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Developments in Weatherable Sheet Molding Compound

By

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Abstract

The desire for weatherable sheet molding compound for use in a wide range of applications is growing due to the potential of eliminating paint or coatings on the molded article. The elimination of paint or protective coatings can result in significant cost savings and an improved environmental profile for the article. These savings can be realized if existing coating facilities are at capacity or if a greenfield investment is being considered.

Weatherable sheet molding compound (SMC) technology has been previously available but has been designed for specific applications. Transfer of this technology into other application areas has resulted in some performance issues. This paper discusses new developments in weatherable sheet molding compound technology that allow its use in a wider range of application areas.

Introduction

Weatherable SMC technology has been available for several years (1, 2, 3). These weatherable SMC composites were mainly designed for non-Class A exterior body parts and specifically for composite pick-up truck bed assemblies. As a result, the composites were designed to be black in color and were highly reinforced to meet the rugged requirements of a truck bed. The composites made with these technologies show very good color and gloss retention when exposed to accelerated and natural weathering conditions.

As the technology was expanding in both truck box and other weather exposed applications, some characteristics that detracted from the overall composite performance were identified. This paper addresses these characteristics and describes the technology applied to resolve these issues.

An economic analysis of the use of weatherable SMC in specific applications under a variety of scenarios was conducted. In many cases, the potential savings experienced when utilizing this technology is significant. Detailed analysis and major cost levers will be discussed.

Additionally, requests for colors other than black have led to initial development of white and gray versions of weatherable SMC.

Background

Sheet molding compound has a long history of use in automotive body panel applications (4). From the rear air deflector on a Chrysler station wagon, generally thought to be the first commercial application of SMC, to the Class A body panels of the Chevrolet Corvette® and the durable and functional In-bed Trunk™ of the 2005 Honda Ridgeline®, SMC has proven itself to be a cost-effective engineering material.

Traditionally, molded SMC parts are primed with a sprayed liquid coating or with an in-mold coating prior to arriving at the OEM assembly plant. The SMC parts along with other metal parts can receive another primer/surfacer coating followed by a color base coat and clear top coat. The painting of parts simultaneously insures a consistent color match and durability to the effects of weathering.

The coating process, primarily designed and optimized for metal parts, can result in coating defects on SMC parts. The coating defects have been largely addressed with new "tough" SMC technology and products (5, 6, 7). However, many OEM's are embracing powder coatings as a way of reducing the emission of volatile organic compounds (VOC's). Powder coatings pose other challenges for SMC. While newer SMC formulas are resolving these issues (8), molded-in-color technology completely sidesteps painting concerns.

In many applications, a molded-in-color part is desired to avoid the cost and environmental concerns with post-applied coatings. These applications are best suited to parts where color match is not extremely critical and where assembly processes either prohibit or make coating the part difficult. A key performance requirement of such a molded-in-color part is durability to weathering.

Experimental

Several experiments were conducted to address processing and product characteristics that detracted from the composites overall performance in the expanded application areas of interest. These other applications included pick-up bed top rail moldings, tonneau covers, and other sun-exposed surfaces. The methodology was to improve those characteristics of issue without affecting the weathering performance of the current 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” x 12” matched metal flat mold one side of which contained the textures Camera Case SZ and Corinthian LJ. These 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.

Accelerated weathering was conducted to test specification SAE J-1960-kJ with the modification that boro-silicate inner and outer filters were utilized. The property of gloss was determined using a standard gloss meter at 60° geometry. The property of color was determined using a standard spectrometer. The L* value from the CIEL*a*b* color space was reported due to the primary black pigmentation of the samples.

Results and Discussion

Weatherable SMC that has been available in the industry and is discussed in the literature shows excellent durability to both accelerated and natural weathering. Figure 1 shows the lightness/darkness stability of weatherable SMC as compared to an automotive topcoat primer (referenced as P207) using accelerated (Atlas C14000 weatherometer) and South Florida testing protocols. Figure 2 shows the gloss retention of weatherable SMC as compared to an automotive topcoat primer under similar testing. The data suggests that both color durability and gloss retention are similar to that of a black automotive topcoat primer.

