Improving the Performance and Application of HIGH SOLIDS PROTECTIVE COATINGS

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Environmental regulations continue to drive the development of coating technologies with low volatile organic compound (VOC) content. For many applications, the focus has been on waterborne alternatives, with coating systems available today that equal or outperform their older, solvent-based counterparts. Where protective coatings are required, however, waterborne formulations do not yet provide the level of performance needed, both in terms of application behavior and applied film properties. Instead, high solids systems have been the preferred method for meeting the regulatory requirements for lower VOCs. Even this approach presents challenges, though. Several developments in resin and additive technologies are, however, enabling the formulation of high solids protective coatings that have application and performance properties similar to conventional high-VOC systems.

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WHY NOT WATERBORNE?

Although most paint and coating manufacturers and resin and additive producers are working to identify solutions for the formulation of waterborne, high performance protective coatings, limitations of the technology remain that have not yet been overcome. "With the very high performance requirements needed for corrosion resistance, durability, chemical resistance, and dry time under widely varying global exterior application conditions, the use of waterborne coatings is still very limited in the protective coating and marine segment," says Jeffrey Arendt, a technical account coordinator with Arkema. Generally, notes Kiran Baikerikar, a senior R&D manager for Dow Coating Materials, high solids systems are preferred over alternative low-VOC technologies for applications requiring heavy duty performance (e.g., C4–C5 corrosion resistance or very high resistance to chemical immersion) or for applications in adverse environmental conditions (e.g., low temperature or high humidity). Specific examples for epoxy coatings include applications in marine coatings and tank linings for chemical and potable water tanks, while polyurethanes are used for heavy equipment and military applications.

High solids coatings are more tolerant of poor surface preparation and are used in original equipment manufacturing (OEM) and maintenance applications where this issue is a concern, according to Jeff Danneman, an advanced research associate with Reichhold. Ramesh Subramanian, R&D director for Nuplex Resins, adds that the ability to achieve thicker film builds is another advantage of high solids coatings over waterborne formulations. In addition, in the case of in-situ field applications, high solids protective coatings are more tolerant of variable weather conditions, particularly with temperature and humidity, and from an applicator point of view, the transition from solventborne to high solids coatings is much smaller than from solvent based to waterborne, notes Kees Van Der Kolk, global technology director for PPG Protective and Marine Coatings. "Also with respect to application, higher solids coatings enable fewer coats to reach the desired film build, thus facilitating increased productivity, efficiency, and labor savings," says Baikerikar. Furthermore, older paint application systems that are not constructed of stainless steel and do not have adequate temperature and humidity controls are also generally not suited for waterborne systems, but will accommodate high solids coatings, adds Michael Vecellio, North American OEM technology director with Axalta Coating Systems.

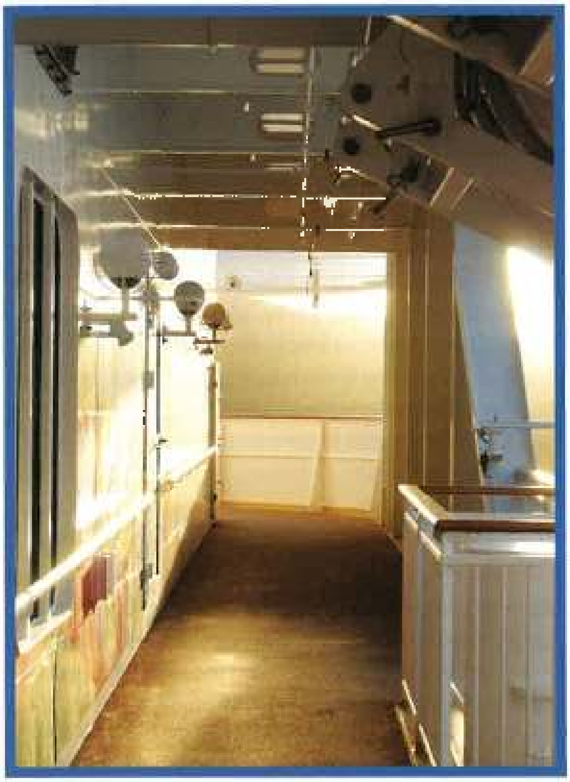
CHALLENGES WITH HIGH SOLIDS

Even though high solids formulations are preferred for many protective applications, the development of effective high performance systems does present numerous challenges to both raw material suppliers and coating manufacturers. "The main issues for high solids protective coatings are related to applying thicker films without sag, the humidity dependence of some high solids chemistries during both manufacturing and application, maintaining a simple component ratio for these typically two component systems, and managing the rheology of lower molecular weight resins," observes Subramanian. Many of these issues are related, and as a result, achieving low-VOC content through a high solids approach creates challenges in terms of viscosity and film build control, with the former affecting sag and the latter determining the curing properties, according to Danneman.

