Evolution of High Solids, High Performance UV Coatings for Spray Application

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Abstract

With the push for increased cost savings and more eco-friendly coatings, more demand has arisen for 100% solids coatings, especially in terms of spray applied coatings. 100% solids coatings have been around for quite some time with such applications as roll coat or gravure coating, but spray applications have always proved to be especially challenging. This is especially the case in automotive applications where demands for exterior durability and high quality appearance standards are always of utmost importance. Resins which tend to have good weathering properties tend to be higher in molecular weight and thus are generally quite high in viscosity, which leads to application issues. Solvents have historically filled this gap, enabling viscosity reductions and rheology control which are integral in producing the show quality parts that have become an industry standard and a quality requirement. However, technology advancements with resins and additives have made the once unobtainable now possible at least for UV curable coatings.

Introduction

There are many various methods of applying coatings, but perhaps the most universal and flexible for a wide array of part configurations is spray application. Flow coating has long been a choice of application methods in the forward lighting market segment of automotive based on the high transfer efficiencies and minimal waste; basically only solvent loss. However, in recent years as lighting designs have become more elaborate with styling, components such as reflector bezels and lenses have become increasingly harder to coat with the longstanding method of flow coating. This is also particularly in part due to the fact that the OEMs have continually been raising the bar on exterior weathering requirements as a means of improving quality.

Based upon current part configurations, flow coating can have limitations in a consistent control of film thickness across the part. In maximizing weathering performance control of film thickness is crucial as a low film thickness can dramatically affect long term weathering performance. In turn, tier one suppliers are redesigning their lines to be centered more on spray application. Spray application not only allows a more consistent control of film thickness across a wide array of parts, it also has the ability to paint parts with more complex shapes and deep recesses, which would not otherwise be possible with flow coating. Though spray application is more flexible, it can have slightly lower transfer efficiency. In order to improve process controls without sacrificing part cost and efficiency, there has been a greater demand for the development and implementation of high solids sprayable systems, with the ultimate goal of achieving a system that can be applied at 100% solids. This paper will discuss the various challenges associated with the development of high solids weatherable and non-weatherable UV systems and the current reality from a technology perspective.

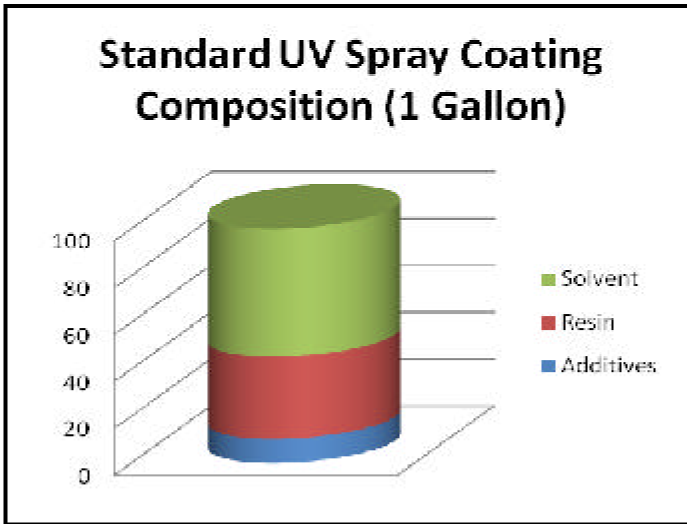
The Push for High Solids: Environment, Regulations, and Cost

