

Balancing Air Assisted Atomization for Improved Conformal Coating Quality

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Abstract

Polymer coating materials protect electronics from harsh environments, assuring safe and reliable performance. To reach the highest level of reliability, coatings must be selectively applied to avoid keep out zones and critical components, such as connector pins, test points, and relays.

To gain better control over selectivity and eliminate the need for masking, manufacturers often choose to automate their conformal coating process. Air assisted atomization is commonly used in automated processes because it accommodates a wide range of material viscosities. The spray created when external air pressure is applied to the fluid stream provides excellent coverage on the sides of components, and is cost effective. When atomization benefits are combined with properly characterized selective coating equipment, yield and throughput can also be increased.

Successfully atomizing the coating fluid relies on multiple factors including fluid chemistry and the amount of air assist applied. Fluid property requirements depend on the desired coating protection and are often defined before the coating equipment is selected.

An optimized spray pattern is determined by the results that appear on a coated board. And identifying the air assist settings to achieve that optimized spray pattern is an iterative process. Issues such as overspray, cobwebbing, and inconsistent pattern thickness can occur. When attempting to resolve these issues, air assist is typically increased or decreased. Unfortunately, these adjustments can introduce an imbalance that leads to amplified complications. If a manufacturer is unable to resolve issues quickly, they might choose to reintroduce manual activities – forgoing the cost savings, consistent quality, and other advantages that come with automation.

Introduction

Automotive, consumer appliance, computer, electronics, and medical device manufacturers are introducing an increasingly wide range of electronic devices to support the growth of the global electronics market. These devices perform important tasks in a variety of settings, including harsh environments where exposure to moisture and contaminants is common. To ensure safe and reliable performance, conformal coating barriers are typically applied to protect sensitive electronics. Polymer coatings provide protection from environmental hazards and they prevent the occurrence of internal failures related to corrosion and electrical short circuit. Ultimately, product designers must consider the final operating environment to determine the coating coverage requirements, identifying areas that require coverage and the coating material that will provide the best protection.

With selective atomized spray coating applications, the coating material and coating equipment must work together synergistically to successfully support the required level of coating protection for each application. In many instances coating fluid is determined before the coating equipment is selected. High quality coating results depend on the alignment of application settings and coating equipment capabilities. See Figure 1. Specifically, the level of applied air assist is a key factor that must be sufficiently supported through the coating equipment to avoid a host of issues that can occur in an atomized spray coating process.

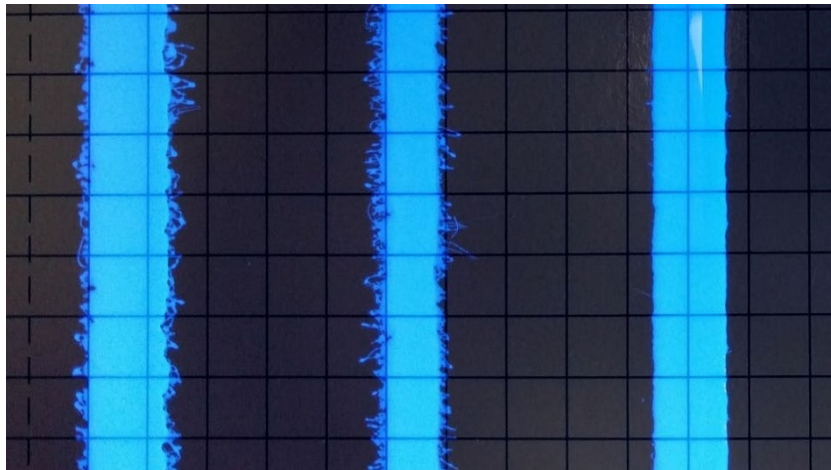


Figure 1 – Three industry applicators yield different results for atomized spray applications. Optimized settings for air assist differ by the technology selected.