The main difference in high solids versus traditional solvent based coatings is the use of lower molecular weight resins in order to achieve a sprayable viscosity. "Systems based on less viscous resins lack the intrinsic rheology of conventional formulations, and thus there is little viscosity build following solvent evaporation, and resin crosslinking requires more time to build sufficient molecular weight to contribute to the rheology," Arendt explains. In addition, denser and heavier high solids coatings are more likely to suffer from sagging, running, and slumping, which is even more of an issue when applicators look to use fewer, higher build coats to achieve target specifications, he adds. Furthermore, high solids systems require the use of complex spray equipment due to the higher formulation viscosity, which presents challenges in sprayability, pumping, and handling of the formulation, particularly in colder environments, Baikerikar notes.

Formulators of two-pack reactive high solids coatings must also be aware of the issues raised by using higher reactive resin concentrations, according to Van Der Kolk. "A careful balance is required to maintain coating reactivity versus acceptable pot life, particularly for products that are meant to be used under tropical or low-temperature conditions," he notes. Van Der Kolk adds that a higher resin concentration also leads to denser crosslinked net works that may result in less flexibility and stress buildup when cured, which in turn may increase the susceptibility to micro-crack formation during the lifespan of the coatings, typically in areas with high thicknesses and at weld seams.

Incorporation of pigments into high solids formulations is yet another challenge. "It can be difficult to combine high volume solids with high pigment volume concentration (PVC) and still achieve



easy spray application and high performance," comments Baikerikar. In addition, metallic flake control to achieve the same final color position in high solids formulations as that observed for conventional solventborne systems requires significant expertise, according to Vecellio. He adds that high solids metallic coatings are also more susceptible to circulation degradation and can require special flakes to maintain color control.

There are also production challenges when manufacturing high solids coatings. "The removal of solvent and the need for higher levels of certain rheological additives can cause incorporation, gloss loss, and rheology modifier activation issues," he states. For example, the higher levels of fumed silica and organoclay often required can affect the gloss and increase the spray viscosity.

Also, organoclay activation requires polar activator solvents, which are limited in very high solids systems. Traditional polyamide rheology modifiers, meanwhile, require higher temperatures to activate in very high solids, low-solvent formulations and can require extra time to cool before packaging.

Simultaneously meeting varying VOC level requirements and the wide variety of expected performance levels around the world is another significant challenge when formulating high solids protective coatings, according to Beth Ann Pearson, global products manager for Metal & Plastics with Sherwin-Williams Product Finishes. "In addition, global coatings manufacturers must ensure compatibility with changing standards and regulations and different approaches to formulation and applications," she says. For example, she adds, North America relies heavily on the use of exempt solvents that have been classified as having no effect on the environment or VOC calculations when added to meet stringent VOC levels without sacrificing application quality or overall performance, as well as on the use of differing applications methods, including air-assisted airless spray, bell, electrostatic, and disk. "Adding to this complexity," she continues, "is the need for coating manufacturers to keep costs in check, particularly given that the use of exempt solvents often leads to cost increases."

RESIN AND ADDITIVE APPROACHES

Given that the use of low molecular weight resins and the consequent viscosity is a critical issue for high solids protective coatings, it is no surprise that significant effort has been invested in improving both resin and rheology control technologies. Curing agents (drier systems) and flexibilizers have also received attention, considering the problems that can arise with curing of thicker film builds.

Because the resins used in high solids coatings contribute less to the final application rheology profile, additives must now exhibit greater control and do so with minimal undesirable side effects, according to Arendt. Rheology modifiers for these systems must offer high efficiency and incorporate with greater ease," he notes. Research also continues in the area of reactive diluents to develop resins at lower viscosity levels, which could result in the advancement of solvent-based systems with lower VOCs and a lower demand for exempt solvents, thus improving efficiency, reducing cost, and advancing environmental attributes, according to Pearson. Van Der Kolk adds that stress buildup must be minimized by compatible resin flexibilizers and engineered curing agents, and for two-pack high solids epoxies, low-viscosity polyamine and polyamide curing agents can result in greater susceptibility of coatings to so-called surface amine blushing (reaction with CO_2 and H_2O). "To address this issue, chemical modification is required in order to prevent intercoat adhesion problems when multiple coats are to be applied," he says.

