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USING TEST OPTIMIZATION TO IMPROVE REWORK EFFECTIVENESS

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ABSTRACT

Currently with increasing PCBA density and complexity, it has become challenging to produce higher yields. Sometime we have to face a large number of rework boards in manufacturing. We use **A**utomated **X**-ray **I**nspection (AXI) and 2DX for finding the defective location and type for printed circuit boards, however most AXI machines were designed to test boards directly from the SMT line (not for rework board). We are faced with two questions: 1) How can we effectively use test machines to diagnose the defects? And 2) How can we reduce defects for the current SMT line with Real test data and results?

This paper will discuss the following:

1. The X-ray machine is a Non-Destructive method for detecting defects on PCBA boards. How can we effectively use different X-ray machines (AXI and 2DX)?
2. How can we reduce test time? Set right Algorithm and Threshold for programming; manual test mode only for critical parts; several programs are just for critical components.
3. Real time data feedback to line. Prevention is much more important than detection.

We have done the following:

1. Evaluated AXI, 2DX, AOI, and other test machines' capability in order to understand their advantages and disadvantages, and to use them efficiently.
2. Kept the machines at the optimized conditions. Maintained AXI programs with high detection coverage and low false call ratio.
3. Performed sampling test for production boards at AXI.
4. For some critical parts, used individual program to test them at AXI or examine at 2DX.
5. Studied and analyzed the AOI, AXI, 2DX data, provided REAL time feedback to SMT line.
6. Used SPC data, focused main existing defects daily, found root cause, and solved issue as soon as possible with process, test and SMT programming engineers.

Key words: AXI, 2DX, AOI, SPI, Efficiency, and Yields.

INTRODUCTION

As PCBA becomes more complex, the X-ray machine as a Non-Destructive test method is widely used in electronics manufacturing, especially for components under RFI (radio frequency interference) shield. This year we faced the challenge of having numerous rework boards, and in the meantime we still ran the similar products on the line. This presented the following questions: How can we effectively use different X-ray machines: AXI and 2DX? How can we reduce test time? How can we use real time data feedback toward our SMT process? We had to answer these kinds of questions more practically and seriously than we did before. In this paper we will review what we have been doing for the last year, and share it with our SMT field colleagues.

The board we worked with was a complex board which had CSP (pitch size = 0.4mm), QFN (0.5mm), BGA (0.8mm), 0402, 0201. There were about 60 solder joints per cm^2. The PCB thickness was about 1.23mm. More than 82% components were under RFI shield. With current test machines' capabilities, we focused on SPI, AOI, AXI testing data and analyzed data on a daily basis, and reduced defects as soon as possible. We used AXI to sample test the production board and not only used X-ray test for rework because prevention was most important. In the meantime, we also introduced new AXI machines, evaluated machines, and worked with the vendors to improve the machine's performance. Working closely with manufacturing engineers, the SMT yields were increasing obviously since we put the effort in these testing methods: SPI, AOI, and AXI that will be explained in the Methods & Improvement section.

In conclusion, we will list what we learned from our progress, and what we are planning to do with it. SMT Improvement is not a simple job, and there are many items we can consider for further actions.

METHODS AND IMPROVEMENT

All test machines do not increase value during the SMT manufacturing. However no one can ignore them before having zero defects products. How can we effectively use test machines? For this product, we had SPI and AOI machines for each line, and an AXI machine for almost 10 lines. Therefore we focused on SPI and AOI test data and used them to improve our process. We used AXI as sampling test and for rework boards.

SPI

Based on SPI DPMO data (Figure 1), we introduced Nano-Coating stencil to the product. The Nano-Coating was applied only to the walls of the apertures and the bottom sides (side facing the printed circuit board). Due to the chemical composition of the Nano-Coating, intrinsic and durable properties are guaranteed: Better solder paste release, enlarged area ratio, enlarged aspect ratio, reduced number of stencil cleaning cycles. Nano coated stencil provided in comparison to traditional stencils 6 to 18 % higher solder paste transfer relating to the nominal volume. The solder paste SPI images for Nano coated and laser cut stencil for CSP (pitch size = 0.4 mm) are shown in Figure 2. The stencil aperture reduction from 9.5 mils to 8.6 mils was possible with the Nano coated stencil and solder paste deposit was not smearing out of the pad with Nano coated stencil. Figure 3 indicates that the solder height Cpk increased to 1.55 from 1.25 after using Nano coated stencil replace laser cut stencil for CSP component. Figure 4 listed the paste height dispersion between stencil types: Laser Nickel, Nano, and Electro Forming Stencil which is a new type that is used hardened Nickel (NiEX). Figure 5 shows that the usage of the Nano coated stencil performed well and reduce the solder short for CSP.