As the weatherable SMC technology was being evaluated in other potential applications, a dimensional control issue was identified. The dimensional control issue was seen primarily at lower fiberglass concentrations and resulted in increased part location variability. The weatherable SMC at 35 percent by weight fiberglass concentration was molded on a relatively flat rectangular part. Deviation in actual part location from nominal design was measured at the perimeter of the part. Figure 3 shows the deviation from nominal for the Weatherable SMC and a standard SMC used in production. The increased deviation from nominal of the weatherable SMC as compared to the standard SMC shows up as warpage in the part.

In the laboratory, we measure the shrinkage of a composite by comparing the dimensions of a 12” x 12” x 0.100” flat compression molded panel to the tool it was molded in at room temperature. This shrinkage, or expansion if the part is larger than the mold, is expressed in mils/inch where a mil is one-thousandth of an inch. If the composite shrinks, it is typically preceded by a minus sign (-) and if the composite is larger than the mold or expands it is typically a positive value. Figure 4 shows the flat panel shrinkage of the control SMC and the weatherable SMC. Additionally, the weatherable SMC shrinkage is measured at the fiberglass concentrations of 35 percent and 50 percent by weight. As the data indicates, the weatherable SMC at 35 percent fiberglass shrinks considerably more than the control SMC and more than the weatherable SMC at 50 percent fiberglass.

Extensive development work was conducted to reduce the shrinkage of the composite matrix while maintaining the excellent color and weathering characteristics. The variables thought to contribute to shrinkage and that were studied include the resin/LPA (Low Profile Additive) system, filler concentration, fiberglass type, and initiator system. Figure 5 shows the effects of these variables on shrinkage and L* value, to determine the effect on color, and overall surface appearance. The resin/LPA system was the only variable to have had a significant effect on shrinkage while maintaining color and surface appearance.

The formulation based on the resin/LPA system that showed the improvement in shrinkage control was submitted for accelerated weathering. Figures 6 and 7 show the change in L* value and the gloss retention properties of both the standard weatherable and the low shrink weatherable SMC. The change in L* is very similar to that of the standard weatherable SMC indicating acceptable performance. The gloss retention of the low shrink weatherable SMC is unchanged at 100 for 3750 hours of exposure.

The low shrink system is currently being evaluated in white and gray colors for use in a range of other applications. Both accelerated and natural weathering is underway with initial results showing good performance.

The cost associated with painting an automotive part can be significant especially if the construction of a new paint facility is required. Previous models have been generated to compare the cost of a weatherable composite to a painted steel or composite part. An updated study compares these costs and their effect on final part cost for a pick-up truck box. The model takes into account materials including paint, labor/assembly, burden for the cost of a paint line, and molder profit. It does not account for the value of special storage features that can be offered to the customer when designing in SMC (4).

The major assumptions in the model are shown in Figure 8. Other assumptions include the cost of paint at $60 per gallon and the paint coverage factor of 0.012 per square foot to accommodate overspray. The steel part adjustment for ribs, flanges, etc. accounts for 30 percent overage versus net shape while the composite bed is molded net shape and is assumed to have a scrap rate not exceeding 10 percent.

For the purposes of the study, the paint facility including wastewater treatment requires an investment of \$8 million (MM), is amortized over 10 years, and can accommodate three or more programs.

Investment for steel stamping tools and fixtures is estimated at \$3 million while composite investment is estimated at \$1 million. Labor costs for a steel bed is estimated using a union wage rate of \$20 per hour and for a composite bed at a non-union rate of \$14 per hour.

Using this model the cost per part of a pick-up box made from steel, painted SMC, and weatherable SMC can be compared. Figure 9 shows this cost comparison. A pick-up box made from steel is estimated to cost \$129.33 compared to \$143.46 for painted SMC and \$122.22 for weatherable SMC. This results in a potential cost savings of \$7.12 per vehicle and \$1.2 million over the life of a typical program. A potential of \$8 million is avoided for the investment in a paint facility and associated environmental controls.

In addition to the cost saving associated with a weatherable pick-up box, other benefits exist due to the nature of the composite material and/or the absence of coating. The weatherable SMC has the same design flexibility and benefits versus steel as standard SMC. Corrosion issues are eliminated and the molded-in-color of the weatherable SMC makes any chip damage less visible to the consumer.

