High Throughput Dispensing Using Multi Port Jet

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Abstract

Flat panel display manufacturers are always investigating new techniques to improve productivity and reliability. For fluid dispense processes, Jet dispensing has shown benefits over traditional needle dispensing. Recent advancements in nozzle design and construction techniques enable jet dispensing capabilities far exceeding what has been previously achieved.

1. Introduction

As display manufacturers are required to increase production efficiency and yield, improvement to processes will be necessary. One of the processes in OLED (organic light emitting diode) and TFT (thin film transistor) is dispensing gaskets of sealant. Specialty formulated U.V. fluids are used to bond and space the glass to the substrate. This process requires a thin line of UV fluid sealant to be dispensed on a glass substrate. The most common employed method for dispensing the sealant gasket is needle dispensing using an auger applicator.

Speed of needle dispensing is inherently limited by wetting capability of the fluid to the glass substrate. For good dispensing quality, the dispenser must not be moving faster than the exit velocity of the fluid from the needle orifice. If the dispenser moves faster, the fluid will be pulled along the surface of the glass, causing a number of quality issues because the fluid does not have a chance to wet the surface properly. If the dispenser is going too slowly, the fluid will plow ahead of the needle tip resulting in stringing issues and improper amounts of fluid delivery. The dispenser should be moving slower than the fluid (velocity coming out of the needle) to allow good wetting of the surface, and minimum stringing. The fluid exit velocity from the orifice is given by the following equation.

$$V_{orifice} = \frac{Q}{A_{orifice}}$$

Where:

Q = Fluid flow rate

A = Cross-sectional area of needle orifice ($\pi D_2^2/4$)

Recently some manufacturers have adopted jetting techniques used in flip chip underfilling to enhance throughput and quality. See figure 1.

Figure 1- Examples of a Jet Applicator (left) and an Auger Applicator (right)

This paper examines benefits of jet dispensing technology to enhance throughput and quality of dispensing seals. It also explores the throughput enhancement of a multi port jet dispensing. Multi port jet dispensing can provide the throughput of multiple head machine while the ease of setup and reliability of a single head machine.

2. Jet Dispensing Process

Jet dispensing is completely different from needle dispensing. During jet dispensing a mechanical device ejects a drop of fluid from a nozzle which has a small orifice. Orifice sizes are available from 50 microns to 500 microns, depending upon the desired dot size. The flow rate from a jet is the firing rate times the dot volume. Unlike other jetting technologies like thermal ink jets, or piezoelectric jets, a mechanical jet can eject small dots of very thick adhesives, up to 400,000cps. Figure 2 shows a schematic of a mechanical jet.

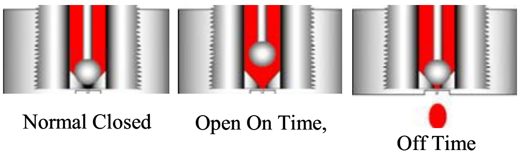

Figure 2: Jet schematic

Jet dispensing can form a line by dispensing series of dots that are joined to form a line during the lamination process. The lamination process compresses dots causing them to expand and merge. Once the dots merge, the fluid flows to form a straight line which then can not be distinguished from a line dispensed with a needle (Figure 3)[1].

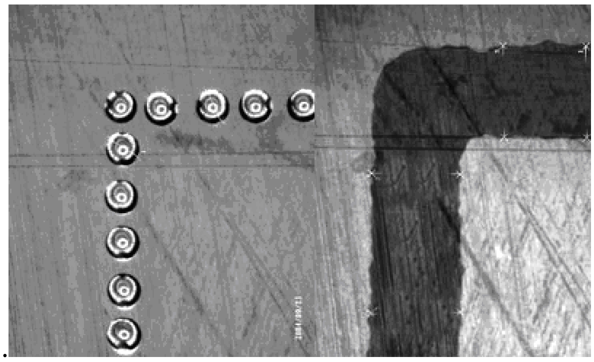

Figure 3: Dispensed dots (left) are laminated to form a seal line (right).

In addition to faster dispense speed; jet dispensing has other advantages over traditional needle dispensing. The advantages include broader process window due to dispense height insensitivity as well as better corner shaping[1].

2. Multiple Port Jet Dispensing

Jet applicator is enabled by a piston like actuation powered by a pneumatic, electric or piezo powered actuator. Increasing the frequency of valve actuation is one way to increase the dispense speed of UV lines. This method has inherent limitation induced by the characteristics of the actuator.

Mechanical actuations are typically limited to 200 to 300 actuations per seconds. For pneumatically actuated devices, this limitation is often due to the response time of the pneumatic solenoid or its pneumatic flow coefficient (Cv). For piezo actuated devices, the limitation is most often due to thermal considerations.

