Delivering High Performance Automotive Corrosion Coatings Through The ELVD Conduit

John R. Kochilla (Atotech USA Inc. Rock Hill, SC, USA), Craig V. Bishop (Atotech Worldwide, Rock Hill, SC, USA), Jim Tyler (Atotech Worldwide, Strongsville, OH, USA), Paul C. Wynn (Atotech Worldwide, West Midlands, UK)

Automotive coating transition timetables have historically been anything but aggressive, especially when considering Corrosion Resistant Coatings (CRC). Balancing technological advances with; validation, cost, safety, and global availability typically paralyze the automotive CRC transition process. Today, thrusts towards End of Life Vehicle Directive (ELVD) compliance provides a platform for technologically advanced coatings to shorten the time required to satisfy the automotive adoption process. Although the said platform may facilitate accelerated adoption, by no way has this manifested itself in reduced validation. On the contrary, automotive CRC validation requirements have increased in both magnitude and scope. Black and clear/silver electrodeposited ELVD compliant coatings will be; required to exhibit more consistent corrosion performance when subjected to increasingly severe and numerous tests, compatible with a wider range of intimate materials/fluids, required to exhibit more accurate and precise friction characteristics, and ensured quality by multiple levels of the supply chain.

CRC Commercialization

Corrosion resistant coatings, by design, prolong a desirable material state. Typical accelerated corrosion coating testing requires test vehicle exposure to a controlled or known corrosive environment. Coating performance is recorded as a function of time and/or corrosion severity. Non-automotive CRC commercialization typically follows a known sequence (Commercialization Flow 1).

Commercialization Flow 1

Invention/Formulation → Pleasing Corrosion Performance → Verify Performance Internally (N Replications) → Verify Performance Externally (N Replications @ Customer Facilities) → Production Trials → Installation

Commercialization flow 2 illustrates the fact that the automotive CRC commercialization requires more steps[**].

Commercialization Flow 2

Invention/Formulation → Pleasing Corrosion Performance → Verify Performance Internally (N Replications[*]) → Verify Performance Externally (N Replications @ Customer Facilities) → Production Trials → Production Vehicles Tested at Independent, Accredited Facilities → Appeal for Accreditation According → Automotive OEM/Tier Supplier's Health Environment Safety (HES) approval → Release of New or Updated Specifications → PPAP for Each Part Genre → Permanent Installation

The automotive CRC commercialization process progresses at different rates in various markets. Historically, automotive CRC markets struggling to reduce costs or those requiring high performance technologies (niche) become early adopters. High technology markets, by definition, become early adopters through constant trials and aggressive implementation of new processes. Fierce price competition drives the other early adopter category. Early adopters, requiring low cost inputs, are not significantly motivated by increased coating performance. Technologies offering process savings attract these early adopters. Some early adoption processes have fit both categories, offsetting high cost structures while also providing increased performance.

Implementations of sustainable innovative processes have in many instances successfully inhibited/delayed low-cost global competitor advances[***]. Although success and failure go hand-in-hand with early adoption ideologies, reaping the rewards of an emerging technology boils down to risk assessment. One clear example of early adopter success has been Zinc alloys. Zn alloys, regardless of formulation origin, have found two early adopter automotive markets. Strip

[*] N replications is a function of commercialization strategy and target market requirements
[**] In some instances the process is shortened in order to satisfy a particular time-sensitive need
[***] Decreased shipping distances, increased quality, and realization of scale economies are other tactics which have been equally successful in warding off global competitors

steel platers[5] and European job shops[8]. Said markets have benefited from the early embrace of zinc technologies through increased corrosion performance. An additional benefit to early zinc alloy adoption is the likely increase in zinc alloy demand due to ELVD restrictions.

Transnational Automotive Corporations

Automotive OEM and tiered suppliers operating in all major industrial regions[*] define Transnational Automotive Corporations (TAC). The number and breadth of TAC is increasing. Global distribution is a prerequisite to working with most TAC. Competition among TAC is strong at the component, assembly, and distribution levels. Five significant global drivers influence TAC strategies[3].

