CASE STUDY: TOUGH LOW MASS CLASS A SMC

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Abstract

Fuel is one of the single largest expenses for fleet owners, and it accounts for nearly 50 percent of a truck's operating cost. Lowering a vehicle's weight is a proven method of increasing operational economy whether in fuel consumption, or additional capacity; and in the trucking industry this is a pressing need. A unique collaboration, amongst a commercial fleet owner, a heavy truck manufacturer and their suppliers, achieved a cost-effective and significant weight savings, through the use of tough low mass Class A sheet molding compound (SMC). This paper/presentation describes the customer's objectives, issues encountered and commercial results achieved with the new technology.

Introduction

Ashland Distribution and Valvoline, divisions of Ashland Inc., recently purchased 40 new Navistar TranStar®[1] Series regional haul tractors featuring hood assemblies made from Ashland's tough low-mass SMC technology. The tough low-mass resin system uses patented technology and produced truck hoods that were approximately 21 pounds lighter than standard composite truck hoods. The reduction in weight leads to potential fuel savings or additional hauling capacity for the trucks.

Fleet owners indicate that any weight the manufacturer takes off of the truck helps reduce overall weight and can provide better fuel efficiency. While the increased payload capability may be incremental, all efforts at mass reduction come together to reduce the delivery cost.

Background

Vehicle weight is recognized as a concern of the heavy truck industry. The weight of the vehicle directly impacts the hauling capacity and fuel consumption. Computer models used by Ashland fleet management show that at current diesel fuel prices, and typical heavy truck consumption rates, fuel costs can account for up to 80 cents per mile traveled.[1]

In addition to other benefits, many heavy truck manufacturers have moved to using thermoset composites for the body panels on their cabs, roofs, and air deflectors. With today's regulations and fuel prices, additional ways to reduce weight are being considered.

Recognizing the need for lightweight composites, Ashland Inc. embarked on development activities utilizing nano composite technology combined with polyester resin and low profile expertise. This development resulted in three patents and a family of products and formulations suited for both the reinforcement and Class A parts required of composite assemblies.

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[1] *Registered trademark, Navistar, Inc.*

CORE Molding Technologies, Inc. is a leader in manufacturing composite assemblies for the transportation and other related industries. As a long-time supplier to Navistar, CORE provided the equipment and expertise in compounding, molding, and assembling the truck hood components. CORE and Ashland have conducted extensive development activities on low-mass SMC for several years. CORE manufactures the low-mass compound under the trade name Nano-Lite™[2].

Navistar is a leading producer of medium, heavy, and severe service vehicles. As a major supplier of vehicles to Ashland Inc., Navistar was ready to manufacture and deliver 40 trucks based on the low-mass technology. These trucks were provided with the same quality and service represented by all of their products. The hood assemblies were shipped to Navistar's Garland, Texas, facility where the TranStar® Series trucks were produced. With the assistance of Navistar, Ashland will document the performance of the low-mass parts on the 40 trucks and provide this information back to Navistar. The performance and durability of the truck hoods will be assessed over an 18-month inspection period.

Low Mass SMC Technology

The concept and practice of low-density SMC is not new to the transportation industry[1]. Hollow glass micro-spheres are used in many applications to lower the density of SMC parts. Issues with keeping the micro-spheres in suspension during the SMC compounding process, along with lower mechanical properties in the final molded product, however, have limited the use of this approach. Additionally, SMC containing these micro-spheres can show signs of breakage at the surface and is not suitable for Class A applications because of the resulting defects.

The technology of the tough low-mass SMC is outlined in several technical papers published and presented at industry conferences and conventions.[2 3 4] Along with the use of nanoclay products, technology in resin and low-profile additives is utilized to obtain the performance characteristics of the SMC. Tough SMC technolgy, as practiced in standard density SMC, is used to significantly reduce paint defects that are typically seen in assembly plant paint facilities. Table I shows the formulation for the Class A SMC that was used on the outer body panels.

