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Molded Fiber Glass Companies

Evaluation Guide for Selecting the Best FRP Composite Process for Your Project

Liquid Composite Molding (LCM) vs. SMC

ABSTRACT

In this report, we compare and contrast the properties of the two major material forms used in compression molding of modern Fiber Reinforced Plastic (FRP) products. Compression molding of FRP in matched metal dies is the most cost effective method of producing high value composites in production volumes from thousands to millions of pieces annually. This process has the best combination of cost, quality and properties of all composite forming methods. The two major material forms are Liquid Composite Molding (LCM) and Sheet Molding Compound (SMC). Both forms take advantage of the benefits of FRP including; corrosion resistance, high strength to weight ratio, dimensional stability, parts consolidation, dielectric strength, minimal finishing, high repeatability, low tooling costs, and design flexibility.

The principal difference between LCM and SMC compression molding is whether or not the fiber reinforcement moves, or flows, as the mold closes to form the part. LCM uses a variety of preformed fiber reinforcements that are positively placed in the mold exactly where they need to be in the final molded part. A measured charge of liquid resin paste is placed on a portion of the reinforcement and a controlled closure of the press flows the paste throughout the stationary reinforcement to fill the mold. In contrast, SMC is a leather-like, pre-manufactured sheet combining fiber reinforcement and paste that is cut and stacked to cover a portion of the mold. The controlled closure of the press flows the compound (fiber reinforcement as well as paste) to fill the mold cavity. In other words, the LCM process flows the resin through stationary reinforcing fibers to fill the mold cavity and the SMC process flows both resin and reinforcing fibers to fill the mold cavity.

Table 1 (page 2) summarizes the material and processing properties that are similar in LCM and SMC.

Table 2 (page 3) summarizes the material and processing properties that are significantly different in LCM compared to SMC.

Table 1. Properties that are similar in LCM and SMC

PROPERTY	LIQUID COMPOSITE MOLDING (LCM)	SHEET MOLDING COMPOUND (SMC)
Raw Materials	Resin, Reinforcing Fibers, Fillers, Additives	
Fiber Content (by weight)	10-75%	
Strength (Average tensile and flexural)	Varies the same with formulation	
Dimensional Control	Excellent	
Hardness	40 Barcol	
Surface Quality		
•Orange Peel	Class A	
•Paintability	Very Good	
•Bond/IMC Adhesion	Excellent	
Part Details		
•Texture	Yes	
•Thickness	0.03 inch up to several inches	
Process		
•Cycle Time	Nominal less than 3 minutes but depends on part geometry	
•Net Shape	Yes	
Tooling		
•Tool Steel Core and Cavity	Yes	
•Stops and Heel Plates	Yes	
•Integral Heating	Yes	
•Telescopic Shear Edges	Yes	
•Ejectors	Yes	

Similarities in LCM & SMC Properties

The raw materials of LCM and SMC are primarily thermosetting resin, fiber reinforcement and inorganic fillers such as calcium carbonate or clay. They typically account for 95% of the weight of the composite, the balance being release agents, curatives, pigments and other functional additives. The relative amounts of the ingredients can be the same for SMC and LCM resulting in identical physical properties such as density, hardness and flammability. A useful feature of these composites is the ability to tailor the properties to specific uses. For example, flammability and smoke characteristics can be adjusted to meet strict codes for mass transit interiors; electrical resistance can be adjusted from ohms (dissipative) to 10^{12} ohms (insulating); and mechanical stiffness is adjustable from flexible to rigid.

The thermosetting resin gives these materials good stiffness and high temperature retention of mechanical properties. Thus, much of the growth in use of SMC and LCM is in metals replacement. A useful design analogy to metal forming is that LCM is more like sheet metal and SMC is more like a casting. One of the unique features of both SMC and LCM is low profile technology, which allows the molded part to have exactly the same dimensions as the room temperature steel molds.

This amazing property not only yields excellent dimensional control, it results in large panels as smooth as the best sheet metals.

Fiber content is easily measured and indicative of strength and toughness. Therefore it is commonly specified. Although usually reported as "weight percent", it is the volume fraction of fiber that provides strength. The orientation of the fiber is also critical to strength. As compared to a composite with isotropic fiber orientation, a composite with all its fibers aligned in one direction will have over three times the strength in the direction of orientation but only one third the strength at 90° to that direction. From a design standpoint, a common misapplication is to assume isotropic laminates in vectorless stress fields. This simplification is appropriate for metals design but leads to both non-optimized composite designs and to unexpected failures. Composites are optimally used in designs that orient reinforcement strengths to the loads.

