

Tough, Low Mass SMC Development for Transportation Applications

By

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Abstract

The need for low mass composites in the transportation industry has intensified as OEM's have looked for ways to reduce vehicle weight in the face of rising oil prices, increasing regulation, and political unrest in the major oil producing countries. Low mass SMC is not a new concept and has been practiced in the industry for several years. However, the limitations of traditional low mass technology have restricted its use to specific applications. The combination of properties to produce low mass Class A SMC without glass microspheres while maintaining the required mechanical and physical properties has not been available. With the introduction of tough SMC technologies in the last few years, molders as well as OEM's are demanding this technology for future applications to benefit from the performance advantages they bring. This paper will report on recent developments in tough, low mass Class A SMC that achieve a specific gravity of 1.6 and are more robust to molding conditions and exhibit lower water absorption properties than previous developments. Technology and properties of tough, low mass structural SMC with a specific gravity of 1.15 and 1.5 will also be discussed with emphasis on improved mechanical properties as compared to traditional low mass SMC.

Background

Sheet molding compound (SMC) has made significant advances into cosmetic and structural body parts for automotive, truck and recreational vehicles. While lower density SMC materials have and are being used commercially, compromises in surface smoothness and mechanical properties have limited its growth. Improvements in thinner steel and low-density metals such as aluminum and magnesium have provided competition to composites for these applications.¹

Low density SMC has been prepared by substituting hollow glass microspheres for a portion of the filler system. Glass microspheres routinely allow SMC with a density of 1.4g/cc or less to be made. The glass microspheres are difficult to disperse, can be crushed minimizing their effectiveness, typically result in a drop in mechanical properties, and make painting of the part difficult to impossible after sanding or repair

A significant amount of research has been conducted on various mineral fillers, glass and ceramic hollow microspheres, cellulose based materials and polymeric microspheres in an effort to reduce density^{2 3}. This work identified several types of highly structured materials with the ability to maintain both mechanical properties and surface cosmetics as the overall filler concentration of the SMC was reduced. Additionally it was found that low concentrations of nanoclay acted to initiate microvoiding of the LPA as the UPE resin cured.

The advent of tough SMC systems has significantly improved the painting performance of Class A SMC.⁴ Any new SMC technology will need to demonstrate the "tough" characteristic to be considered for use in body panel applications. This paper will focus on work conducted on the tough low mass technology for structural and Class A SMC applications since the last publication. These advances/modifications have focused on optimizing the effectiveness of the nanoclay performance, improving sheet quality and thickening response, addressing the impact of mold temperature on surface smoothness, and lowering the water absorption of the molded composite.

Experimental

Several experiments to improve surface smoothness, water absorption, and overall processability without significantly affecting mechanical properties were conducted. Along with many formulation variables studied of particular interest were nanoclay types and thickening systems.

SMC was compounded on a 24 inch SMC machine using typical compounding methods. Compression molding was conducted on a 100 ton hydraulic press using a 12 inch by 12 inch matched metal flat mold. Flat panels were molded at a thickness of approximately 0.100 inches. Standard ASTM and/or ISO methods were used to determine mechanical and physical properties. Water absorption properties were determined using ISO 62 at both 24 hour immersion and 10 day humidity exposure.

Surface smoothness was determined using an ALSA surface analyzer. The ALSA is an upgraded version of the LORIA surface analyzer and provides the

characteristics of Ashland Index (AI), Distinctness of Image (DOI), and Orange Peel (OP).

Results and Discussion:

Tough low mass Class A and structural formulations previously discussed (1,2) are shown in tables 1 and 2. The Class A formulation has a specific gravity of 1.55 and does not utilize hollow microspheres. Structural formulation A has a specific gravity of 1.45 and formulation B has a specific gravity of 1.25. The formulation at 1.25 does utilize hollow microspheres to assist in density reduction. The typical mechanical properties of these formulations are shown in table 3.

These tough low mass formulations depend on nanoclay and other specialty fillers for many performance characteristics. This nanoclay requires partial intercalation or exfoliation in a carrier resin/surfactant system. This process requires a separate step during SMC compounding or a pre-dispersed clay/resin product would need to be supplied. To eliminate this extra and potentially costly step, several nanoclay products were evaluated in the standard formulation. The nanoclays were evaluated both pre-dispersed in a resin carrier and as a dry solid directly added during A-paste production.

Properties that nanoclay can have an effect on are tensile and flexural modulus. Table 4 compares the original nanoclay (A) with one identified in the study (B) that gives improved results. As the data indicates nanoclay B can be added directly to the paste mixture (i.e. does not require partial intercalation/exfoliation in a resin system) and maintains acceptable modulus properties in the Class A system. Both nanoclay types A and B can be added dry to the structural system and maintain modulus properties.

