Practical Production Applications for Jetting Technology

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Abstract

Dispensing liquid materials, specifically adhesives, onto substrates and printed circuit boards (PCB’s) with repeatable dot-to-dot quality and minimal assist time is a complex process. The key is to choose the dispensing heads that lends itself most closely to the requirements of a specific production process. Understanding how the dispensing heads work and what jetting technology’s strongest and weakest attributes are is essential. This paper will outline the benefits and limitations of jetting materials. Specific attention is paid to underboard support and contact impact issues. This paper also outlines the parameters and the control required in production applications of jet technology. After reviewing the parameters and profile of this method of dispensing, the areas where this technology lends itself to production are explored. Specifically, yield, throughput and setup time advantages from using this leading edge technology is explained. Also covered are the limitations and future development map for jetting.

Adhesive Dispensing in the Surface Mount Assembly Process

Although Surface Mount Technology (SMT) has become a mature process and has been implemented worldwide, the demands for smaller, faster, more complex and lower cost assemblies keep the industry in a constant state of evolution. Smaller PCB sizes; finer-pitch layouts, dense multi-layer circuitry and mixed technology boards, not to mention the increasing range and mix of surface mount component sizes and types (see **Figure 1**), pose challenges for the SMT process engineer. These challenges require the process engineer to review and understand all phases in the SMT assembly line as well evaluate new innovations that will help move the process to the next level. The technique for application of surface mount adhesive (SMA) is one of the in-line processes that are evolving, driven by the common goals to increase speed and to accurately dispense smaller dots resulting in less rework and improved reliability. The primary purpose for using surface mount adhesive during the assembly process is to keep the surface mount devices (SMD) in place before and during the wave or reflow soldering process. SMA can also provide the added benefits of mechanical strength, thermal conductivity, dielectric strength and chemical inertness throughout the life of the assembly.

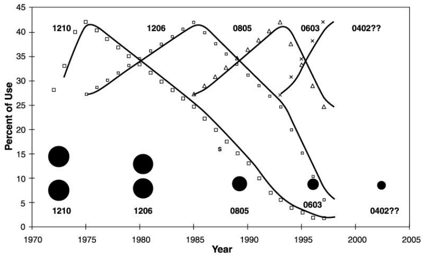

FIGURE 1 –Component Sizes Are Dropping

Characteristics of Surface Mount Adhesive

Surface mount adhesives are specially formulated for different application techniques. For syringe dispensing, the adhesive must readily flow through the dispensing heads. As soon as the adhesive reaches the PCB, the adhesive must recover to keep it from spreading and contaminating the circuit pads. These properties are part of the rheology of the adhesive.

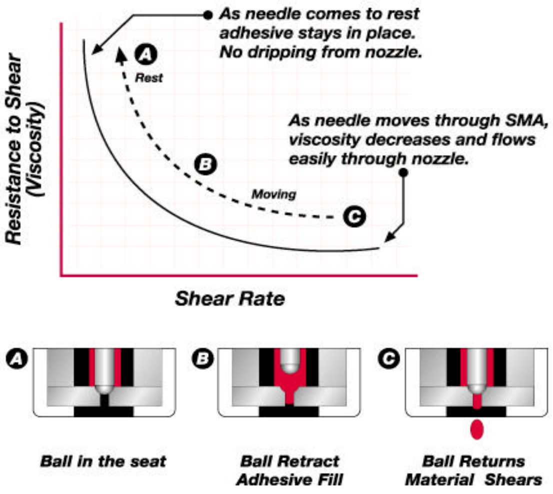

FIGURE 2 – Relationship with Adhesive Rheology

Viscosity is the resistance of a fluid to flow and is one of the primary rheologic properties used to determine is an adhesive is dispensable. With non-Newtonian fluids like surface mount adhesive, viscosity decreases with increasing shear, which explains how the fluid flows easier as it moves through the fluid path of the dispenser. ***Figure 2*** graphically depicts how the viscosity of the fluid decreases as the shear rate increases. The adhesive must also have the ability to restructure and recover its viscosity as soon as it reaches the surface of the PCB. The property of the fluid that allows the material to return to its original viscosity is part of the thixotropy of the adhesive. The thixotropy of the fluid is another critical component in successful syringe dispensing.

