Conductive Class A SMC Systems

John Young, David W. Brown AOC,LLC
September 25-27, 2002

ABSTRACT

In most automotive or truck body panel applications require a conductive coating in order to be painted at the Original Equipment Manufacturer (OEM). This coating step is usually done at the SMC molders shop by either the application of a conductive in-mold coating (IMC) or a conductive primer. Conductive SMC eliminates the requirement for the SMC molder to apply a conductive coating. This can lead to cost and timesavings at the molder without sacrificing the quality of paint application. This paper will describe the latest innovations in the development of Conductive Class A SMC systems.

INTRODUCTION

The goal of this paper is to present information on new technology that increases the value and robustness of SMC composites. Our belief is that this type of innovation will lead to more applications using SMC in the future. This innovative technology is a new Class A SMC that is conductive.

Solving Body Panel Paint Defects. After many years of searching for a solution to paint pops, the SMC industry now has at least two approaches to solving this nagging problem that has limited the growth of SMC body panels. The two approaches are:

1. New primer - sealers recently introduced by BASF (UV – Thermal) and Redspot
2. Revolutionary SMC formulation technology introduced by Budd Company.

Both approaches are currently being used in production as a means of improving first run capability of SMC parts through automotive finishing systems. Performance to date has been equal, or in some cases, better than steel.

For several years the automotive OEM's have utilized electrostatic painting techniques as a means of reducing overspray. This painting technology results in less wasted paint and reduced solvent emissions.

In order for electrostatic finishing to work, the parts being painted must be conductive. Typical SMC is a terrific electrical insulator, and as a result of this nonconductive capability of SMC, molders have been required to apply a coat of conductive primer, or conductive "in-mold coating" (IMC) prior to delivery of the body panel to the assembly plant.

The new primer-sealers are very effective in sealing the micro-cracks and the porosity that captures the paint solvents. This sealing capability eliminates paint pops during the baking cycle. However, the conductive version of the UV–Thermal primer sealer is very costly. Also, at the time of this paper, it is displaying the best results in reducing paint pop defects. For example, some production Class A parts are displaying below 5 defects per 1000 units. So, as a lower cost alternative, a conductive Class A SMC substrate has been developed that eliminates the need for the primer to be conductive. The nonconductive UV-Thermal primer-sealer is much lower in cost than its conductive counterpart. With sufficient "core conductivity" (in short the ability of the panel to effectively attract paint) SMC parts can be painted much like steel.

Conductive carbon black. As mentioned before, thermoset composites, including SMC will normally behave as insulators. Special types of carbon black must be used to make the formulation conductive. The main properties that are important in making a carbon black "conductive" are listed below:

1. Smaller particle size (i.e. greater surface area per unit weight).
2. Higher or more complicated structures.
3. Surface chemistries that have very low amounts of oxygen on the surface of the carbon.

Unfortunately, these properties are not ideal for producing dispersions with sufficient conductive carbon black levels. They tend to produce dispersions with much higher viscosities than their non-conductive counterparts. Also, how the conductive dispersion is made (mixing time, temperature, mixer type, etc) is critical in producing a "conductive" dispersion. Improper mixing can destroy the conductive properties of the dispersion.

Finally, to make a composite panel conductive, an optimum percentage level of conductive carbon black and the right combination of raw materials are required. This includes the type and amount of the polyester, the low profile additives, and the filler. If there is an insufficient amount of conductive carbon black in the composite, continuous electron transport through the part does not occur (i.e. conductivity is prevented). As the level of conductive carbon black is increased, there is a critical level where the electrons can jump to and from each aggregate. This is where conductivity begins; it is known as the "Tunnel Effect". Finally, there is also a point where a slight percentage increase in the conductive carbon black results in a much increased and consistent level of conductivity. This is known as the Percolation Threshold.

Electrostatic Painting. Electrostatic painting is accomplished by negatively charging atomized paint particles so that they are attracted to the grounded conductive composite panel. An electrode is located at the tip of the electrostatic spray gun. The paint is finely atomized as it moves past the electrode, and during that process the atomized particles become ionized and negatively charged. An electrostatic field is created between the charging electrode and the grounded composite panel. As a result of this electrostatic attraction, spray that would normally be wasted to the surroundings should in practice end up on the back and sides of the composite part.