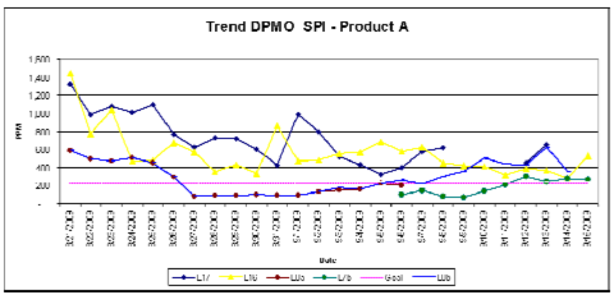

Figure 1. SPI DPMO data

Since SPI was the first test machine to detect defective solder joint with its height, area, volume, we preferred to detect as many as possible defects at the beginning of SMT process[2]. Therefore we worked with our SPI vendor, and installed the latest software version 7.7 for the Cyberoptics SE300 and inspected critical areas such as the CSP was restricted.

Our recommendations for SPI founding are as follows:

1. Any repeat defect continuously found three times should be reported to the line leader/supervisor and the line should be stopped.
2. The line leader/supervisor should justify whether the issue is due to the stencil, paste or any setup issue for paste printer or SPI, etc.
3. If stencil clogging is found then the stencil should be cleaned.
4. If the paste level is low then paste should be added.
5. Otherwise engineering should be notified for future solution.
6. SPI should scan 100% coverage and report to any alert operator for clarification.
7. For any insufficient solder less than 60% of the target volume, the board should be cleaned and re-printed especially on the BGA and QFN components.

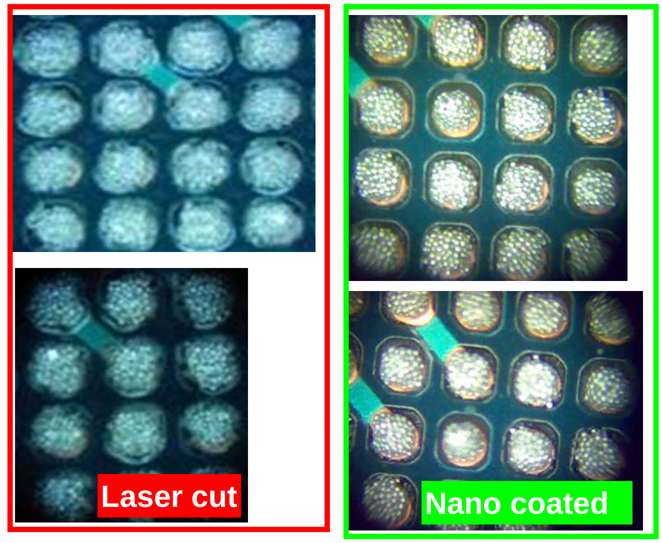

Figure 2. SPI images for CSP with Laser cut and Nano coated stencil.

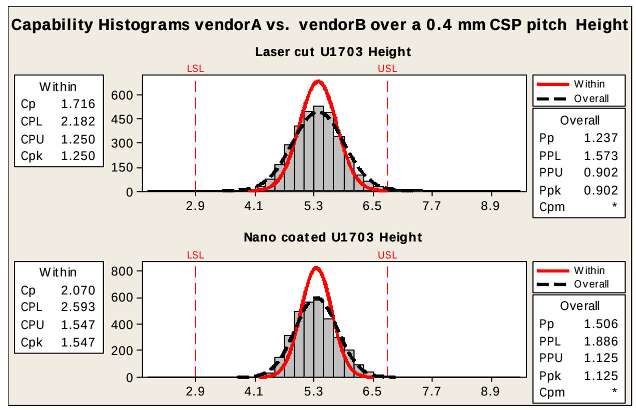

Figure 3. Cpk for CSP with Laser cut and Nano coated stencil.

