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Exterior Durability Comparisons of Various Gel Coat Systems

ABSTRACT

Today's gel coat producers have a wide array of materials at their disposal to formulate coating products for the composites industry. This leaves the composites manufacturer the decision of what product to use based on cost, processing and performance characteristics. In most cases the performance characteristics are dictated by the expectations of the end consumer. One such expectation is the relative durability of the composite part upon exposure to various environmental conditions such as light, heat and water. In particular, it is the parts relative ability to retain its original color and gloss.

This paper explores the various base resin chemistries available to the gel coat chemist and the relative cost versus benefit analysis of exterior durability. Gel coats of different base resin chemistries were formulated into like products in several common colors. Composite panels of these like products were constructed and exposed to ultraviolet radiation, heat and moisture using accelerated weathering techniques. Comparisons are drawn between the chemistries in their relative ability to promote gloss and color retention. The performance differences between conventional monomer systems and the new MACT compliant low monomer systems are also investigated.

Other performance aspects of the gel coat can also be very important. Physical property differences such as elongation, heat deflection temperature and water resistance are also examined. The information presented should help the composite manufacturer make an informed decision on the particular gel coat product to be used depending on the consumer's durability expectations.

INTRODUCTION

The performance characteristics of an unsaturated polyester gel coat can be separated into two fundamental areas: the application characteristics of the product during the composite molding process and the in-service performance of the coating during the parts life. During the application process the gel coat must spray and cure such that no cosmetic defects such as porosity, pre-release, color separation and resin tear take place. The final part must have appealing cosmetics, gloss and richness of color. In-service performance characteristics include resistance to cracking, water, thermal shock and weathering. The resistance to water, cracking and thermal shock depends on choices made in the entire laminate structure whereas the resistance to weathering is almost exclusively dependent on the gel coat chemistry.

Environmental exposure conditions contribute to the surface degradation of the gel coat film. Exposures to light, heat, and water all lead to eventual change in color and gloss of the gel coat. The irradiation of ultraviolet light in the gel coat film causes free radical formation and the development of yellow color bodies. Eventual surface erosion of the resin rich area of the gel coat film causes a loss of gloss. The yellowing is most offensive to the end consumer in lighter colors where the yellowing is highly visible whereas the loss of gloss is more visually offensive in darker, more chromatic colors.

The gel coat formulator takes into account the numerous application and in-service performance requirements in the design of a gel coat product. One of the first steps in the design of a gel coat is the decision of what base resin or combination of base resins to use as the basic backbone in the formulation. Many considerations go into this selection as many of the final product attributes and potential failings come about because of this choice. Consideration needs to be taken for the expectation of the composites manufacturer in the way the material will process in their production environment. Consideration also needs to be given to the end consumer and their expectation of exterior durability for the product as well as any other in-service requirements.

There are many other aspects to the final gel coat formulation, in addition to the base resin, that can have dramatics effects of the application and in-service performance characteristics. In the aspect of this paper, only the relative effect of the base resin on in-service performance characteristics will be investigated.

TESTING

Several commonly used unsaturated polyester gel coat bases were obtained for testing. Included were orthophthalic, ortho NPG, isophthalic, iso NPG as well as an iso NPG and proprietary base used for the manufacture of low HAP coatings. An illustration of the molar composition of these bases is given in Figure 1. The test program consisted of formulating gel coats from these bases with the formulas all standardized to the same basic composition. The two low HAP base resins were formulated into a typical low HAP coating. A generic representation of these two formula types is given in Figure 2. All conventional and low HAP products were formulated to the same respective HAP contents for equivalent comparative testing within the two gel coat types.

After the construction of the gel coat materials, test laminate panels were produced. The gel coats were initiated with 1.5% MEKP and applied to a wet mil thickness of 20 mils on a glass mold. Once the gel coat had sufficiently cured, a laminate was constructed using four layers of 1 ½ mat. The first layer used a standard vinyl ester skin coat and subsequent layers used a standard bulk DCPD laminating resin. The panels were allowed to cure for twenty-four hours prior to removal from the glass mold and subsequently allowed to post-cure at room temperature for another seven days prior to testing.

