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Adhesive Deposit Performance Characterization using Standard X-ray Analysis Tools

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Introduction

Quantifying SMT adhesive dispensing performance has typically been attribute analysis via a microscope. Individual adhesive deposits were inspected for strings or tails, extra dots, missing dots and dot diameter. These attributes were typically measured with an eyepiece reticule and a light microscope. This tedious and subjective method has been replaced by a highly quantitative, extremely quick automated method using the vision engine of a real time X-ray. The details of this method are discussed as well as practical applications for glue benchmarking and dispense parameter fine-tuning. The output of this method includes dot diameter, spherocity and area. Adhesive deposit consistency of both dispensing and printing are compared using this novel measurement method.

Analysis Tool

To analyze adhesive deposits, the analysis tool by CR-Technology Inc. (Figure 1) was used.[1] This system, RTI-580 Real Time Image Enhancement and Analysis System, is designed for X-ray BGA analysis. BGA's assembled on boards are imaged by the X-ray system, and diameter, shape and area are measured by gray scale image analysis software. Although epoxy adhesives for SMT do not have enough X-ray absorption properties to get a robust enough image for analysis, the adhesive deposits can be imaged with a regular light camera with backlight. Digital black-and-white images are imported into the X-ray system and recognized by the system as BGA spheres. To get clear images, ceramic substrates were selected for this test. For calibration purposes, a ruler image was taken with the same magnification and brightness.

After importing the images of the coupons, the image enhancement and analysis system will recognize the 48 adhesive dots on the display. It measures the diameters, areas and shapes of all dots. All data is displayed in the window (Figure 2).

Figure 1 - CR Technology X-ray System

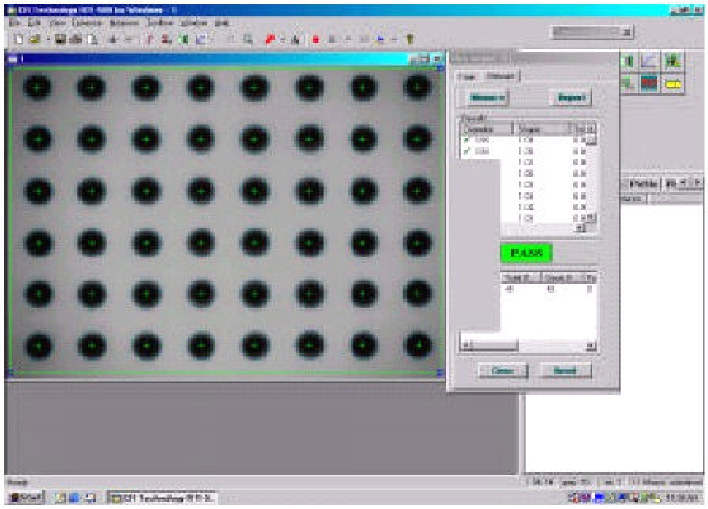
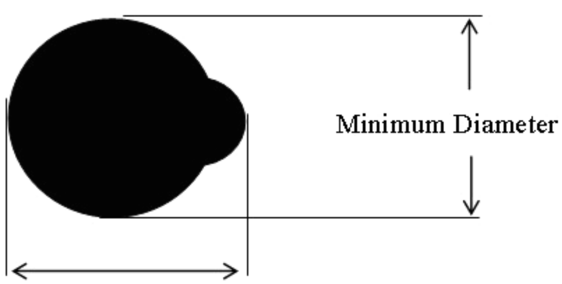


Figure 2 - RTI-580 Measurement Display

Data Analysis

In this system, *Diameter* indicates its maximum diameter and *Shape* calculates a ratio of maximum diameter over minimum diameter. If the shape value is 1, the maximum diameter and minimum diameter are the same, so the dot is a perfect circle. If the maximum diameter is bigger by 30% than the minimum diameter, the shape value will be 1.3. From this measurement, stringing or tailing can be recognized (Figure 3). *Area* counts pixels in calibrated units (mm^2). If the diameter values are uniform, it doesn't guarantee that all of the dots are consistent, the shape and area may be varied (Figure 4). If the shape shows very close to 1, but the size (area or diameter) is irregular, it could mean that the dispensing has good shape but big or small dots are distributed throughout the pattern. In order to know the true dot consistency, all three attributes (diameter, shape and area) should be compared. The system will simultaneously measure all 48 dots; data is then exported to an Excel file for analysis.