Table I: Tough Low Mass Class A SMC Formulation

Materials	pts. by wt.
TLM Class A Resin System	70
TLM Class A LPA	30
Divinyl benzene (63%)	6
5% pBQ solution	0.2
t-butyl perbenzoate	1.5
t-butyl peroctoate (50%)	0.27
Zinc Stearate	4.5
Nano Clay Based Filler	15
Mineral Filler	10
Clay Filler	34
B-Side	5
Fiberglass Roving, 1" Chopped	91
(weight %)	34%

This formulation was compounded on CORE Molding's existing equipment with no modifications necessary. Conventional A and B paste mixing equipment, and in-line metering and delivery systems were used. Table II shows the typical mechanical properties of the Class A formulation and compares them to the Navistar CEMS D-22 material specification.

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[2] Trademark of Core Molding Technologies, Inc.
3 Trademark of Ashland, Inc.

Table II: Tough Low Mass Class A SMC Properties

Property			
		Navistar CEMS D-22	
		Type II Grade B	Type II Grade C
Tensile Strength (MPa)	85	55.2 min.	72.4 min.
Tensile Modulus (GPa)	9.2	8.3 min.	10.3 min.
Elongation	1.25		
Flex Strength (MPa)	180	137.9 min.	165.5 min.
Flex Modulus (GPa)	8.9	8.27 min.	9.65 min.
HDT °C	296		
InPlane Shear, Mpa	15.7		
Notched Izod Impact @ 23C, J/m	750		
24 hr. water absorption	0.8	0.5 max.	0.5 max.
CLTE (-30C to 30C), 1/C	2.36E-05		
Shear modulus, Gpa	4.1		
ALSA Index[1]	58	100 max[2]	100 max[2]
Mold Shrinkage[3], %	0.09		
Glass Content, wt. %	34.5		
Specific Gravity	1.55	2 max.	2 max.
[1] - Advanced Laser Surface Analyzer			
[2] - Navistar TMS-9523			
[3] - expansion			

With the exception of water absorption, all Type II Grade B requirements can be met. The Advanced Laser Surface Analyzer ALSA Index[5] of 58 demonstrates that a Class A surface can be obtained using this technology. Typically a Class A finishes fall between ALSA indices of 40 – 80. Table III shows the formulation for the structural SMC that was used for the reinforcement panels on the hood assemblies.

Table III: Tough Low-Mass Structural SMC Formulation

Materials	pts. by wt.
TLM Structrual Resin/LPA System	100.5
Polyethylene Powder	2.05
Zinc Stearate	4.5
t-butyl peroctoate (50%)	0.25
t-butyl perbenzoate	1.45
Black Pigment Disp.	5
Minneral Filler	20
Nano Clay Filler	3.45
B-Side	6
Fiberglass Roving, 1" Chopped	91
(weight %)	39%

Again this formulation was compounded on conventional SMC equipment using typical compounding methods. Table IV shows the physical properties of the low mass structural SMC and compares the properties to the Navistar CEMS D-22 material specification.

Table IV: Tough Low-Mass Structural SMC Properties

Property			
		Navistar CEMS D-22	
		Type II Grade B	Type II Grade C
Tensile Strength (MPa)	105	55.2 min.	72.4 min.
Tensile Modulus (GPa)	15	8.3 min.	10.3 min.
Flex Strength (MPa)	245	137.9 min.	165.5 min.
Flex Modulus (GPa)	12	8.27 min.	9.65 min.
HDT °C	>235		
Notched Izod Impact @ 23C, J/m	950		
24 hr. water absorption	0.3	0.5 max.	0.5 max.
Mold Shrinkage*, %	0.008		
Glass Content, wt. %	39		
Specific Gravity	1.48	2 max.	2 max.

This compound easily meets and falls well within the Type II Grades B and C requirements. Following a typical maturation period, the SMC was molded using traditional molding techniques and procedures. Scrap rates were comparable to the original production parts. In general, the compounding and molding of the tough low-mass SMC was equivalent to the typical production process at CORE molding.

Hood Assembly

During manufacture of the TranStar® hood for Navistar at Core Molding Technologies, eight fiberglass pieces and approximately 10 metal stampings were assembled to produce the completed hood unit. The units were then shipped to Navistar's Garland, Texas facility for final assembly. As production was shifted into the special build of Nano-Lite™ SMC components for this order, part tolerances as well as the bonding performance were monitored closely and no changes from standard materials were observed in bonding, appearance, or part dimensions. The mechanical strength of the bonded assembly was verified by tearing down a completed unit with air hammers and crow-bars as shown in Figures 1 and 2.