In addition to the modulus properties, the nanoclay has an effect on surface smoothness of the molded composite. Table 5 shows the ALSA surface properties of Ashland Index (AI), Distinctness of Image (DOI), and Orange Peel (OP) of the original tough low mass class A formulation and the formulation using nanoclay B. Virtually no difference in surface smoothness is seen with the un-dispersed (dry added) nanoclay and type B appears to be the best choice. While the structural formulation does not generate class A surface smoothness, it was noted that nanoclay B showed increased fiber print and a generally poorer appearance than those parts based on nanoclay A. Since the structural formulation is less sensitive to nanoclay type and incorporation method on modulus properties, nanoclay A appears to be a better choice.

Optimization of the original tough low mass Class A formulation showed an unexpected dependence of

surface smoothness on mold temperature. Figure 1 shows the effect of mold temperature on the ALSA surface values. Significant improvements in surface properties are seen at the lower (275/285°F) mold temperatures.

The original tough low mass class A formulation also shows relatively high water absorption properties. While this high water absorption is not unexpected as the percentage of resin in the SMC is significantly higher and the density is lower, it is over most OEM specified maximum values. Attempts at lowering the water absorption property through thickening system modification were conducted. It is known in the industry that replacing MgO as the thickening agent with CaO significantly reduces water absorption. This thickener modification resulted in lowering the 10 day water absorption from 1.2% to 0.6% making it suitable for most OEM specifications. However, the thickener modification had a significant affect on surface smoothness. Figure 2 shows the effect of thickener type on the ALSA values of AI, DOI, and OP. The CaO thickening system results in a significant increase in AI and significant decreases in DOI and OP indicating poorer surface quality.

Several DOE's were conducted to identify a thickening system that would provide an acceptable thickening response, low water absorption, and little if any affect on surface smoothness. The result of the experimentation is a thickening system that achieves all of the requirements. Figure 3 shows the thickening response of the Class A SMC formulation with MgO and with the improved thickener system. The improved thickener system gives a flatter response than MgO.

SMC based on the TLM thickener shows less surface smoothness sensitivity to mold temperature than the MgO thickened SMC. Figure 4 shows the effect of mold temperature on the ALSA values of AI, DOI, and OP for the improved thickener system. Unlike the MgO thickened system, the DOI and OP increase with increasing mold temperature with only a slight increase in AI. While the overall best surface smoothness is achieved with MgO thickening at lower temperature, the TLM thickener based SMC molded at 300°F provides adequate Class A performance.

The water absorption properties of the SMC based on the TLM thickening system are significantly lower than the MgO based SMC. Figure 5 shows both 24 hour immersion and 10 day humidity absorption results for the two systems. The SMC based on the TLM thickening system shows a 38% reduction in 24 hour water absorption and a 48% reduction in 10 day humidity absorption properties. These lower absorption values allow the SMC to meet most OEM specification requirements.

Conclusions

Improvements in tough low mass SMC have been made that allow for easier and less costly processing, less sensitivity to molding conditions, and lower water absorption properties. These improvements were obtained through selection and optimization of nanoclay products and the development of an improved thickening system. It is hoped that these improvements will allow the industry to look again to low mass technologies to reduce vehicle weight.

	parts by weight
Unsaturated Polyester Resin Component	69
Low Profile Additive Component	27
Monomer	6
Parabenzquinone (5%)	0.6
t-butyl perbenzoate	1.5
t-butyl peroctoate (50%)	0.27
Mold Release/Viscosity Reducer	4.5
Nanoclay Based Filler	15
Mineral Filler	10
Clay Filler	34
MgO dispersion	5
1" Chopped Fiberglass Roving	34%

	A	B
	parts by weight	
Unsaturated Polyester Resin/LPA Component	104.7	103.5
Polyethylene Additive	2	--
Parabenzquinone (5%)	0.4	0.4
t-butyl perbenzoate	1.45	1.45
t-butyl peroctoate (50%)	0.25	0.25
Wetting and Dispersion Additive	--	0.9
Mold Release	4.5	4.5
Calcium Carbonate	--	9.5
NanoClay Based Filler	3.5	1.75
Mineral Filler	20	--
Glass Microspheres	--	36
MgO dispersion	4.5	5.5
50/50 1"/2" Chopped Fiberglass Roving	35%	39%

	Class A	Structural	
Specific Gravity	1.55	1.45	1.3
Tensile Strength (MPa)	86.1	98	93
Tensile Modulus (GPa)	9.7	9.9	9.9
Elongation	1.24		
Flex Strength (MPa)	168	215	211
Flex Modulus (GPa)	8.6	9.3	9.4
Glass Content, wt. %	35.2	36	42

