# Carbon Nanotube Infused Coatings

A new zinc primer nanocoating, developed through collaboration between the U.S. Army Engineer Research and Development Center Construction Engineering Research Laboratory (ERDC CERL) (Champaign, Illinois) and Tesla Nanocoatings, Inc. (North Canton, Ohio), uses carbon nanotube (CNT) technology to inhibit the corrosion of steel. The new hybrid coating technology combines superior physical performance properties as a barrier coating with a high degree of cathodic protection (CP) as a sacrificial coating. The resulting nanocoating primer provides the foundation for a coating system that can deliver corrosion protection to a multitude of steel or aluminum surfaces—everything from fuel storage tanks and bridges to aircraft and ships.

Formulated with fullerene carbon nanotubes (CNTs), the zinc primer is part of a complete two-coat system that produces corrosion protection comparable to traditional three-coat zinc-rich epoxy systems for steel and aluminum structures exposed to corrosive environments and subjected to damage from impact and abrasion. By incorporating the CNT-based nanotechnology in the coating formulation, the developers were able to overcome the limited adhesion, flexibility, and impact resistance that can be associated with traditional zinc-rich primer formulations while improving coating system performance and service life.

“The traditional coating system that the U.S. military relies on to protect its steel structures is generally one coat of an epoxy zinc-rich primer, an epoxy intermediate coat, and a urethane topcoat for ultraviolet protection,” says Susan Drozdz, a chemist with U.S. Army ERDC CERL and a NACE International-certified Level 3 Coating Inspector. “It is a good coating system, but here was an opportunity, with this nanocoating, to make that system better,” she comments.

CNTs generally are the stiffest and strongest material known, and these properties lend themselves to very useful applications in corrosion prevention and materials science, says Todd Hawkins, president and chief executive officer of Tesla Nanocoatings. During the curing process, the single-walled fullerene CNTs used in the coating binder self-assemble into rope structures and form a reinforcing network throughout the coating. This network of CNT ropes enhances the coating’s barrier properties by imparting the nanotubes’ stiffness and strength, which provide up to a 400% improvement in tensile and fatigue strength and increase impact and abrasion resistance. The CNT network also inhibits crack initiation and propagation, which prolongs the coating system’s service life as a barrier coating. “The idea with this coating is to create a tough, durable, almost plating-like barrier coating,” comments Hawkins.

In addition to their overall toughness, the fullerene CNTs used in the zinc nanocoating have a higher electrical conductivity than other grades of CNTs, Hawkins says. In the event that the coating barrier is breached or degraded, he notes, the zinc primer also functions as a sacrificial coating. The network of CNT ropes, along with conveying strength, also acts as a system of quantum wires that can pass electrons through the binder and between the substrate (which is cathodic) and the sacrificial zinc dust (which is anodic). Because the fullerene CNT material is conductive—the current carrying capacity of the CNT is 1,000 times greater than copper—a lower concentration of zinc dust (~50% less by weight as compared to a traditional zinc-rich epoxy) will facilitate the zinc particles remaining in electrical contact with each other and the steel substrate to provide sacrificial CP.

“A traditional zinc-rich epoxy primer is good for corrosion protection, but it takes a significant amount of zinc to provide the level of corrosion protection that is needed,” says Drozdz. Typically, cured organic zinc-rich primer coatings are 65 to 95% metallic zinc powder. The heavy zinc loading ensures that the zinc particles come into contact with each other and the bare steel substrate to create the electrical pathways necessary to achieve CP of the steel surface. When coatings are heavily loaded with metallic pigment, the reduced integrity of the coating film makes it brittle and susceptible to chipping and cracking.