Figure 1: Hood Assembly Tear Down

Figure 2: Fender Assembly Tear Down

The pictures of the tear down show the deep fiber tear that is an indication of good adhesion at the joint. All in all, the assembly process was transparent to the manufacturing facility. The only difference observed was the enthusiasm from the associates who noticed the significantly lower weight of the hoods. and who support a shift of all production to the new lighter-weight materials.

Truck Assembly

Assembly of the TranStar® units with the tough low-mass SMC hoods was no different than other production units. The hoods were received, inspected, tacked and put through the paint ovens, where a 1-K basecoat and 2-K clearcoat, both from Akzo-Nobel Coatings, were applied. The hoods were baked at 230 degrees Fahrenheit for thirty minutes and inspected at the end of the paint ovens prior to reloading on carriers to be staged for installation on the trucks. Four of the thirty-nine initial units built needed some kind of repair after topcoat application for handling or processing issues. None of these were due to the switch in molding compounds but were typical of hoods received in production material. All four of the repaired units passed the inspection after paint the second time and were used on sellable vehicles to Ashland.

Vehicle Inspection and Performance

Upon receiving the order to purchase the vehicles with the tough low-mass SMC hoods, Ashland and Navistar cooperatively planned so that Ashland would periodically inspect the hoods to assess performance. The performance factors are based upon a summary of a shaker test done for this model hood prior to introduction of the truck in 2003. The table below summarizes a shaker analysis of hood performance and was given to Ashland as a tool to guide in inspection of the hoods.

Table V. Shaker Analysis Summary

Test Duration	Test Incident
16%	Adjusted hood
60%	Some surface cracking seen under the washer of the hood mounted mirror
70%	Hood appears to be debonding at lower right side
100%	Test time complete-no further hood incidences recorded

The slight amount of damage that occurred during the test was not considered detrimental to the function of the hood. The hood achieved 800,000 equivalent miles in the regional haul vocation. Going forward, Ashland is conducting regular quarterly or 15,000-mile inspections to document how the hood is performing. Any issues related to a change in material are being noted. To date, no material issues have been documented.

Figure 3. Completed low mass SMC hood assembly on fleet vehicle.

Fuel Savings and Economic Impact

Each newly completed low mass SMC hood weighed approximately 79 pounds. This represented a savings of about 21 pounds or 21% versus the original hood assembly's 100-pound weight. When compared to other material options used for heavy truck hoods, the low mass SMC may save as much as 65% versus galvanize steel and have a comparable weight to that of aluminum.

Table VI. Comparison of weight savings and estimated costs of alternate materials.

	Standard SMC (baseline)	**Low Mass SMC**	**Galvanized Steel**	**Aluminum**
Specific Gravity (g/cc)	1.9	1.5	7.8	2.7
Volume of Material (litres)	23.9	23.9	8.3	12.4
Part Weight (lbs.)	100	79	144	74
Weight Saved (lbs.)	---	21	(44)	26
Cost per Part *(% of baseline cost – raw material only)*	100%	115%	110%	225%

The weight savings of the low mass SMC hood alone would not appreciably impact the fuel efficiency of a truck that has a fully loaded trailer at the maximum over-the-road allowance of 80,000 pounds. However, studies have shown that lighter weight in combination with other measures, such as reduced rolling resistance and better aerodynamics, can improve truck fuel efficiency[5]. The 21-pound weight savings of the hood has a directional contribution to this goal.

On the other hand, the weight savings allows 21 pounds of additional bulk product to be loaded per truck per trip. The majority of Ashland's trucks are short haul bulk trucks that carry liquid goods or pelletized resins. For loading, the trucks are driven onto scales and filled from storage silos until the total weight of the truck (cab and payload) reach the legal transport limit of 80,000 pounds. The additional 21 pounds of product carried by each truck can be sold to customers with no additional freight cost. Based on a North American fleet of 400 trucks, this relatively small unit improvement has leverage and will translate to an estimated $2.5 million of additional revenue for Ashland each year when the entire fleet is converted to low mass SMC hoods. Figure 4 shows the anticipated benefit.