Diameter:	Maximum Diameter
Shape:	Max. Diameter / Min. Diameter
Area:	Count surface pixels

Figure 3 - Dot Measurement

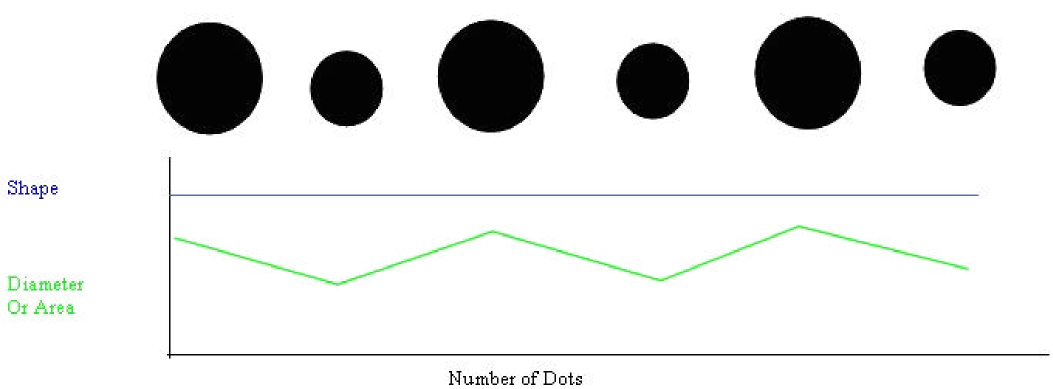


Figure 4 - Inconsistent Dots Size

Printing and Dispensing

To deposit SMT adhesive on boards, many manufacturers are moving from dispensing to printing methods. Each method has its own merit and demerit. It is well known that dispensing is flexible to switch product designs by changing dispensing programs, but has a longer tact time. Conversely, printing is much faster for its tact time, but to switch products, changing a screen is required. Each manufacturer has their own portfolio of products, some with high volume and low product mix, or low volume and high product mix. It is common knowledge that printing is faster than dispensing but it is currently not well published which method is more reliable for quality. This quick automated measurement method supports a large study of dot quality between printing and dispensing methods. For this study an array of dot arrays was designed (Figure 5).

Substrates

White Alumina (Al_2O_3) substrates (4.5” by 4.5”) were used for better black-and-white vision contrast. Forty-eight (8 x 7) dots targeted with 0.8mm diameters were deposited in a 0.42” x 0.3” array, with 25 arrays on each substrate. 12 substrates for each adhesive tested generated 14,400 dots for measurement and analysis per adhesive. In this study a 10mm length is equivalent to around 500 pixels. This means the precision of the measurement is 0.02mm. If higher precision is needed, a higher magnification can be used at a penalty of measurement time. This precision (0.02mm) was considered good enough to measure 0.8mm size glue dots for this study.

To generate equivalent data, the aperture for printing was fixed at 0.76mm (30mil) in diameter. This is a very common dot size used for adhesive deposit (Table 1). For the dispensing, a 0.4mm needle (ID) was used and dispense parameters were set to generate a 0.8mm dot diameter.

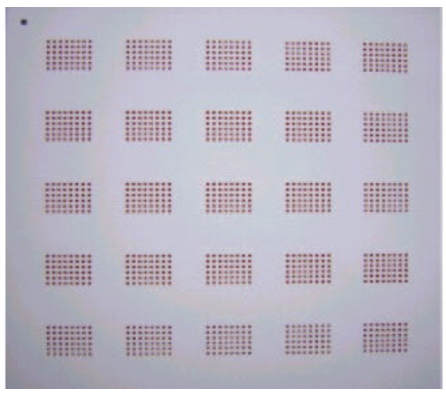


Figure 5 - Test Pattern

Table 1 - Dot Diameter

Components Size	Typical Diameter Range
1608	0.4 - 0.6 mm
2125	0.6 - 0.8 mm
3216	0.7 - 0.9mm
SOT 23	0.7 - 0.8mm
SOIC	>1mm

Adhesive

To perform this test, three types of Heraeus SMT adhesives were selected for the test (Table 2), PD955PR (Glue A) for printing, PD966M (Glue B) for dispensing and PD944 (Glue C) for both methods. Glue A was designed specifically for printing with the ideal rheology for printing. It is very stable for environmental factors such as humidity and temperature, which makes this adhesive possible to leave on a screen for long time. Glue B is specific for high speed dispensing. This adhesive has rheology for quick breaking that avoids stringing, satellites and generates an ideal dot shape. Glue C is for general dispensing purposes. This was picked for both dispensing and printing methods as control in this test. All adhesive can be printed, but depending on the printing conditions dot quality may vary.

