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September 25-27, 2002

Development of a Gel Coat With Improved UV Stability

ABSTRACT

The ability of composite materials to penetrate into business sectors dominated by other construction materials has been limited by a cost-effective means of achieving acceptable performance characteristics with current gel coat technologies. In many cases, the limiting factor has been the gel coats ability to retain its original color and gloss upon continual ultraviolet exposure as compared to the performance of alternate coating technologies. The upcoming MACT requirements regulating the composites industry will also have a detrimental effect on the ability to use many of the current techniques in formulating the high performance gel coats currently on the market.

This paper will describe the development of a gel coat that has been developed to optimize the coating's color and gloss retention upon ultraviolet light exposure. The development process will be outlined in detail and the weathering attributes will be illustrated with Xenon Arc and Q-UV weather test results. These results will compare the new coating's benefits over existing conventional and MACT compliant products. Physical property and blister resistance differences will also be examined.

INTRODUCTION

Gel coat performance characteristics 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, prerelease, color separation and resin tear take place. The final part must have appeal-

ing 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. Proper construction techniques are also essential to obtaining the optimal in-service properties of the composite part. Poor workmanship can generate loss of water, cracking, thermal shock and UV resistance.

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. Previous studies have shown that the presence of aromatics in the gel coat greatly enhances the formation of these free radicals and subsequent yellowing [1]. These aromatic structures come from monomers used in the gel coat as well as in the polymer backbone. Eventual surface erosion of the resin-rich area of the gel coat film causes a loss of gloss. The yellowing characteristic is most offensive to the end consumer in lighter colors where the yellowing is visible whereas the loss of gloss is more visually offensive in darker, more chromatic colors.

Current gel coat technologies have not been able to compete in markets with extreme UV durability requirements such as the automotive, heavy truck and architectural segments. These markets have been dominated by other coatings and construction materials with superior resistance to weathering. Many of the high performance gel coats previ-

ously commercialized will no longer be available once compliance to the EPA MACT requirements is necessary. This pointed to the need for further gel coat performance enhancements in a MACT compliant product.

DEVELOPMENT

A development project was undertaken to determine a means for improving the weathering characteristics of polyester gel coats. The criteria of the development included the following characteristics.

- Physical properties similar to those of conventional Iso NPG gel coats commonly used today
- Insure that MACT compliant products could be formulated using the gained techniques

The application characteristics of the new development needed to be similar to current commercially available conventional and MACT compliant gel coats.

Three main areas of change were investigated for their effects on the weathering characteristics of the coatings. This included UV stabilizer packages, monomer type(s), and changes in the base polymer backbone.

The UV stabilizer packages investigated included absorbers and sterically hindered amines (HALS). These products work by the following mechanisms [2].

The physical absorption process protects both the deeper sections of the coating and the substrate from the high-energy fractions of sunlight. These are absorbed and lead to isomerization, causing the molecule to transform into an excited structure. When the molecule reverts to its original condition, the absorber releases the energy into the environment as thermal energy. With UV protectors of the hindered amine light stabilizer type, stabilization results from the trapping of intermediately developed radicals. HALS, in contrast to UV absorbers, protect chemically rather than physically.

Alternate monomers were investigated enabling the final gel coats to be formulated with lower styrene levels and therefore less aromaticity. Various changes in the actual polymer backbone were also made to determine the effect on weathering characteristics.

An array of possible modifications were formulated into samples and checked against the minimum specifications set forth for physical properties and application/processing characteristics. The samples surpassing these criteria were used in the construction of composite panels where the gel coat was spray-applied to a thickness of 16-20 mils on a glass mold, laminated and cut into coupons. These coupons were weather tested using accelerated weathering techniques. They were tested by an outside laboratory in accordance with SAE J1960 and internally with a Q-UV using A340 bulbs. SAE J1960 is a method common to Automotive industry specifications that uses a xenon arc weather-o-meter using standard equipment test parameters. It has been shown previously that xenon arc results correlate very well with actual outdoor exposures [3].

The accelerated weathering test coupons were evaluated for color change and gloss retention. Based on these results, an optimal system could be determined. This system was formulated into a MACT compliant white gel coat and then compared to a commercially available conventional Iso NPG gel coat and MACT compliant marine gel coat. It was compared to these products in physical properties, 150 °F water immersion, and accelerated Q-UV testing.