There are many formulations of adhesives from a number of suppliers. Characterizing different materials and determining the best dispensing parameters for a specific application are important factors for implementing a robust dispensing process.

Methods for Dispensing SMA

Surface mount adhesives are applied using one of three methods: dispensing, printing or pin transfer. Pin transfer and printing are both methods of mass dispensing adhesive on a printed circuit board. Needle and jet dispensing are two methods to selectively dispense adhesive on a printed circuit board.

Mass Dispensing

Pin transfer is one of the fastest methods of applying adhesive to a printed circuit board. A dedicated tool with an array of pins is designed to match the adhesive dot pattern on the PCB or substrate. The pins are dipped into a tray of adhesive, which wets the pins in predictable amounts. The pins are then touched to the PCB and the adhesive transfers to the board. Pin transfer is used in high volume applications that have very long production runs. The primary limitations of pin transfer are the following:

- The expense of the tooling which has to be redone when the dispense pattern changes.
- The adhesive can absorb moisture or easily become contaminated through exposure in an open tray.
- Applying adhesive to land patterns for components smaller than 3216 (1206) is difficult using the pin transfer method.

Stencil or Screen-Printing (**see Figure 3**) is also a very fast method of applying surface mount adhesive on a printed circuit board. A stencil or screen with holes (voids) that correspond to the desired adhesive dot pattern is carefully aligned over the PCB. A squeegee wipes a wave of adhesive over the stencil that forces the adhesive through each hole, depositing the adhesive dots on the board. The major limitations for stencil printing include:

- Cleaning the stencil (both during and after a production run … clogged stencils can lead to missing dots) is a difficult process when using adhesives.
- Costs (in time and dollars) to retool each time the dispense pattern is revised.
- Exposure of the adhesive to air and moisture, making it susceptible to contamination.

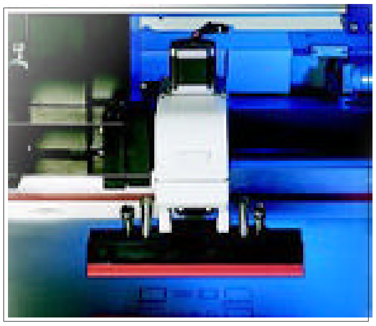

FIGURE 3 – Screen Printing SMA

The majority of the time, mass dispensing can only be accomplished on an unpopulated printed circuit board. The use of stencil printing to apply adhesive has grown slightly in the past 24 months, mostly replacing for pin transfer.

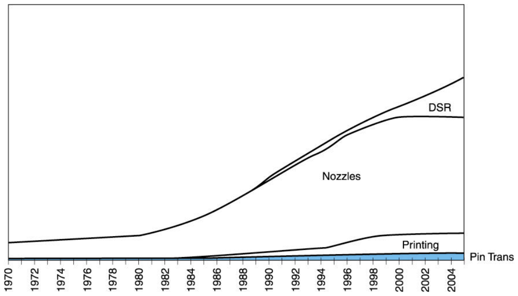

FIGURE 4 – Selective Dispensing Preferred Method for SMA

Selective Dispensing

Selective dispensing can be used on both populated and unpopulated boards. It is also compatible with processes that require another material, such as solder paste, to be applied to the board prior to dispensing adhesive. The adhesive is discretely dispensed using an X-Y-Z positioning system with a specialized dispensing heads compatible with the requirements of the application. Currently, needle dispensing is the preferred method for dispensing adhesive in the SMT production process (see **Figure 4**). The three dominant contact-based methods for discrete SMA dispensing are Time/Pressure (also known as Air/Over), Auger Pump, and Positive Displacement.

Time/Pressure dispensing is the oldest of the three technologies and is still an acceptable method of dispensing in applications where high speed and smaller dot sizes are not a requirement. A syringe of material is pressurized and controlled with a needle valve to control the amount of adhesive to be dispensed. The primary advantage of time/pressure is that it is a simple and inexpensive method to dispense fluids. The major disadvantages include:

- Pressure cycling causes heating in the air of the syringe, which in turn changes the viscosity of the fluid, resulting in inconsistent dispensing.
- As the syringe empties, the air to adhesive ratio changes (see **Figure 5**). The air compresses easily, acting like a shock absorber, resulting in a slower and less accurate response to the air pulse leading to less repeatable dispenses. Dot sizes will vary depending on the amount of fluid in the syringe.

