Cost and Environmental Concerns

Lead to NEW Auto Coatings Technology

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The automotive industry is, not surprisingly, very concerned with cost. Like most other industries, it also faces increasing environmental regulations. At the same time, vehicle manufacturers must continually meet the demands of consumers for improved performance. These difficult market conditions have led coatings producers to search for opportunities to improve technology—not only in their coatings formulations, but also in all aspects of the coating process—for both automotive OEM and refinish applications.

Today, when cost reduction is mentioned in the automotive industry, more and more people consider a holistic approach and evaluate entire systems, including design, material selection, and processing/application techniques. Coatings are not exempt from this evaluation.

"The economy is driving the automotive industry," states Professor Jamil Baghdachi, coordinator of the Polymers and Coatings Graduate Program at Eastern Michigan State University. "Coatings companies are under tremendous pressure to reduce cost. At the same time, consumers are more sophisticated and have higher expectations for the appearance and durability of their cars. Environmental hurdles must also be overcome. Paint manufacturers therefore must look at how both the formulation itself and the application process can affect the quality of the paint job."

For car manufacturers, painting is an additional step in the production process that they would avoid if possible. "Ideally, we wouldn't paint at all if we didn't have to," says Kathy Minnich, North American manager for Materials Engineering & Testing at Ford Motor Company. Until mold-in-color technology can produce cost-effective parts with a high gloss, metallic look, however, paint remains a necessity.

Above photo courtesy of DuPont.

Paint producers must work to convince car manufacturers that the paint application process, when considered by itself, is a very cost-effective system. "To overcome the perception of automakers and suppliers that most coating processes are expensive, coating manufacturers need to undertake more R&D activities for better penetration of technologies in the industry," says Frost & Sullivan research analyst A. Sumithra. "With automakers pressuring coating suppliers to provide high quality products at the lowest possible cost, there is an increasing interest in coatings technologies that are cost-effective while simultaneously offering better performance," he adds.

The automotive industry, however, is very conservative, and even significant advances in technology take several years to commercialize. Extensive testing is first required, and even then many technologies are slow to be adopted due to the economic uncertainties associated with introducing new features.

Nonetheless, working in close relationship with their customers, automotive coatings manufacturers are tackling new resin and additive technologies, and methods for managing color harmony. They are also working with applications equipment companies to develop more effective automated methods for getting paint onto the vehicles.

The number of coatings companies receiving recognition as part of the 2007 PACE Awards is a testament to the commitment of paint producers to develop advances in technology. The recipients of the 13th annual Premier Automotive Suppliers' Contribution to Excellence (PACE) awards, presented by Microsoft, SAP, Transportation Research Center Inc. (TRC Inc.), and *Automotive News*, were determined by a group of independent judges to be leaders in superior innovation, technological advancement, and business performance.

DuPont Automotive Coatings won a 2007 PACE Award for its new EcoConcept finishing system. Volkswagen AG, who worked closely with DuPont to develop and commercialize the new process, was honored with a PACE Collaborator Award, highlighting the importance of the strong relationship established between the two companies.

"The EcoConcept finishing system combines two coating steps into one waterborne basecoat, so the automobile manufacturer can eliminate an entire spray booth and its associated drying equipment," says Marty McQuade, vice president and general manager, DuPont Automotive Systems. According to the company, the benefits of the system include lower emissions of greenhouse gases due to reduced solvent use, lower energy consumption, and higher productivity. The consolidation of the auto assembly paint line can result in up to a 30% overall savings. Volkswagen has implemented the EcoConcept system at its Puebla, Mexico, and Pamplona, Spain, plants, and is considering its use for a paint shop that is to begin operations in Russia in 2008.