RESULTS

The SAE J1960 xenon arc testing yielded the gloss retention results shown graphically in Figure 1. The 1200 hour exposure yielded several possible formula variants with near 100% retention of the gloss. The four R3 variants were eliminated from consideration due to the inferior results as compared to the other products shown. Figure 2 illustrates the graphical representation of the overall color change (DE) in the xenon results. All of the test samples performed fairly well with DE results of 2-3 units being typical. The R3AB showed the least amount of color change at 1.8 units but had been ruled out because of its poor gloss retention.

Figure 3 illustrates the gloss retention of the ten variants in Q-UV weather testing. A little more separation between the variants is seen in this testing as compared to the xenon due to the length of exposure. As in the xenon testing, the R3 variants exhibited poor gloss retention as compared to the others. The R2AA and R2BA samples showed the

best overall retention. In figure 4 the overall color change is shown for the samples in the Q-UV test. More separation in results is also seen here with the R2AA and R2AB samples showing the least amount of color change. Based on the xenon, Q-UV and application characteristics of the variants, R2AA was chosen as the basis for the gel coat formula modification.

With the information gained in the initial screening, the R2AA type of modification was imparted to a white, MACT compliant gel coat formulation. Figure 5 illustrates the physical property differences between this modification, a conventional gel coat and a standard MACT compliant gel coat. The properties were tested on non-thixed, non-pigmented versions of the product at their formulated monomer levels. The improved UV performance does show a slight loss in flexural and tensile properties but shows a significantly higher heat distortion temperature. This would correlate to better cosmetic appearance in the finished part.

The 150°F water exposure test results are shown in Figure 6. The improved performance product shows equivalent or better blister resistance than the conventional Iso NPG and MACT compliant products. There was also a significant reduction in fiber prominence with the modified gel coat. This is probably due to the higher heat distortion temperature of the modified version. Figure 7 highlights the significant benefit of improved gloss retention from the R2AA modification versus the conventional and MACT compliant product. Failure of the conventional product at less than 25%

retention occurs at 1700 hours and the MACT compliant failure occurs at 2700 hours. The improved UV performance gel coat continues as of this writing with over 2800 hours exposure with a 92% gloss retention. Figure 8 illustrates the overall color change of the samples in the same testing. The improved performance and MACT compliant products show very little change as compared to the conventional product.

CONCLUSIONS

This development work has demonstrated the ability to dramatically improve the resistance of gel coats to UV degradation. This can take place without any major loss in process and application characteristics of the gel coat. The gel coat also shows improved cosmetics and maintains an excellent resistance to water. This will enable the composite fabricator to enter market segments with tough durability requirements that have typically been dominated by other types of construction materials.

REFERENCES

- [1] Hansen, Dr. M., Nygard, H., Haavaldsen, Dr. J.T., Sandve, K., "Development of High Performance Gel Coat with Better Properties and Weathering", Composites 2000, September 2000, Las Vegas, Nevada, USA.
- [2] "UV Protection and Coatings for Plastics in the Automobile Industry", Paint & Coatings Industry, October 2001
- [3] Crump, Scott L., "Evaluating the Durability of Gel Coats Using Outdoor and Accelerated Weathering Techniques: A Correlation Study", Composite Fabrication, November/December 1995.

Figure 1.

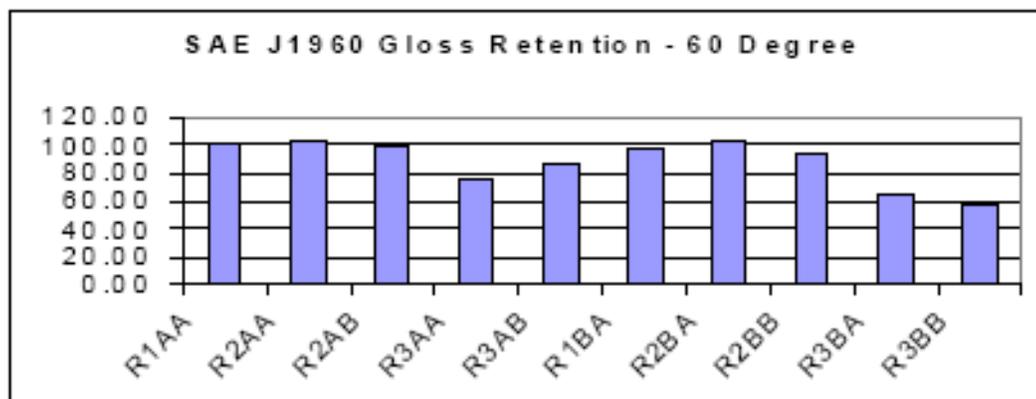


Figure 2.

