Feature

UV Technology for High-Performance Industrial Applications

By Ben Curatolo

Ultraviolet (UV) coating technology is widely used for decoration and protection in many different applications in a wide range of industries. The environmental benefits of UV technology are well documented for the reduction of emissions of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs).[1,2] Additional advantages include faster cure, improved process efficiency, source reduction and sustainability. The capabilities of UV coating technology have now been extended to the high-performance corrosion protection of steel and aluminum alloy surfaces in industrial and aerospace applications.

Corrosion is a tremendous problem and cost to society. About a decade ago, as part of the Transportation Equity Act for the 21st Century, the U.S. Congress mandated a comprehensive study to provide cost estimates and national strategies to minimize the impact of corrosion. The study was conducted by CC Technologies Laboratories, Inc. of Dublin, Ohio, with support from NACE International, The Corrosion Society, and the U.S. Federal Highway Administration. This study, titled "Corrosion Cost And Preventive Strategies in The United States," is the most comprehensive reference on the economic impact of corrosion—estimated at a staggering annual cost of $276 billion.

According to the study (reported to the Office of Infrastructure Research and Development), corrosion and metal wastage arising from oxidation as caused by exposure to the elements and reactivity between dissimilar materials costs many segments of the U.S. economy billions of dollars every year—including aircraft; motor vehicles; bridges; gas and liquid transmission pipelines; water and sewer systems; electrical utilities; ships; railroad cars; petroleum refining; pulp and paper processing; food processing; and home appliances.[3] The U.S. Government Accounting Office now reports that the annual cost of corrosion in the United States has grown to $400 billion.

Figure 1

Field application and cure of UV technology at cold temperatures

Table 1

Superior performance of UV technology for corrosion protection of steel

Corrosion resistance rankings for high-performance coating systems*				
Coating Layer Description	**Layer Wet Mils**	**Total Wet Mils**	**Total Dry Mils**	**Corrosion Resistance Ranking***
UV Topcoat UV Primer	2 2	4	4	1=Best
Epoxy	22	22	16	2
UV Coating	2	2	2	3
Urethane Epoxy	5 10	15	10	4
Epoxy	14	14	10	5
Urethane	10	10	6	6
Urethane	3	3	2	7=Worst

*Corrosion resistance ranking based on ASTM D 1654 ratings of scribed steel panels after 672 hours ASTM B 117 salt fog testing

Epoxy and polyurethane paints are the commercial materials that are typically used for high-performance, corrosion-resistant applications. Epoxy paints are used as primers and in applications where maintaining color and appearance are not as critical. Polyurethane paints are generally used as topcoats and in applications where color and appearance must be maintained. These paints can only be used in a relatively narrow temperature range and present many disadvantages, including corrosive or toxic components in two-part systems which must be mixed; and have a limited pot life with viscosity continually increasing until full cure. There is commonly an extended period of time before full cure is achieved, especially at low temperatures.

Pollution is a significant disadvantage of commercial high-performance paints for corrosion resistance since these materials typically contain solvents, VOCs, HAPs and, in many cases, chemicals on the Toxics Release Inventory. Urethane paints contain isocyanates, a significant health hazard, and many paints for corrosion-resistant applications contain chromium compounds that also represent a significant health hazard. Not only are polluting compounds and health hazards problematic for the use of these commercial paints, but performance of these systems is sometimes lacking with regard to corrosion resistance.

When epoxies are used as the complete paint system for corrosion resistance, performance disadvantages can include brittleness and poor weatherability with yellowing and changes in gloss when exposed to sunlight. When polyurethanes are used as the complete paint system for corrosion resistance, performance disadvantages can include poor adhesion to metal surfaces.

To avoid performance disadvantages of the two individual systems, these materials are often used in high-performance applications as multilayer systems—with epoxies as the primers containing corrosion inhibitors and providing adhesion to metal substrates; and urethanes as topcoats to provide appearance properties of color and gloss that are more stable to sunlight and weather.

By formulation with urethane acrylates and chromium-free corrosion inhibitors, high-performance corrosion protection has been demonstrated with solvent-free UV coating technology. For example, accelerated corrosion testing on steel has shown that superior corrosion resistance can be obtained with high-performance UV coatings as compared to conventional epoxy and urethane corrosion-resistant paints having much higher thicknesses. For example, 2 mils of UV-curable paint provides protection superior to that of 14 mils of epoxy, 10 mils of polyurethane, or 5 mils of a polyurethane topcoat over 10 mils of an epoxy primer. In addition, a UV-curable system of 2 mils UV topcoat over 2 mils UV primer provides superior corrosion protection to that of 22 mils of epoxy. UV cure is complete within seconds, and improved performance is obtained using 100% solids UV technology with significantly lower material usage and coating weight (Table 1).