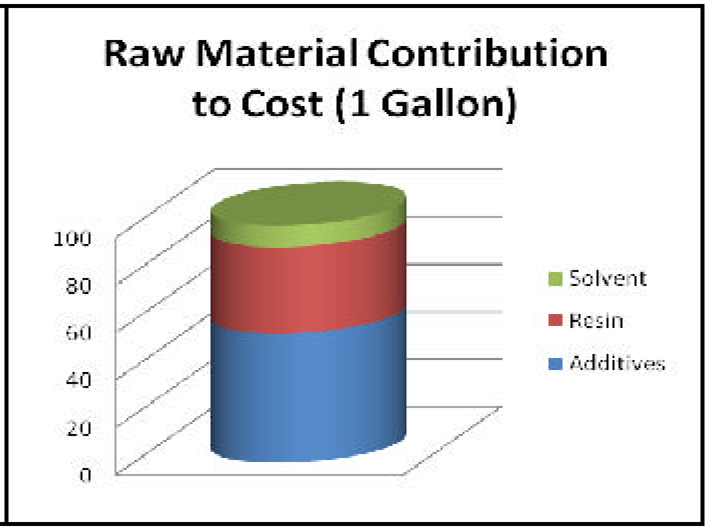
As touched upon earlier, several factors are driving the push for high solids coatings. Paramount to this push are environmental concerns and increased governmental regulations which control the type and amount of solvent emissions that are permitted. Although, due to increased competitive pressure, cost is of equal importance, especially when considering the competing factors of reduced labor costs which are associated especially with regions such as China and India. Increasing solids content of a coating makes sense in that costs can be spent on aspects of coating that will be encompassed into the part and not lost up the stacks. In most cases, there is even a likely cost associated with controlling the escaping solvent through incineration costs in order to be compliant with environmental and federal regulations. Reducing solvent content can also mean that additional costs can be eliminated through lowering energy costs associated with high flash temperatures and the long flash oven itself. There is also an additional benefit in efficiency through potential increased throughput due to the shorter cycle times. All of these factors lead to a lower associated part cost.

Part Cost Vs. Price per Gallon

Often, price comparison has been judged by the price per gallon (or other unit of sale) alone. However, in the cases of high solids coatings, the gallon cost can be very misleading so it is important to look at part cost (figure 1). In this illustration a 45% weight solids coating which is quite typical for spray applied coatings is being evaluated. In examining a gallon of coating it is quite evident that roughly half of the composition is solvent, which is depicted in green. However, as one might recognize in the second illustration in figure 1, cost of the solvent makes up a relatively small amount of the price of the gallon of coating. Considering this impact, one can readily see that when the solvent is eliminated there is a substantial impact on the overall cost of the gallon of coating. Based on this it is important to take into consideration the part cost, which is dependent on the specified film thickness that the coating requires as well as the density of the coating material. Reclaim-ability of the coating or the potential for the coating to be collected and reused is also of utmost importance to take into consideration. This will be discussed later. All things being equal, high solids coatings are quite cost effective when all aspects are taken into consideration.

Figure 1. Paint Composition versus Price per Gallon Influence for a standard UV spray coating at 45% solids.





Development Challenges

When considering the formulation and development of high solids coatings it is important to distinguish between non-weatherable versus weatherable coatings as the approach, complexity, and thus the timeline are quite different. Non-weatherable coatings are generally interior or short life cycle coatings that are not typically exposed to direct sunlight. They can also be basecoats or undercoats which are protected by a weatherable topcoat. Weatherable coatings or exterior durable coatings are designed to resist attack from outdoor elements. Exterior durability requirements for UV hardcoats by the OEMs are generally understood to encompass 5 years in Florida with minimal yellowing and no degradation of the coating with respect to cracking and clarity as seen through haze, gloss or transmission measurements. Though each development has its own level of difficulty, weatherable coatings have more inherent difficulties associated with the development path. The following information will help to explain these difficulties in order to understand and appreciate the evolution of a 100% solids, high performance, sprayable, UV coating.