Table 2 - Adhesives

	Print	Dispense	Feature
Glue A	X		Best for printing
Glue B		X	High speed dispensing
Glue C	X	X	General purpose

Equipment and Adhesive

For deposit equipment, a DEK 265GSX printer and a Camelot Gemini screw pump system dispenser were used. Camelot Gemini's screw pump system makes high speed and consistent dispensing possible. DEK 265 is an accurate automatic controlled printer that gives consistent print repeatability.

Conditions

Printing and dispensing conditions and tact time for one substrate (1,200 dots) are in Table 3. Conditions were optimized for each product. [2] Printing was about 7 to 10 times faster than dispensing for this design. However, on an actual production line, number of dots on one board is design dependant. It may be 500 dots per board, or 50 dots. In this test, dispensing tact time for 100 to 120 dots per board could be equivalent to printing. Furthermore, dispensing tact time is decided by not only number of dots on a board, but also the dispensing order and distance between dots. Generally, it is rare that the dots form a line like this test board on a production line, so the real tact time for dispensing should be slower due to additional X-Y movement losses. For printing, Glue A can be printed with single print, but needed slow and longer separation distance due to its sticky rheology that results in high green strength. Glue C is a dispensable glue so it has a different rheology and needed to be printed with a print and flood-print cycle to avoid air bubble entrapment. One of printings' best points is that the tact time doesn't change no matter how many dots are in a board.

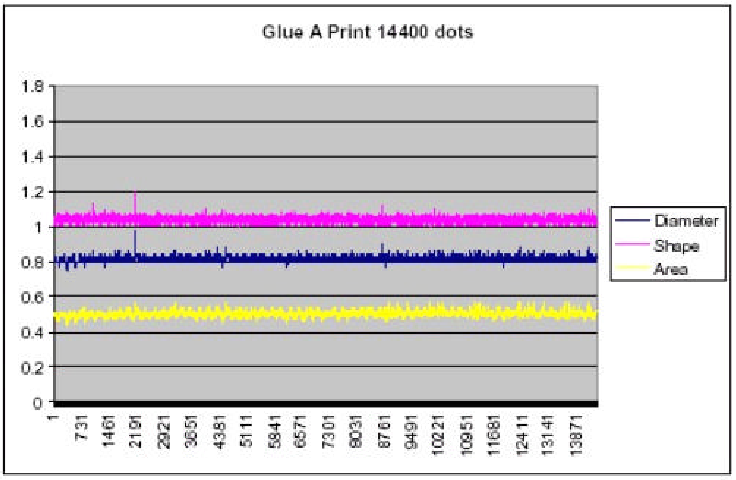
Table 3 - Conditions

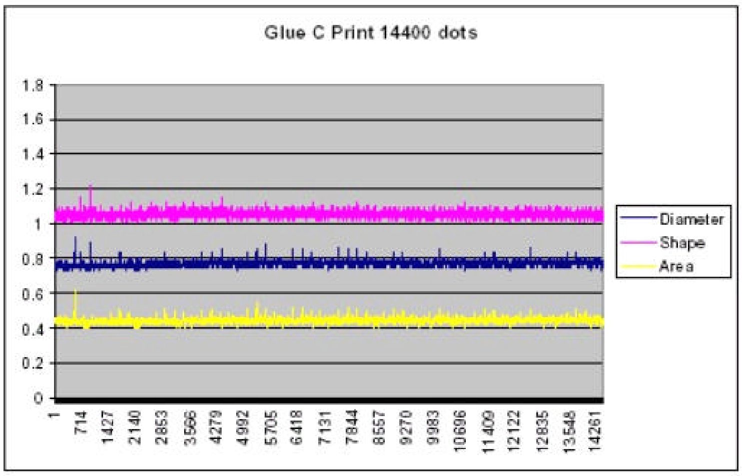
Print		
DEK265	Glue A	Glue C
Stencil Thickness	150um	150um
Aperture Size	0.76mm	0.76mm
Squeegee	300mm Metal	300mm Metal
Method	Single	Double
Pressure	6Kg	5Kg/0.6Kg
Speed	25mm/sec	100/100mm/sec
Separation	0.5mm/sec for 3 mm	0.5mm/sec for 1mm
Print Gap	0mm	0.6mm
Tact	20sec	17sec