RECENT SOLUTIONS

With respect to additives, several rheology modification technologies have been developed to improve the performance of high solids protective coatings. Nuplex Resins, for example, has introduced dispersed urea crystals and surface-modified resin particles as new rheology modifiers for this application. Arkema, meanwhile, has developed organowax polyamide rheology modifiers that can activate in very high solids and solvent-free systems at easily achievable production temperatures. "Because it is not necessary to push these materials to unusually high incorporation temperatures, extra processing time is not needed for heat generation and post-production cooling, unlike conventional polyamide products," notes Arendt. He adds that each of the products—one for high solids and the other for 100% solids coatings—also

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offer sag performance robustness over a wider processing temperature window than previously possible. Arkema also offers pre-activated pastes that simplify the processing needed to incorporate polyamide powder rheology additives, as well as liquid additives for addition to high solids formulations with different polarities. Pearson also points to improved thixotropes that provide both improved rheology and coating stability.

Van Der Kolk also appreciates the wider availability of reactive diluents and resin flexibilizers, which is enabling more paint engineering flexibility and providing new opportunities to drive solid content to higher levels with even better long-term protective performance. Advanced nanotechnologies and the development polymers derived from renewable resources are also providing unique solutions to coatings development, according to Vecellio. "In addition, dual functional polymers and oligomer technologies have been under development and are beginning to make it into the market place that are enabling higher solids coatings that maintain desired film properties," Vecellio says. Nuplex, for example, offers castor-oil-based resins and is extending acrylic polyol technology—originally developed for the vehicle finish market for protective coating applications—that provides fast cure with a balanced pot life, according to Subramanian.

Dow has applied high throughput technology to significantly accelerate the synthesis, formulation, and application testing of high solids systems. As a result, the company has developed novel resin technologies that offer benefits in ease of application, lower VOC, and higher performance, according to Baikerikar. "In particular, our new developments in epoxy technologies have enabled high solids, high PVC coatings that can be applied with conventional spray equipment and demonstrate equivalent performance compared to traditional epoxy systems."

Advancements in anticorrosive pigment technology are also important for Sherwin-Williams. "Corrosion protection is no longer solely dependent on the resin system; anticorrosive pigments can increase the lifetime of a coating system, translating to cost savings for the end user," Pearson asserts. A focus on the implementation of compact process technologies is also allowing end users to coat effectively and quickly by making the coating process leaner in some way, such as through a faster cure time or the elimination of a coating layer, according to Pearson. She points to a new MIL-PRF-22750G Type III high solids epoxy recently introduced by Sherwin-Williams that can be applied direct-to-metal (DTM) as a single-coat application over zinc phosphate steel or treated aluminum.

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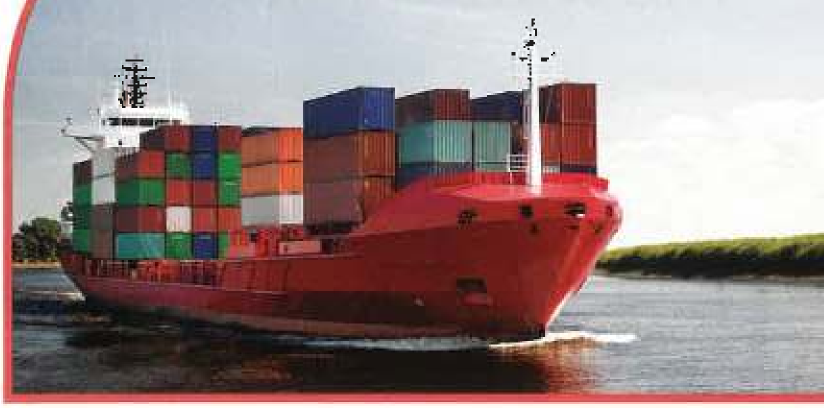

"It is important to keep in mind that, as with any type of coating, careful selection of the polymer, pigment, and additives is required to ensure that a high solids protective coating formulation meets the regulatory, performance, and applications requirements," Danneman states. Developing new, innovative protective coatings with higher solids content also requires more than paint engineering work, according to Van Der Kolk. "PPG invests in research that provides a better fundamental understanding of crosslinking, substrate adhesion, and failure mechanisms. With a greater understanding of the chemical and physical interactions of the various high solids materials and their substrate adhesion performance, more direction and guidance can be provided to determine further innovation routes for resins, resin flexibilizers, and curing agent technology, which in turn drives future higher-solids technology," he explains. The overall result, according to Van Der Kolk, is an improved ability to reduce VOC emissions while realizing equal or better performance from heavy duty coating systems.

"The industry is making real progress in developing new technologies to address performance requirements for demanding, high solids, industrial coating applications," agrees Baikerikar. "At Dow, for example," he continues, "we are developing approaches to further reduce VOCs and push the performance limits for durability, low temperature cure, and corrosion, thermal, and chemical resistance." Pearson also stresses that, while waterborne may be the up-and-coming technology, manufacturers such as Sherwin Williams are not abandoning current users of solvent-based high solids coatings who rely on suppliers for technological advancements. "End users who work with a manufacturer that is a leader in both waterborne and solvent-based technologies receive the most benefit," she concludes.