The experimental test program involved three different aspects of evaluating the gel coat in-service performance characteristics. Included were accelerated weather testing, water resistance and physical property testing. For the accelerated weather testing, a portion of each test panel was placed in a Q-UV weather-o-meter with gloss and color difference readings taken on a periodic basis. The weather-o-meter used UVA 340 bulbs and was set with eight hours of light at 50°C followed by four hours of condensation at 40°C. In water resistance testing, panels were exposed to water at 100°C for a period of 100 hours. These panels were then rated for color change, cracking, fiber prominence, blistering, and loss of gloss. The final testing involved the measurement of the product physical properties. Castings were made of each of the gel coat formulation less the thixotrope, pigmentation and filler. These items were removed to insure no air was entrapped in the casting, which would influence the final test results. The castings were postcured at 100°C for 5 hours prior to testing.

RESULTS

The Q-UV testing yielded the color change results of the various conventional gel coats in Figure 3. The orthophthalic gel coat shows more significant color change than the Ortho NPG, isophthalic and Iso NPG bases. The two NPG bases performed very similarly with the straight isophthalic base showing slightly less change. The low HAP gel coats are shown in Figure 4. When comparing to the conventional results of Figure 3, it is quite obvious that both the Iso NPG and proprietary low HAP products are vastly superior to the conventional products. Within the low HAP products, the proprietary resin base is showing slightly less color change as compared to the iso NPG. At the writing of this paper, the low HAP gel coats have seen more exposure time than the conventional products. Figure 5 illustrates the gloss retention results of the conventional products in Q-UV testing. Here also, the orthophthalic gel coat shows inferior results to the straight isophthalic, ortho NPG and iso NPG where the gloss is decreasing at a faster rate than the other bases. Figure 6 illustrates the relative gloss retention of the low HAP Iso NPG and proprietary bases. When comparing these extended exposure results to the conventional results in Figure 5, the low HAP iso NPG shows similar gloss retention to the isophthalic, iso NPG and ortho NPG bases. The proprietary low HAP base shows superior gloss retention results to all of the conventional products and to the low HAP iso NPG.

The 100°C water exposure test results are shown in Figure 7. The test panels were rated for blistering, color change, fiber prominence, cracks and change in gloss. The panels were rated in each category with 0 being no change and 5 being complete failure. The most obvious result from this testing was the inferior resistance to blistering of the orthophthalic based gel coat system. Somewhat surprisingly, the straight isophthalic system showed equivalent resistance to blistering to the iso NPG and ortho NPG products. None of the other properties showed any significant differences between the various systems though the orthophthalic system showed more of a noticeable color change than the various other systems.

Figure 8 shows the various differences in physical properties between the various base resin systems. All of the conventional monomer level resin/gel coat systems show improved tensile and flexural properties over their low HAP counterparts. This is due to the lower styrene levels as well as the lower molecular weight of the actual polyester alkyds. The orthophthalic and ortho NPG products show lower HDT values as well as lower elongation values. This can potentially lead to more print and distortion with gel coats using these bases.

CONCLUSIONS

The base resin is only a portion of the final gel coat performance generally equivalent or superior to the conventional gel coat systems. This is especially true in their resistance to yellowing based on UV exposure. Even more superior resistance to UV exposure can be obtained with proprietary low HAP technolomance characteristics, but several conclusions can be drawn from the presented test results. Other variants of these general base resin chemistries may be developed where improvements can be made in some aspects. However, the generalities presented here should be typical of these systems. Figure 9 shows generic cost comparisons of the various resins presented. The orthophthalic base is arbitrarily set to one. It should be noted that this is only the base resin cost contribution to the gel coat formulation. Other important raw materials to the formulation have their own contributions and are used based on the required process and performance characteristics. One of the most important aspects of the testing shown here is that the Low HAP products aregries.

Within the conventional gel coat systems testing has shown that orthophthalic based gel coats should only be used in the manufacture of composite parts where weather and water resistance is not a necessary attribute of the part. For composite parts where exterior exposure takes place and good weather resistance is a requirement, the isophthalic, iso NPG and ortho NPG products all are very similar. These same three conventional resin systems also showed an equivalent resistance to water. The isophthalic and Iso NPG systems tend to show more favorable physical property results over the other systems. The choice of an appropriate base resin system for a gel coat system should be based on the in-service expectations of the final consumer. It is important to communicate effectively with your gel coat or base resin supplier to effectively select an appropriate system for the end use of the composite part.

Figure 1.