Challenges related to atomized spray coating include achieving clean edge definition, uniform coating coverage, and avoiding cobwebbing of solvent-based materials. On visual inspection, you may notice one or more of these issues occurring on the substrate. Process engineers are tasked with identifying the cause and air-assist settings are often adjusted in an attempt to improve the coating results. The following sections describe the coating requirements, process development, and complications that occur if too much or too little air assist is applied in these situations.

Determining Coating Requirements

To reach the highest level of reliability, coatings must be selectively applied to provide coverage on critical components and to avoid keep out zones (KOZ). Keep out zones are areas where fluid should not be applied. At a minimum, coating coverage is recommended for solder joints and exposed leads. For full board coverage, coating is required beyond the exposed joints and includes side wall coverage and coating on bare board areas. Common KOZs include connectors, test points, screens, mounting and grounding holes, and switches. In these areas, the presence of conformal coating fluid can interrupt connectivity and function. As mentioned, the coating location requirements are determined by the board design and required protection.

Fluid selection is dependent on the final operating environment and the desired level of protection. Coating fluids are generally categorized as acrylics, urethanes, silicones, or epoxies with each type providing different characteristics. When selecting a fluid type, it is important to align the inherent beneficial characteristics with the product reliability requirements. Table 1 below summarizes the benefits and limitations by fluid type. Fluid selection plays a critical role in determining the coating application method. Atomized spray is a versatile application method that supports a wide range of viscosities, from acrylic to higher viscosity urethanes and silicones. Atomized spray also provides 3-dimensional coverage benefits because fine spray particles adhere to surfaces and are less prone to wicking away from components.

Table 1 –Fluid Types: Benefits and Limitations

FluidType	Reparability	Moisture Protection	Abrasion Resistance	Solvent/ Chemical Resistance	Mechanical Strength	Flexibility
AR Acrylic	Good	Good	Good	Poor	Fair	Fair
UR Urethane	Poor	Good	Good	Good	Good	Good
SR Silicone	Fair	Fair	Poor	Good	Poor	Good
ER Epoxy	Very Difficult	Good	Good	Good	Good	Poor

If the coverage requirements, level of required protection, and accompanying fluid selection align well with a spray application, the next step is to determine whether to use a manual or automated coating process. A manual operation is very labor intensive, depends largely on the operator's expertise, and usually involves masking. Human error is unavoidable in a manual process making it difficult to maintain consistency and traceability. One benefit of a manual process is the operator's ability to make immediate adjustments that yield cosmetically appealing boards. Some manufacturers rely on extensive, labor-intensive masking and operator rework. These processes are expensive in terms of personnel, throughput loss, and material cost.

For high-quality efficient conformal coating, large-scale manufacturers use automated selective coating processes. Automated processes are attractive because dispense quality, process control, reliability, and repeatability can be achieved while reducing material cost. In addition, the use of selective coating equipment in an automated coating process is a reliable way to increase yield and throughput while reducing rework and process cost. To realize the optimal benefits, the process and equipment must be properly characterized.

Process Development

As mentioned, spray coating application settings must be aligned with the coating equipment capabilities to ensure high quality coating results. Dispense height, coating speed, air assist, board topography, and surface conditions are all factors that affect spray quality. Board topography and surface conditions are dependent on the product design and the upstream assembly processes. Often these conditions are fixed when the coating process is being developed. Variations in dispense height and coating velocity impact the uniformity of the coating pass and the sharpness of the edge, as shown in Figures 2 and 3. These factors are often limited by board component height, cycle time, and other process constraints. Therefore, air assist is the obvious process setting that can be manipulated to overcome these limiting factors.