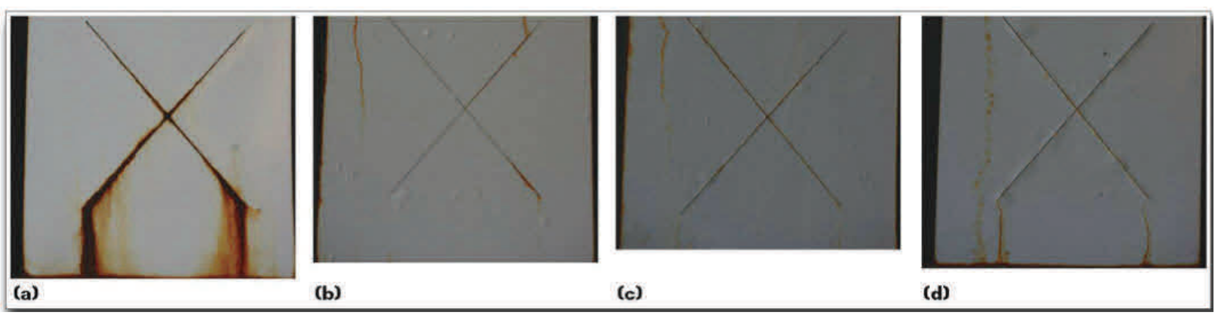
“What we have done with the nanocoating is reduced the amount of zinc loaded into the primer and still maintained the amount of corrosion protection we need through the addition of the carbon nanotubes,” Drozdz explains. By reducing the zinc dust loading in the primer, the coating’s solids level is optimized and more resin is available to bond to the substrate. The resulting balance between the amount of pigment and the amount of resin in the film improves the film’s integrity and facilitates optimization of its barrier properties (such as surface adhesion, flexibility, abrasion and impact resistance, and tensile and fatigue strength), which are further enhanced with the reinforcing CNT rope network.
The zinc primer nanocoating has good adhesion even when surface preparation is less than adequate, and the reduced film thickness and lower metal content decrease the overall weight of the coating system. Should a holiday develop, the reduced load of metallic zinc in the nanocoating still functions as a sacrificial anode and protects the bare area due to the conductivity of the CNTs. “We don’t have as much sacrificial material there,” says Hawkins, “but we have an amount that will extend the life of the coating if it is damaged.”

The CNT network improves porosity of the zinc primer as well. When a coating is heavily loaded with zinc dust, the interface between the zinc particles and the resin can form pathways for moisture and oxygen from the environment to move through the coating to the surface of the substrate.. When the amount of zinc is reduced, the result is an impermeable film with fewer pathways for moisture and oxygen to reach the steel. The zinc primer nanocoating is an epoxy polyamide resin system, although the CNT additive can be incorporated into a variety of binder systems. For some applications, the primer nanocoating is formulated with aluminum or magnesium pigments instead of zinc, which provide environmental benefits and additional weight reduction when needed.

According to Drozdz, project managers could see a 30% savings on application costs with a two-coat system that incorporates the zinc primer nanocoating. “By dropping one full coat and maintaining all the corrosion protection and other properties we need, we can see a tremendous savings in initial project costs,” she says, noting that the Army Corps of Engineers is continually seeking ways to effectively protect structures and facilities from corrosion while working with ever-tightening budgets.

The zinc primer nanocoating has undergone more than six years of testing, which include outdoor exposure and weathering tests, fresh water immersion tests, and salt water immersion tests. For the first field application of the zinc primer nanocoating, conducted in 2008 in a demonstration and validation project under the Department of Defense (DoD) Corrosion Prevention and Control Program, the primer was applied to a 200,000 gal (757,000 L) fuel storage tank at Fort Bragg, North Carolina (see photo) as part of a three-coat epoxy/polyurethane system. Results from subsequent monitoring showed no deterioration in the performance of the coating.

The technology innovation was recognized 2012 with a R&D 100 Award in 2011 and a U.S. Army ERDC Research and Development Achievement Award in 2012.




Coupons showing typical three-coat zinc-rich coating system (a) vs two-coat zinc primer nanocoating and three different topcoats (b, c, d) after 5,000 hr exposure in ASTM B117 salt spray (fog) test.