Non-weatherable Developments

Basecoat systems for applications such as automotive lighting or PVD trims applications generally serve as a base layer for the deposited metal in applications and are a good example of a non-weatherable coating. In the case of automotive lighting, the reflectors which are basecoated and metalized are made up of bulk molding compounds often referred to in short as BMC. This substrate is very heat resistant, which serves well in lighting conditions where lamps can reach high temperatures. Although, as it is porous it will not mold into a highly polished surface, therefore a coating is required as a surfacer or level coat in order to achieve the mirrored finishes that are essential for efficient light reflection and overall appearance. Based on this requirement the basecoat must have good flow characteristics and allow good adhesion for deposition of the metal layer. Additionally though, because the optics are most often molded into the reflector, the coating must be able to cover well across many sharp edges and designs without issue of runs or sags. As mentioned earlier, lighting components can get quite hot so the coating must have a sufficient heat resistance and crosslink density in order to prevent reflow or movement of the basecoat which will potentially disturb the metal layer and result in crazing, iridescent or dulling phenomena. As basecoats are protected within the lamp assembly, weathering requirements are not essential and thus eases the job of the formulator.

Weatherable Development

In contrast to basecoats, weatherable coatings such as UV hardcoats, require stabilizer packages to protect the coating and underlying substrate from degradation by UV light. One of the components of the stabilizer package is a UV absorber (UVA), which absorbs wavelengths of light that can damage the polymer chain. Oddly enough, this is often the same region of the UV light spectrum where photo-initiators absorb, forming the free radicals that in turn cause a polymerization reaction which create the coating network. Various types of UVA(s) have different absorption curves in which varying levels of the UV spectrum is targeted. As the UVA can limit light getting to the photo-initiator, it is therefore essential in selecting photo-initiators that are not activated within the same region. This factor of weatherable coatings can limit available photo-initiator options and thus the choices available. This comes into play as different photo-initiators can have different effects on cure within the depth of the coating matrix. A poor cure can potentially lead to weaknesses in the integrity of the film especially during humidity resistance or temperature cycling tests. There is also a factor of loading level which can lead to concerns of initial color quality as seen in issues of higher initial yellow values. This is particularly important in markets such as lighting or with protective coatings over light, white or metallic surfaces where visual appearance is a high concern for quality.

Critical to appearance, especially in terms of spray application, is the viscosity of the coating system. In order to achieve low enough coating viscosities suited for good appearance with spray application, monomers serve a vital role. As certain substrates can be especially sensitive to attack from specific monomer types, it is important to have an understanding of the target substrates in the development. A formulation approach for a 100% solids coating over polycarbonate or polycarbonate blends is quite different than the approach in developing a coating aimed at BMC. This is due to the fact that BMC substrates are much more resistant to chemical attack than that of polycarbonate. This is sometimes not always evident on lab scale or plaque testing alone, but can be influenced by part design, wall thickness and molding parameters of the substrate material. These factors can create weak points which are more sensitive and prone to attack from aggressive monomers. A challenge lies in the fact that the coating must have a sufficiently wide process window in order to accommodate a large array of part designs, varying substrates grades, and potential for varying degrees of part stress, without negative implications on performance. It is also important that the coating meets a wide array of OEM specifications as finishers most often will have limited number of production lines to accommodate multiple OEMs programs and projects. Rare are the days of a finisher dedicated to a single OEM or single part design or model on a single production line. Based on these properties, potential monomer candidates and amounts can be severely limited.

Also influencing the amount of potential monomer content is the weathering performance needed for the system. Elevated monomer levels can decrease performance as measured with artificial and natural weathering test methods. This is not a concern with basecoats targeted for reflector bezels, but is crucial for exterior durable hardcoats. Therefore, exterior hardcoats rely less on utilizing common monomers for needed viscosity reductions. Rather, they rely more on unique oligomers or main resin backbone.

The balance of maintaining weathering properties while minimizing the viscosity for acceptable spray appearance is perhaps one of the most difficult aspects of a high solids formulation development. The most common of oligomer base resins, which are most influential on exterior durability, by nature tend to be very high in viscosity and based upon very high molecular weight species. Traditionally these resins were co-blended at moderate amounts with solvents or monomers in order to reduce viscosities to a workable level from a production processing standpoint. Obviously going 100% solids eliminates solvent as a viable choice. Similarly, monomers can help, but in most cases are still ineffective in reducing viscosity to the required minimum for proper spray application. Again, weathering properties can be compromised when additional monomers are added in order to achieve proper appearance targets.