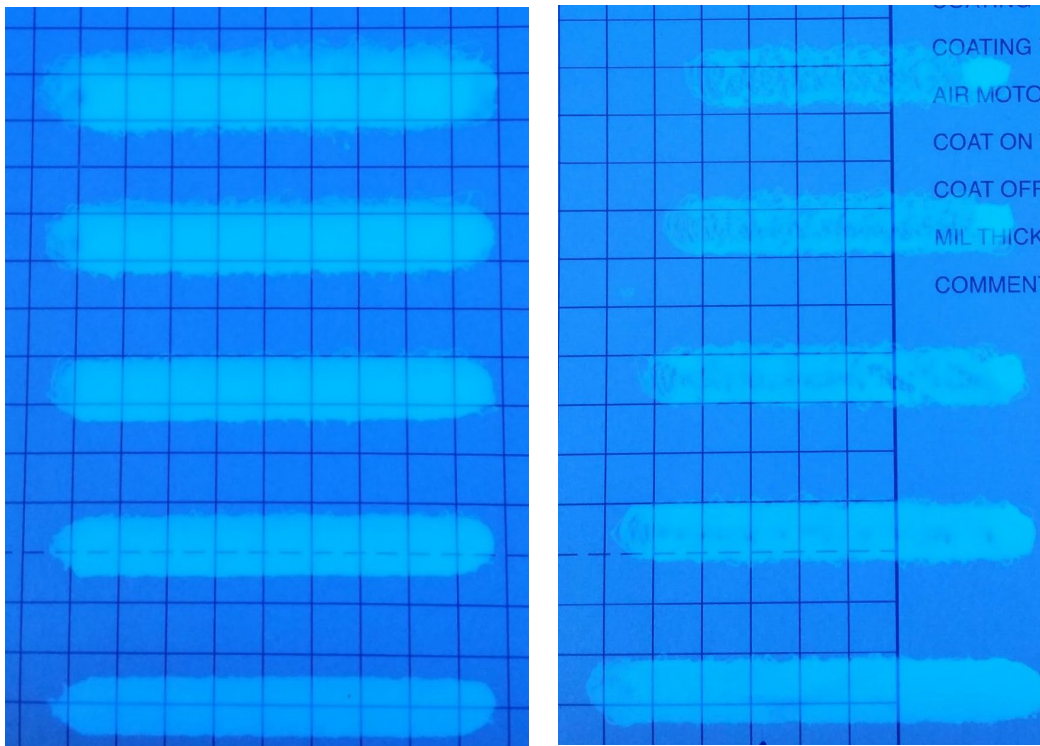


Figure 2 – (Left) Changes in dispense height ranging from 6-14mm. As the dispense height increases, the pass width becomes wider and the edge is less defined. In this example, all other parameters were held constant.

Figure 3 – (Right) Increasing the coating velocity beyond the defined application settings can result in an incomplete coating pass and compromise the fluid output quality.

Identifying the ideal air assist settings to achieve an optimized spray pattern is an iterative process, and results are determined by factors at the applicator and board level. Without alignment, issues such as overspray, cobwebbing, and inconsistent pattern thickness can occur. When attempting to resolve these issues, air assist is typically increased or decreased. The following sections discuss process development considerations at the applicator and board levels.

Air Assist at the Applicator Level

When defining the necessary amount of air assist, we should start by observing how the fluid is dispensed from the coating applicator. The amount of air assist at the nozzle will affect the occurrence of incomplete atomization, overspray, and cobwebbing conditions.

Understanding Pattern Shape

With some applicators air assist patterns are dispensed in a round, conical shape emphasizing uniformity in all directions. Other applicators apply shaping air after the material is atomized to mold the pattern into shapes that achieve a narrow or wide pass. These shaping air patterns can deviate from a symmetric round pattern to create oval patterns or a rectangular pass that widens the spray pattern on the surface. In other instances, the fluid is rotated into a swirl as it leaves the applicator. In this case, the air assist adds dimensional complexity.

Applied air assist can be increased or decreased to shape the pattern width. Increasing the air assist adds energy to the system that can result in a wider pass width. The following principles will apply, regardless of pattern shape.