Regardless of the choice between LCM and SMC, both materials provide extreme design flexibility. The designer can specify combinations of physical and chemical properties as well as part configurations that are not possible with any other material system.

Table 2. Properties that are different in LCM and SMC

PROPERTY	LIQUID COMPOSITE MOLDING (LCM)	SHEET MOLDING COMPOUND (SMC)
Strength		
•Minimum Value	Higher	
•Standard Deviation	Lower	
Local Tailoring	Yes	Limited
Density	Can be Lower	Low-side limited by minimum required filler content.
Toughness (Impact and Hot Strength)	Better	Good
Surface Quality (Waviness)	Better	Good
Part Details		
•Ribs	No	Yes
•Bosses	Limited	Yes
•Molded - in hardware	Yes	Limited
•Molded - in studs	No	Yes
•Molded - in cores	Yes	Limited
•Thickness	Limited	Yes
Process (Required Molding Pressure)	100-500 psig	700-1,000 psig

Differences in LCM & SMC Properties

Fiber Reinforcement.

LCM laminate fiber content can be routinely varied from about 15% to 50% by weight with random fibers and up to 75% by weight with oriented fibers. The fiber content and orientation throughout the LCM part can vary as required by the application because the fiber reinforcement is pre-placed in the mold and does not move during the molding operation. Standard SMC will contain between about 10% and 50% fiber by weight with special formulations containing up to 75% fiber by weight. Fiber content throughout the SMC part is very consistent as a result of the compounding process and the coupled flow of resin and fiber during molding. For the same reason, fiber content throughout the SMC part cannot be tailored or optimized to meet application requirements. Fiber orientation in SMC is greatly influenced by compound flow as the mold closes and is therefore more difficult to control.

Fiber Length.

The most common fibers are E-glass rovings chopped to a length (or blend of lengths) from 1/8" to 4". There is a relationship between fiber length and strength – longer is stronger. For polyester resins the strength curve is asymptotic at about one inch. Since longer fibers do not flow as well, most SMC fibers are one inch long. LCM fibers are often longer because it improves the integrity and the permeability of the mat. Some types of impact performance and toughness are improved by the longer fibers. Both SMC and LCM can incorporate continuous fibers if required. Because the fibers do not flow, LCM can also incorporate fabrics and non-woven reinforcements.

Fiber Orientation.

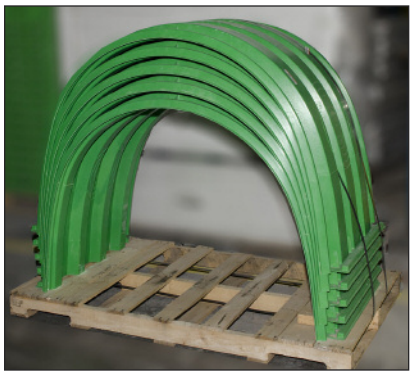
The orientation of reinforcing fiber in the LCM laminate is determined by its positive placement in the mold cavity. Since the LCM reinforcement does not move during mold closure, the fiber orientation is highly tailored and predictable. The fiber orientation in SMC laminate is more difficult to predict and control. Because the fiber flows with the resin, the fibers tend to orient themselves in the direction of flow. This phenomenon can be controlled to some extent by charge size and location but this practice generally causes performance trade-offs with other laminate properties.

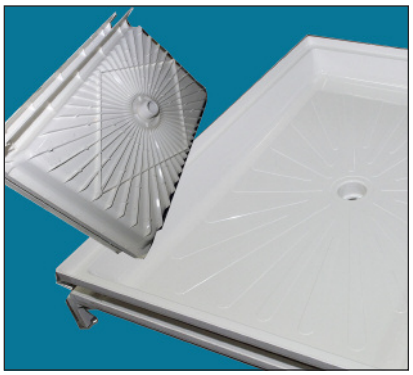
Ribs and Bosses.

Because of the difficulty of pre-forming glass fibers to details such as ribs and bosses, LCM is limited to generally uniform cross section shapes. The pre-combined fibers in SMC on the other hand flow easily to conform to many complex shapes.

Material Density.

In order to properly flow during the molding process, SMC must have at least a given proportion of mineral filler. This restricts the density or specific gravity of SMC on the low end. LCM does not have such a restriction and therefore given identical part thickness, LCM can produce a lower density part.