DuPont was also the first company to introduce a wet-on-wet painting system that eliminates a baking cycle, reducing process time and energy consumption. The innovative primer and basecoat system allows two-color painting with just one pass through the paint shop. The process was developed through a cooperative effort between DuPont, Ford's Truck Plant in Kentucky, and Ford Global Vehicle Operations in Dearborn, MI. This cooperation enabled the technology to be developed and implemented within 18 months. In 2003, Ford was able to make an additional 39,000 two-tone super-duty pickups as a direct result of the new technology.

The process involves a wet accent color basecoat applied over a wet primer. The vehicle enters the initial primer bake with one color already in place. The second (main) basecoat and a clearcoat are applied in the normal manner, with only limited masking and demasking. With this process, the finished product has a higher intrinsic quality and fewer defects than with previous two-tone processes, yet DuPont process this requires less labor and less paint. DuPont won a PACE Award for this innovation in 2004.

On the environmental front, DuPont has developed SuperSolids technology, yet this DuPont process requires less labor, enabling the development of 90% solids formulations for protective clearcoats that reduce VOC emissions and improve scratch and mar resistance. This technology won the U.S. Environmental Protection Agency (EPA) Clean Air Excellence Award.

Currently the company is developing experimental formulations for easy clean finishes using DuPont Teflon® and glow-in-the-dark colors, among others. "Our goal at DuPont is to develop technology that will make it possible for automobile manufacturers to meet or exceed environmental sustainability mandates, improve business productivity goals, and respond quickly to changing consumer tastes," notes McQuade. The end result is more durable colors and special effects that can differentiate a vehicle for the manufacturers.

PPG was named a finalist for the 2007 PACE Awards for its Air Dry Waterborne Adhesion Promoter, which is being commercialized in North America on plastic fascias. The product combines the benefits of zero hazardous air pollutants, ultra-low VOCs, and superior physical properties in an adhesion promoter that does not require baking prior to topcoat application, according to the company. In addition to exceeding the requirements of upcoming Maximum Achievable Control Technology legislation, the product helps improve

process efficiency by eliminating the need for promoter baking, resulting in both reduced overall topcoat usage and reduced waste and paint sludge. In addition, it provides more robust fuel resistance for topcoated parts, as well as improved high-pressure car wash adhesion.

BASF Coatings received a PACE Honorable Mention award for its Power Fill UV Primer. When used as a sealer, the product eliminates a complete step (the adhesion promoter or etching primer) due to its powerful, direct adhesion to many substrates, according to the company. Because it is a urethane-based coating, however, it still offers fast-drying, easy sanding characteristics.

More recently, BASF introduced its Integrated Process II coating system that is centered on specially formulated basecoats that combine all the functions of a primer, such as stone chip protection and ultraviolet resistance. According to the company, the new system meets the requirements for automotive finishes with regard to appearance and functionality, while shortening the coating process through elimination of the primer application section and oven, which can then be used to increase capacity. "Overall, the result is reduced investment and operating costs, material and energy savings, improved productivity, and increased eco-efficiency," explains project manager Dr. Wolfgang Duschek.

In this new system, there is no primer, but two waterborne basecoats that are color matched. The initial basecoat serves to absorb UV radiation. A second basecoat is then applied. Together, the overall paint finish is as durable as what is obtained with traditional primer technology, states BASF. Existing equipment can be used. Only a second paint supply system is required. Elimination of the primer application section of the coating line includes the cleaning, sanding, dust extraction, water treatment, waste disposal, and pre- and post-treatment operations as well as the coating application itself. The coating conveyor line can be shortened as much as 17%, according to the company.

BMW Group has integrated the BASF system into its MINI production line at its Oxford, UK, plant. The two companies cooperated extensively to make this project a successful effort. In the primer application area that was no longer needed, BMW installed a second basecoat/clearcoat line with the goal of increasing production from 200,000 vehicles to 240,000 vehicles per year.

