ROUNDTABLE Q&A ON WATERBORNE DTM COATINGS, PART 2

By Leo Procopio, Paintology Coatings Research LLC

In the July issue of *CoatingsTech*, we asked industry experts for their views on waterborne direct-to-metal (DTM) coatings. Topics included important trends driving their development efforts and recent products that they have introduced. They also discussed some of the key benefits and disadvantages of waterborne technologies for metal coatings, as well as some misconceptions about waterborne DTMs that exist in the market. They also shared opinions on some of the challenges remaining for this category of coatings, and they offered some advice for formulators attempting to create new waterborne DTM coating products. This is the second part of that discussion; the first part can be found in the July digital issue of *CoatingsTech* at *www.coatingstech-digital.org*.

Participants in the Q&A roundtable discussion include industry experts from several raw material suppliers involved in the production of a range materials used in waterborne DTM coatings, including resins, additives, and corrosion inhibitors.

The participants include:

- **Mark Langille, Ph.D.**—Customer applications specialist, Paints & Coatings, at ANGUS Chemical Company
- **Anthony Gichuhi, Ph.D.**—Paints & Coatings R&D director at ICL Phosphate Specialty
- **Sudhir Ananthachar**—Technical manager (Coatings) Crosslinkers BL at Evonik Corporation
- **Andrew Thorn**—Industry manager for Coatings at Heubach Group
- **Joey Ruiz, Ph.D.**—Principal scientist at Solvay
- **Claire Reynier**—Global marketing manager for Industrial Coatings at Arkema
- **Ivan Tyre**—Senior applications chemist at Alberdingk Boley
- **Gregory Monaghan**—Applications manager at Specialty Polymers
- **Chris LeFever**—R&D Technical manager at Engineered Polymer Solutions (EPS)
- **Chuck Jones, Ph.D.**—Technical manager, Resins for Industrial Coatings at BASF
- **Ronald Brashear**—Marine and Protective Coatings End-Use manager, North America, at BYK USA Inc.
- **Kiran Baikerikar, Ph.D.**—Associate R&D director for Industrial Coatings at Dow
- **Matthew Padaon**—Lead technical specialist for Industrial Coatings at Dow

What do you see as some of the remaining challenges in the development and use of waterborne DTM coatings? Are there particular properties that need to be addressed?

Gichuhi (ICL): One of the biggest challenges with these coatings is poor adhesion to cold-rolled steel. If adhesion can be improved, this is half the battle. Waterborne DTMs lag behind the traditional 2- or 3-coat system when it comes to corrosion resistance and weathering. Adhesion remains challenging on bare steel. Very high-gloss DTMs often perform poorly compared to their matte or flat counterparts because the addition of inhibitive pigments to these high-gloss coatings detracts from the gloss and so may not be used. Liquid corrosion inhibitors are favored over pigments because of their negligible impact on gloss. However, their performance trails that of most traditional anticorrosive pigments. Reducing the water permeability or absorption of DTMs is critical to achieving the targeted corrosion resistance. Often self-crosslinking coatings show better corrosion resistance than the standard 1K acrylics. Polyurethane dispersions (PUDs) have bridged some of the performance gaps of waterborne DTMs, but their performance still falls far short of C4 or C5 corrosion categories.

"Another challenge that needs to be addressed in waterborne DTM coatings is adhesion to a broad spectrum of metals as well as metals of different qualities."

–Chris LeFever, EPS

In case you missed it, see **Roundtable Q&A, Part 1** in the July issue.

Jones (BASF): One challenge is developing more sustainable technologies with equal or better performance. For example, the market is driving towards lower VOC levels and eliminating chemistries that are harmful to applicators and/or the environment.

Brashear (BYK): In the eyes of some, waterborne DTMs suffer from the inadequate performance of their predecessors when compared to solventborne options at that time. While true back then, it does not apply with modern systems. As the industry becomes younger there are fewer individuals who hold this misconception and waterborne DTMs are being investigated as truly viable options in the industrial and DIY market segments. Low-temperature and high-humidity application continue to pose problems, and I am not aware of any recent developments that have addressed either issue.