Part Weight.

Under the same design stress conditions, LCM can produce a lighter weight part compared to SMC. This is the result of more consistent strength, higher impact toughness and the flexibility to design with lower density laminates. See Material Density and Mechanical Properties sections for further discussion.

Mechanical Properties.

LCM creates composite structures that provide higher design strength allowables than similar laminates made from SMC. Since 1974, the Molded Fiber Glass Companies (MFG) has periodically compared its modern LCM processes with state-of-the-art SMC formulations.

Recently, MFG completed its latest test runs on nearly 500 samples taken from truck hoods that were compression molded using the two forms. The current samples were taken from two current model truck hoods – one a three-piece hood of SMC, the other a one-piece hood of LCM. The LCM hood had an average glass content of about 20% by weight and the SMC hood was slightly higher at about 25% glass content by weight.

Similar sample maps were developed for each hood with specimens oriented in various important directions (longitudinal, cross-car, vertical and horizontal). ASTM D638 tensile and D790 flexural strength tests were performed on the samples. Results for samples from each area of the hoods were averaged and plotted in boxplots and frequency histograms as Figures 1 through 6.

•Flexural Strength.

Figure 1 is a pair of boxplots comparing the flexural strength of LCM and SMC samples. Flexural Strength describes the amount of force required to bend and break the material when a specific thickness test piece is bent. A test piece is supported at both ends, a force is applied to a small, concentrated area in the center and the force and amount of bending is measured. Results are reported in pounds per square inch (psi). See ASTM D790 for specifics.

The horizontal line near the center of each plot shows the sample mean, or average flexural strength. The box areas above and below the mean line each represent one quartile or 25% of the data samples. The whiskers above and below the boxed area each represent the remaining quartiles. The figure clearly shows that although the average flexural strength of the two forms is about the same, the LCM form produces much less variation than the SMC form. A closer look shows that as many as 35% of the SMC samples have flexural strength below the weakest LCM samples.

Figures 3 and 4 are the flexural strength frequency histograms for the LCM and SMC samples. These histograms show that although the average strength of both the LCM and SMC samples are about the same, the variation in flexural strength is much greater in SMC than in LCM. In fact, 6 of 14 SMC sample areas had average flexural strength below the lowest performing areas in the LCM part.

•Tensile Strength.

Figures 2, 5 and 6 show results of the tensile strength testing on the LCM and SMC parts. Tensile strength describes the amount of force (tensile stress) required to break a sample of specific dimensions when the material is stretched to its breaking point. The tensile stress at failure is divided by the cross-sectional area of the sample and results are reported in pounds per square inch (psi). See ASTM D638 for details. The tensile strength comparison results are similar to the flexural strength in that the average tensile strength of the two forms is about the same but the variation in the LCM parts is much lower than the SMC parts. One particularly important result in the tensile strength test is that the highest frequency (or mode) of SMC strength samples is at the lowest end of the scale whereas the mode of LCM strength samples is above the average strength.

Although the current testing shows that some areas of SMC can have very high strength compared to LCM, it is the low end of the variation that causes parts to fail. In both the design process and end use, when any area of laminate is subjected to stress, it is the weaker

locations that fail, similar to the weak links in a chain. The more consistent, controllable and predictable properties of the resulting laminate make LCM the process of choice when flexural and tensile strengths are important.

•Impact Strength.

Figure 7 is a comparison of impact strength, or toughness, of LCM and SMC laminates as measured using the Dynatup testing method. This method measures the reactive load produced when a weighted dart is dropped onto the laminate surface from a controlled height. The important performance measurements are the energy absorbed (Max Load x Drop Height) and the height where penetration of the dart into the material occurs.

The LCM laminate performs about 25% better than SMC in the energy absorbed in this test. Also, penetration occurs in the SMC at the 24 inch drop height while the LCM required a drop height of 45 inches for penetration to start.

Molding Pressure.

The molding pressure for LCM is usually a fraction of that required for SMC. Therefore, the press tonnage required is less for LCM than for SMC for a given part area. This is because the viscosity of the LCM paste is very low compared with that of SMC and no reinforcing fibers are displaced in LCM, as they are in SMC. In practice, this allows compression molding of larger parts in LCM than in SMC for a given press tonnage and within the platen size limits of the press.