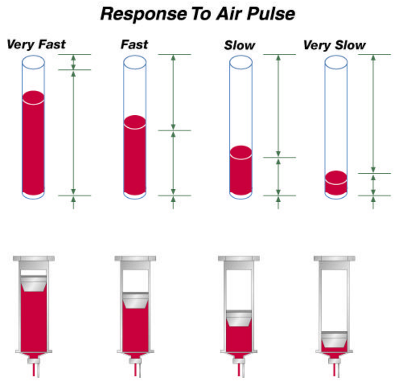

FIGURE 5 – Time-Pressure Limitation

Auger pump dispensing is a much more repeatable way of dispensing adhesive at a higher rate. The auger pump's primary component is an "auger" feed screw that can be turned on and off by a motor (see **Figure 6**). The motor is turned on for a set time, causing the auger screw to move a precise distance. As the screw turns, it shears the adhesive, forcing the material down the thread and out the needle, producing a very precise and consistent adhesive dot. The major disadvantages of the auger pump include the following:

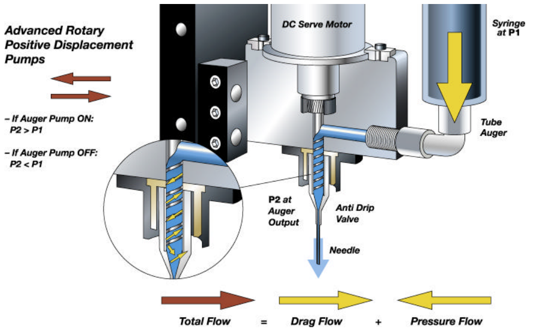

FIGURE 6 – Auger Operation

- Viscosity variations in the fluid can cause poor repeatability, (though less sensitive to changes in viscosity than time/pressure).
- Repeatable and good quality dots require that the dispense gap (the distance between the needle and the substrate or PCB) must be the same from dispense to dispense. Maintaining a consistent dispense gap requires contact with the board, which increases cycle time and complicates the process. It also requires a positioning system that can make accurate moves in the z-axis.
- The number of dots per hour will degrade for larger dots, since a longer "on" time is required to dispense more material.

The piston pump (see **Figure 7**) is a true positive displacement method of dispensing adhesive, which means changes in viscosity will have no effect on the quality and repeatability of the dots. A piston is used to change the volume of a reservoir that is fed from the main syringe. The displacement of the piston in the reservoir results in an equivalent positive displacement of fluid through pump. Since the pump's flow rate is a function of the piston's speed and diameter, changes in viscosity, needle size and supply pressure have no effect on the flow rate. The primary disadvantages of the piston pump include the following:

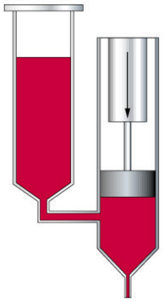

FIGURE 7 – Piston Pump

- The piston pump is more expensive than the time/pressure and auger pumps. The method for cleaning the piston pump is more complex compared to the time/pressure and the auger valve.

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Needle dispensing of adhesive can achieve fairly high dispense rates (greater than 40,000 dots per hour) if the application requires only single, small diameter dots be dispensed on the board. Real-world applications typically require many different size dot diameters to accommodate the different size components that populate a board. A larger component may require multiple dots of adhesive at a single placement site. Both of these factors will negatively impact product throughput in terms of units per hour (uph). Non-contact, jet-dispensing can help minimize the impact on uph since no z-motion is required and the jet can dispense multiple shots of adhesive faster than the time required for a traditional needle dispenser to dispense a large diameter dot.

Jetting Technology: Non-contact Method for Selective Dispensing

The newest technology for applying adhesive to the surface of a substrate or printed circuit board is non-contact jetting. Jetting offers many advantages over traditional methods of dispensing SMA, but it also has certain limitations. It is important to have a fundamental understanding of the theory of operation of the valve to appreciate the advantages of this technology in the production environment.