Baikerikar (Dow): Honestly, the greatest challenge remains the perception that waterborne DTM coatings are inferior to their solventborne counterparts, although we have made great strides to overcome this bias via demonstration of real-world performance. As more and more waterborne products are launched and proven in the field, the industry will become even more comfortable and proactive in transitioning to waterborne DTM coatings due to their multiple benefits.

A number of the remaining challenges for waterborne DTM coatings are no different than the challenges faced by incumbent coatings technologies, although waterborne systems can be more sensitive to them. For example, the development of waterborne materials that demonstrate consistent performance and drying behavior across extremes in environmental conditions during the application process remains a challenge. Another challenge is demonstrating robust performance, adhesion, and wetting on poorly prepared metal surfaces that may contain contamination from cutting oils, previous paint layers, or rust.

Ananthachar (Evonik): Higher solids is difficult to achieve with waterborne DTM coatings. Another challenge for waterborne DTM coatings is chemical resistance, especially in immersion service, which is not as good as high solids and solventborne systems.

LeFever (EPS): Generally, waterborne DTM coatings cannot be applied at low temperatures and need a greater amount of energy to properly cure. This is due in large part to the energy required to drive water out of the system, in contrast to conventional solvents. Another challenge is the process of implementation of waterborne coatings in manufacturing. Doing so requires significant investment, as waterborne resins are typically not used in the grind stage. Not having a grind stable polymer then requires an independent pigment stabilization process. This means that a dedicated vessel for grinding and milling operations is likely needed. Another challenge that needs to be addressed in waterborne DTM coatings is adhesion to a broad spectrum of metals as well as metals of different qualities. These include metals with residual processing oils where solventborne coatings have historically been used without issue.

Thorn (Heubach): I believe improvements can definitely be made in the area of waterborne DTM industrial maintenance coatings. Some of the latest waterborne resins designed for improved performance (color development, corrosion resistance, etc.) require very specific additives for optimal performance. By creating additives and anticorrosives with a very broad formulating latitude, we are giving formulators a higher chance of success when optimizing their systems.

Ruiz (Solvay): Drying time, adhesion to some difficult-to-adhere-to metal substrates, and costs resulting from additional functional groups added to the resins remain as challenges for converting all the solventborne systems to their waterborne counterparts. It is important to note that cost-in-use needs to be carefully balanced with the performance of the final coating applications as the end-user may not be willing to pay a premium for this conversion. However, with increasingly stricter regulations, end-users may not have many options available. DTMs are also branching out toward applications that require more stringent performance, such as reaching more than 250 hours of salt-spray testing and good adhesion in order to replace epoxy/hybrid systems.

Langille (Angus): Recent developments in resin chemistries have targeted improvements to critical properties such as adhesion and corrosion resistance, but aesthetic requirements are also important. The final film surface needs to be flawless and defect-free, which can be a challenge when many of the additives that help create defect-free films, such as surfactants, defoamers, and flash-rust additives, can negatively contribute to protective properties if used at too high a level. The development of new resin chemistries needs to be matched with the correct selection of additives to create DTM formulations that meet all the required performance needs.

Monaghan (Specialty Polymers): The driver behind the push to higher performance is the desire for corrosion resistance at lower film thicknesses, giving the industrial applicator equal performance at lower cost. To accomplish this, it is important to consider new technologies that don't involve a compromise in some other property. These new technology polymers must not be significantly more expensive, however, or the cost advantage from the thinner film is lost.

Tyre (Alberdingk Boley): As market trends move toward lower and lower VOC content, many of the binders available to the market have issues with block resistance, hardness, and in some cases oil resistance. Designing the polymer with a multiphase morphology can certainly enhance performance, but there is a balance for optimal properties considering the ratio of soft-to-hard phases in the polymer. Other properties such as exterior durability are also needed—specifically, creating durable films with very good gloss retention and low dirt-pickup resistance. Additives have a critical role in formulations as well in helping to achieve excellent performance.