1.) Drivers for global integration
2.) Drivers for environmental compliance
3.) Drivers for learning and knowledge acquisition
4.) Drivers for increased quality
5.) Drivers for low cost inputs

Market Stimuli

Multiple CRC market stimuli exist. TAC, as a result of the five significant global drivers, have become increasingly interdependent. Initially some TAC planned on minimizing the ELVD affect by segregating European Union (EU) markets. Such an endeavor would require segregation of materials based on product destination. The reality was that TAC interdependence strictly prohibited any chance of segregated implementation. The ELVD represents the single largest change to CRC composition since the widespread removal of cadmium. The said ELVD induced change results from the elimination of hexavalent chromium when used as a corrosion inhibitor[**]. Considering the lengthy CRC approval process, many questions remain pertaining to the conversion from hexavalent chromium to alternative technologies. China's entrance into the World Trade Organization (WTO) in September of 2001 will either be the single largest change to where CRC coatings are applied or the single largest change to CRC pricing. The effects of China's WTO entrance have already supported the aforementioned statement.

Implementation of advanced CRC coating technologies is currently not an option, but a necessity. CRC performance specifications rewritten to exclude hexavalent chromium were commonly accompanied by an increase in performance demands. CRC cyclic corrosion, NSS, and material compatibility are only a few examples of performance demands that have been raised. Many early adopters who prepared according to the initial ELVD time schedule were dissatisfied with the postponement of ELVD implementation. Total ELVD implementation by

[*] North and South America, Europe, and Asia

[**] Total use of hexavalent chromium is not restricted by the ELVD or interpreting bodies such as USCAR or VDA. Hexavalent chromium restrictions concern the presence of hexavalent chromium. The use of hexavalent chromium is prohibited only when hexavalent chromium remains on the final surface

July, 2007 will require strong project management skills. A sustained decrease in automotive demand[*1], increased availably of low cost labor, and elevated energy costs continue to place enormous price pressures on CRC applicators.

Response

In an effort to drastically decrease new CRC implementation time frames, use of collaborative commerce (c-commerce) and concurrent development have emerged as options. C-commerce requires vendors, applicators, and end-users to share data, collaborate on design decisions, synchronize activities, optimize trials/tests, and jointly solve problems as they emerge[2]. Adaptations of processes in the presence of customers can be an intimidating proposition. Economies of communication, gained by having decision makers from the pertinent areas of the supply chain, can greatly change project progression. Many applications of c-commerce facilitated the development, manufacture, and full implementation of new CRC coating systems with amazing speed. Strong relationships between significant supply chain members permitted real-time knowledge exchange. C-commerce in conjunction with concurrent corrosion testing significantly reduces the time required to implement automotive CRC coatings.

Examples

C-commerce and concurrent development was required to produce a new highly corrosion resistant system while satisfying the future demands of the ELVD. Demand for the aforementioned coating system was scheduled to predate the ELVD implementation schedule. Few, if any, new automotive corrosion specifications include the use of ELVD banned substances. Traditional combinations of electrodeposited Zn materials in conjunction with organic coatings were ELVD problematic due to chromate use between the two layers[7]. Many requests for black CRC in excess of 60-cycles without base metal corrosion were made. As a result c-commerce and concurrent development: Two black systems and one clear CRC system were found capable of meeting the requirements in bulk applications using ELVD compliant systems. Electrodeposited ZnNi (12-16% Ni), a carboxylic acid free trivalent passivate, when topcoated with either a cathodic e-coat, an aqueous based dip spin organic topcoat, or a thermally cured clear organic sealer in all cases met the strictest automotive industry standards worldwide. Specifications are under construction to accommodate the said systems.