SMC Manufacturing Equipment

Robotic Preform Equipment

Figure 1 **Flexural Strength (FS) Comparison Boxplots**

Liquid Composite Molding (LCM) and Sheet Molding Compound (SMC) produce laminates with the same average flexural strength. However, the variation in strength at random orientations throughout the part is much less in LCM than in SMC. Glass content is 20% by weight for LCM samples and 25% for SMC samples.

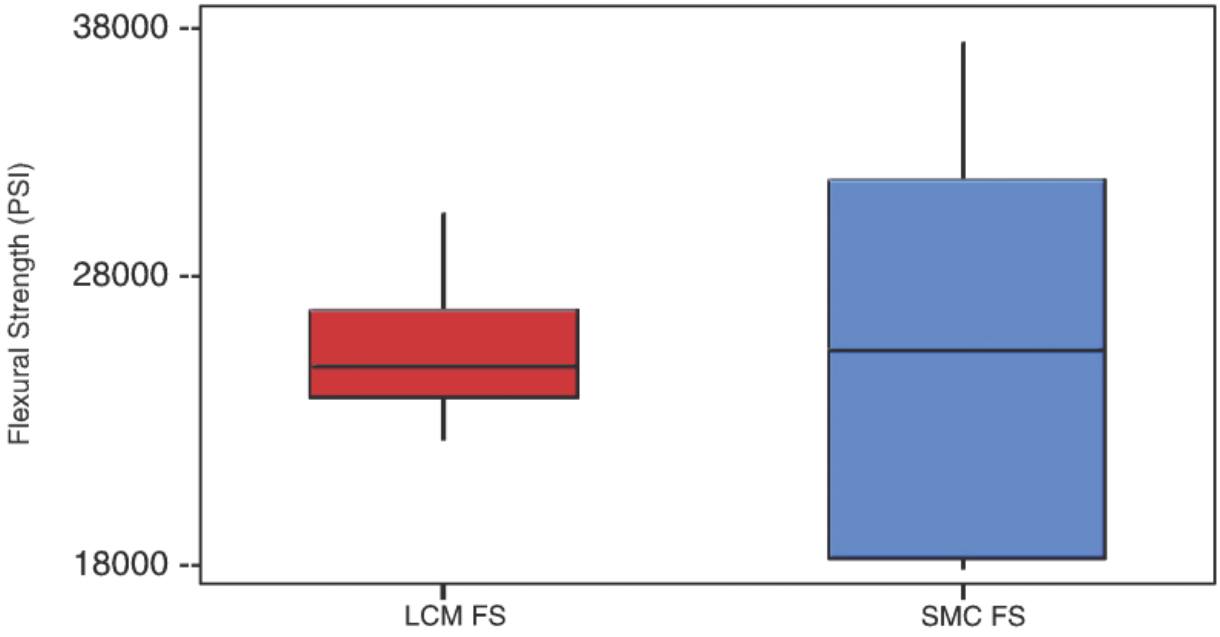


Figure 2 **Tensile Strength (TS) Comparison Boxplots**

Liquid Composite Molding (LCM) and Sheet Molding Compound (SMC) produce laminates with the same average tensile strength. However, the variation in strength at random orientations throughout the part is much less in LCM than in SMC. Glass content is 20% by weight for LCM samples and 25% for SMC samples