As all components of the formulation are critical to the element of success of the development, particular focus has been from the resin side on increasing weathering performance while trying to lower viscosity. This request has been especially challenging. And it is especially challenging based upon the need to develop and incorporate unique and innovative technologies which is counterintuitive to the price targets that are typically demanded from this market. Current technology is available to meet both application and performance targets, but not always under the desired cost model as it is traditionally calculated. In order to find a compromise on cost without affecting performance, application methods must be considered.

Application

Numerous types of equipment are available for spray finishing applications. Perhaps the best suited for 100% solids applications are rotary atomizers. These systems have proven very successful as a means of spraying high viscosity systems with a quality appearance due to their ability to finely atomize and break apart the coating into smaller size. The reality unfortunately is these types of systems can be quite expensive and are generally an option that most finishers do not want to consider. As the majority of finishers currently utilize HVLP or conventional type guns, they want a system which can be adapted to these types of guns. For low capital expenditure the best compromise is the use of heated spray systems. This type of system allows the use of existing guns with a heat exchanger in order to drop coating viscosity to application viscosities. An additional advantage to using this type of system is that quality in production consistency can be controlled very efficiently despite the potential plant temperature swings that can occur daily or seasonally. Also based on the global nature of business, many finishers strive for identical production systems throughout various their various regions of operation in the world, which also can vary greatly in temperature extremes. So incorporation of heated paint systems can also help finishers standardize and control their process companywide on a global scale.

It is important to note that a heated paint system or rotary atomizer does not allow any sprayable UV solventborne coating to be converted to a 100% solids system by simply eliminating the solvent package. As noted with the challenges above, there is still a lot of detail that has to be optimized within the coating and process. Temperature control alone is insufficient at allowing the dramatic viscosity reductions that are required for appearance requirements especially for thin film target applications. The main benefit of a heated spray system is consistency and allowing the technology to be available at an obtainable price.

Reclaim

In looking at heated spray systems, stability of the coating system is very important. For a good understanding of stability it helps to consider a coating reclaim process. For many years now reclaimable solventborne systems have been used in the UV finishing industry. This ability to reclaim the coating has greatly improved the applied cost and efficiency of the coating. The process involves the collection of the UV overspray from the spray booth in a controlled and consistent method to avoid contamination and compromise of the coating material. With solvent based coating systems, a fair amount of the solvent evaporates and thus the material must be rebalanced with appropriate solvent before reusing the material.

During the reclaim process the coating is subjected to stresses such as shear and exposed to various environmental conditions (heat/humidity). It is critical during these exposure conditions that no chemical or physical changes occur within the liquid coating such as rheological changes, phase separations or precipitation. In a solvent based system, some of these chemical or physical changes can actually be masked by the rebalance and filtration process with the material. However, with 100% solids coating composition, it is nearly impossible to conceal any of these changes that might occur. In keeping with this, it is also imperative to ensure that there is no degradation of the final cured film properties in respect to visual appearance or performance. Extensive testing ensures a stable quality product through this entire reclaim process.

Summary

In considering the evolution of high solids coatings one can readily see the direct influence that the reclaim process has had on the progression towards high solids sprayable coating systems. With a good foundational understanding of maintaining coating stability in 100% solids systems, greater focus can be spent at formulating these systems for application and performance. Based upon the previous discussion above, this is a challenge by itself.

As with all things, feasibility is generally measured by cost. With most coating developments, a technology solution is for the most part at hand, but the greatest challenge lies in finding a solution which meets the required performance aspects at an affordable market price. From this perspective, 100% solids sprayable basecoats are today feasible and a commercially viable option for the automotive market and beyond. Very close at hand with feasibility and affordability is the market realization of 100% solids highly weatherable hardcoats for spray application.