites can divert waste streams away from landfills back into useful products. This can at times contribute to a lower product cost.

During processing, thermoplastic-based composites that do not conform to first-quality products can be recycled, reground, or otherwise salvaged, thereby avoiding their disposal. This characteristic of thermoplastic composites usually translates into a lower effective scrap rate.

Finally, at the end of the useful life of the vehicle, more and more components in addition to steel and glass are being recycled. Given appropriate identification, composite components with known polymers and reinforcements can be reclaimed and recycled into very similar products. This feature has not truly been exploited in the US due to the long useful life of today's automobiles. However, if it were implemented during the beginning of vehicle component design and at the material specification stage it would contribute to a reduced environmental impact and lower component cost.

Composite products employing thermoplastics can be recycled during the processing stage and at the end of vehicle life. In this was they can help reduce the environmental footprint.

Future Industry Trends &
the Outlook for Thermoplastic Composite Structures

As the consumer demands more from today's automobiles, OEM's and suppliers are tasked with a tremendous challenge. Among the top priorities for vehicle users today are the following items:

- Value
- Performance
- Versatility
- Environmental awareness (i.e. integration of recycled materials, better fuel efficiency, etc.)
- Safety

As with nearly all other development, the advancement of the composite industry in the automotive sector will depend upon its ability to simultaneously meet all these demands. Hopefully it has and will become clearer that composites such as those described herein have been designed with these priorities at heart.

Attempts are proving successful at paving the way for quantum leaps in the field of *recycling,* and as such the *environment*. This will ultimately translate into *increased value* as input material costs and manufacturing waste stream costs become lower. Other development efforts are in the process of addressing *increased performance and versatility* of thermoplastic composites. And finally, there are some unique ways in which thermoplastic composites can *enhance the safety* of both the exterior and the interior of today's vehicles.

Regarding avenues for future development, considerable opportunity still exists in the arena of incorporating a myriad of different polymers into thermoplastic composites. Polypropylene is optimal for certain applications but obviously the appropriate polymer will depend on specific product requirements. Nylon, Polyethylene, PET, and ABS among others are all effective thermoplastics for meeting today's composite needs.

Other development is underway in the area of glass-free reinforcing fibers. This would include natural fibers and synthetic fibers.

While recycling represents a major opportunity, roadblocks still exist. For example, when reprocessing the composites mentioned in this paper into a suitable raw material for another use, certain challenges lay ahead. Glass fibers are not easily recycled and can cause problems in both reprocessing and incineration. Natural fibers which have been extensively tested are easily ground up and vaporized during the extrusion process, and easily burn during incineration.

Other recycling challenges exist in the area of logistics. Development of the recycling infrastructure is in its infancy. Ideally the collection industry would mature in order to sort target polymers and composites for recycling. Additionally, distribution and reprocessing methods must be refined to optimize their potential. As with most complex opportunities, the task of managing the appropriate scale, volume and quality of feedstock is the key to efficiency. Other raw materials such as steel and aluminum have a long history of being recycled, which has spawned a whole network of collection, separation, and reprocessing. As waste disposal costs and the price of oil continue to increase and global environmental issues become prevalent, recycling efforts for thermoplastic composites will increase in priority. This awareness will inevitably contribute to creative new thermoplastic composites for the automotive industry. And those of us that capitalize upon today's opportunities will be the pioneers and ambassadors of the exciting potential of this technology.

Supporting Figures, Tables, and Data

Figure I: Concept of Load Floor Composite.

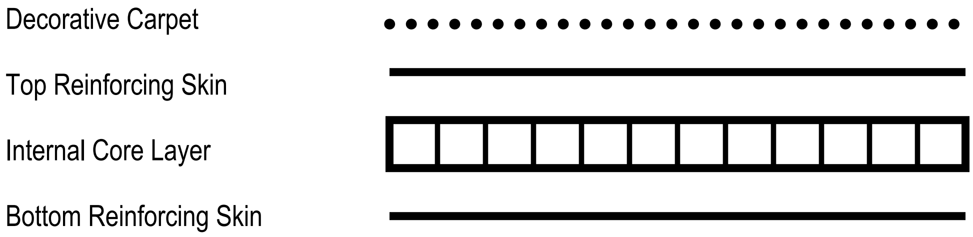
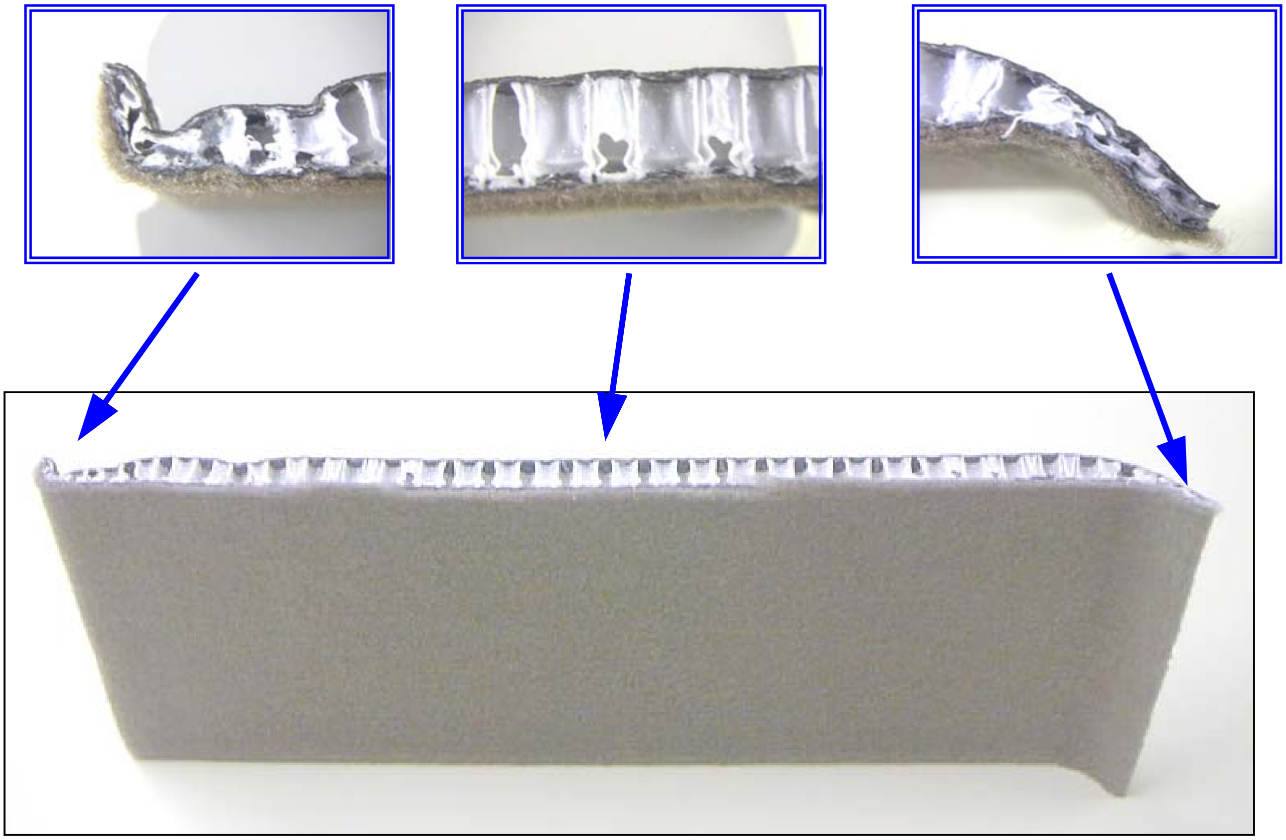