Another way of further increasing the speed of jet dispensing of UV lines is to dispense multiple dots from a single actuation of the jet applicator. This can be achieved by utilizing a nozzle with multiple ports (figure 4).

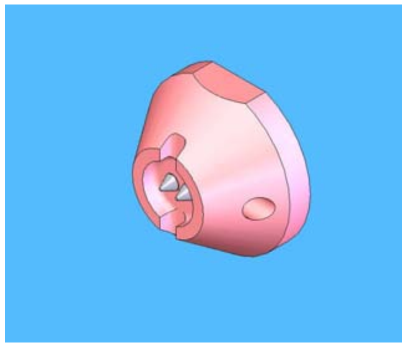

Figure 4: Example of multi (dual) port nozzle that can be employed with a Jet Applicator

Utilizing a multiple port nozzle also requires adjustment and enhancement to the accompanying hardware of the jet applicator. In order to use multi port jet dispensing to dispense rectangular patterns, a 90 degree nozzle rotation is required. This 90 degree rotation is illustrated in figure 5.

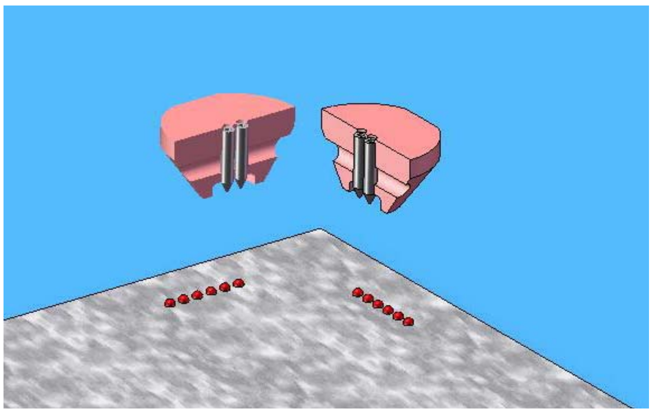

Figure 5: Rotation Illustration of Multi-port Nozzles.

3. Test Results for Throughput Enhancement

Under best conditions, the dispense line velocity using needle is often limited to 80 mm/s. Due to limitation of acceleration capability of the robotic platform, dispense speed is often slowed to 60 mm/s or slower while dispensing the corners of rectangles.

Standard jet dispensing is capable of 160mm/s while multi port jetting is capable of 320 mm/s with a dual hole configuration or 480 mm/s with a 3 hole (tri-hole) configuration.

To evaluate throughput improvement, five machine configurations are compared. These configurations are listed in table 1.

Platform Configuration	**Dispense Speed**
Dual Head Needle	60 mm/s
8X Head Needle	60 mm/s
Single Head standard Jet	160 mm/s
Single Head Jet Dual Port Nozzle	320 mm/s
Single Head Tri Port Nozzle	480 mm/s

Table 1: Machine configurations

Dual and 8X head needle platform refer to a platform with 2 and 8 heads respectively. Each head is equipped with a needle dispense applicator capable of dispensing at 60 mm/s. The next 3 platform configurations are based on a single head equipped with a single jet applicator. First is equipped with a standard single port nozzle, next is equipped with a dual port nozzle (figure 3), and the last is equipped with a nozzle that has 3 ports.

The dispensing speed of these five machines were compared for dispensing UV gasket seals on a generation 4 glass substrate with 899 seals as shown in Figure 6.

Throughput of each platform configuration was estimated using an excel spreadsheet simulation. Simulations were also verified via an actual wet dispense.

All tests took into account identical time burden for vision (fiducial mark find) and height sense. All non-dispense moves utilized maximum XY acceleration of 1g and a maximum Z acceleration of 2 g's. The time required for height sense for jet dispensing was assumed to be 2 second per glass since jetting is not height sensitive [1]. The throughput numbers do not take into account the time needed to load or unload parts.

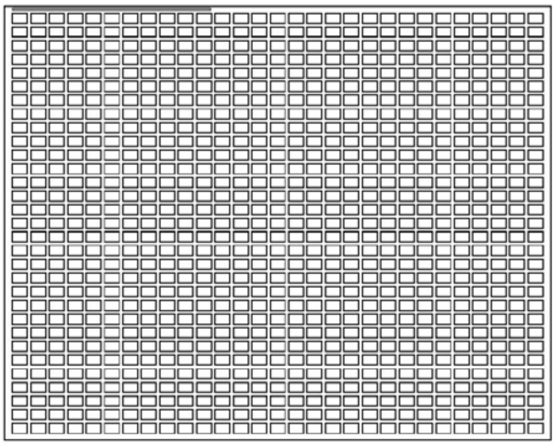

Figure 6: 899 displays on a Gen 4 glass (920 X 730 mm)

The test results are shown in figure 7. The results shows that a platform equipped with a single dual port nozzle exceeds the performance of an 8 headed machine equipped with 8 needle applicator, each dispensing at 60 mm/s. The result also shows that a platform equipped with a single tri-port nozzle exceeds the performance of an 8 headed machine equipped with 8 needle applicator by 32%.