ISSUES

The two major issues that needed to be addressed to develop a conductive SMC where:

1. What measurement system should be used to determine if a SMC panel is conductive?
2. Develop a conductive dispersion that:
   - A. Imparts conductivity
   - B. Does not compromise any of the SMC's properties or performance
   - C. Can be compounded on the current production equipment

RESULTS AND DISCUSSIONS

Conductivity Measurements. Initially, we used a standard Ransburg conductivity meter to determine if the SMC Ford Electrostatic Conductivity Test. According to panel was conductive. This device measures the surface conductivity of a part. The Ransburg meter provided very erratic readings. Some areas of the composite parts appeared to be conductive, while other areas of the part displayed no conductivity. In discussions with Ford (Global Paint Engineering) it was found that Ford had developed a "Core Conductivity" test. This test measures the conductivity of the total part, not just the conductivity of the surface of the panel [Ford Test Method BI 128-07]. the Test Method, "This procedure is used to determine the electrostatic surface conductivity, grounding, and grounding path of plastic parts prepared for electrostatic painting". however, what it is really measuring is the parts ability to dissipate a charge, or in other words, the part's core conductivity. Basically, the test procedure is as follows: The composite part is grounded and the entire part surface is charged with an electrostatic handgun for one minute. The residual charge is measured at several locations and the residual voltage is recorded. If the residual voltage is less than 1000 volts, the material is considered to be suited for electrostatic painting. As mentioned before, it was found that this test is a superior measurement tool of a parts ability to attract prime and or paint in an electrostatic environment compared to surface conductivity measurements. Thus, we proceeded to use the Ford test to determine the level of conductive additive needed to meet "core conductivity" requirements.

Formulation Development. The SMC formulation we started with was based on AOC's Atryl® Class A SMC system. This system has been used in successfully in the industry for over 10 years. This system is very robust and has been producing

Class A automotive and truck body panels using a variety of IMC, primer and paint systems.As stated earlier our initial surface conductivity results with the Atryl® system using the Ransburg meter were inconsistent. Therefore, in an attempt to overcome the inconsistency, relatively high levels of conductive dispersion were required. However, once we began using the Ford test as our conductivity measurement, we discovered that a much lower level of conductive dispersion was required to display consistent conductivity. Core conductivity was displayed on parts that displayed little or no surface conductivity by way of the Ransburg meter. Also, our initial testing indicated that there is a threshold level of the additive package that is needed to insure core conductivity [See Figure 1]. Of course, this mimics the Percolation Threshold described earlier. It shows that a "threshold" level of the conductive additive is required to ensure that the part is conductive. It is not a gradual progression, above the threshold level there is a consistent level of conductivity, but below this minimum level the part is nonconductive. Therefore, there are two main factors to consider to determine the optimum level of the conductive dispersion. First, it is beneficial to the overall formulation to use the lowest level of conductive dispersion due to viscosity, processing and cost issues. Second, it is very important to be safely above the threshold level to ensure a robust conductive system. Therefore, still using this same SMC system, an optimum conductive dispersion level was determined. This system met the requirements for core conductivity, without compromising properties or performance.

Finally, the conductive additive can be added as a separate dispersion package or as an SMC B-side (including thickener). In this study we added the conductive dispersion in the B-side [Table 1].

SMC Properties. Tables 2-5 display the various properties of the SMC substrate. Panels were molded under standard conditions: 150ºC and 6.9 MPa. Table 2 displays the mechanical properties of the SMC composite versus the Ford M3D145-A spec for Class A SMC systems. Tensile, Flex, Izod, Specific Gravity, 24 Hour Water Absorption and Glass Content were measured. Also, the properties measured were an average of six subsets. As displayed in the table, the properties compare favorably to the Ford specification.

Table 3 describes the LORIA Surface and shrinkage properties for the system. Class A is usually defined as a "Long Term Waviness" measurement of less than 85. The values here surpass this measurement and compare favorably to the Standard Class A non-conductive system. As for cold-tool-to-cold-part shrinkage, this of course is an expansion system.

Tables 4 and 5 display some of the SMC processing and molding parameters. Table 4 describes the cure and flow data of the system (again at 150ºC/6.9 MPa). Compared to the Standard Class A system, this system has comparable cure data, however the flow data displays slightly lower values. This is something that is still being optimized. Finally, Table 5 describes some typical thickening values of the system. This can be modified either by modifying the A-side to B-side ratio of the system, or by developing a new B-side if necessary.