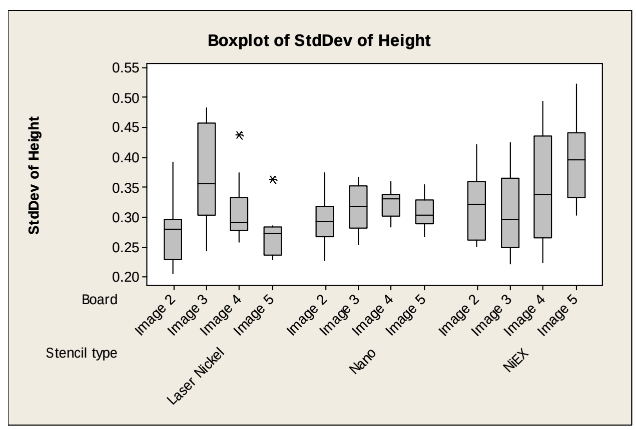

Figure 4. Paste height Variation between stencil types: Laser Ni, Nano and NiEX.

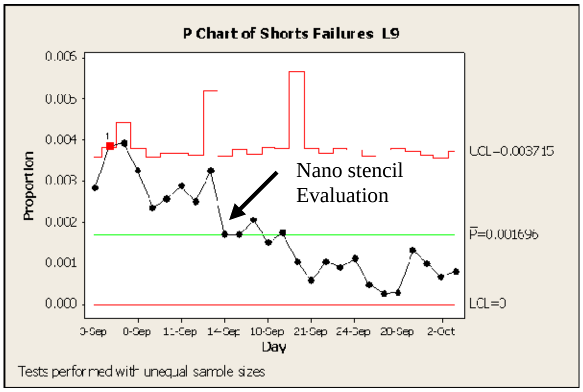

Figure 5. P chart of Short failure for CSP part

AOI

We used AOI data monitor SMT process daily and solved the defects issue. Figure 6 shows AOI weekly and daily DPMO sample data. The main issues identified were misalignment components which were U1703, L1001, and L140 as shown Figure 7a. This defect was mainly attributed to a PCB manufacturing issue, and stencil was re-designed to minimize the impact. However U1703 was impacting our yield on board level test even by keeping an eye on stencil cleanliness. U1703 was the top #1 defect based on Figure 7a (AQT of Agilent AOI data). Therefore we assigned this item to a team. After a deep analysis, we found that Head #2 on placement machine was placing the U1703 as misplaced. Acceptance tolerance on the AOI was reduced < 70 microns having this in place. We reduced to almost zero defects due to misplace U1703. Figure 7b indicates the defective location after our action, and U1703 disappear from the Pareto graph. So then we needed to focus defects on U801. Usually we focus top three defective locations every time. Figure 8 shows AOI DPMO was decreased after our actions for several weeks.

Currently we are working for these items in order to increase AOI capabilities.

1. Adding feeders' information on every single AOI program, so it will help and expedite SMT real defect.
2. Scanning system so defect can be uploaded on our data collection system: Further analysis can be made; having all the failed boards' information in Flex Flow system.
3. Our DPMO target < 100 or less for mobile boards

Our recommendations for AOI founding and work with IT engineers are as follows:

1. We linked the AOI system to the Alert Trigger system in order to stop testing if there were three consecutive failures with the same problem, plus an additional rule to react faster.
2. Make sure the AOI defective information is available for SMT technician and process engineer in real time.

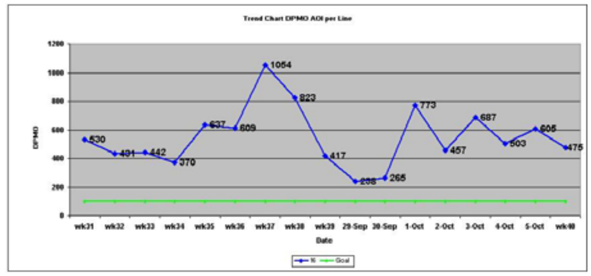

Figure 6. AOI weekly and daily DPMO

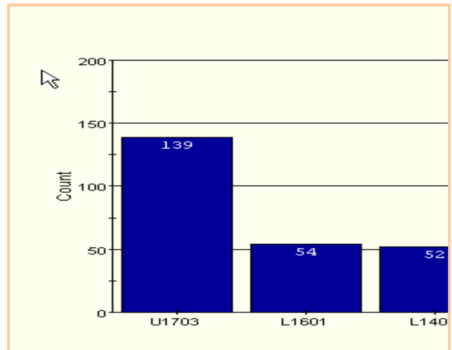

Figure 7a. Before our action.