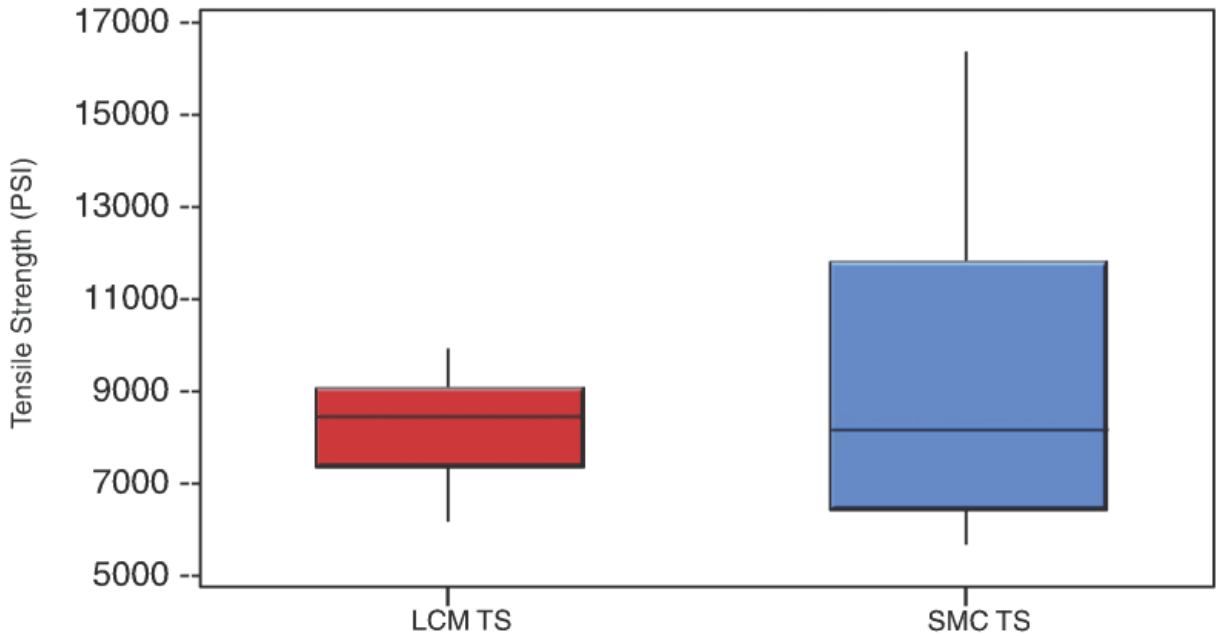


Figure 3 **Liquid Composite Molding (LCM) Flexural Strength (FS) Histogram**

Distribution of Flexural Strength test results for samples taken from a truck hood molded in the Liquid Composite Molding (LCM) form. Variation is low with a minimum sample flexural strength of about 21,000 psi. Glass content is about 20% by weight.

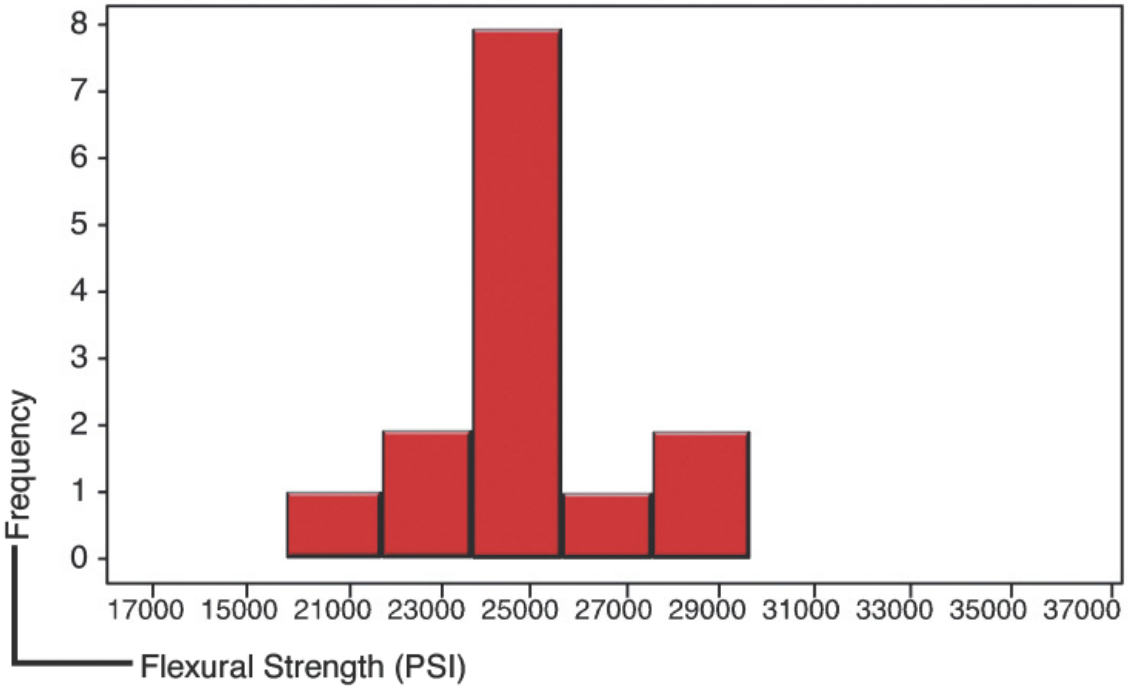


Figure 4 **Sheet Molding Compound (SMC) Flexural Strength (FS) Histogram**

Distribution of Flexural Strength test results for samples taken from a truck hood molded in the Sheet Molding Compound (SMC) form. Variation is higher with a minimum sample flexural strength down to about 15,000 psi. Glass content is about 25% by weight.