Reynier (Arkema): In an industry that demands higher performance metal coatings with fewer coats at a lower VOC, obstacles must be overcome to ensure that performance is not sacrificed. Waterborne DTM binder technology has faced issues with gloss, adhesion, block and corrosion resistance compared to high-VOC solventborne or multicoat systems. Recent developments in waterborne acrylic binder technology have displaced the idea that performance expectations must be lowered when transitioning to waterborne systems.

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–Joey Ruiz, Ph.D., Solvay

What advice would you give to a formulator who is looking to develop a new waterborne DTM coating and trying to optimize corrosion resistance?

Thorn (Heubach): First, choose a resin that is suitable for the metal it is being applied to, and check that the resin does not have any adverse effects with the chosen anticorrosive/anticorrosive complex. Beyond that, I would stress the importance of balancing the water solubility of the anticorrosive or anticorrosive complex with the PVC of the coating. Not all anticorrosives are created equal! Anticorrosives can vary in quality and consistency between lots, depending on the manufacturer. Physical properties, such as water solubility, pH, mean particle size, and particle size distribution all vary. Zinc ions (Zn^{+2}) can potentially flocculate other pigments and destabilize waterborne polymers. Additives such as surfactants and dispersants can detract from corrosion resistance if not chosen wisely.

Baikerikar (Dow): Careful raw material selection is key when formulating for high performance. For waterborne acrylic DTM coatings, the polymer selected will have a major influence on barrier properties of the film, and it is important to keep in mind that not all polymers are optimized for metal protection. Alongside the polymer, additives such as defoamers, dispersants, surfactants, and rheology modifiers can also affect corrosion resistance in two ways—these materials facilitate properties such as coating stability and wetting of target substrates, but their inherent water sensitivity can decrease corrosion resistance when used in excess. When developing formulations, formulators should consider the chemistry of the raw materials as well as their use level. Also, rigorous testing must be performed in conditions that best simulate real-world conditions as film formation can be influenced by the environmental conditions an applicator may encounter.

Ananthachar (Evonik): Formulators must thoroughly understand the environment in which the coating will be used, for example, interior/dry, exterior normally dry, frequently wet by saltwater, chemical exposure, etc. Once formulators understand the application environment, they can then dial in the barrier properties that the coating needs to provide and select the appropriate coating chemistry and corrosion inhibitor package. Formulators must also make use of tools like EIS (electrochemical impedance spectroscopy) for early screening of barrier properties, followed by accelerated corrosion testing in the lab. If time permits, the formulator must try to correlate the laboratory test results with field test results. I would highly recommend also conducting voice-of-customer exercises to completely understand the technical requirements.

Ruiz (Solvay): Choosing the right binder system will simplify the design of the coating formulation, as it is possible to provide all the right performance properties without the inclusion of too many additives, which may in turn hurt the final paint performance.

Langille (Angus): Always keep in mind your selection of additives, including dispersants, surfactants, rheology modifiers, pH control additives, and flash-rust inhibitors. Although only used at low levels, additives can greatly enhance or inhibit many performance properties. A poor choice of additives can mask the performance of an otherwise well-performing resin system while the right choice of additives can dramatically enhance a multitude of performance properties, including critical protective properties such as weatherability and corrosion resistance.

Monaghan (Specialty Polymers): Starting with a high-performing polymer is critical, but it is easy to compromise corrosion resistance through incorrect formulation strategies. It is often more important to follow polymer manufacturers' guidelines than to just plug a polymer into an existing formulation to compare performance. Often the polymer manufacturer has screened formulation modifications, so one should not assume that making changes such as increasing levels of anticorrosive additives will provide improved corrosion resistance. It is also important that initial screening tests be done in a formulation or coatings system similar to what will be used in the field. A good example is in primer-plus-topcoat coating systems, where the primer and topcoat work together to give good corrosion resistance, and corrosion tests of the primer alone can be misleading.

Reynier (Arkema): Generally, coatings must acquire a certain degree of surface leveling in order to have an acceptable surface appearance. Therefore, a rheology modifier that displays good thixotropic properties helps to achieve the best compromise between sag resistance and leveling. This is an essential feature for direct-to-metal coatings that must be thick to protect the substrate and have an initial aesthetically pleasing film appearance, as it will not be covered by a topcoat.