The Importance of Complete Atomization

Air-assisted atomization creates a spray when external air pressure is applied to the fluid stream. Through atomization a mist of fluid is applied in small droplets. These small droplets adhere well and provide complete coverage on side walls. Additionally, the break in surface tension means that fluid is less likely to slide down the sides, resulting in fillets around components. Sprayed fluids can also be applied in thin layers to gradually build up thickness. However, these benefits depend upon sufficient atomization of the fluid.

In Figure 4, the pattern on the left breaks the fluid stream into strings of material that are not adequately dispersed, leading to incomplete atomization that translates into splatter on the board. Splatter at the board level will be discussed in a later section. Upon visual inspection, the spray on the right has sufficient atomization, creating a more consistent and uniform mist. During setup, process engineers must verify that fluid is exiting the nozzle with sufficient atomization to ensure a well-established process. Fluid streams can be analyzed by dispensing over a purge station.

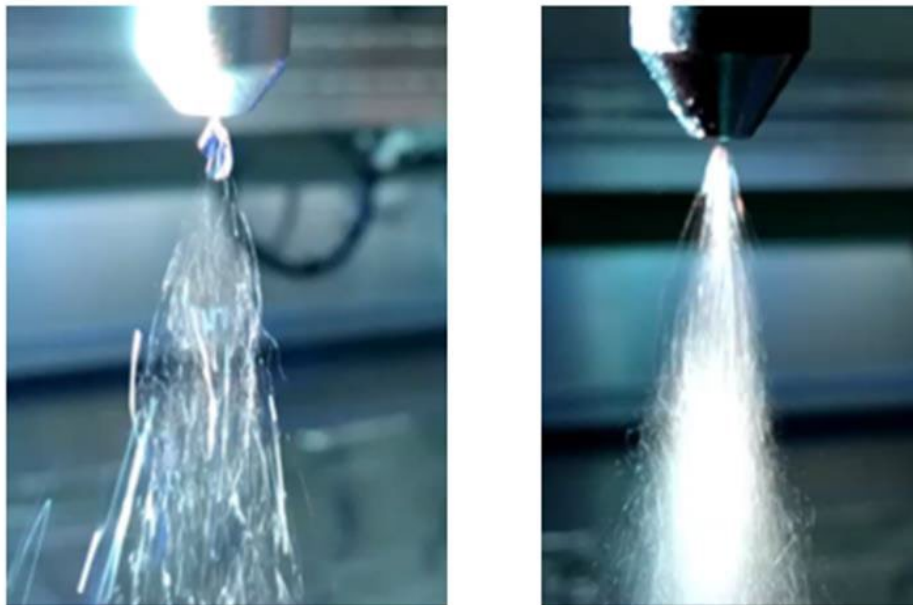


Figure 4 – Incomplete atomization caused by insufficient air assist (Left). A sufficiently atomized spray pattern (Right).

For each application, the ideal air assist settings depend on the fluid and the coating equipment. The take away is understanding how to identify when the applicator has enough air assist to properly atomize the fluid being dispensed.

The straightforward solution to address incomplete atomization is increasing the air assist. But if air assist is increased indiscriminately, excess air assist can introduce energy that disrupts predictability. When fluid is dispersed into a fine mist, any excess energy causes fluid particles to migrate which leads to overspray.

Overspray and Transfer Efficiency

Overspray occurs when fluid particles travel beyond the intended coating pass, and settle in KOZs or entirely off the board. See Figure 5. The term “transfer efficiency” is used to describe the amount of material that is successfully transferred to the board. When fluid is diverted beyond the intended coating pass, transfer efficiency is decreased and material is wasted. Additionally, fluid particles can settle on pallet carriers and conveyor chains leading to ongoing maintenance.

To reduce overspray and increase transfer efficiency, air assist must be decreased enough to fully atomize without generating overspray.