Implementation of new technologies was desired for automotive CRC paint applications over non-electroplated surfaces as well. The need for low energy, high performance, chrome-free, iron phosphate replacements prior to painting ferrous, aluminum, and magnesium substrates exist. Sludge, energy, and quality issues[*] place iron phosphate at a disadvantage. Conventional

---

[*] When compared to 1995-2000 demand.

[*] Sludge from iron phosphate clogs nozzles and can drastically affect performance in spray applications. Increasing the stages in a pre-treatment process can reduce this problem. Capital expenditures however are rarely embraced, especially when environmentally and economically friendly chemical alternatives exist. Iron phosphates are also well known to operate differently based on substrate material.

processing requires a cleaner that removes metal processing materials prior to application of an iron phosphate. Iron phosphate promotes paint adhesion and reduces lateral corrosion (among other things). The common use of cleaners and phosphate in the same processing step creates many problems. Many different organic compounds are removed from machined surfaces when cleaned. A diverse mix of materials in a job-shop environment increases the variety of emulsified organic compounds. Iron phosphate salts are typically insoluble in aqueous solutions and during processing, creation of said salts are unavoidable. Said salts when exposed to emulsified organic compounds, form many different types of scale and sludge. Implementing a no dump, low energy, solvent-free cleaner in conjunction with ambient temperature phosphate replacement required a concerted effort. A bioremediated[**] spray cleaner in conjunction with a thin organic sub-coating (analogous to a primer) is moving through the commercialization process and is on pace to be fully implemented in under a year. Annual savings for the said process completely offsets the entire pre-paint chemical costs while also increasing the corrosion performance. This is one such example when both the performance and cost benefits were simultaneously achieved.

The need for high performance lubricants in both the threaded and non-threaded electroplated zinc fastener markets required accelerated commercialization timelines as well. ELVD requirements and limited process steps further complicated the said task. Stand-alone and integrated dry film lubricants provided the desired coefficient of friction(s) and decreased variation required by the automotive industry. Integrated dry film lubricants are used in conjunction with sealers, mixed within the same processing tank, to gain performance attributes of both chemistries without additional processing steps. Through c-commerce, a chemical vendor, applicators, and a TAC, quickly developed and implemented a solution to the problem. The drop in hexavalent chrome-free technology affected the Americas, Europe, and Asia in less than two years.

[**] Bioremediation in this context refers to the intentional incorporation of organisms into processing solutions for the purpose of removing fats, oils, and greases. Bioremediation is environmentally friendly and provides a way to convert crude oil to carbon dioxide and water after a spill.

Summary

Commercialization of CRC is a time intensive process. Early adopter experience is an important survival skill that must be constantly balanced against production demands. Many global and local drivers affect the automotive marketplace and influence decisions. Although complex automotive industry needs are unyielding, options exist for satisfying the needs in time-sensitive situations. Globally executing c-commerce and concurrent development can be effective, however implementation requires significant resources and high levels of trust between all participants.

Bibliography:

(1) Internal Correspondence
(2) Russell, R.S; Taylor III, B.T.; Operations Management, 4th Edition, Jan, 2003. pp 52
(3) Transitional Management, 1st Edition. Jan, 2003. pp 209
(4) M. Silomon, C. V. Bishop, P. Wynn; Galvanotechnik 91(2001) 11,S.2932-2939
(5) Mitsuo Kurachi & Kazuo Fujiwara, Trans JIM, 11(1970), 311-317
(6) Silomon, (ibid)
(7) Dr. Loar, Gary W.; Romer, Klaus R.; Aoe, Tetuhiro J.; Zinc-Alloy Electrodeposits for Improved Corrosion Protection; Plat. Surf. Finish. 78 (1991) 3 S.74-79
(8) Volkswagen AG, TL 244, "Zink/Nickel-Legierungsuberzuge"
(9) Dr. Vogel, Roland; "Dark Spots, Gray Veil and White Corrosion", Diss. Atotech GMBH, 030/34985-979,- Version 6/01