EVALUATED RESINS - MOLAR RATIOS							
Common Name	EG	DEG	PG	NPG	MAN	PAN	IPA
Orthophthalic	1.00	0.80	1.20		1.00	1.80	
Ortho NPG		0.20	0.50	1.70	1.00	1.00	
Isophthalic		1.00	1.10		1.00		0.90
Iso NPG			0.50	1.50	1.00		0.90
Iso NPG - Low HAP			0.40	1.40	1.00		0.70
Proprietary - Low NAP							
EG = Ethylene Glycol							
DEG = Diethylene Glycol							
PG = Propylene Glycol							
NPG = Neopentyl Glycol							
MAN = Maleic Anhydride							
PAN = Phthalic Anhydride							
IPA = Isophthalic Acid							

Figure 2.

Conventional Gel Coat Formulation			Low HAP Gel Coat Formulation	
Unsaturated Polyester Resin Alkyd	35		Unsaturated Polyester Resin Alkyd	37
Titanium Dioxide	15		Titanium Dioxide	15
Fumed Silica	2		Fumed Silica	1.5
Functional Fillers	12.75		Functional Fillers	18.25
12% Cobalt	0.25		12% Cobalt	0.25
Styrene Monomer	35		Styrene Monomer	28
Total:	100		Total:	100

Figure 3.

Conventional Gel Coat Q-UV Testing - Color Change

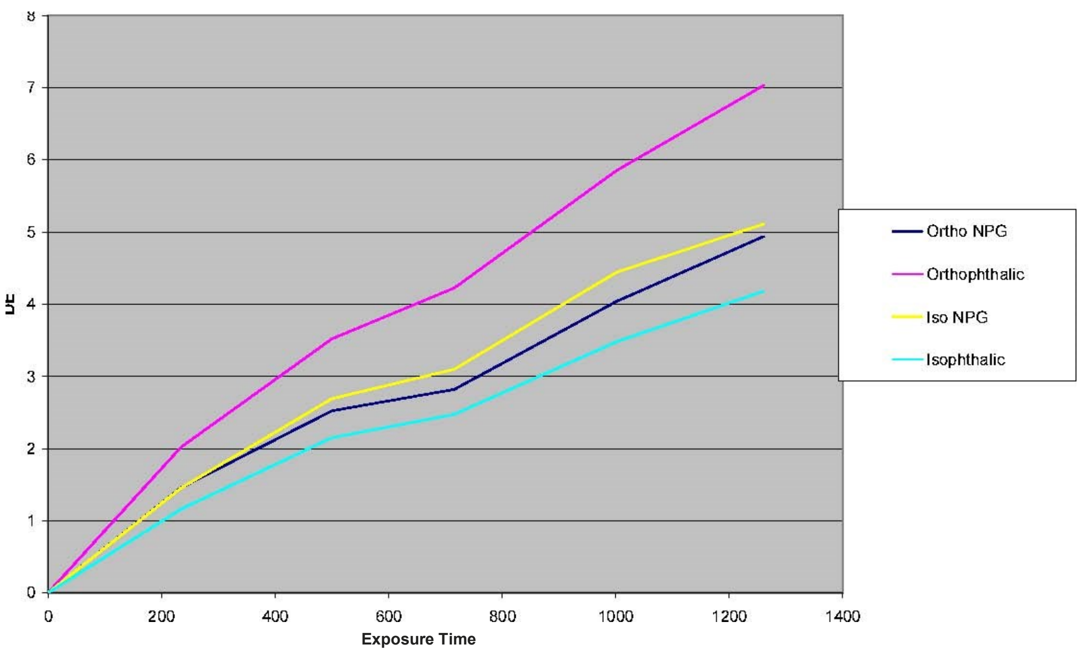

Figure 4.