In a separate project, BASF has been developing coatings for the "BioConcept Car," a sustainability project to develop a racing car made largely out of biogenic materials. The company is responsible for developing the optimal coating solution for these new materials. "BASF is using the project to demonstrate that it is possible to coat a wide range of materials with a sustainable and eco-efficient paint concept and environmentally friendly coating technology," says Thorsten Schlatmann, head of R-M Distribution Germany for the company.

The actual task entailed developing coatings for the BioConcept Car's doors, fenders, bumper, hood, and hatch, which are made of biofibers impregnated with a liquid bioplastic. The coatings have to perform well in the extremely dirty environment of a race track, plus meet the expectations of the media and make a positive impact on the public. In addition, the colors on the sponsors' advertising decals had to be precisely matched.

BASF's tailored solution was to use its R-M waterborne paints, specifically the ONYX HD line, and its COLORMASTER 2 color matching system to find the right color for the basecoat. The company's high solids, very low-VOC STARLUX CP product provided the necessary performance for the clearcoat. Flexibility in the mixing and application process was important as well. "The primary challenge was developing the correct paint system for an unusual substrate," Schlatmann notes. "We developed an individual solution for the special demands posed by biogenic materials."

The main idea behind participation in the BioConcept Car project for BASF was to demonstrate the company's commitment to developing technologies for the future. "We are already working with the automotive industry on potential solutions for to morrow. As a paint manufacturer that is active in research, we are preparing today to meet future needs," says Schlatmann.

On the application side, the Dürr Group's U.S. company, Dürr Systems, Inc., received an Honorable Mention in the 2007 PACE Award competition in the Manufacturing Process and Capital Equipment category for the development of paint shop equipment fuelled by renewable energy resources. The equipment, first installed at the BMW Manufacturing Co. in Spartanburg, S.C., uses methane gas collected from solid biodegradable municipal waste as an al-

ternative fuel to natural gas, and is part of a site-wide project to use renewable fuels throughout the facility.

Automation is critically important in the application of automotive coatings. "The expectation of OEMs is to automate the painting process for every engineered part—both interior and exterior," says Minnich. "Of course, automation must provide consistent product quality. Film thickness, cure conditions, and preparation of the parts (cleanliness with respect to dust and fingerprints) all affect the performance and aesthetics of a coating," she adds. And the entire process must of course be cost effective.

Robots have been used for automotive paint application for several decades now. The latest developments in robotic technology have focused on increasing the transfer efficiency, lowering material usage and waste, and improving quality. Today's systems can be readily installed into existing facilities with minimal impact to established booth structure.

These paint robots tend to be application specific. Because they are designed for one particular application, the new systems are associated with lower initial capital investment and operating costs. These robots also have a much smaller footprint and are designed to paint in smaller spray booths yet still maintain the flexibility needed for varying vehicle sizes. In many cases, the robots are mounted on an overhead rail system. The new technology has also made it possible for paint robots to handle both solventborne and waterbased formulations without a decrease in performance.

Photo courtesy of Ciba Specialty Chemicals.

The FANUC P-500iA paint robot is one example of such a new system. According to the manufacturer, this robot provides excellent uniformity and spray process efficiency while significantly reducing capital costs related to the price of the robot system itself, and also has a reduced space requirement (up to 40% less), which results in lower booth construction costs. Maintenance costs are typically lower as well. The FANUC systems can be installed in a week or sometimes less. In addition, the elevated robots provide a view of the paint application process as it is occurring.

Henkel has taken a holistic approach to addressing cost issues related to automotive coating processes. The company's Transportation Resources And Coating Knowledge (TRACK)-Site Solutions offers reduced manufacturing costs while providing more durable, environmentally friendly coatings formulations. The system combines the resources of the Henkel Integrator Group (HIG) with Autophoretic® Coating Chemicals (ACC®) to eliminate outdated manufacturing steps. By eliminating the need for nearly 45% of the handling steps, Henkel's TRACK-Site Solutions are reducing the complexity of the automotive coatings process and reducing manufacturing costs by up to 10%.