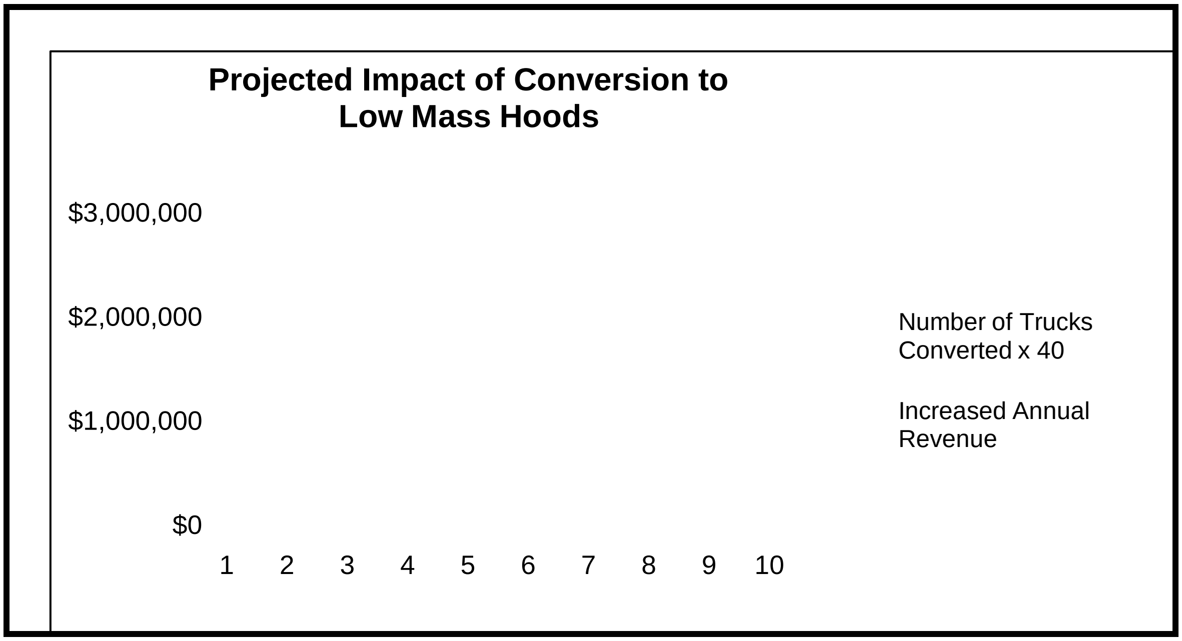

Figure 4. Projected Revenue Impact of Low Mass Hoods

Conclusions

Composite hood components, based on low-mass SMC technology, were manufactured and assembled on 40 Navistar TranStar® tractors. The low-mass hood assemblies were approximately 21 pounds lighter than standard composite truck hoods. The reduction in weight leads to potential fuel savings or additional hauling capacity for the trucks. The processing of the low mass materials throughout the entire process was equivalent to current production. Physical properties along with durability testing of the low-mass composites show equal performance as compared to traditional SMC. Regular inspections will be conducted to document how the hoods continue to perform and any issues related to the change in material will be noted. To date, no material issues have been documented.

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[1] Average United States diesel fuel price of $4.718 per gallon @ 5.5 – 6.0 miles per gallon average fuel economy. Ashland, Inc. and etrucker.com as of July 2008.
[1] Krantz, Francis V., "Advanced Laser Surface Analyzer," Composites 2005 Convention and Trade Show, Sept. 2005.
[1] Gaspari, John de, "SMC Goes for Lighter Weight, Easier Flow", Plastics Technology, March 1, 1996
[2] D. Fisher, "Development of Tough, Low Mass Class A SMC", *Composites 2005 Convention and Trade Show*, Sept. 2005.
[3] Helena Twardowska, "High-Strength, Low-Density Structural SMC Formulations", *Composites 2005 Convention and Trade Show*, Sept. 2005.
[4] R. Seats, D. Fisher, H. Twardowska. "Tough Low Mass SMC Development for Transportation Applications", "COMPOSITES 2006 Convention and Trade Show ", American Composites Manufacturers Association, October 18-20, 2006.
[4] McCallen, Rose et al, "Progess in Reducing Aerodynamic Drag for Higher Efficiency of Heavy Duty Trucks, Society of Automotive Engineers, Government and Industry Meeting, April 1999.