Conclusions

The modification in resin/LPA system has successfully addressed the dimensional control issue of the weatherable SMC by controlling polymerization shrinkage much better than the original system. Validation experiments have been conducted on two separate compression molded parts and dimensional measurements taken from check fixtures have shown the low shrink weatherable SMC to meet dimensional tolerances. The low shrink weatherable SMC technology is being evaluated in white and gray colors for expanded application utility.

A new and comprehensive economic model has been generated to study the cost of a weatherable SMC and its effect on final part cost for a pick-up truck box. Analysis shows a pick-up box made from steel to cost \$129.33 compared to \$143.46 for painted SMC and \$122.22 for weatherable SMC. This results in a potential cost savings of \$7.12 per vehicle and \$1.2 million over the life of a typical program.

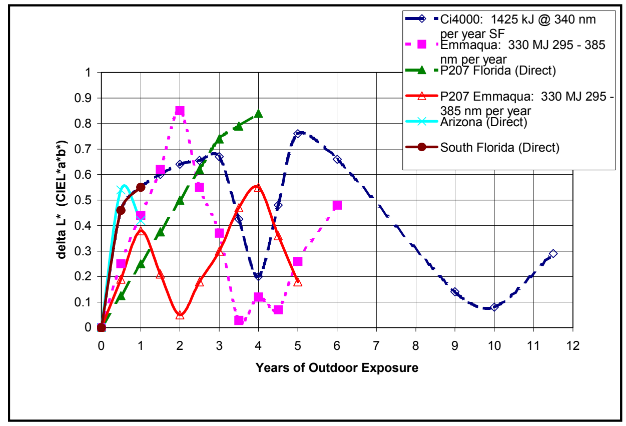

Figure 1. Color change with respect to exposure.

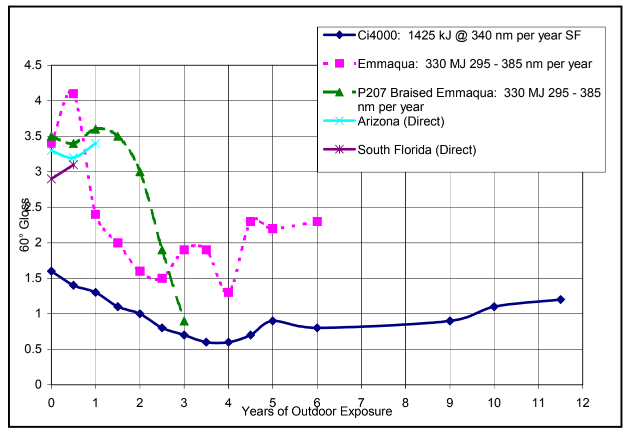

Figure 2. Gloss change with respect to exposure.

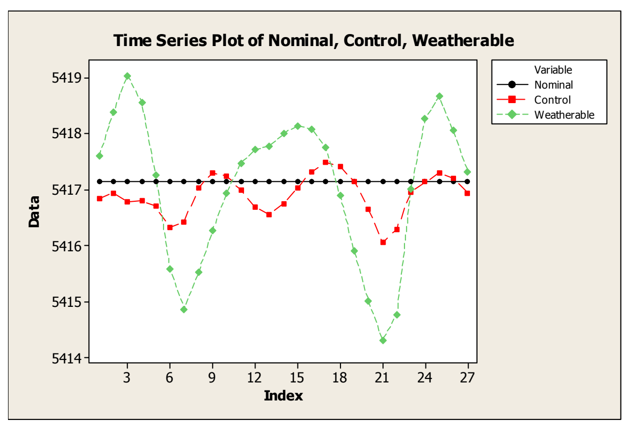

Figure 3. Deviation of part location from nominal.

Material	Shrinkage, mils/in
Control SMC	0.1
Weatherable SMC, 35% fiberglass	-0.6
Weatherable SMC, 50% fiberglass	-0.36

Figure 4. Flat panel shrinkage measurements.