Finally, Figure 2 describes the Ford SMC Water Absorption Test [9069 v3]. In this test, panels (or parts) are baked and then placed in a 37.8ºC/100% humidity oven.

Panels are then weighed at 3 and 7 days immediately after removal from the oven. The panels are also measured at 10 days immediately after removal from the oven and then again 1 hour after removal from the oven. The water absorption is then calculated. According to the spec, the panels must display a water absorption value of less than 0.7% to pass. Again, the conductive system easily passed. This test has proven to be a good indicator of potential blister issues in the substrate after ELPO bake. Higher water absorption values may lead to a higher tendency to blister after a high temperature bake. Lastly, the panels that went through the temperature and humidity exposure were baked at 190ºC for 45 minutes to simulate an ELPO bake condition. Like the Standard Class A system, no blisters were detected in the conductive system.

CURRENT STATUS

The Class A Conductive SMC is now in production scale up. The non-conductive BASF UV-Thermal primersealer is the primer-sealer in this scale-up.

CONCLUSION

A Conductive Class A SMC system that is production worthy and meets customer's requirements has been developed. It is being evaluated on other applications where core conductivity brings value to the customer. Our goal is to grow the SMC Composites business through innovation and new technology that answers our customers needs.

REFERENCES

1. Lambourne, R. 1987. "Paint and Surface Coatings," Camelot Press, Southampton.
2. ITW-Ransburg Publication. 1999.
3. Patton, Temple C. 1973 "Pigment Handbook," John Wiley & Sons, New York.
4. Ford Test Method, BI 128-07.
5. Ford Test Method, M3D145-A.
6. Ford Test Method, 9096 v3.
7. M. S. Harber and J. J. Young, "Carbon Black: Theory and Uses in Thermoset Composite Applications," International Composites Expo, 2001.

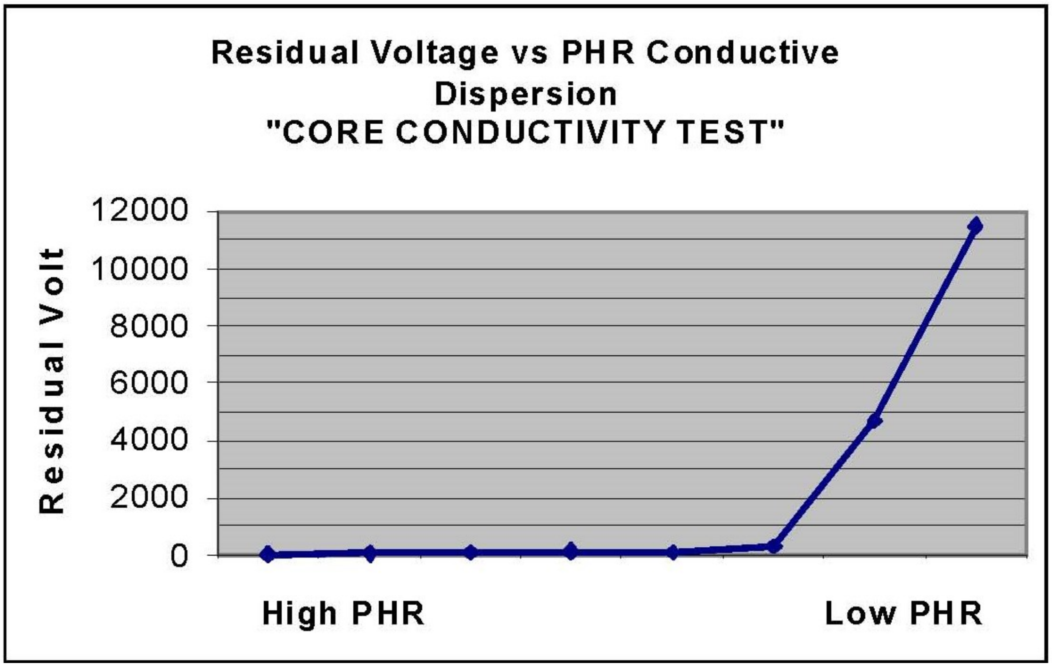

Figure 1. Ford Electrostatic "Core Conductivity" Test

MATERIAL	Description	Percent
AOC XV-2506	**Class A 1-pack Resin System**	**21.59**
AOC S508	Processing Additive	0.68
AOC CT-INH5	5% pBQ Inhibitor Solution	0.10
29B75	Catalyst	0.36
Calcium Stearate	Mold Release	1.04
Huber W4	Calcium Carbonate	43.21
AOC XV-2507	**Conductive B-side**	**5.02**
A+B Side TOTAL		72.00
OC 973 1" Glass		28.00
SMC TOTAL		100.00
A-side: B-side Ratio: 13.3 to 1		