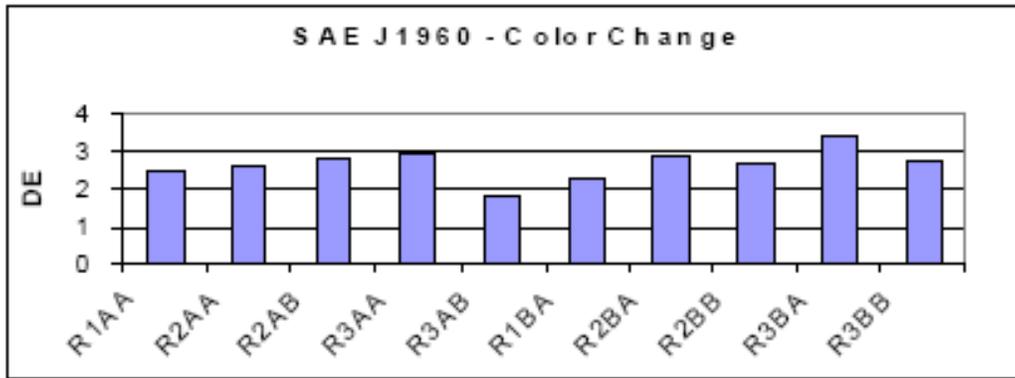


Figure 3.

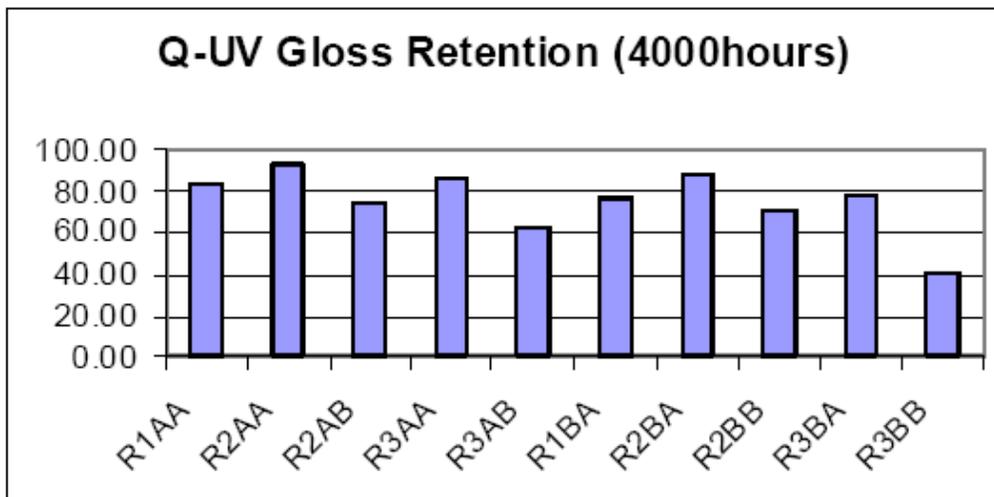


Figure 4.