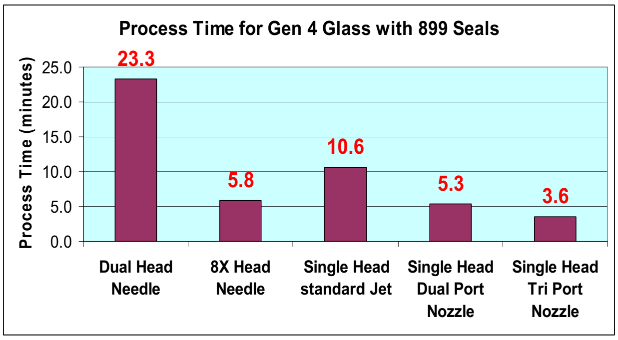

Figure 7: Process Time (minutes)

4. Cost of Ownership

An important aspect of multi port jetting is that it provides sufficient speed such that it allows using a single head machine. Single head machine has less setup time and higher reliability than an equivalent multi head machine.

A cost of ownership (COO) model was built upon the Semi E35 standard. See Figures 8 & 9.

Needle Dispenser		
Enter parameters in blue cells		
Lifetime Equipment Costs T$ =	$7,267,329	
Fixed costs, F$		
Initial equipment cost =	$566,667	1 set
Initial spares cost =	$22,667	
Initial training cost =	$10,000	
Initial system qualification cost =	$10,000	
F$ =	$609,333	
Labor costs, L$		
Labor cost per shift per year =	$25,000	
Number of shifts planned per day =	3.0	
L$ =	$375,000	
Recurring costs, R$		
Consumables $ (seals, needles, etc.) per shift =	$50	
Material Use (excess epoxy, solvents, etc.) $ per shift =	$10	
Utilities $ per shift =	$10	
Floor space cost per year =	$11,520	
Warranty period (years) =	1	
Non-warranty maintenance & spares cost per year =	$20,000	
R$ =	$505,100	
Yield cost, Y$		
Net number of units processed per shift =	26076	
Average number of defective units per shift =	222	
$ Value of unit processed =	$5	
Y$ =	$5,777,895	
Yield =	99.1486%	

Lifetime COO/part = (T$/N(t)) =	$0.0535
Lifetime Units Produced N(t) =	135,733,690
Total Units Produced: N(t) = L * T * Y * U	
Lifetime of equipment (years), L =	5
Gross thruput (uph) =	4495
Utilization U = 1 - ((SM + USM + A + S + Q) / H)	
All Shifts Total Production Hours per week, H	
Production Hours per shift =	7.5
Days production per week =	7
Number of weeks scheduled per year =	50
H =	157.5
Scheduled Maintenance, SM	
Setup & cleaning (hrs/week) =	10.5
Other PM (hrs/week) =	1.0
SM =	11.5
Unscheduled Maintenance, USM	
MTBF (hrs) =	170
MTTR (hrs) =	1.0
Operator/Engineering process assist, MTBA (hrs) =	9.0
MTTA (hrs) =	0.5
USM (hrs/week) =	9.7
Other Equipment Down Time (A+S+Q)	
Non-process assist time (hrs/week), A =	7.0
Standby (idle) Time (hrs/week), S =	3.0
Qualification/process verification (hrs/week), S =	4.5
Utilization U = 1 - ((SM + USM + A + S + Q) / H) =	77.3%

Total Lifetime Cost Breakdown Summary:	$	%			
Equipment:	$609,333	8.4%	Consumable parts:	$262,500	52.0%
Labor:	$375,000	5.2%	Material:	$52,500	10.4%
Recurring:	$505,100	7.0%	Utilities:	$52,500	10.4%
Yield:	$5,777,895	79.5%	Floor space:	$57,600	11.4%
			Non-warranty maintenance:	$80,000	15.8%
Total lifetime cost:	$7,267,329	100.0%	Total lifetime recurring costs	$505,100	100.0%

Figure 8: COO model for Needle Dispenser

JET Dispenser		
Enter parameters in blue cells		
Lifetime Equipment Costs T$ =	$3,296,550	
Fixed costs, F$		
Initial equipment cost =	$1,133,333	1 set
Initial spares cost =	$45,333	
Initial training cost =	$10,000	
Initial system qualification cost =	$10,000	
F$ =	$1,198,667	
Labor costs, L$		
Labor cost per shift per year =	$25,000	
Number of shifts planned per day =	3.0	
L$ =	$375,000	
Recurring costs, R$		
Consumables $ (seals, needles, etc.) per shift =	$13	
Material Use (excess epoxy, solvents, etc.) $ per shift =	$3	
Utilities $ per shift =	$10	
Floor space cost per year =	$11,520	
Warranty period (years) =	1	
Non-warranty maintenance & spares cost per year =	$20,000	
R$ =	$268,850	
Yield cost, Y$		
Net number of units processed per shift =	28082	
Average number of defective units per shift =	55.5	
$ Value of unit processed =	$5	
Y$ =	$1,454,034	
Yield =	99.8024%	