Low HAP Gel Coats Q-UV Testing - Color Change

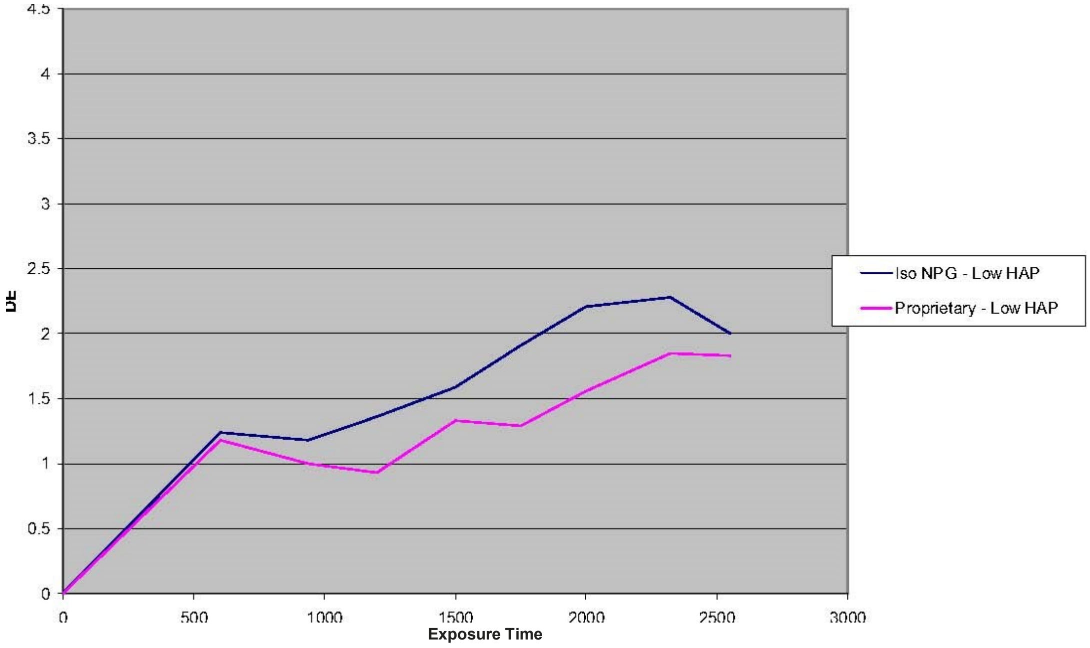

Figure 5.

Conventional Gel Coat Q-UV Testing - Gloss Retention

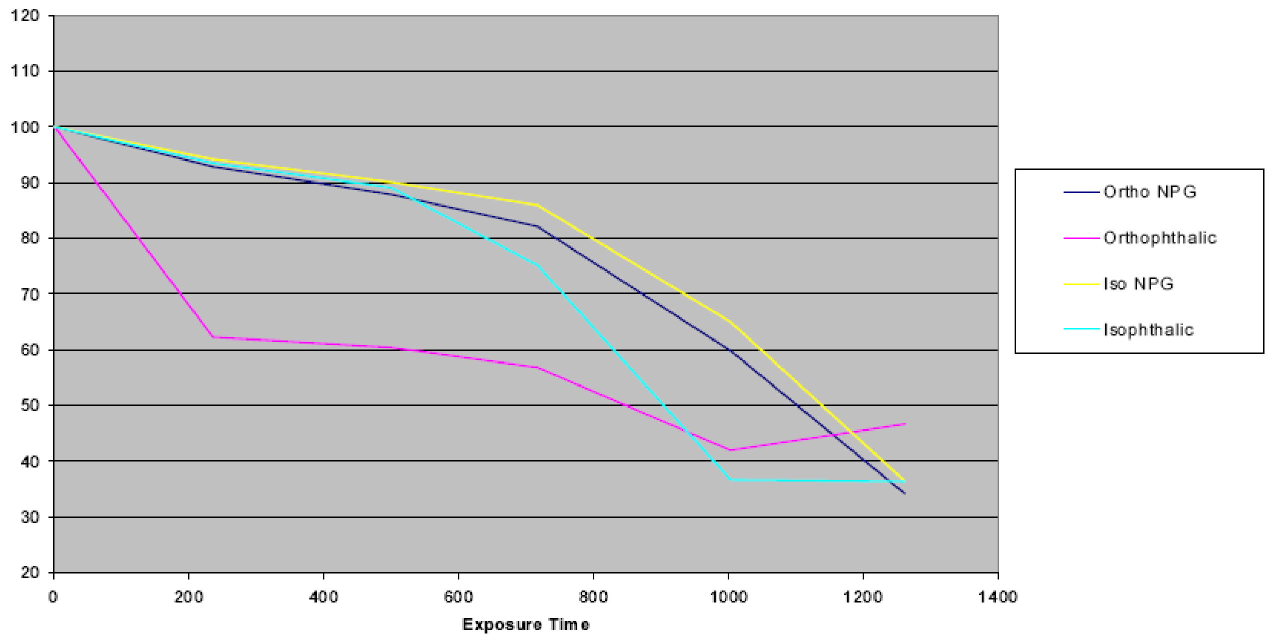

Figure 6.