Figure 2

Field application and cure of UV technology at warm temperatures

With improvements in the technology of portable handheld UV lamps, field application and cure of high-performance, corrosion-resistant UV coatings is now possible for even the largest of structures with a UV lamp passed over the surface slowly in the same manner as a surface is painted with a spray gun or roller.

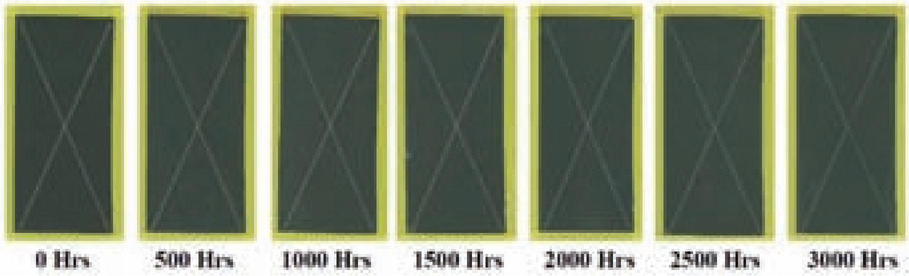
Just as any surface can be painted with only a few individuals spraypainting or rolling, a UV coating can be applied and cured on that same surface by only a few individuals applying paint and following with a UV lamp. An efficient process can be performed with one person applying paint and another following with a UV lamp—each with proper protective shielding as shown by the painter in Figure 1. Cure is achieved with a motion that can be described as "painting" the surface with the handheld UV light (passing the light over the surface slowly in the same manner as a surface is painted with a roller or spray gun) with the movement of the lamp taking approximately the same amount of time as applying paint to the surface. For large surfaces, multiple painters and multiple lights can be used.

When compared to drying of conventional paints, UV cure is relatively independent of temperature and humidity conditions. The field application and cure shown in Figure 1 occurred in very cold weather in Ohio in November, with a UV primer and UV topcoat each applied by roller at an ambient temperature of 34°F and each cured within 10 seconds per square foot of area with a portable UV lamp as shown. No conventional paint technology would have cured under those conditions, but the UV coatings cured completely with good performance. Good cure performance has also been demonstrated under typical ambient summertime conditions as shown in Figure 2.

Fast cure to complete final properties in a matter of seconds under a UV lamp represents a tremendous advantage in expanding the conditions in which it is possible to conduct painting operations for field-applied coatings. Cure-within-seconds provides many advantages, including time savings, improved efficiency and higher quality coatings due to the elimination of long cure periods when temperature, humidity or other factors could cause damage to uncured coatings. In addition to complete cure at low temperatures (which is currently impossible with conventional paints), it is also possible

FIGURE 3

Corrosion protection of 2024-T3 aluminum alloy in ASTM B-117 salt fog testing



to apply and cure UV coatings even when rain is expected soon afterward. This is especially advantageous at hot summertime locations where conditions are often ideal in the morning and rainy in the afternoon. With UV technology, after UV cure, the coating has full properties and will be unaffected by rain, unlike conventional materials.

In addition to improved corrosion protection of steel, recent work has also demonstrated the suitability of UV coating technology for high-performance corrosion protection of high-strength aluminum alloys for aerospace applications. For instance, environmentally friendly multifunctional UV (MUV)-curable pigmented coatings have been developed to replace both the strontium chromate epoxy primer and isocyanate-containing polyurethane topcoat for aerospace applications.[4] This high-performance MUV coating technology has satisfied major requirements of aerospace primer specification MIL-PRF-23377 and aerospace topcoat specification MIL-PRF-85285, including low-gloss camouflage appearance; good adhesion; hardness; solvent resistance to methyl ethyl ketone and Skydrol® hydraulic fluid; and excellent ASTM B-117 corrosion resistance, with the scribe lines of 2024-T3 aluminum alloy panels remaining shiny after 3,000 hours of salt fog testing (Figure 3). These high-performance properties are obtained with immediate cure using a high-intensity UV lamp and in the complete absence of any solvents, VOCs, HAPs, isocyanates, chromium compounds or any hazardous materials whatsoever. Similar properties are obtained using low-intensity, handheld UV lamps.

Conclusion

UV coating technology is suitable for high-performance industrial applications requiring corrosion resistance. When compared to commercial epoxy and polyurethane paints on steel surfaces, high-performance, solvent-free, UV-curable coatings provide improved protection with dramatically faster cure and much lower material usage. In addition, excellent cure is obtained with UV technology at temperatures too low for standard paint to be used. UV coatings also provide corrosion resistance for high-strength aluminum alloys used in aerospace applications. Clean and green UV technology not only improves efficiency in many manufacturing processes, but also addresses important societal issues such as the need to improve health aspects of high-performance coatings; reduce VOCs, HAPs and other pollution; and provide safer and more efficient alternatives for corrosion resistance in important markets representing major infrastructure of the United States, including vehicles, bridges, storage tanks and piping.

References

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