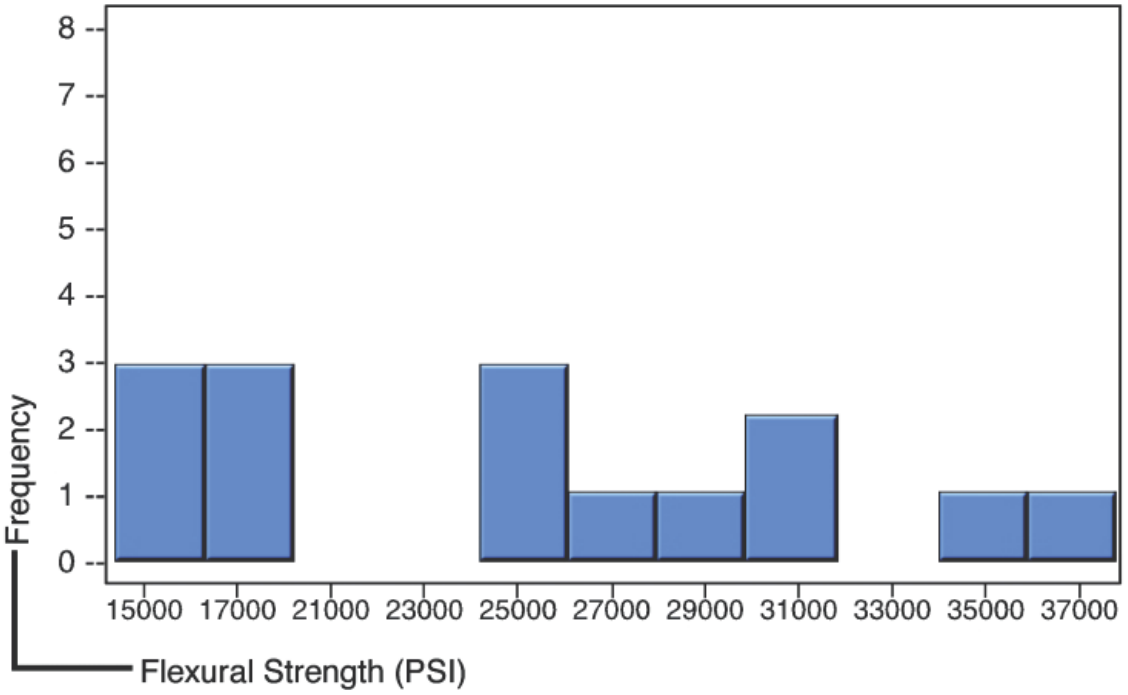


Figure 5 **Liquid Composite Molding (LCM) Tensile Strength (TS) Histogram**

Distribution of Tensile Strength test results for samples taken from a truck hood molded in the Liquid Composite Molding (LCM) form. Variation is low with a minimum sample tensile strength of about 6000 psi. Glass content is about 20% by weight.