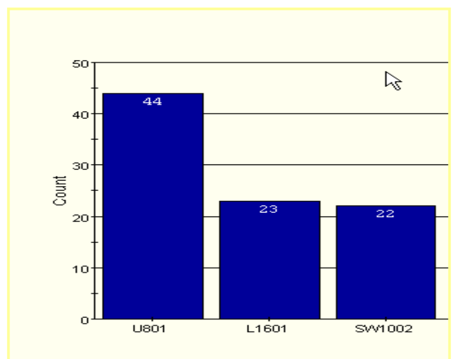

Figure 7b. After our action

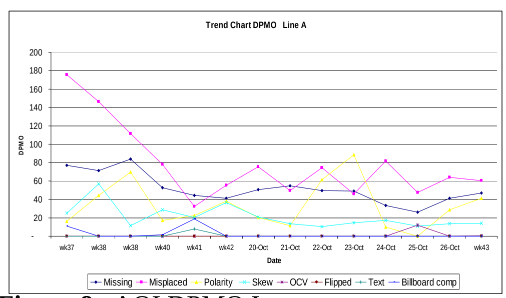

Figure 8. AOI DPMO Improvement

AXI

Because we did not have 5DX on each SMT line, we usually expected to develop 5DX program with full coverage for a new product if we had AXI machine time. This was the easy way to provide defects with real time to our process, especially for new process and package. Sometimes we also used measurement (variable) data to identify our process: We used BGA voids % to optimize oven profile[1]. After the process became stable with different and necessary actions, we preferred to reduce 5DX test time by using sampling or reducing test coverage.

We usually only tested BGA, PTH, and some critical components at 5DX. However we made sure that AOI and/or ICT covered the components which 5DX did not test. We used test tool software (Coverage Analysis System) for SPI, AOI, 5DX, and ICT test coverage study as shown in Figures 9a to 9d. Before optimization test, 10% of the components had repeat test and only 86% of the components had been tested as shown in Figure 9a. At the beginning, 5DX coverage was only 17% (Figure 9b).

Sometimes we adjusted 5DX program test coverage due to a process issue or other testing machine limitations. An example is shown in Table 1. QFN U5001 was tested at AOI at the beginning; however AOI was challenging to detect all QFN defects, especially for open and insufficient. So we put U5001 on 5DX test again. This part was also under RFI shield and it was also no access to test on ICT. This QFN tested on AOI too because AOI can detect short easily, so if it was short, the defective information would feedback to SMT line early. With this information, we saved the testing cost and also balanced the line better than before, and could make defective pin information feedback to line quickly. Figure 9c and 9d shows the test coverage as almost 100% after optimization, and repeat test coverage is 46%, 1% components (RFI shield) are not tested. The software can list all components' testing status.

In order to keep the 5DX machine at the optimized test conditions, we listed preventive maintenance as a regular schedule: Weekly, bi-monthly, and semi-annually. We also maintained 5DX program with good detection coverage and reasonable false call by using defective board from ICT with real defects escaped. Fine tuning 5DX program is on going.

As already stated, 5DX is designed to test boards from the SMT line directly. However we needed to check BGA after rework. Therefore we only generated BGA for the program whereby it may have more slices than the regular program. The false call rate may be higher than the regular program.

AXI is not a machine, it is a system and a test tool for solder joint inspection with attribute data, and it also can be a process improvement tool with measurement (variable) data[2]. Our recommendations are as follows:

1. Fine tuning is on going as process changed.
2. Suggest using golden defective board to test before and after bi-monthly confirmation and adjustment. Verify the same defective number and check the machine working conditions.
3. Feedback loop with repair station operator, ICT, Function test, and Final test technicians. AXI programmers need real defective board for further fine turning.
4. Monitor false call rate on going. It is easy to escape real defective call with too many false calls for rework station operators.
5. Use variable data of AXI to improve/optimize process.