Figure2: Illustration of Load Floor Composite.



Supporting Figures, Tables, and Data (Cont.)

Figure 3 Load Floor in Vehicle

Figure 4 Load Floor Stowage Bins

Supporting Figures, Tables, and Data (Cont.)

Figure 5 Load Floor Dirt Management Area

Figure 6 Load Floor hinge

Supporting Figures, Tables, and Data (Cont.)

Table I: Load Floor Physical Properties.

Property	Units	Polypropylene (Polymer Only)	GComp^R Reinforcement	Load Floor Composite[§]
Density	g/cm^3	0.92	1.18	0.19
Glass Fiber % (by wt.)	%	0	40	22
Flexural Strength	MPa (psi)	34.5 (5,000)	103 (15,000)	31 (4480)
Flexural Modulus	MPa (psi)	1200 (175,000)	4800 (700,000)	875 (126,000)
Flexural Rigidity[§§]	mN*m^2(lb*in^2)	160 (55)	300 (104)	12530 (4330)
Compressive Strength	MPa (psi)	N/A	N/A	4.06 (590)
Deflection at 250 lbs	mm (in)	N/A	N/A	1.8 (0.07)

[§] Notice the dramatic improvement in the mechanical properties of the final composite structure as compared with its component parts and their raw materials. Data is provided by Georgia Institute of Technology, School of Chemical Engineering.

[§§] Values are for samples of equal weight (thicknesses are variable to compare samples of like weights).

Chart I: Composite Flexural Rigidity Comparison.

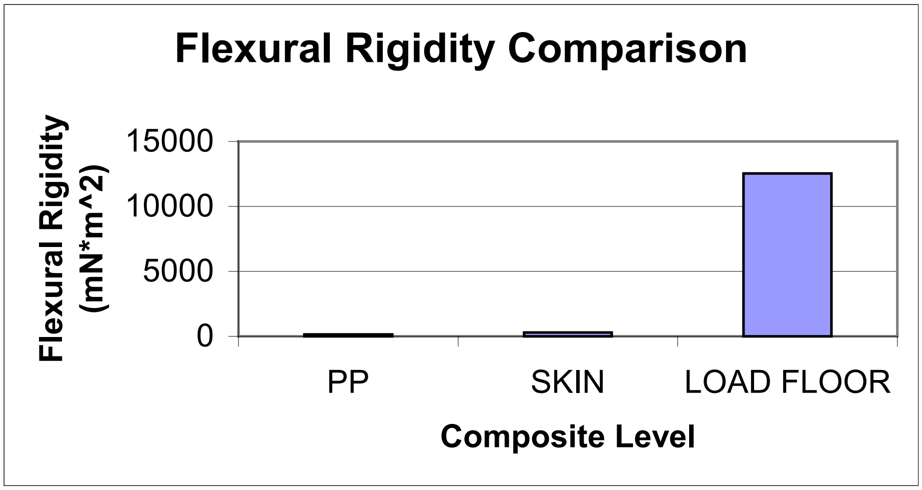


Table 2: Composite Attributes.

Property	Skin	Core	Carpet	Load Floor Composite[§]
Compressive Strength	☑	☑		☑
Flexural Stiffness	☑			☑
Tensile Strength	☑			☑
Low Density (Lightweight)		☑		☑
Formability	☑	☑	☑	☑
Acoustic Absorption			☑	☑
Recyclable	☑	☑	☑	☑
Economical	☑	☑	☑	☑

[§] Notice the composite exploits the best attributes of each component member. Table provided by Georgia Composites, Inc.

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