

Enhancing Gel Coat Longevity With Advanced Surface Chemistry Technology

by

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Introduction

The surface chemistry and physics of a material determine how the material interacts with the surrounding environment. Surface chemistry and surface topography (roughness) control whether a material is reactive or non-reactive, the level of surface energy, and the effects of environmental exposure. Reactivity and surface energy have a direct bearing on the performance of coatings in the course of environmental exposure. This paper will describe the effects of environmental exposure and surface treatments to enhance weathering performance of polyester gel coat and other surface coatings.

In dealing with the polymers which comprise polyester gel coat, the polymerization or molecular crosslinking interaction will have an effect on surface properties and exposure performance. If 100% polymerization was present in the gel coat film, uniform performance characteristics could be expected. However, in actual practice a crosslinking density of 94% to 96% would be indicative of normal production curing of these materials. Because of this, there are several component materials to be considered in the "world" of a gel coat film. The two chief components are the polyester polymer and styrene monomer, which is the crosslinking agent in the system. Both of these polymer components are subject to degradation through the effects of ultraviolet exposure and to a lesser extent are affected by reactive atmospheric compounds.

Gel Coat Degradation Mechanism

Outdoor exposure degradation of both polyester gel coat finishes and linear urethane paint finishes is characterized by embrittlement, color change and loss of gloss. Embrittlement and color change are the result of photo-initiation, which occurs during exposure to the ultraviolet wavelength band of natural sunlight. In the case of polyester gel coat, exposed surface molecular bonding sites and non-polymerized polyester or styrene components,

ultraviolet exposure.

Within the polymer matrix, carbon-carbon double bonds are subject to initiation by free radical attack. Within the mostly polymerized matrix, the addition of free radicals, through UV exposure, increases the surface hardness, while degrading the strength of the bond sites. The result is what is described as embrittlement. The same mechanism is responsible for UV initiated color change observed in gel coat film surfaces. Color change is primarily a result of reaction at the interface of pigment particles and the encapsulating base resin. In addition, color change is indicative of modification of surface chemistry.

The photo-oxidation mechanism is responsible for gloss degradation in the course of ultraviolet exposure. The loss of visible gloss is an effect of kinetic chain length propagation, which causes molecules to "sluff-off" polymer chains. The result is a reactive surface, where small polymer units undergo rapid photo-initiation.

Effects Of Surface Topography

The microscopic contour of the surface plays a role in resistance to UV induced surface reactions. The result of a rough (on a microscopic scale) surface is that more surface area is available for UV exposure. In addition the "peaks" or high spots of the topography may present areas only a limited number of molecules wide. These localized areas are subject to a higher rate of photo-oxidation than the "valleys". Presenting a smooth surface at the microscopic level reduces the rapidity of UV exposure degradation. Two methods of creating a "smooth" surface are available. Polishing uses fine abrasive to mechanically wear down high spots and create an averaging of topographical height excursions. The second method is found with the use of glazes. When properly applied a glaze will fill surface contours and harden into a new smoother topography at the approximate level of the average "peak contour".

Inter-Facial Phenomena - The Effects Of Surface Energy

The reactivity of a surface determines how it will interact with other materials. Chemically inert surfaces have less interaction with the environment and therefore degrade at a slower rate than reactive surfaces. Surface energy is related to the measure of chemical reactivity, in that materials with low surface energy tend to be non-reactive, while materials with high surface energy have active molecules available for interaction with other molecules.

Observing how a fluid, such as water, behaves on a surface is an indicator of reactivity. The angle at which a bead of fluid contacts the surface offers insight into the level of reactivity or available energy of a surface. Reactive surfaces interact with water and are readily wet, causing a sheeting effect of a flow stream. A droplet on a reactive surface will have a low contact angle (fig. 2). Non-reactive surfaces wet poorly and therefore have a high contact angle, creating a bead that meets the surface in an acute angle. Reactive surfaces are hydrophilic, as contrasted to hydrophobic characteristics observed with low energy surfaces. A reduction in surface energy is an advantage to reduce interaction with the

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are subject to the chemical changes which occur during

environment and more specifically ultraviolet exposure.

Non-reactive surfaces generally exhibit a low coefficient of friction. On a subjective basis, this may be noted by a slippery feel to the touch. These surfaces do not attract other molecules. On the other hand, a reactive surface tends to attract molecules passing over it, and may react with, or exhibit an affinity to another material. For example, a reactive surface might be like rolling a velcro ball across a velcro carpet. A non-reactive could be likened to rolling a bowling ball across an ice surface.

Reduced reactivity or surface energy can be provided by surface treatments, which create an inert state on the surface. A reduction in friction between the surface and air flow or liquid flow has been noted with surface treatments providing "inertness". The result is less force is required to move the surface through the medium.