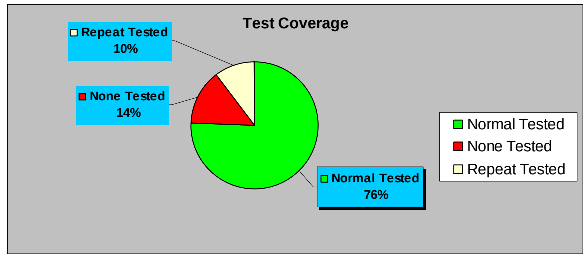

Figure 9a. Test coverage before optimization

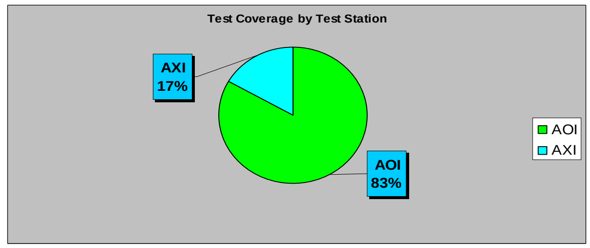

Figure 9b. AOI and AXI testing % before optimization

	BOM List	Package	AXI Test	AOI Test	ICT Test
Before	U5001	QFN65_9X9_5MM	NO TESTED	TESTED	NO TESTED
Now	U5001	QFN65_9X9_5MM	TESTED	TESTED	NO TESTED

Table 1. QFN U5001 testing information

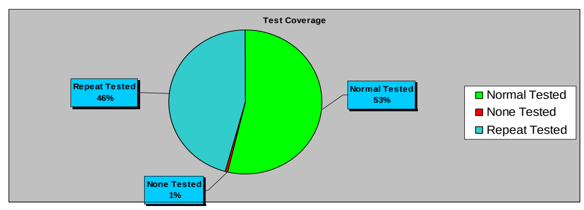

Figure 9c. Test coverage after optimization

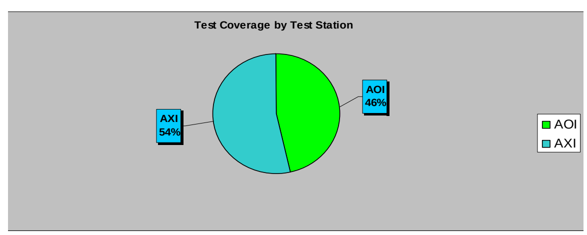

Figure 9d. AOI and AXI testing % after optimization

AXI Evaluation

Recently we evaluated some other AXI machines capabilities at our manufacturing line, and determined their advantage and disadvantage, and used the machines efficiently. We used the production board for programming speed, inspection speed, defect detection capabilities tests, and Gage R&R study. The boards have QFN, BGA, Fine pitch Gullwing, 0402, 0201, and the newest models contain POP components too.

Vendor A was 5DX, and we used it as the reference for the evaluation. Table 2 lists Gage R& R results. We used the same pins and components for the data collection. All results were obtained with the same analysis method and software (Minitab). At least 30 pins for each package, three operators, and each tested three times for the Gage R&R data collection. Our target was < 10% for Gage R&R, and 30% was acceptable. The vendor B and C data were better than 5DX, and only one item was > 30% for each vendor.

For AXI programming time, none of the vendors' machines could meet our expectation (< 10 hours). For inspection test time (tested number of pin/second), vendor B was slower than 5DX, and vendor C was much faster than 5DX; however vendor B had 100% components test coverage, and vender C did not.

For real defects escaped, we only used a small number boards for testing: None of the vendors met our target (defects escaped < 5%). Vendor B was similar to 5DX, and vendor C had more room to improve. For false call ppm, none of the vendors had good performance: its ppm was less than 2000. Figures 10-11 listed QFN void and Fine Pitch Gullwing insufficient defects detected images from each AXI. The images are not that clear for insufficient solder for Fine Pitch Gullwing as shown in Figure 11. That maybe the reason why all three AXI machines didn't meet our expectation: defects escaped < 5% with our evaluation boards.

Figure 12 shows the attribute Gage R & R results from software Minitab for vendor B. We tested nine times for one board with nine defective and 17 good components. The inspected and matched percentage was 96.15 for within Appraisers, and Appraiser versus Standard. Vendor A had better data than vendor B, but vendor C data was worse than vendor B.

While we are still working with these vendors at our manufacturing line and use their machines for testing our products, we are still looking for good AXI machines to meet our needs.