	Shrinkage	L* Value	Surface Appearance
Resin System Type			
I	-0.6	25.8	good
II	0.1	26.6	good
III	0.2	29	mottled
Filler Conc.			
130 phr	-0.6	25.8	good
160 phr	-0.51	27.1	good
180 phr	-0.46	30.1	visibly lighter
Glass Type			
A	-0.6	25.8	good
B	-0.58	24.9	good
C	-0.61	26.3	good
Cure System			
Single Peroxide	-0.6	25.8	good
Dual Peroxide	-0.6	25.9	good

Figure 5. Effect of formulation variables on shrinkage control and surface appearance.

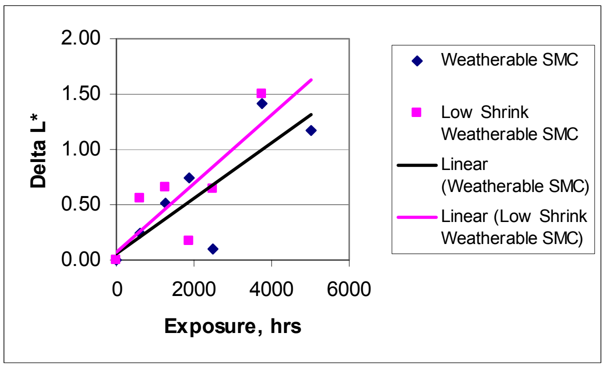

Figure 6. Color change of the low shrink weatherable SMC system.

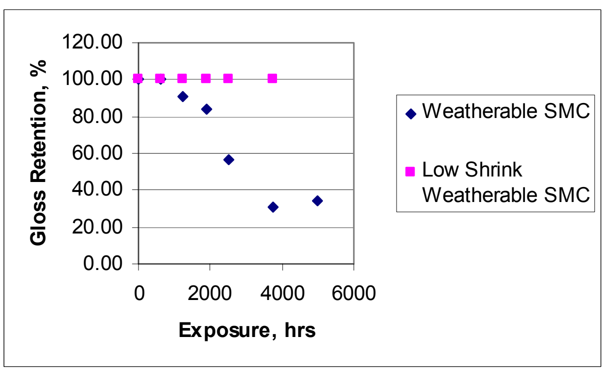

Figure 7. Gloss change of the low shrink weatherable SMC system.

Assumptions	Steel	Weatherable SMC
Production Run	3 years	
Annual Volume	60,000 units	
Material Cost/Lb.	$0.45	$0.85
Paint Line and Tooling Investment	$11.0 MM	$3.0 MM
Normalized Part Thickness (mm)	0.8	3.05

Figure 8. Cost model assumptions.

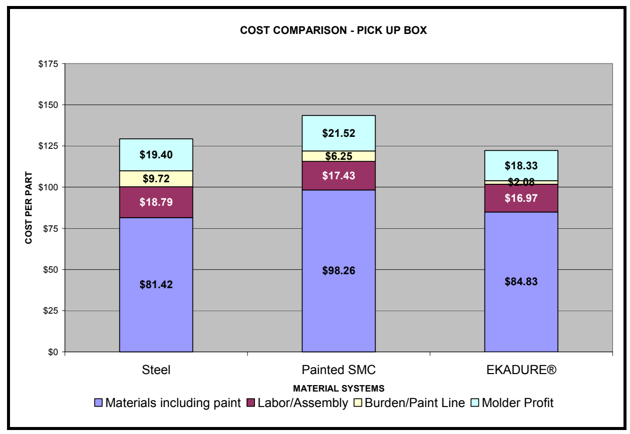

Figure 9. Cost comparison for steel, painted SMC, and weatherable SMC.

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Cedric Ball is Global Marketing Manager for Ashland, Inc. headquartered in Covington, Kentucky and with offices in Dublin, Ohio. Cedric has worked for more than 20 years in the automotive and composites industries beginning his career at General Motors/Saturn Corporation. After leaving GM, he spent several years at Owens Corning in various marketing and business development roles until his start with Ashland in 2004. Combining his experiences in both the automotive and composites markets, Cedric is currently responsible for Ashland Composite Polymers' sales and marketing to the transportation segment worldwide. He also serves as chairperson of the Automotive Composites Alliance's (ACA/ACMA) Marketing and Technical Committee.

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