Cobwebbing of Solvent-Based Materials

Cobwebbing is another symptom of excessive air assist that occurs when solvent-based materials are atomized. By design, solvents used in most conformal coating materials feature a low vapor pressure to reduce drying and curing time. When air assist is too high, it can effectively flash-off the solvent and accelerate the drying process. When air is applied, the solvent in the droplets evaporates and dries out in mid-air creating a polymer chain before contacting the substrate; the formation of these polymer chains is referred to as cobwebbing or “the cotton candy effect.” These polymer chains can contaminate boards and interfere with automated coating system performance. Adding more solvent or incorporating a slower evaporating solvent are two common methods used to prevent cobwebbing. Monitoring the amount of applied air assist can also reduce cobwebbing.

The following section discusses how these conditions including incomplete atomization, overspray and cobwebbing are indicated at the board level.

Air Assist at the Board Level

The right amount of air assist must be applied to achieve complete atomization and avoid overspray and cobwebbing. When faced with resolving atomization issues, it is helpful to understand how air assist imbalance results in complications at the board level.

Understanding Edge Definition

Edge definition refers to the straightness of the coating pass edges. The term “feathered edges” is used to describe an edge definition with a tapered shape, rather than a defined line. Round spray patterns, when moved in any direction, create a gradient of material thickness from the center outwards. The spray pattern angle is directly correlated with the amount of feathering that occurs. Too much or too little air assist can lead to process issues that affect edge definition quality including splatter, splashing and overspray.

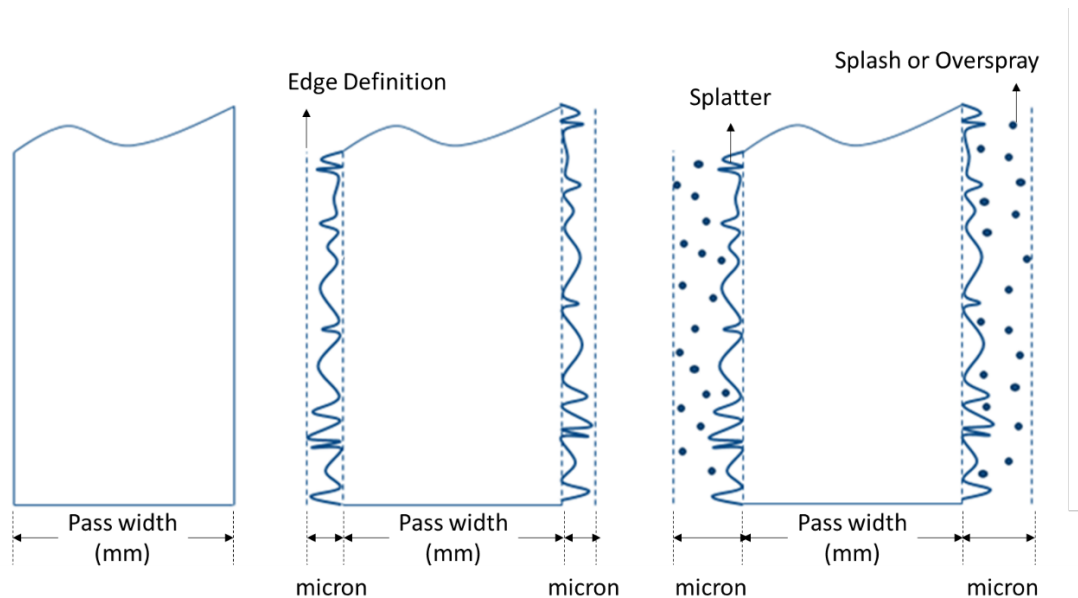


Figure 5 – Splatter, splashing, overspray and edge definition

The image on the left in Figure 5 illustrates the Pass Width. Pass width is defined as the dimension of complete coverage in a single coating pass. The middle image illustrates edge definition and indicates where splatter occurs. Edge definition is the spread of material beyond the width of a single coating pass. The image on the right indicates overspray or splashing of material that extends beyond the main coating pass and the edge definition.