Formulation	Class A		Structural		
	A	B	A	Dry	B
Incorporation Method	Dispersed	Dry	Dispersed	Dry	Dry
Tensile Modulus, GPa	9.7	9.6	10.6	10.1	10.4
Flexural Modulus, GPa	8.6	8.9	10	9.8	9.8

Table 5: Effect of Nanoclay on Surface Smoothness

Nanoclay Type	A	B
Incorporation Method	Dispersed	Dry
ALSA Values		
AI	63	65
DOI	80	82
OP	7.3	7.1

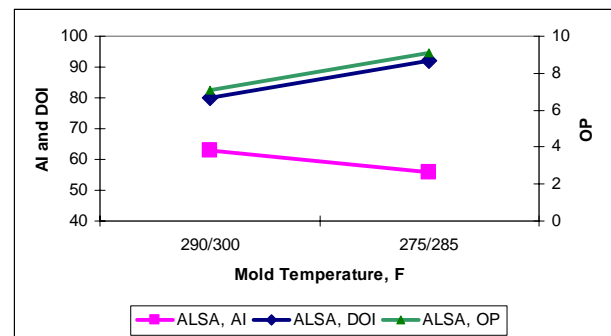


Figure 1: Effect of Mold Temperature on Surface Smoothness

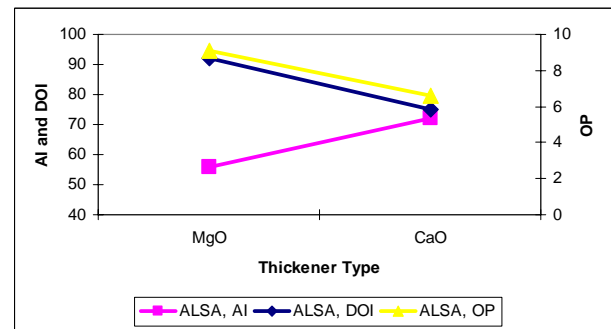


Figure 2: Effect of Thickener Type on Surface Smoothness

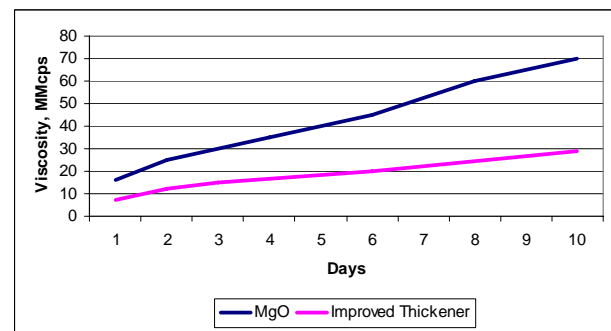


Figure 3: Thickening Response of Thickener Types

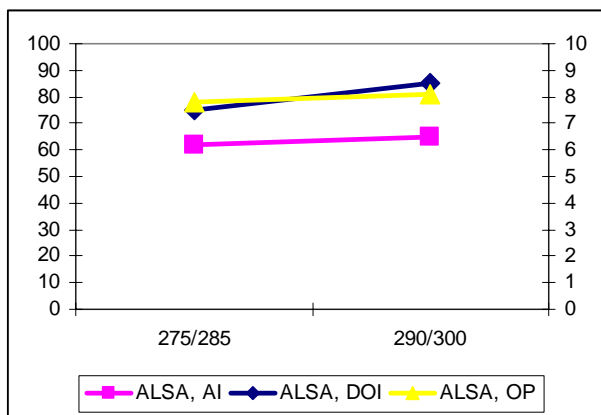


Figure 4: Effect of Molding Temperature (Improved Thickener System)

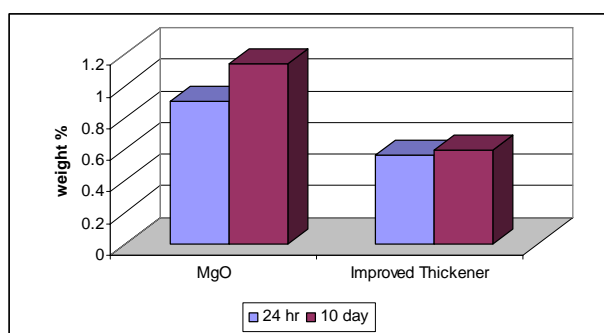


Figure 5: Water Absorption Properties

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¹ "Lighten Up for the 21st Century", *Wards Auto World*, September 1999

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 "Composites 2004: The Sky's The Limit Composites Technology Soars", *Automotive Design and Production*, March 2004