Lifetime COO/part = (T$/N(t)) =	$0.0224
Lifetime Units Produced N(t) =	147,142,965
Total Units Produced: N(t) = L * T * Y * U	
Lifetime of equipment (years), L =	5
Gross thruput (uph) =	4495
Utilization U = 1 - ((SM + USM + A + S + Q) / H)	
All Shifts Total Production Hours per week, H	
Production Hours per shift =	7.5
Days production per week =	7
Number of weeks scheduled per year =	50
H =	157.5
Scheduled Maintenance, SM	
Setup & cleaning (hrs/week) =	2.6
Other PM (hrs/week) =	1.0
SM =	3.6
Unscheduled Maintenance, USM	
MTBF (hrs) =	170
MTTR (hrs) =	1.0
Operator/Engineering process assist, MTBA (hrs) =	9.0
MTTA (hrs) =	0.5
USM (hrs/week) =	9.7
Other Equipment Down Time (A+S+Q)	
Non-process assist time (hrs/week), A =	7.0
Standby (idle) Time (hrs/week), S =	3.0
Qualification/process verification (hrs/week), S =	3.0
Utilization U = 1 - ((SM + USM + A + S + Q) / H) =	83.3%

Total Lifetime Cost Breakdown Summary:	$	%			
Equipment:	$1,198,667	36.4%	Consumable parts:	$65,625	24.4%
Labor:	$375,000	11.4%	Material:	$13,125	4.9%
Recurring:	$268,850	8.2%	Utilities:	$52,500	19.5%
Yield:	$1,454,034	44.1%	Floor space:	$57,600	21.4%
			Non-warranty maintenance:	$80,000	29.8%
Total lifetime cost:	$3,296,550	100.0%	Total lifetime recurring costs	$268,850	100.0%

Figure 9: COO model for Jet Dispenser

In this comparison, assume the takt time is fixed, at 12 minutes per panel for 899 displays which yields 4495 units per hour (UPH). Therefore, a needle dispenser will require 4 heads and the jet dispenser 1 head to get the throughput, but the additional throughput of both systems does not help COO since the takt time is fixed at 12 minutes. Given the set up time for a jet head is the same as an auger pump, it will take 4 times as long to set up the needle dispenser. Also, dispensing failures go with the head per time; since the takt times are the same for this case, the number of failures is proportional to the number of heads. Let's also assume the jet dispenser costs 2 times as much as the needle dispenser and that initial spares are 4% of the dispenser costs. Material waste and consumable part costs are assumed to be the same for each head, however there are 4 needle dispensing heads. It becomes very obvious that the pay back is in the increased yield. Even if the jet dispenser's initial cost was 2 times the needle dispenser, the capital cost per part is less than half of the needle dispenser. See figure 10.

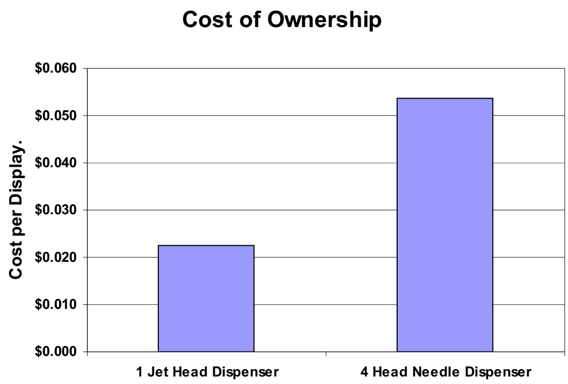

Figure 10: Cost of ownership

5. Conclusion

Utilizing jet dispensing with multi port nozzle greatly enhances dispense speed for UV gaskets. This will allow for enhanced throughput. Alternatively, using multi port jet dispensing allows for equivalent throughput as a multi head needle dispenser, with fewer number of applicator head per machine. Smaller number of applicator per machines results in reduced setup and maintenance time, reduced equipment downtime, which consequently reduces the total cost of ownership. A multi port, single head jetting platforms allows for dispense speeds exceeding that of an 8 head needle platform, while maintaining the reliability and ease of setup of a single head platform.

6. References

[1] Thomas Ratledge, Avances in Jet Dispensing, *IMID'06* (2006).

[2] This paper is based on continuing research being preformed at Asymtek's facility