Jones (BASF): Begin with the recommended starting point formulation from the supplier, then develop the formulation from there. If a resin is not formulated correctly, its corrosion resistance capabilities might not be realized. I also recommend using different test standards in addition to ASTM B117.

Tyre (Alberdingk Boley): The first key choice is selection of a binder that has inherent corrosion resistance and hydrophobicity without the need for anticorrosive additives. Such a binder provides a water impermeable film, eliminating one of the contributing factors to forming the electrochemical cell that causes corrosion. The adage "less is more" then becomes the formulator's mantra with selection of the proper type (usually hydrophobic) and level of coalescent, along with effective wetting and dispersing agents known for reduced water sensitivity. Ideally, it is best to formulate below 25% PVC as higher loading of pigments can create voids in the film, allowing for water penetration. In these cases, the use of anticorrosive additives may enhance the coating, for which a screening process must be completed to balance performance with long-term stability.

Gichuhi (ICL): The best advice is to evaluate finer particle size anticorrosion pigments in combination with liquid organic corrosion inhibitors. The organic inhibitors can provide the early corrosion performance (50–200 hours of salt spray), while the less-soluble inhibitive pigments can provide longer-term corrosion protection. Substrate preparation is key to achieving high performance with waterborne DTM coatings. Zinc phosphatized steel will give better corrosion resistance than iron phosphatized steel, which is better than bare steel. Similarly, galvanized steel will perform better than bare cold-rolled steel. A combination of zinc-based and non-zinc-based corrosion inhibitors will often outperform the non-zinc systems alone. If the coating is very high gloss (> 90 at 60°), liquid corrosion inhibitors will be your best bet, and a ladder study can help dial in the optimal dosage.

LeFever (EPS): Formulating waterborne products is different from formulating solventborne coatings, as you are going from a solution polymer to a colloidal system. The waterborne system is going to be more sensitive to the formulation and, in general, more complicated. The order-of-addition and allowing proper mixing and incorporation of components is more critical in waterborne compared to solventborne systems. A formulator needs to pay special attention to rheology, as solventborne systems tend to be more Newtonian in nature and waterborne systems are pseudoplastic. There are also more ways to form grit in a coating due to the formulating and processing steps required. Steps where grit can be formed in waterborne formulations include solvent shock from the cosolvent, pH shock, flocculation, and defoamer compatibility, just to name a few.

Roundtable Q&A on Waterborne DTM Coatings, Part 2

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–Ivan Tyre, Alberdingk Boley

Brashear (BYK): When developing a system to optimize corrosion resistance, the formulator must do their due diligence and pay the utmost importance to the selection of the binder, as this is the primary contributor to the coating's anticorrosive performance. Every other raw material selected should be done in an effort to support that binder's performance or in the very least minimize any negative impacts.

Optimized system performance must be the goal. As an example, it may not be ideal to select a wetting and dispersing additive that displays the best mill-base viscosity reduction or has the best color development as this may be too hydrophilic in the cured film and have a negative impact on corrosion resistance. The same principle would be true for the other additive classes such as rheology modifiers, surface additives, and defoamers. Additives selection can have a significant impact on anticorrosive performance, and they may be able to make marginal systems better, but additives cannot "cover up" bad binder selections.

Are there any common misunderstandings or misperceptions about waterborne DTM coatings that you would like to address?

LeFever (EPS): There's a common misperception that waterborne coatings always offer inferior performance when compared to solventborne coatings. Individuals who are used to applying solventborne industrial coatings think that waterborne coatings won't offer sufficient levels of corrosion resistance or provide high gloss and gloss retention. However, there are waterborne acrylics that perform very well in industrial applications. For example, coatings formulated using EPS® 2540 have excellent initial gloss with a high depth of image that is comparable to coatings formulated using solventborne alkyd resins.