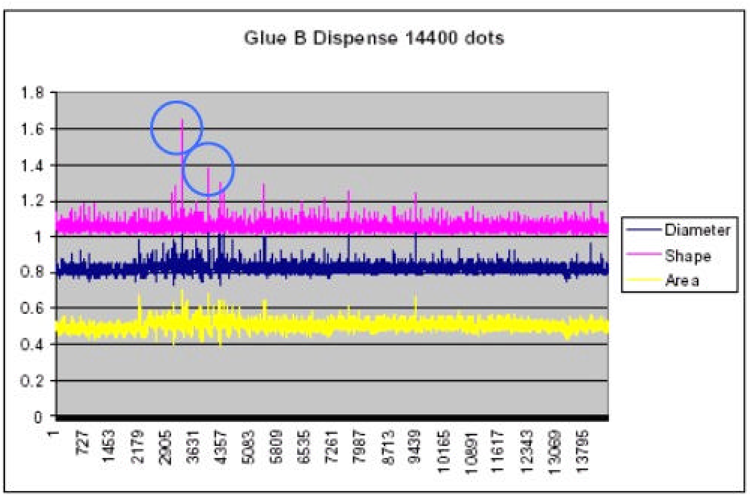
Dispense		
Camelot	Glue B	Glue C
Needle ID	0.4mm	0.4mm
Gap	0.2mm	0.2mm
Dispense time	31ms	35ms
Return height	3mm	6mm
Tact	144sec	181sec

Measurement Results

The following is all data analyzed in this study (Figure 6). Blue lines indicate diameter in mm. Pink lines indicate shape with 1.0 indicating a perfect circle. Yellow lines show dot area in mm^2. Extremely high values on shape (pink lines) in Glue B and Glue C are circled in blue, which indicate stringing (shape values exceeding 1.3).[3] Glue A and Glue C print have smaller over all data distributions.


Glue A Print 14400 dots
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
731
1461
2191
2921
3651
4381
5111
5841
6571
7301
8031
8761
9491
10221
10951
11681
12411
13141
13871
Diameter
Shape
Area


Glue C Print 14400 dots
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
714
1427
2140
2853
3566
4279
4992
5705
6418
7131
7844
8557
9270
9983
10696
11409
12122
12835
13548
14261
Diameter
Shape
Area


Glue B Dispense 14400 dots
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
727
1453
2179
2905
3631
4357
5083
5809
6535
7261
7987
8713
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13795
Diameter
Shape
Area