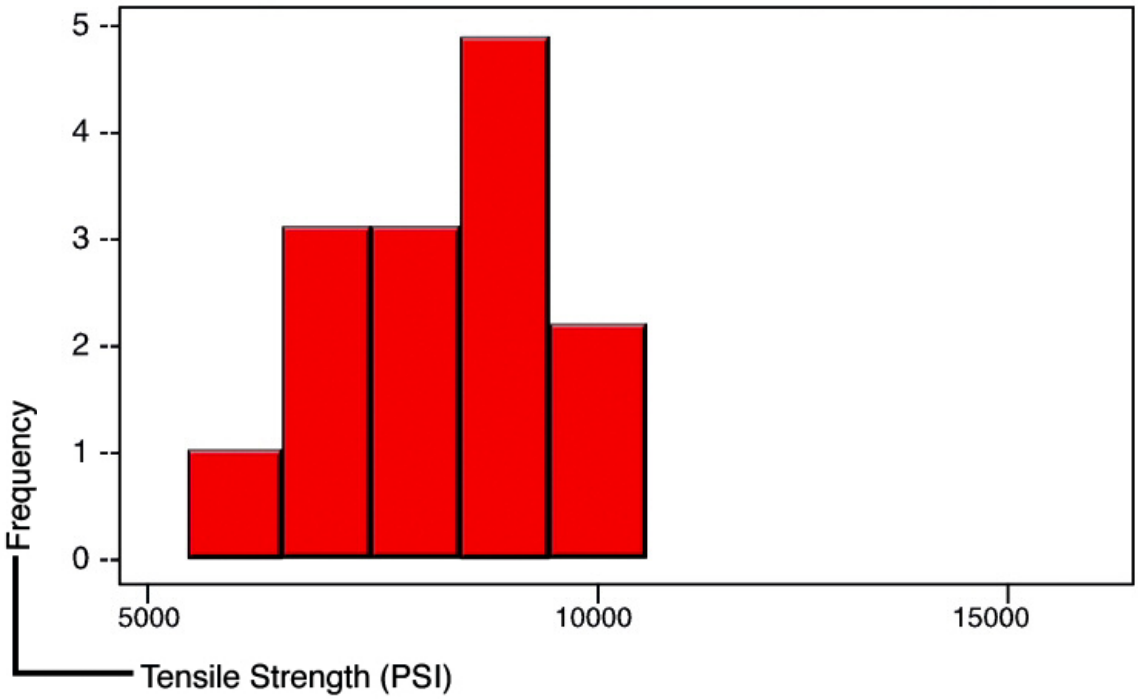


Figure 6 **Sheet Molding Compound (SMC) Tensile Strength (TS) Histogram**

Distribution of Tensile Strength test results for samples taken from a truck hood molded in the Sheet Molding Compound (SMC) form. Variation is higher with a minimum sample tensile strength of about 6000 psi. Glass content is about 25% by weight.

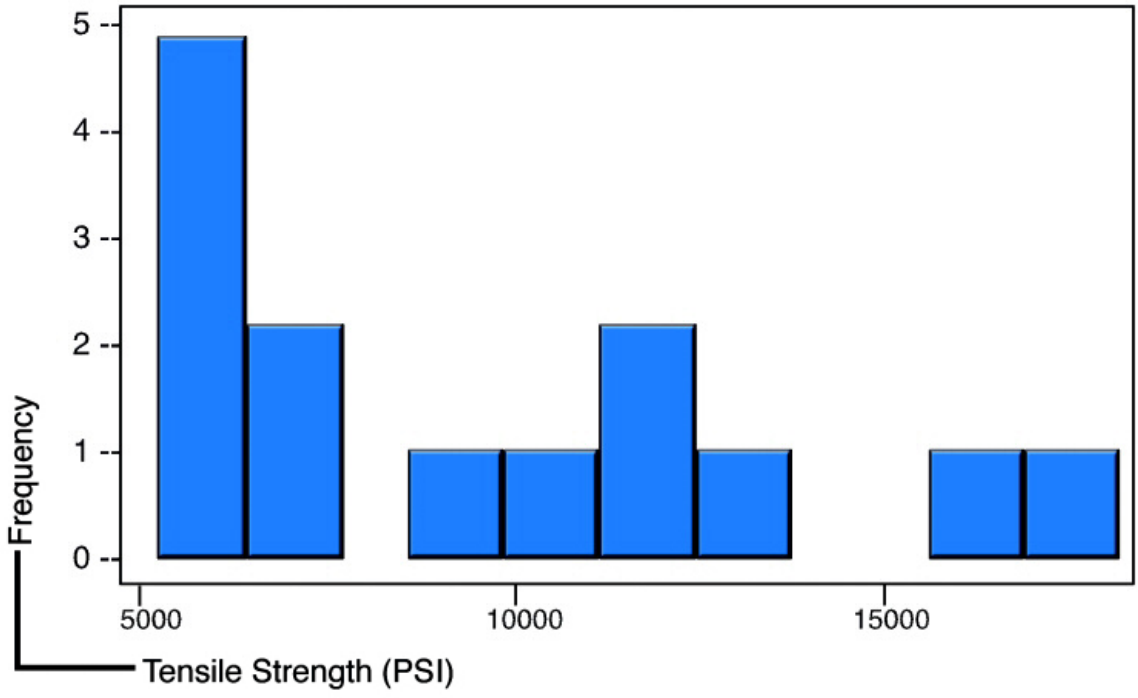
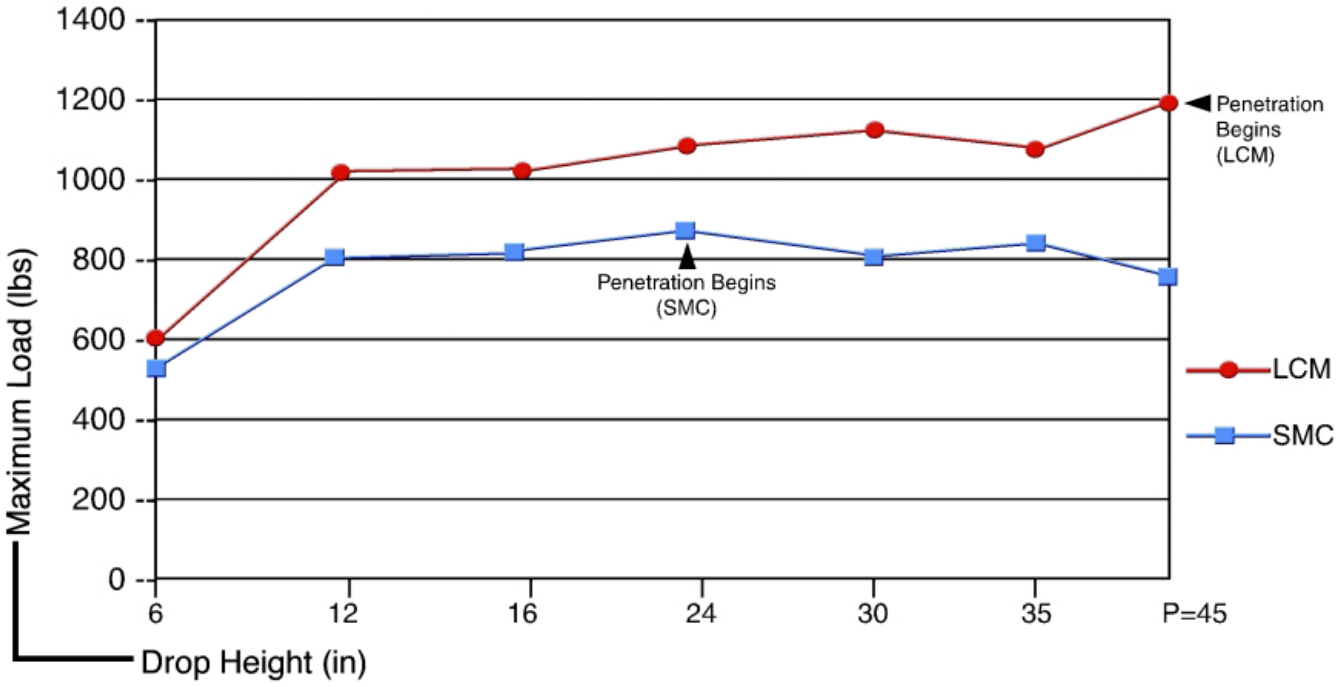