Table 1. SMC Formulation

PROPERTY	SPEC/UNITS	VALUES
Tensile Properties, (ASTM D-638)		
Strength Avg	(56 MPa)	85
STD(n-1)		2.2
Modulus Avg (Tangent)	(MPa)	10,400
STD(n-1)		200
% Elongation Avg	(%)	1.46
STD(n-1)		0.04
Flexural Properties (ASTM D-790)		
Strength Avg	(125 MPa)	179
STD(n-1)		5.8
Modulus Avg (Tangent)	(7,400 MPa)	9,730
STD(n-1)		260
Izod Impact, Notched (ASTM D-256/A)		
Strength per Inch (Avg)	(635 J/m)	910
STD(n-1)		30
Strength per Area (Avg)	(kJ/m*m)	90
STD(n-1)		3.0
Specific Gravity (ASTM D-692)		
Specific Gravity Avg	(2.0 max)	1.86
STD(n-1)		0.01
Water Absorption, 24 HR, RT (ASTM D-570)		
Weight Percent Avg	(max 1.0%)	0.56
STD(n-1)		0.02
% Glass Reinforcement (Loss On Ignition)		
% Glass Avg	(min 25%)	27.4
STD(n-1)		0.6

Table 2. Conducive Class A Mechanical Properties per Ford M3D145-A.

PROPERTY	SPEC/UNITS
Shrinkage (Cold Tool to Cold Part)	
Average Value	-0.045%
LORIA Surface	
Long Term Waviness	70
Orange Peel	10.3
DOI	102

Table 3. Shrinkage and LORIA Surface Properties

PROPERTY	Units	Conductive	Control
Platen Dip Cure (LVDT)			
Average Value	seconds	54	56
Spiral Flow Data			
3day	inches	35	43
7 day	Inches	33	41
14 day	inches	31	36

Table 4. Cure and Spiral Flow Data

Time	Temp (°C)	Brookfield Viscometer	Units	Values
A-side	29.5	RVT#6 @1 rpm	cps	156,000
A-side	29.5	RVT#6 @10 rpm	cps	31,000
A-side	29.4	RVT#6 @20 rpm	cps	21,000
1day	26.5	HBT-TF @1 rpm	cps	7,100,000
3day	26.5	HBT-TF @1 rpm	cps	17,500,000
7day	27.5	HBT-TF @1 rpm	cps	21,000,000
14 day	27.5	HBT-TF @1 rpm	cps	30,000,000

Table 5. Thickening Profiles (Viscosity in cps.)

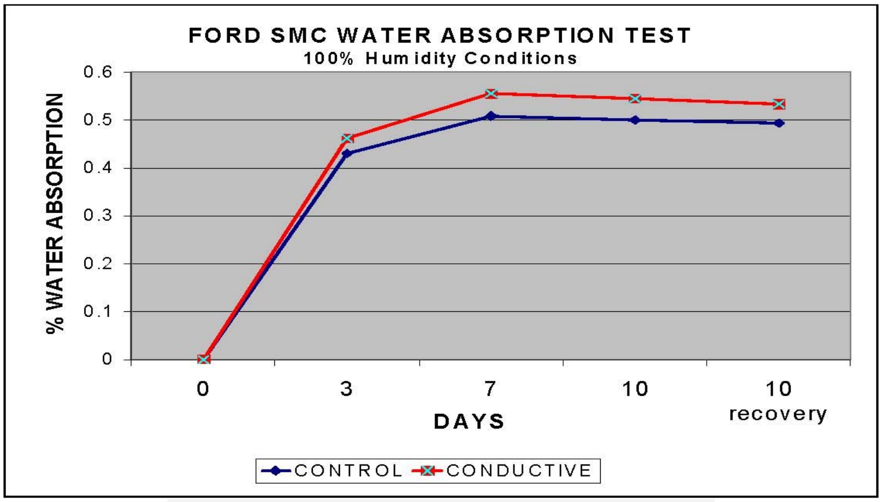

Figure 2. Ford SMC Water Absorption Test