Low HAP Gel Coats Q-UV Testing - Gloss Retention

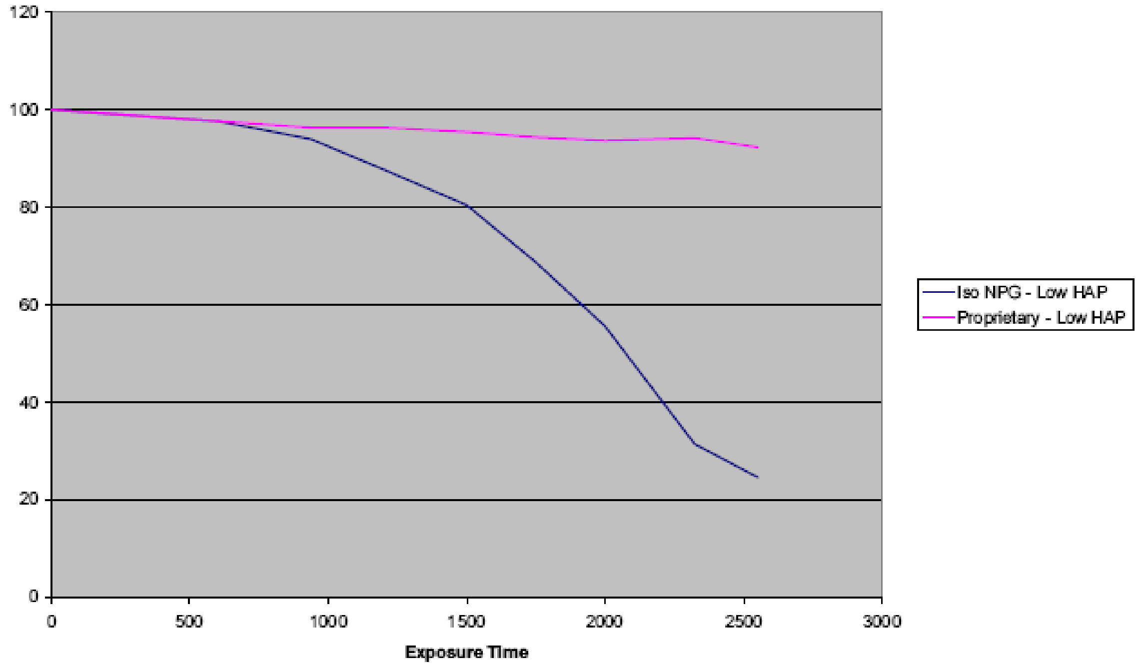

Figure 7.

Product	Blisters	Color	Fiber Prominence	Cracks	Gloss
Orthophthalic	4	2	1	0	0.5
Isophthalic	0.5	1.5	0.5	0	0
Ortho NPG	0.5	1	0.5	0	0
Iso NPG	0.5	1	0.5	0	0
Iso NPG - Low HAP	1	1	0.5	0	0.5
Proprietary - Low HAP	0.5	1	0	0	0.5
Ratings: 0 = No Change, 5 = Failure					

Figure 8.

		ASTM	Orthophthalic	Ortho NPG	Isophthalic	Iso NPG	Low HAP Iso NPG	Proprietary Low HAP
Flexural Strength	(psi)	D-790	18500	20200	20700	21300	18600	16600
Flexural Modulus	(x10^6psi)	D-790	0.55	0.56	0.56	0.55	0.49	0.46
Tensile Strength	(psi)	D-638	10800	10600	12000	12100	10900	9300
Tensile Modulus	(x10^6psi)	D-638	0.53	0.53	0.5	0.52	0.48	0.45
Elongation	(%)	D-638	2.9	2.6	4.4	4.1	3.8	3.5
Heat Distortion	(C/	D-648	66/151	85/185	87/189	90/190	92/198	98/208
Barcol	(934-1)	D-2583	46	45	45	41	39	40

Figure 9.

Relative Base Resin Costs