Essentially, jet dispensing utilizes a closed-loop, positive shut-off piston to dispense adhesive (reference **Figure 8**). The fluid is pressurized at the syringe to ensure a constant flow of material throughout the fluid path of the dispenser. The chamber at the end of the fluid path is heated and the temperature controlled to achieve optimal and consistent viscosity. Using a ball and seat design, adhesive fills the void left by the ball as it retracts from the seat. As the ball returns, the force due to acceleration breaks the stream of adhesive, which is jetted through the nozzle. The broken stream of adhesive strikes the substrate from a distance of 1.0 mm to 3.5 mm above the board and forms an adhesive dot. The uniformity and shape of the adhesive dots are unaffected by variances in the PCB planarity or discrepancies in the needle surface and board surface tension since it never comes in contact with the board.

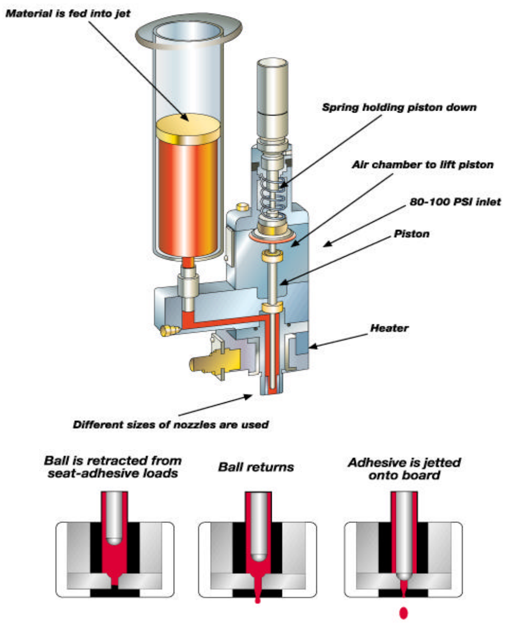

FIGURE 8 – Jet Dispensing Concept of Operation

The jet's spring-driven ball and seat mechanism allows the jet to shoot precisely controlled volumes of adhesive onto the PCB. Since there is no motion in the z-axis, the cycle time from dispense to dispense is significantly reduced (see **Figure 9)**. The time between shots is typically 15 milliseconds compared to 90 milliseconds with conventional needle dispensing. The raw speed of jetting also gives the system an inherent flexibility for delivering different dot sizes from a single dispense head.

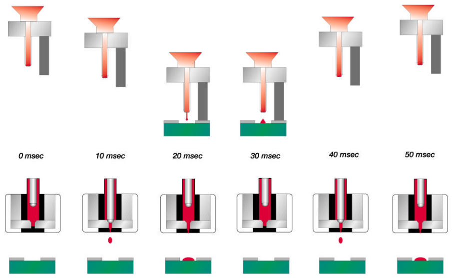

FIGURE 9 – Mechanical Dispensing vs. Non-Contact Dispensing

Unlike traditional needle-based systems that require different diameter needles to change dot sizes, jet dispensing can increase the size of the dot by simply applying from one to five shots of adhesive in rapid succession (see **Figure 10**). This greatly reduces the time-consuming effort of changing needles or using a cumbersome multi-needle dispense head. Eliminating all of the wasted vertical motion, repeated height-sensing steps and wetting dwell times allows non-contact dispensing systems to run at nearly the maximum speeds of their X-Y positioning systems and keep up with high-speed placement systems.

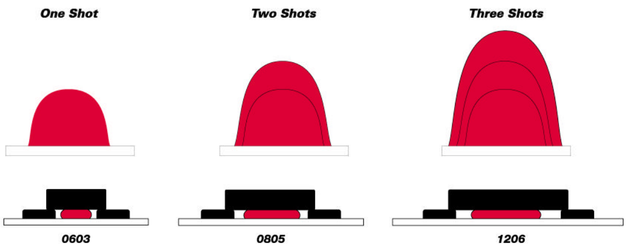

FIGURE 10 – Multiple Shots Make Higher Profile Dots

The primary limitation of jetting technology is the inability to jet materials such as solder paste. Solder balls in the paste will "coin" when they are struck with the ball of the needle. This eventually leads to clogging and requires high levels of operator assistance. Solder paste is an example where an auger pump is the preferred method of selectively dispensing a fluid on the PCB.