Non-Uniform Coverage and KOZs

As mentioned earlier, insufficient air assist causes material to form strings rather than a mist of fluid. At the board level, this translates into an inconsistent coating pass and non-uniform coverage. Uniform coverage and coating thickness are affected by the amount of applied air assist and the coating speed. Recall from Figure 3 that increasing the coating velocity beyond the defined applicator settings starves the coating pass – resulting in incomplete coverage. A uniform spray pattern, however, will yield uniform coverage on the substrate.

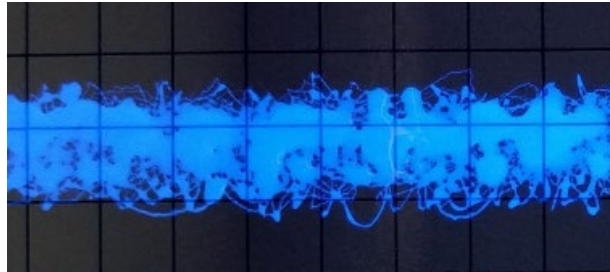


Figure 6 - Incomplete atomization caused by insufficient air assist translates to splatter on the board. This pattern is inconsistent when compared to a properly atomized spray pattern.

As shown in Figure 6, strings of material create an edge definition that extends well beyond the primary coating pass. These strings create gaps in the coating pass and their placement is unpredictable. To compensate, process engineers might require more clearance near the KOZs or decrease the coating velocity to create more film build and a more predictable pass at the expense of cycle time.

Another option to compensate for an inconsistent pass is to introduce additional pass overlap. By aligning neighboring patterns closer together, and in many cases overlapping at the edges, the programmer is compensating for the wider edge definition gradient. However, increasing pass overlap has other consequences. By overlapping passes and doubling material at the pass interface, the coating pattern thickness becomes inconsistent and non-uniform. When slowing down the applicator or increasing the pass overlap, the coating thickness will increase and cause other issues if the thicknesses exceed IPC specifications (IPC-CC-830 specifies thickness limitations on a flat, unencumbered test vehicle; IPC-A-610F specifies thickness for populated printed circuit boards) and violate the final manufacturer requirements for their product.

Splashing and Overspray

Conversely, excessive air assist can cause splashing and overspray where small droplets are deposited beyond the main coating pass and edge definition areas. Figure 7 shows the result of excessive air assist which leads to decreased selectivity, encroachment into designated KOZ areas, and the need for labor-intensive masking and rework.

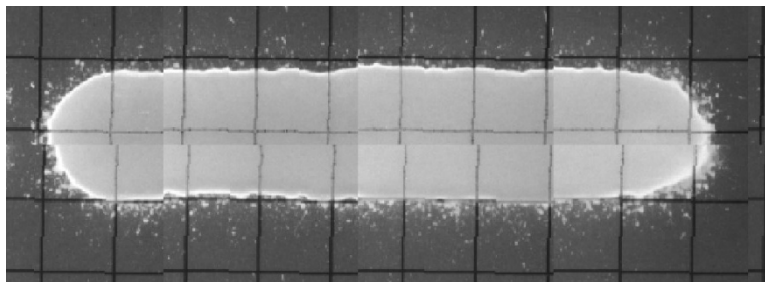


Figure 7 - Excessive air assist on the board leads to splashing and overspray – decreasing edge definition and potentially causing fluid to be dispensed into KOZ areas.

Overspray is caused when atomized particles fall outside the spray cone. Splashing, on the other hand, is defined as the droplets that rebound off the spray material during the spray process, see Figure 8. Splashing is more likely to occur with lower viscosity materials, especially those reduced with added solvent. The concern with splashing and overspray is that particles travel unpredictably and can intrude on KOZs. This decreased selectivity will require expensive, labor intensive rework and preventative masking to ensure fluid is not deposited in unwanted areas.