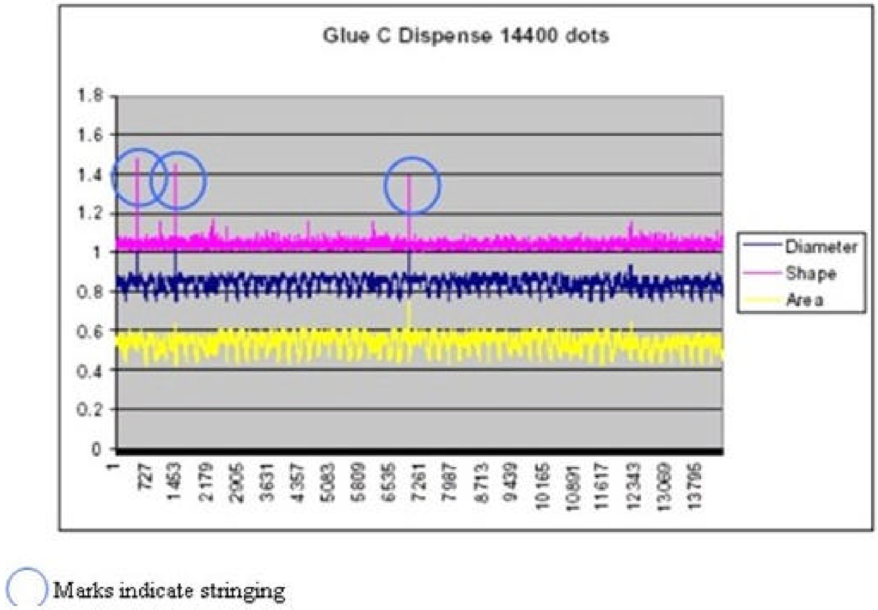

Figure 6 - All Data

The next Figure 7 summarizes the dot data for all adhesives and deposit methods. The bar graph shows standard deviation for diameter, shape and area. The line graph shows average values for diameter (mm), shape and area (mm^2). Glue A print has the best consistency for all three factors. Glue C was neither the best printing nor dispensing adhesive. Glue C dispense has good standard deviation of shape but worse diameter and area deviation. This indicates that the glue dots have a variety of sizes but have a good circular shape. The average diameters are in range of 0.77mm to 0.85mm, and areas are $0.44mm^2$ to $0.54mm^2$. No dot shape can be less than 1. If the value is 1.0, it means the dot is a perfect circle. The measurement values were in range between 1.036 and 1.055. Empirically, higher than 1.3 can be called a dispense defect known as stringing. When an extra dot area and/or diameter is found, it may be a satellite dot or a small dot. The measurement range can be set, so all dots including small dots can be found and measured, or a select dot size range can be specified. For this study all dots were measured and satellite dots were counted. In Figure 7, satellite dots and extremely small dots are not taken into account. Even the standard deviation of 0.04 for Glue C dispense is of marginal quality for SMT mass production lines. To compare to printing method, dispensing conditions were set for the highest speed possible. Glue B was dispensed with 3mm return height, and 6mm for Glue C. If slower tact were allowed, the dot quality would be improved. A standard deviation of less than 0.02 for printing indicates very consistent results. Glue C print showed slightly worse shape values than Glue C dispense. This was because several Glue C printed dots contain micro bubbles (Figure 8).[2] Glue C was not designed for printing originally, so its rheology keeps the micro bubbles in the glue that results slightly higher shape readings.

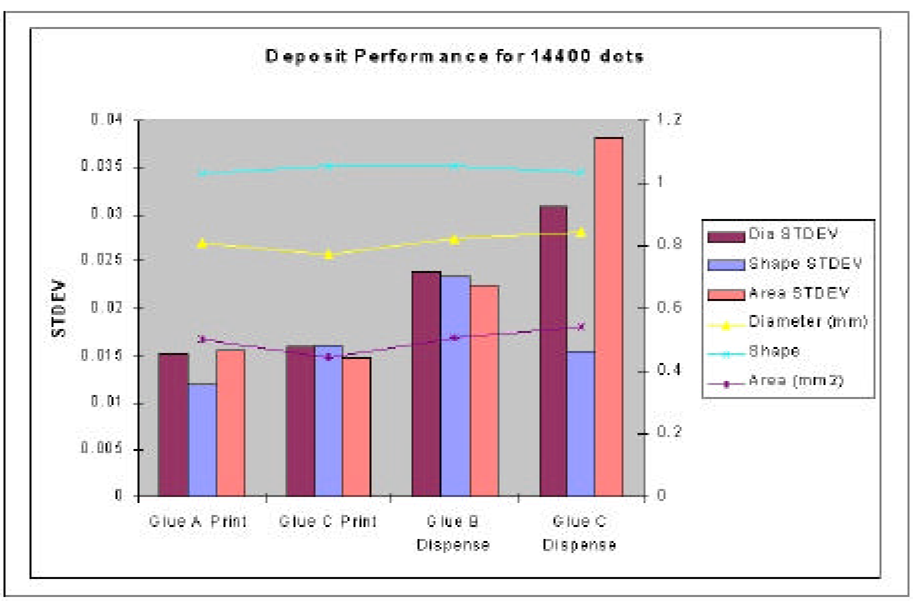

Figure 7 - Deposit Performance

Figure 8 - Printed Dot with Air Bubble

The Figure 9 shows deviation of diameter, a median diameter of Glue C print is 0.77mm while that of Glue A print is 0.8mm, though the aperture diameter is 0.76mm. Glue C dispense has a wide range of diameter and area. Glue C print and Glue A print have very tight distributions with Glue A slightly broader. Glue C dispense has a wide range of diameters ranging from 0.8 to 0.87mm. A tendency of the dot area distribution (Figure 10) is similar to that of diameter distribution. Glue C print and Glue A print have the tightest distributions. Glue C dispense showed wide and low distribution.

For the dot shape (Figure 11), Glue A print and Glue C dispense are closest to perfect circle. From the data, Glue C dispensed dots have very good shape but wide range of diameter and area. That means dots of Glue C dispense don't have stringing but have inconsistent size with good circular shape. Figure 12 shows all measurement data (1200 dots) on one substrate from Glue C dispense. There are five waves in the diameter and area data on one substrate. The shape graph shows one straight line. One substrate has 25 blocks and the dispensing traces 5 rows to deposit all blocks. From this data, it is assumed that the Glue C dispensing has a tendency to generate small dots at the beginning that grow during dispensing and then return to a smaller size towards the end of the cycle. Figure 13 shows Glue A print data of one substrate. Compare to Glue C dispense, it is obvious that diameter and area are more consistent.