Monaghan (Specialty Polymers): There is a perhaps a misperception that since commercial emulsion polymerization processes are close to 80 years old, it is not possible to invent anything new, and everything that can be tried has already been tried. This is certainly not the case, with new technologies pushing the boundaries of what is possible in waterborne DTM paints. For example, the novel epoxy styrene acrylic hybrid chemistry used in RAYKOTE® 2020 can provide good corrosion resistance and adhesion, even on lightly rusted metal or panels contaminated with oily cutting fluids.

Brashear (BYK): The misconception that waterborne systems will never be as good as solventborne systems is beginning to fade. In my opinion, this only applies for true heavy duty/marine applications or in extreme service environments. For most DIY and light industrial applications, waterborne DTM coatings are now offering equal levels of performance to their solventborne brethren, while also providing enhanced regulatory compliance, applicator safety, and economically viable options.

Tyre (Alberdingk Boley): Many formulators have the misperception that waterborne technologies are not as high-performing as solventborne systems, but recent advances in waterborne epoxy and styrene acrylic binders have closed the performance gap. Products are available that have a good balance of properties, are economical and meet regulatory standards. While waterborne coatings require a different way of formulating, complexities can be managed to deliver many of the same benefits as solventborne.

Padaon (Dow): Waterborne industrial coatings have been successfully used for decades and have slowly but consistently been gaining market share compared to traditional solventborne systems. The perception that waterborne technology represents a lower performance technology versus solventborne systems persists but has slowly been eroding away for many years. Recognition of their unique environmental, health, and safety profile, as well as their excellent real-world performance, has helped to drive this transition away from high-VOC solventborne coatings. The perception that waterborne industrial coatings exhibit lower performance often persists with end-users who are used to using solventborne coatings. Waterborne technologies are different and may require some adjustments, such as in drying conditions, to ensure equivalent performance. Of course, there are many examples and lots of data to prove that waterborne systems can perform well in numerous applications.

Gichuhi (ICL): A common misconception is the more anticorrosive pigment used, the better the corrosion resistance. There is a fine balance between the optimal pigment loading and coating performance. Another misconception is that no anticorrosive pigments can be used in very high-gloss coatings. The truth of the matter is that jet-milled pigments can be used at a 40–50% dosage of the standard-size pigments and maintain good gloss. It is important to pay attention to the oil absorption of the pigments. The idea that a good anticorrosive pigment can overcome the weaknesses of the binder is not correct. The binders need to be designed for anticorrosion purposes. They should have good film formation and be compatible with various pigments and additives. Well-adhering binders with superior water resistance and humidity resistance (osmotic blistering resistance) will perform better than vice versa. Lastly, avoid adding excess flash-rust inhibitors because this will increase the water sensitivity of the coating.

Langille (Angus): Waterborne resin technologies have improved greatly over the years and so has our understanding of how to bring out their best performance through the proper selection of additives. With the right combination of resin and additive package, waterborne DTM coatings based on today's technologies and best practice formulation strategies have truly raised the bar for performance and are well-positioned to replace many solventborne systems with less hazardous and more sustainable solutions.

Ruiz (Solvay): First, the definition of waterborne DTM is often misinterpreted. It can be defined as a 1-coat system or a 2-coat system. However, this difference may not be of any consequence for the end-user. Ultimately, the most important factor is the balance between the cost in use and the performance of the coating.

Ananthachar (Evonik): The general misperception in the industry is that waterborne DTMs do not provide good corrosion resistance, or that the technology is not suitable for corrosive environments beyond C2-C3 (ISO 12944). The recent advances in waterborne epoxy curing agent ANQUAMINE® 469 has enabled successful conversion of solventborne container coatings to waterborne technology, and Evonik's waterborne HYBRIDUR® technology is enabling conversion of solventborne topcoats into durable waterborne systems in multiple applications. The close monitoring of EH&S issues associated with coatings spray application by state and regional authorities will further spur advances in waterborne technologies.

Thorn (Heubach): Most notably, the perception is that waterborne DTM coatings cannot meet the same performance level of their solventborne counterparts. Waterborne resin technology, as well as additives for these resins, have greatly advanced during the past decade. If these additives are chosen wisely, the same or better performance can be obtained compared to solventborne systems. ❊

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