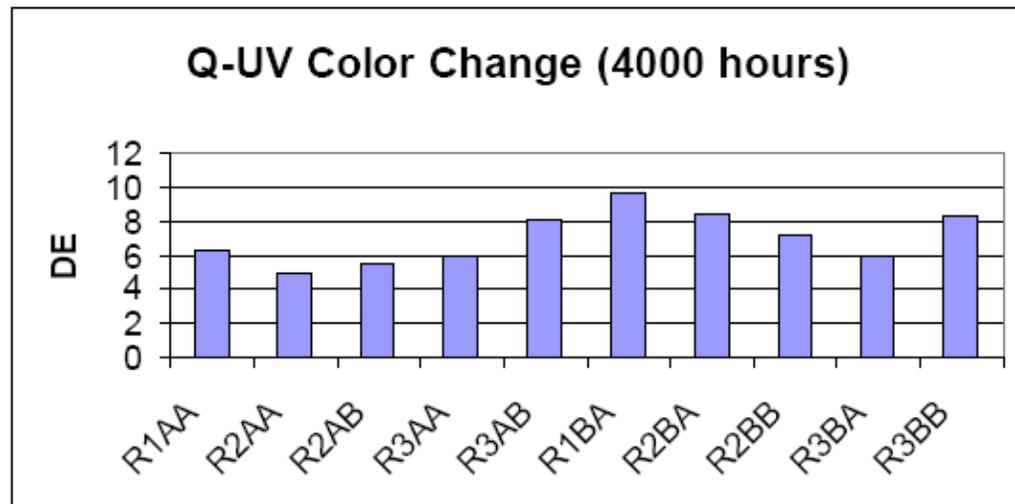


Figure 5.

		ASTM	Conventional 50% Polymer	MACT Compliant 60% Polymer	Improved Performance 60% Polymer
Flexural Strength	Psi	D-790	21,317	18,576	16,559
Flexural Modulus	x10 ⁶ psi	D-790	.55	0.49	0.46
Tensile Strength	Psi	D-638	12,078	10,859	9,293
Tensile Modulus	x10 ⁶ psi	D-638	0.52	0.48	0.45
Elongation	%	D-638	4.1	3.8	3.5
Heat Distortion	°C/°F	D-648	90/190	92/198	98/208
Barcol	934-1	D-2583	41	39	40

Resin catalyzed with 1.0% MEKP-9. Ultimately post-cured for 5 hours @ 100°C.

Figure 6.

Product	Blister	Color	Fibers	Cracks	Gloss
Conventional					
250	0	1	2	0	1
500	0	2	3	0	1
750	0	2	3	0	1
1000	2	3	3	0	2
1250	2	3	3	0	3
MACT Compliant					
250	0	1	1	0	1
500	0	1	2	0	1
750	0	1	2	0	1
1000	0	1	2.5	0	1
1250	0	1	3	0	2
Improved Performance					
250	0	1	0	0	1
500	0	1	1	0	1
750	0	1	0	0	1
1000	0	1	1	0	1
1250	0	1	1	0	1

Rating: 0-No Change ; 5-Fail

Figure 7.

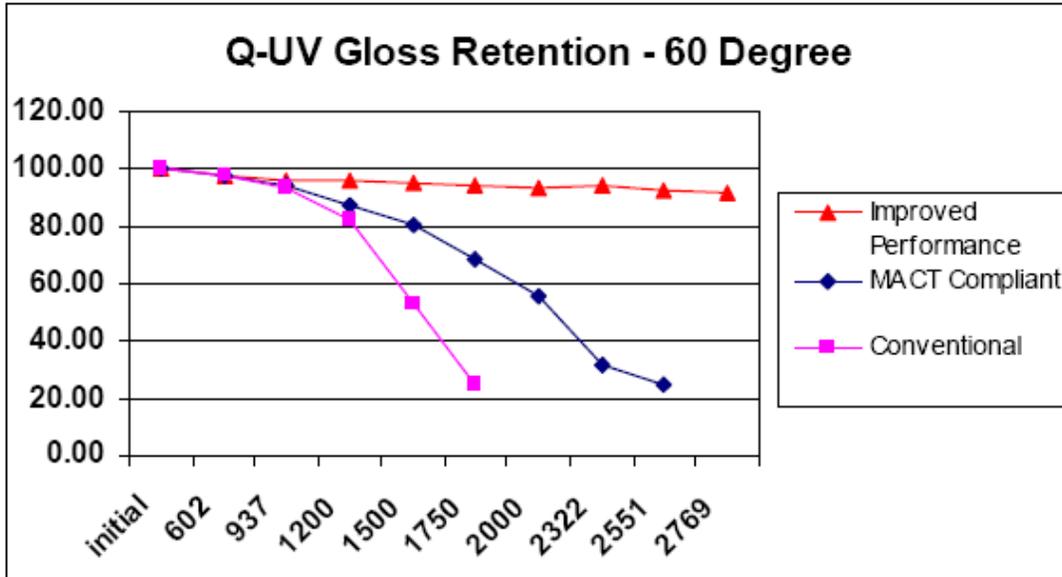


Figure 8.