Advantages of Non-contact Dispensing in Production

In application, the jet is able to "fly" above the board at a fixed height and "jet" the material onto the dispense site without having to contact the board. This presents a number of additional advantages over traditional needle dispensing. Since there is no contact with the board, underboard support is not required. Not only are the mechanics of the machine simplified, both process engineering time and setup time is reduced each time a new board is run through the line. Mechanical contact with the board results in significant vibration that must be dampened out using a good underboard support configuration if repeatable, consistent dot shapes are desired. Jet dispensing removes this source of variability.

Figure 11 identifies reasons why the landing area for the standoff must be considered when using a mechanical standoff. The process engineer must predict which orientation of the standoff to the needle will not land on a trace, pad or previously dispensed adhesive dot. This challenge becomes even more difficult when multiple PCBs are processed in the same production line or when component size variations require a range of dot sizes that exceeds the capabilities of a single needle.

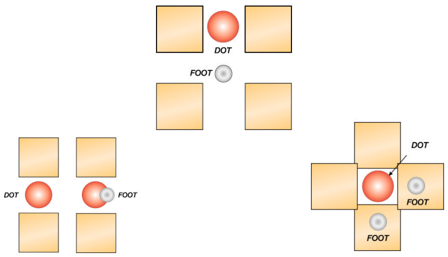

FIGURE 11 – Standoff Landing is Critical

Since needle dispensing is critically dependent on board flatness and accurate z-height to work properly, there is a constant balancing act between the degree of warp in the PCB and the state of wear in the dispenser's mechanical standoff (reference **Figure 12**). Non-contact jetting eliminates these variables from the process control equation.

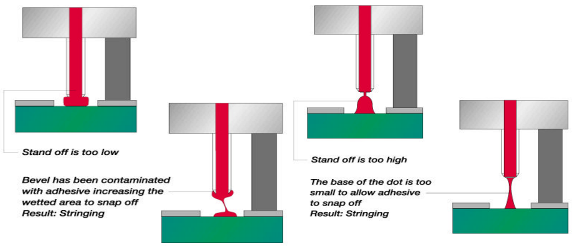

FIGURE 12 – Dispense Gap Variations can Cause Stringing

Jetting – The Solution for Today’s and Future Production Requirements

Today’s real-world SMT production environments require equipment that is flexible and easy to use. It must also address the issues of setup time versus overall throughput. Selective dispensing has the flexibility to be deployed now and fit within the overall production process, addressing both current and future process requirements.

Each method of selective dispensing also has its advantages. Time/pressure dispensing is inexpensive and easy to clean. Auger pumps offer good dispensing control and can dispense a wide range of materials, providing the best value in some applications. The piston pump provides good process control for dispensing precise amounts of fluid, independent of changes in fluid viscosity. The common weakness of each of these methods when dispensing SMA is that they all require contact with the board. Dot quality and repeatability are very dependent on the dispense gap, which introduces a number of critical parameters into the process control equation. It has been long acknowledged that the stability of any process varies inversely to the number of parameters that must be controlled. For this reason alone, process engineers evaluating ways of incorporating non-contact jetting solutions of fluids into their process.

Non-contact jetting has resulted in an overall simplification of the process by providing easier programming, faster setup and more robust process control. The advantages of non-contact jetting include the following:

- Reduced setup and assist time. No needles to change or adjustments are made during production.
- No underboard support is required.
- Dispense gap repeatability no longer an issue.
- Dispensing larger dots does not impact throughput as significantly as other methods of selective dispensing.
- Flexibility with board changeovers.
- Needle/standoff orientation is not an issue.
- Needle standoff location (trace, pads, tracks through adhesive) is not an issue.

Just as all successful new technologies grow to suit a larger range of used, jet dispensing applications are rapidly expanding. For example, jetting has promise in the selective application of silver-filled epoxy, flux and no-flow reflow. These applications can benefit from the ability to shoot fluid at elevated speeds without touching the board.

Jetting surface mount adhesive is rapidly gaining acceptance in real-world production environments, especially in the high volume, high mix world of contract manufacturing where the speed, flexibility and programmability of jet dispensing provide a competitive advantage over time and expense of traditional dispensing techniques.

References:

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