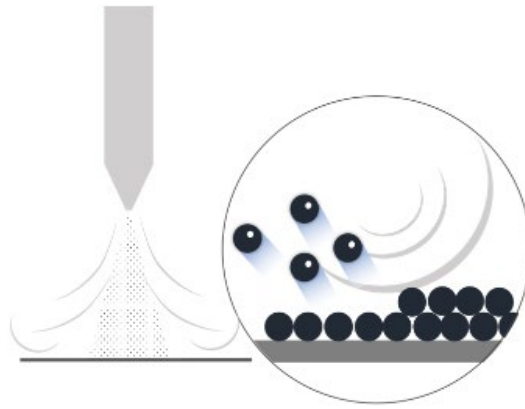


Figure 8 – Excessive air assist causes dispensed fluid to splash beyond the existing coating pass. These splashes may deposit material into designated KOZs.

A Well-Balanced Process

From an engineering standpoint, a clean coating pass provides consistent coverage over critical components and does not encroach into KOZ areas. Optimized spray settings provide more flexibility and control over the entire coating process. A balanced process reduces issues that can occur during the application process, resulting in a wider process window. Parameters such as dispense height and coating velocity can be adjusted more liberally without negatively impacting the dispense results on the board. See Figure 9. Added flexibility can further benefit manufacturing processes by reducing cycle time and rework.

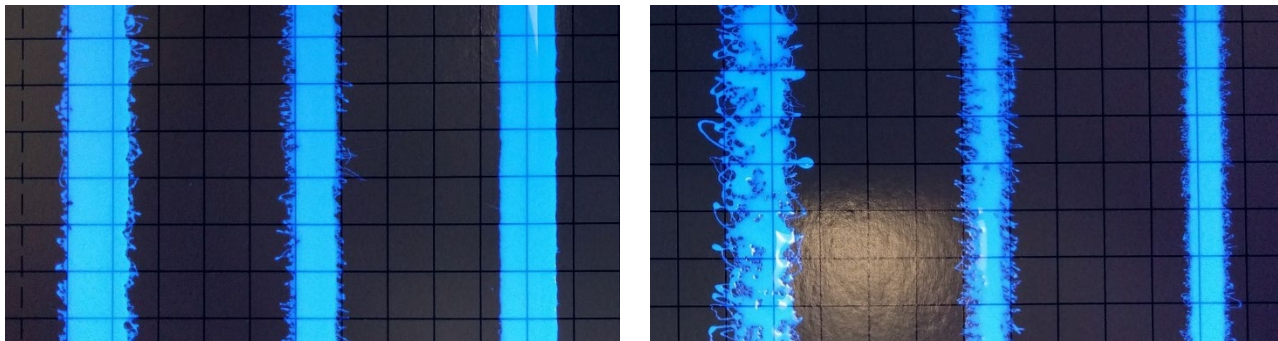


Figure 9 –The figure on the left shows three industry applicators coating at 100mm/s. The figure on the right shows the same applicators and applicator settings at 200mm/s. When the coating velocity is increased, we see that a slower speed compensates for incomplete atomization and splattered edge definition. The applicator on the far right maintains a cleaner edge definition at 200mm/s as compared to two of the applicators on the left at 100mm/s!

Summary

A well characterized atomized spray process requires finding the right balance between too much or too little air assist. In addressing issues like splatter, overspray, cobwebbing, or pass non-uniformity, process engineers can identify where their process falls on the air-assist spectrum and can adjust accordingly. The critical first step is to observe the spray results from the applicator itself. This depends not only on the air-assist or the fluid selected, but also the applicator technology.

Every piece of equipment is unique, and application settings must be aligned with equipment capabilities. To achieve balanced atomization and optimal coating quality, manufacturers need to choose efficient, selective coating equipment that matches their fluid and process needs.