Effects of Porosity

Polyester gel coat appears, under the microscopic, a very porous material. Porosity poses several problems that effect gel coat weathering performance. First, the wall of an individual pore increases the effective surface area in a localized area. There is also a relatively sharp edge at the intersection of the surface and the vertical wall of the pore. This sharp edge is subject to photo-initiation. Second, porosity tends to collect micro-debris. This could include general dirt, buffing compound, wax, oils etc. The reactivity of the debris filling the porosity is a potential problem. With a surface that would be otherwise inert, enough porosity plugged with reactive debris can lead to an overall increase in reactivity. The higher level of reactivity increases UV degradation as well as surface energy or friction.

Protecting Gel Coat Surfaces

There are several issues involved in promoting longevity of gel coat surface: 1) Minimizing the effects of UV radiation 2) Gloss retention 3) Reducing the surface energy level.

There are two distinct methods of dealing with the UV problem. First, is the use of an ablative coating, which erodes during the degradation process. Wax-based products are typical of ablative coatings. Carnauba or carnauba/silicone blend waxes provide protection from photo-oxidation, however are very limited in photo-initiation resistance. Photo-initiation protection with carnauba wax begins to drop off in about 50 hours of exposure, with a considerable loss of protection by the 250-hour exposure point. (fig. 3)

Carnauba based wax products will increase the average gel coat gloss approximately 3% as measured with a

BYK Gardner Micro Tri Glossmeter, using ASTM D-523 (fig. 1). The 3% increase in gloss level is noticeable by observation. Droplet contact angle measurements indicate an initial large reduction in surface energy, which is followed by a progressive increase in surface friction beginning after an average of 73 hours of exposure.

The second method of addressing ultraviolet attack is to employ a method of retaining UV resistant materials on the surface. This calls for an inert surface coating. The paradoxical problem is the lack of reactivity of inert films that produces longevity, also makes them difficult to bond to the substrate. There has been some work to formulate silicone/polymers to achieve this end. The inherent problem with silicone compounds is that they tend to migrate. Because they are difficult to bond, they tend to move to adjacent surfaces and into porous materials. In the case of polyester gel coat, silicone compounds can migrate into the gel coat film. This can cause serious problems with secondary bonding in the case of repair or refinishing. The effects of embrittlement and silicone migration have not been evaluated, but there is some speculation concerning this possibility.

Another approach is the use of polytetrafluoroethylene (PTFE) compounds or a fluoretelomere derivative. PTFE derivatives are slightly more reactive than silicones, but present the opportunity to bond a functionally inert material to a substrate. The chemistry of these compounds also allows the inclusion of photo-resistant stabilization additives. Proprietary chemistry employed in advanced photo-resistant coatings has allowed the self-sticking of inert polymers through a thin film intermediary, which presents a bonding interface. In addition, PTFE derivative compounds do not exhibit the propensity to migrate as with silicones. These compounds are not found to infuse the gel coat film and do not effect secondary bonding during repair or refinishing operations, assuming proper surface preparation routines are followed.

A thin film intermediary can enhance the bonding interface. The intermediary may also incorporate a thermoplastic additive, which seals surface porosity through a glazing function. The glazing action also smoothes the surface topography, thus reducing surface energy and increasing gloss level to a higher value than demonstrated by wax based products. The intermediary film application is followed by the application of the photo-resistant additive bearing inert surface film.

The proprietary chemistry of advanced photo-resistant coatings allows the inclusion of high levels of efficient light stabilizers and UV absorbers. The exceptional efficiency of hindered amine light stabilizers (HALS) in the proprietary polymer formulation provides a substantial reduction in the rate of photo-initiation. The addition of ultraviolet absorbers provides a synergistic effect, which is evident in an even greater reduction of photo-initiation degradation.

Conclusion

The application of a two-component process has the capability to address a number of problems that contribute to gel coat degradation. The use of an intermediary/sealant and an advanced photo-resistant barrier coat is an effective approach to increasing the longevity of polyester gel coat in the course of environmental exposure. In comparison to wax based products, this technology demonstrates; An increased resistance to ultraviolet induced changes in surface chemistry; A reduction in surface energy created by the inert film; And a higher level of

observed gloss. The combination of these factors will contribute to increasing the effective service life of polyester gel coat finishes during outdoor exposure.

The results of developmental testing indicate the feasibility of a commercial product, where high levels of UV protection and gloss enhancement are required. Initial application of this technology has been successfully demonstrated with products specifically formulated to protect gel coat and paint finishes on high performance sailplanes, which are subject to high levels of UV exposure. In addition to photo-effect resistance, the modification of surface chemistry and gloss enhancement characteristics of these formulations has proven to be an advantage, in the case of protecting composite sailplane finishes.

Biography

Robert R. Lacovara is Director of Technical Services for the Composites Fabricators Association, an international Association, representing over 750 member companies. He is a graduate of Glassboro State College and Drexel University, and is a senior member of the Society of Manufacturing Engineers (SME) and the Society for the Advancement of Materials and Process Engineering (SAMPE). Lacovara has held positions as General Manager of a corporation producing aircraft and transportation components, Operations Manager of a major marine manufacturer, and has served on the Delaware Valley College Board of Advisors. He is an author, frequent lecturer and has been in the composites industry for over twenty-five years. He maintains an industry wide international consultancy.