Henkel's ACC coatings contain little or no VOCs, eliminating many waste treatment steps. With these coatings, a greater number of parts can be packed into fewer racks and at angles that are easier for final assemblers to handle, resulting in improved efficiency. HIG has also designed coating packages that reduce manufacturing cycle times and transportation steps plus diminish labor costs by allowing parts to be assembled, coated, and shipped all in one container. Henkel's TRACK-Site Solutions also lower scrap and reworking expenses.

With the rising cost of oil and natural gas, reducing energy consumption and reliance on fossil fuels in the paint application process is also important to car manufacturers. Obviously, the elimination of the primer and associated baking step is one way to decrease energy use. Using biofuels is another. A third method involves lowering the cure temperature. "Coatings manufacturers are working to develop formulations that can cure at lower temperatures. For sheet metal, the goal is to reduce the bake temperature from 280°F to 250°F; and for plastics, the ultimate bake temperature will be 180°F (down from 250°F)," notes Dr. Rose Ryntz, executive director for Materials Engineering and Processing with Collins & Aikman.

Developments in resins technology over the past 25 years have typically been incremental in nature. The most recent developments have been focused in radiation-cured coatings, particularly acrylic or polyethylene/acrylic type resins. Currently their use is limited to non-flexible parts. These coatings provide improved scratch resistance, but cannot be used on flexible parts because they are too hard. Paint formulators are working to develop UV cure systems that will possess greater flexibility while retaining the improved durability got which they are known.

Powder coatings have become very popular for basecoats, but in the U.S. they are not yet commercially applied as clearcoats because they are too expensive.

Photo courtesy of DuPont.

Paint manufacturers are working to develop more economical formulations for powder topcoats that will be suitable for mass application in the U.S. automotive industry. Most likely, companies will switch to powder for clearcoats when regulatory requirements make this method an attractive alternative.

In the very forefront of resin technology is the development of self-healing coatings that can detect and repair superficial damage. "Self-healing is a buzzword at this time, but there have been some announcements by car manufacturers that they are interested in these types of coatings," notes Baghdachi. "The challenge is to develop a self-healing system for automotive clearcoats which have high surface hardness."

Inspired by biological systems in which damage triggers an autonomic healing response, structural polymeric materials have been developed that possess the ability to self-heal. "The natural processes of aging, mechanical damage, and fatigue in polymeric coatings leads to microcracking and other forms of degradation. Eventually these microcracks coalesce to form large-scale cracks that propagate and lead to ultimate coating failure," Baghdachi explains.

At Eastern Michigan State University, Dr. Baghdachi's research group has developed coating systems that contain encapsulated polymers. The capsules break upon exposure to certain environmental conditions such as high temperatures, high humidity, and mechanical force. The particles then break open, releasing curing agents that flow to the site of damage and cure, overcoming microcracks and superficial flaws in the clearcoat. The properties of the repaired coating have been tested and compared to those of the coating when initially applied, and results indicate that this approach is effective.

"Significant changes in the chemistry of automotive coatings will be necessary in the future to address all of the demands placed on automakers," Baghdachi stresses. End of Life (EOL) regulations taking effect in 2025 will require 90% of car materials to be recyclable. In the nearer term, interior odor regulations, further elimination of VOCs, and increased performance expectations will need to be tackled. "Major technological developments in resin chemistries, and of course, other aspects of coatings formulations, will be a pre-requisite for success," he adds.

In the additive domain, nanotechnology has begun to receive significant attention as coatings manufacturers increase their understanding of how the properties of particles change on the nano scale, and what those changes can mean for their formulations. Actually, nanotechnology has been utilized for many years. Clay rheology agents and carbon black pigments, for example, are conventional products that are nanomaterials. However, this greater understanding of the behavior of nano-sized particles has led to interesting new technologies for paint applications.