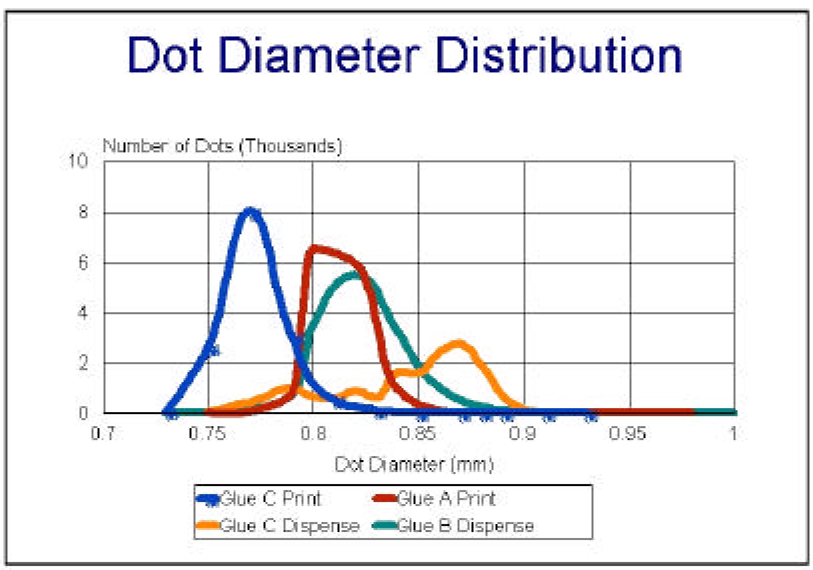

Figure 9 - Dot Diameter Distribution

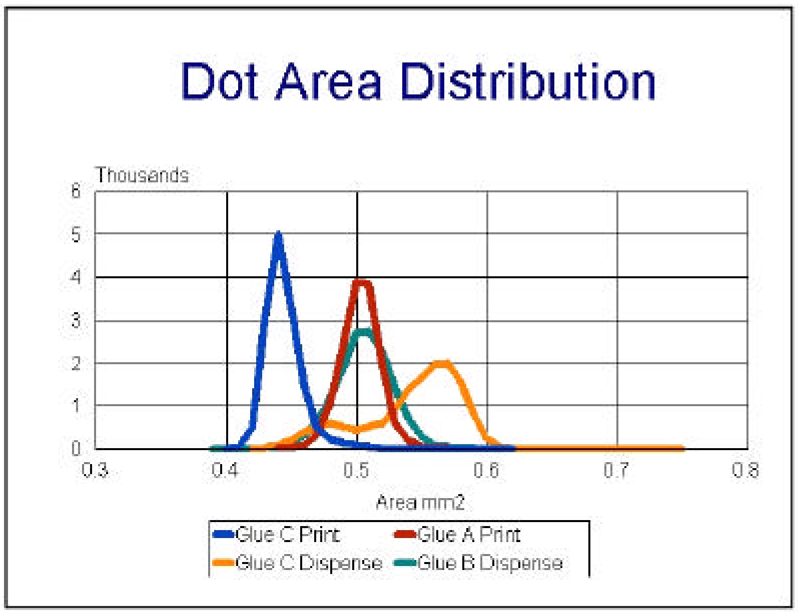

Figure 10 - Dot Area Distribution

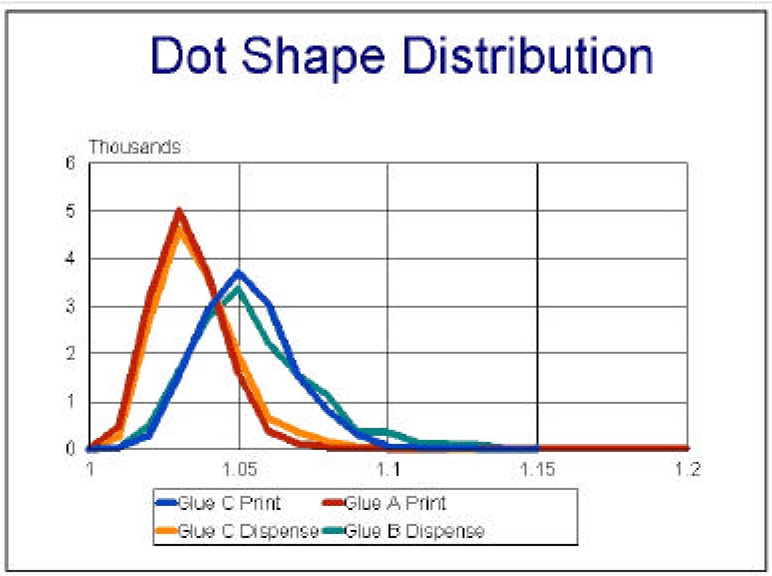

Figure 11 - Dot Shape Distribution

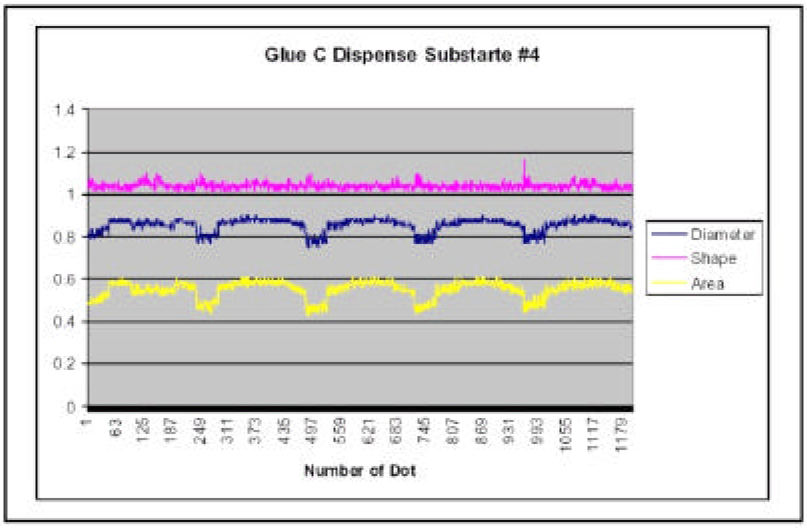

Figure 12 - Glue C Dispense

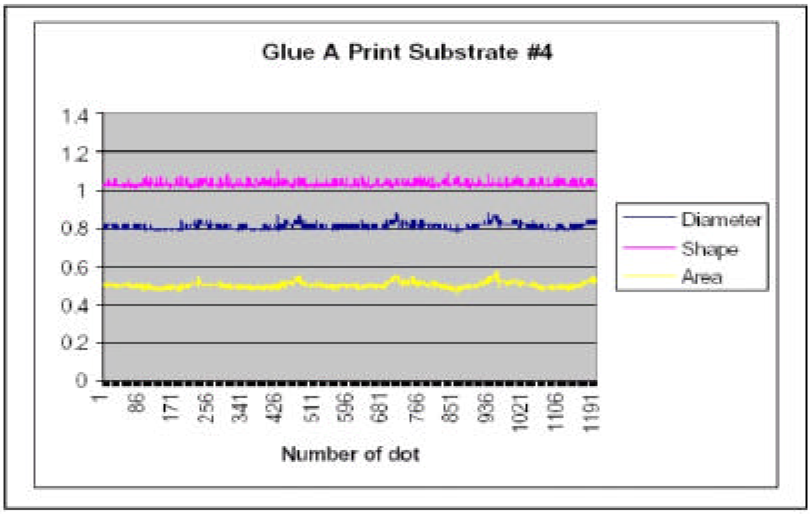

Figure 13 - Glue A Print

Dot Height

Dot height of Glue A print and Glue C print were 0.3mm. Glue B dispense has 0.58mm height, Glue C dispense has 0.52mm height. The forms of the dots are in Figures 14, 15, 16, and 17. Dispensing method generates a higher dot, it is also more flexible to adjust the dot height by changing needle or tip gap. To adjust the dot height by printing necessitates changing the stencil is required.