Gage R&R (variable data)	Vendor A	Vendor B	Vendor C
BGA ball diameter (U603)	4.26	1.98	5.67
BGA ball diameter (1703)	27.49	6.98	10.89
FP Gullwing Fillet length	44.97	12.89	22.43
QFN Fillet length	11.38	32.68	10.2
Chip Fillet length	37.89	11.76	34.26

Table 2. Gage R&R for three AXI machines

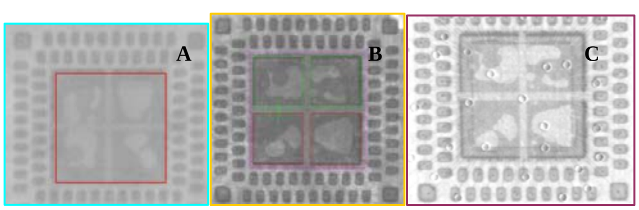

Figure 10. QFN Void (Vendor A, B, C)

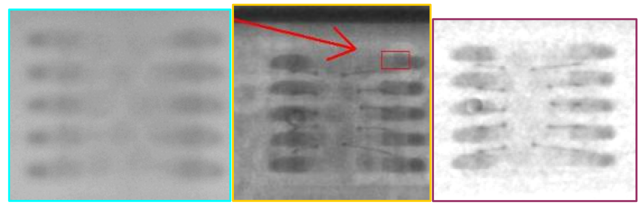

Figure 11. FP Gullwing Insufficient (Vendor A, B, C)

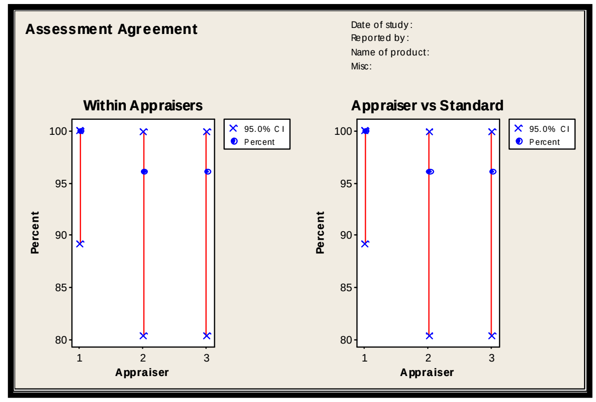

Figure 12. Attibute Gage R&R for Vendor B

2DX

2DX system can achieve the highest level of magnification up to 12,000 X and has the best resolution down to 100 nm. It is a very useful tool for failure analysis, but is also successfully used on the production line. The 2DX machine can tilt the image intensifier down 70 degrees in order to inspect BGA, QFN and other devices for voids, cracks, open joints, head-in-pillow and other defects. The highest level of magnification is available at oblique angle view and full rotation around the suspected joint is very easily accomplished. This is the key for finding and verifying open solder balls, joints and micro-cracks [3]

Compared with AXI, 2DX's disadvantage is that 100% auto inspection mode is not available. Also testing time is longer than AXI when we use 2DX for testing BGA with AUTO mode.

Therefore 2DX and AXI complement each other. For this assembly, we used 2DX for checking rework boards, and also for some critical components such as QFN and microphone. 2DX has a very detailed and clear image permitting to identify questionable solder joints which cannot be determined by AXI. Some packages (POP) and special defects like HIP require higher levels of experience for the 2DX operators.

Our recommendations are as follows:

1. Provide good training for 2DX operators.
2. Use 2DX to identify critical solder joints and packages and set the accurate threshold for the AXI program. Use 2DX for quick NPI delivery while we don't have an AXI program already in place as programming the AXI machine takes long time.

CONCLUSION

1. SPI, AOI, AXI and 2DX are Non-Destructive test machines that we need to use on RFI products due the poor testability, lack of test points and the heavy use of metals shields that complicate inspection and repair.

2. Use SPI and AOI as much as possible to inspect products on lines due to their short test time and early possible to detect defects.

3. Use AXI 100% for NPI and new package size in the new technologies.

4. Use 2DX image and data to set up accurate AXI Threshold for some critical packages. Use 2DX to examine components for which AXI testing cannot be used or the AXI data is unreliable.

5. The optimization testing method is still under observation with variable SMT products. Use a combination of test and inspection processes to inspect complicated boards with the most adequate and efficient manner.

6. We are still looking for an efficient and effective AXI machine which has an AXI advantage but also has a 2DX advantage which has a clear image for solder joints.

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