Durability has become a critical factor for automotive coatings in the past decade. Mar, scratch, and acid etch resistance are all important features for clearcoats now that consumers are expecting years of performance from their vehicle paint job. PPG responded by commercializing its CeramiClear® clearcoat, which is based on patented silica nanoparticle technology that creates a highly crosslinked network at the surface of the coating.

"The real invention was the method we developed to take advantage of the nanoparticles," says Daniel Bardon, manager, Advanced Technologies in PPG's Office of Science & Technology. "The ability to provide proper stabilization and alignment is critical. By coupling the right polymer chemistry, we are able to properly bind the silica nanoparticles so that they self-stratify during cure, placing a high concentration of nanoparticles at the surface, resulting in a glass-like layer." Silica, while not the hardest nanoparticle, was ideal for creating a transparent clearcoat. Other harder particles such as alumina, zinc oxide, or zirconia typically cause haze formation.

The technology was initially developed in response to a need from Daimler Chrysler for its high-end models. The two companies actually worked together to develop the product. PPG then developed an aftermarket refinish clearcoat that provides approximately the same level of protection as the factory-applied CeramiClear clearcoat. Now PPG is working to develop a cost-effective and even higher performing version that can have broader applications in the OEM market. The technology works with traditional electrocoat, primer, and waterborne basecoat systems and is environmentally benign.

UV resistance is another area where nanotechnology can provide improved properties for automotive coatings. BYK-Chemie recently introduced additives containing zinc oxide nanoparticles that can improve UV protection while having only minor influence on haze or gloss. The 20–40 nm diameter particles are dispersed in different media and are easily incorporated by low shear into aqueous, solventborne, or solvent-free coating systems. For improved scratch resistance in clear coatings, BYK-Chemie has surface-treated alumina and silica particles available. According to the company, the inclusion of surface modification with surface-active compounds enhances the performance of these nanoparticles without orientation or crosslinking. Reduction of particle size from micron to nano enables the formulation of coatings that exhibit an enhanced resistance against mechanical and photochemical degradation.

Bardon also sees a huge potential for nanotechnology to improve corrosion resistance. Conventional chrome-based corrosion inhibitors are being phased out for environmental reasons and current alternatives have caused a decrease in corrosion-resistance performance. Nanosized pigments do not have these concerns. In addition, new color effects are possible. "The ability to bring the particle size down to under 100 nm opens up new color space opportunities," he explains.

PPG has developed polymer encapsulation technology that makes it possible to melt organic pigments down and form them into stable nanoparticles that can be blended as a dry powder. These highly transparent pigments have new color depth qualities that have not been seen before, providing opportunities for automakers to add unique color effects.

Photo courtesy of BASF.

Some special effect pigments are also now incorporating nanoparticles. Unlike traditional pigments which are based on absorption and emission characteristics, the color properties of nanoparticles are derived from their physical behavior—more specifically, the alignment of the nanoparticles. The nanoparticles are incorporated into the pigment and their alignment affects the visible color. Depending on the angle at which they are viewed, coated surfaces will appear to be different colors. These properties can be tuned by adjusting the particle size, which in turn affects spacing and refractive index.

PPG is also exploring the use of nanotechnology for many other applications. Nanoparticles in automotive coatings would be designed to absorb infrared radiation, resulting in cooler cars, increased fuel efficiency, and reduced energy consumption. Coatings with nanomaterials for internal parts may also become easier to clean. Nanoparticles may also some day be incorporated as sensors in coatings to detect corrosion or other failures. In the distant future, it may also be possible to have coatings use nanotechnology to take absorbed energy and convert it into electricity.

Biobased additives are also receiving attention. For internal automotive applications, some coatings producers have turned to organic amides to provide improved slip and scratch resistance. These amides are waxy and provide the desired characteristics, according to Ryntz. Unfortunately, they are also sticky and tend to result in increased dirt pick-up, so there is a trade off. Formulators are looking for ways to take advantage of the positive attributes while reducing the stickiness of these additives.