Figure 14 - Glue A Print

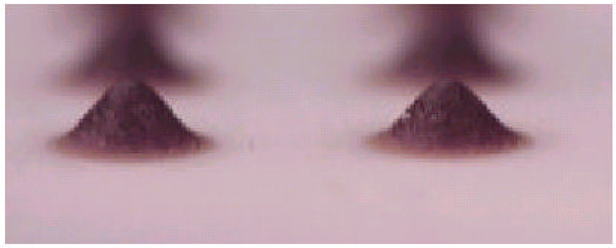

Figure 15 - Glue C Print

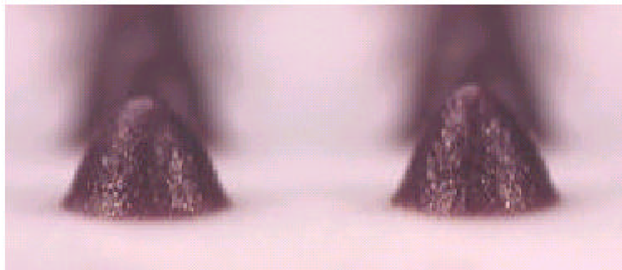

Figure 16 - Glue B Dispense

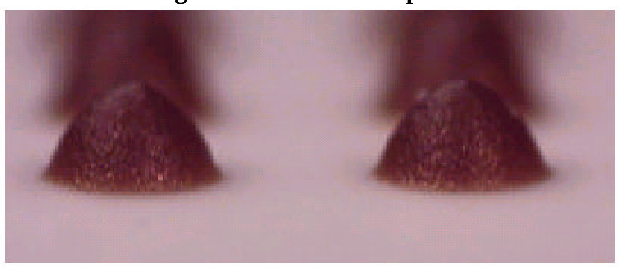

Figure 17 - Glue C Dispense

Dot Defects

Table 4 shows dot defects. For printing, Glue A and Glue C had zero defects. For dispensing, Glue B had 2 stringing, 2 satellite dots and 1 small dot, and Glue C had 3 stringing, 7 satellite dots and 1 missing dot out of 14400 dots each. Glue B was designed for high speed dispensing, so it has fast breaking for the tailing typically formed between the dispensed dot and the glue on the needle tip during needle return. It causes less stringing and satellite dots in spite of short return height and small tact time. For the reliability of adhesive deposit, printing is better. Dispensing defects may be improved if return height is increased, but the higher retum height slows dispense time. Dispensing conditions should be balanced between tact time and deposit quality.

Table 4 - Dot Defects

	Stringing	Satellite dot	Small or missing dot	Total defects	Defect ratio	Tact time
Glue A Print	0	0	0	0	0 PPM	20sec.
Glue C Print	0	0	0	0	0 PPM	17sec.
Glue B Dispensing	2	2	1	5	350 PPM	144sec.
Glue C Dispensing	3	7	1	11	760 PPM	181se.

Figures 18 & 19 represent typical dot defects of dispensing. Although there is no defect for printing glue in this study, it is possible to have print defects with improper printer setup. Figure 20 is a Glue C print air bubble defect that happened during print conditions adjustment prior to this study.

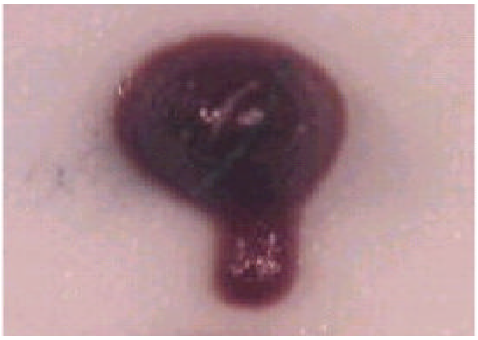

Figure 11 - Stringing

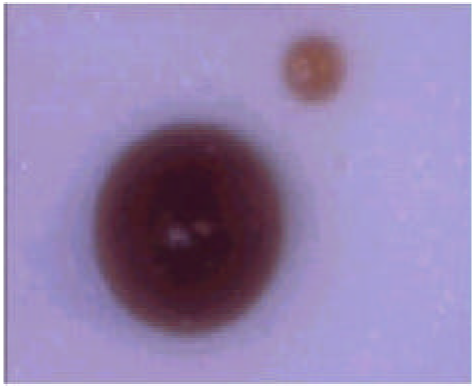

Figure 12 - Satellite Dot

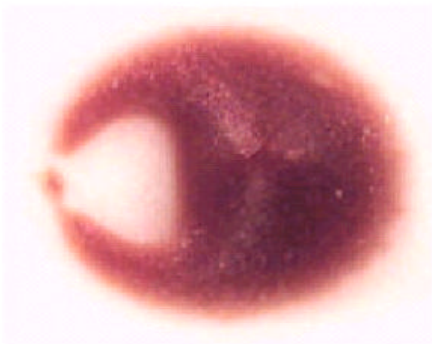

Figure 13 - Air Bubble Defect

Conclusion

From this evaluation and measurement system, printing method showed better quality performance compared to dispensing. Once the condition has been fixed, printing method gives consistent adhesive deposit on boards. When the numbers of dots on the boards are more than 100, printing gives faster tact as well. So printing is the more suitable method for SMT adhesive for mass production manufactures, while dispensing is flexible and good for manufactures that perform less production and where frequent product change is required. As to quality of dispensing, the standard deviation of 0.25 for Glue B is considered acceptable; it is influenced by substrate conditions, temperature, glue level in the syringe, needle condition and so on. It could be better if longer tact time is allowed, but it is a balance of manufacturers demand between quality and speed. Dispensing dots have higher dot shape. It is favorable to higher standoff components such as QFP's.

References

1. CR Technology, Inc. RTI-580 Image Enhancement and Analysis System, User's Manual, Oct. 2000.
2. Lathrop, Richard, R., Optimizing the Print Performance of SMT Adhesives, Apex Proceedings, Feb. 2002.
3. Kondo, Mitsuru, Dispensable Adhesive Benchmarking, Nepcon West Proceedings, Mar. 2000.