Figure 7 Impact Strength Comparison of Liquid Composite Molding (LCM) and Sheet Molding Compound (SMC)

Liquid Composite Molding (LCM) laminate demonstrates higher impact strength than sheet Molding Compound (SMC) laminate. Dart penetration begins at nearly 50% higher level for LCM compared to SMC.



Summary

The current study compares and contrasts the properties of Fiber Reinforced Plastic (FRP) composites produced from Liquid Composite Molding (LCM) and Sheet Molding Compound (SMC). Careful selection and application of either form yields high quality products and provides extreme design flexibility. The designer can specify combinations of physical and chemical properties as well as part configurations that are not possible with any other material systems. Because of the versatility of FRP/Composites, the designer is encouraged to collaborate with a molder and/or material supplier to optimize the application.

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MFG Is a Full Spectrum Composite Manufacturing Supplier

Molding Technologies

- Open Molding (Hand Lay-up, Spray-up)
- Vacuum Infusion Processing (VIP) or RTM-lite
- Resin Transfer Molding (RTM)
- DCPD RIM (Reaction Injection Molding)
- LCM Process with Preform Reinforcement – MFG PRiME™ Process
- Compression Molding/SMC
- Direct Long Fiber Thermoplastic Molding (D-LFT)

Other Value-Added Processes

- Robotic Gel Coating
- In-Mold Coating (IMC)
- SMC/BMC Compounding
- Directed Fiber Preforming, APP
- Bonding and Assembly
- Robotic Routing and Water Jet
- Prime and Topcoat Paint
- In Line Sequencing

13 Strategically Located Factories in North America Providing Nimble and Cost-Efficient Fabrication

The best value supplier is strategically located for your needs – perhaps near your operations, supply source, market or a specific labor market. MFG has established the largest full-service network of molding factories in North America. This factory network is supported by a shared foundation of engineering, design, R&D, procurement and program management that ensures consistent quality and service company-wide. This structure allows us to provide the most competitive cost structure possible.

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