Recyclability issues are also important with regard to additives. Producers must consider carefully what additives are being incorporated into automotive coating formulations. For example, flame retardants can no longer contain halogens such as bromide and chloride functionality. Heavy metals, of course, are also no longer acceptable.

The number of types of plastics used will also most likely diminish as concerns about recyclability grow in importance. Today, however, there is a plethora of different plastics used in the manufacture of automobiles. In addition, many parts come from numerous suppliers, some of which are prepainted. "It is difficult to get a perfect match—color, gloss, and overall appearance," states Ryntz.

Everyone perceives color differently, which adds to the problem. "The color space is a distorted sphere, and it is very difficult to get exact matches. It is a difficult problem, with no simple answers," Minnich adds. "Ford provides all of its suppliers with a narrow window of acceptability with respect to color and appearance. Two suppliers can both be within that window, but there can still be a mismatch on color."

Digital management of color may be a possible answer to this problem. "The industry is focusing its attention on reading colors digitally through multi-angle spectrophotometry and interpreting the results through color formulation software that allows for global con-

Photo courtesy of Akzo Nobel.

sistency," explains Scott Stayart, business manager, Color Services—NAFTA, with Ciba Specialty Chemicals.

Currently, the challenge is getting the formulation software to accurately interpret the information from the reading instrument and correctly formulate the color. According to Stayart, this goal is particularly difficult given the complex nature of effect coatings. Separately, there is the challenge of getting the transportation industry to recognize and adopt the array of advanced color tools that are currently available.

While there is an established system in place for managing color from different suppliers of exterior and interior components, it is not perfect. "A software platform that can link paint suppliers, component manufacturers, and automakers could reduce the cost of color mismatch," asserts Ciba's NAFTA industry manager for Transportation Coatings, Charles Cameron. "Accurate color matching and the communication of the results are extremely important in assuring that the consumer sees color harmony throughout the vehicle."

Ciba is looking to accelerate and simplify the current methods of matching color while improving the increasingly complex process of matching effect coatings. "We are providing solutions to customers to help them consistently communicate accurate color throughout the global supply chain, from designers to specifiers to coatings manufacturers. The ultimate goal is to supply our customers with an accurate, quick, cost-effective method for color management," Stayart comments.

During the 1990s, BASF and Audi jointly developed a mathematical system for comparing the colors of automotive basecoats and clearcoats including coatings containing metal or mica flakes. The system, which utilized spectroscopic analysis, was shown to be comparable to (but more precise) than the human perception of color. BASF used this research to develop a software program and related procedures for controlling and comparing paint color at supplier and final assembly plants.

The Color Controlled Accuracy and Responsibility (ColorCARE) system is a monitoring and early-warning system which ensures perfect color matching. Hand-held spectroscopes are used to gather the necessary data. The system includes a database and the analytical tools that allow for consistent, objective control of color throughout the entire production process. It can be used to analyze new batches of paint or to compare painted parts coming from different suppliers.

According to BASF, suppliers can ensure that the color of their parts is within the standard and will be perceived as matching the painted body before the parts ever leave the suppliers' plants. The result has been a significant reduction in rejections of paint or painted parts. The company won a 2004 PACE Award for the ColorCARE system. Audi has implemented the system throughout its production network.

This last example is one of many discussed that involve a joint effort between the coating formulator and the car manufacturer. Technology development never occurs in a vacuum, and the automotive industry is no different. "Cooperation is essential," states Minnich. "OEM's are applying the product that the paint companies make and are generating waste (solids and emissions). In addition, coating properties impact other parts that must be incorporated into the vehicle."

As a result, coatings producers must be fully aware of how their formulations will affect plant operations and the ability of automakers to complete the production process. Regulatory requirements and energy consumption issues must be factored in as well. And of course they must provide the desired level of performance. "Introducing new technology is a risky endeavor. Successful projects, therefore, definitely require a team approach," adds Minnich. CT