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Implementing Total In-line Solder Paste Inspection

One EMS company found converting from sampled solder paste inspection to high-resolution, 100 percent inspection helped meet the challenge of high-density fiber optic panel assembly.

By Rick Gunn

With rapidly growing customer demand for high-density printed circuit boards (PCB) loaded with chip scale packages (CSP) and flip chips, this corporation* made a strategic decision at one facility to improve their process capability (CPk) by implementing in-line, 100 percent solder paste inspection. To achieve better first-pass yields (FPY) at in-circuit test (ICT), they decided to implement post-print inspection on an SMT production line used for a telecommunications industry customer's high-density, multi-board panels containing state-of-the-art 0.008" diameter pads.

CASE STUDY

On the Production Line

This facility houses five SMT lines, both high-volume and high-mix (Figure 1). All were equipped with a post-print, sampling inspection system located directly after the screen printer. By replacing the existing system with a high-speed, 100 percent inspection system, they hoped to improve printing quality without compromising line speed, repeatability or overall throughput.

The faster system is capable of examining every pad on every board, including ultra-fine-pitch and flip chips, to identify both systematic and random printing errors before boards are loaded. This continuous, real-time feedback combined with higher resolution measurement capability was expected to produce FPY improvements.

System Acceptance Criteria

The following feature, performance, capability and price requirements necessary for the new system were identified as follows:

- 100 percent inspection at line speed, inspecting 10 to 20 times faster than the current system, three-dimensional (3-D) height, true volume and area measurement down to 0.008" diameter pads (i.e. flip chip and CSP)
- High-resolution, 12-bit height data to compute summary 3-D measurements
- Accurate results (CPk ≥1.67) for even the smallest features or components
- High-resolution gauge repeatability and reproducibility (GR&R) for height and volume measurements of <10 percent of typical 30 to 50 percent process tolerances
- Ability to combine high-speed and high-resolution inspections within the same program
- Simple, intuitive Windows NT-based operator interface
- Minimum overhead for off-line machine programming from Gerber data, with less than 1 hour to program a simple board and less than 2 hours for a complex board
- Product changeover times of 15 minutes or less
- Ability to collect and store data for off-line analysis and report generation
- Price <$225K including hardware, software and training
- Payback period of less than one year.

The system met or exceeded all requirements, and initial production runs demonstrated a 30 percent ICT yield improvement. Following are the procedures that were used to verify the inspection system's ability to meet the criteria.

Machine Programming and Operator Training. Hardware and software training took place onsite over a period of one week, including an overview of the mechanical operation and detailed instructions on the system's application software (Figure 2).

Off-line Repeatability Test to Verify Machine Performance. To verify machine performance

Figure 1. An example of a high-volume, high-mix SMT assembly line.

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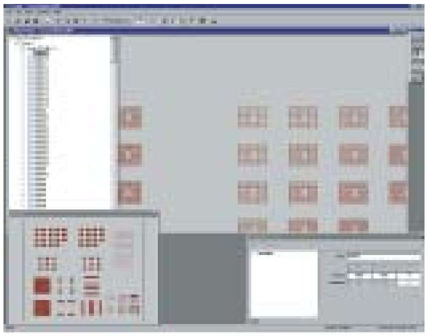

Figure 2. Typical TEACH interface display.

on solder paste, a sample board was programmed and inspected 20+ times. All measurements were logged on the system and transferred to a Microsoft Excel spreadsheet where the standard deviation was calculated; the results confirmed that the system met or exceeded the required GR&R[1] specification.

CPk Test on an Idealized Certification Target. CPk is a measurement of machine process capability to determine if a process (in this case, solder paste printing) is meeting specification limits and producing "good" parts. CPk is determined by comparing the width of the specification limits to the width of the process variation. The capability index is the ratio of the specification tolerance to the natural process variation. Typically in electronics assembly, a process is deemed capable if the ratio is 1.67 or greater. Before performing a CPk test, the process must be in control and "true" measurement values must be known.

Natural process variation is determined by repeatedly measuring an idealized target whose precise measurements have been verified according to National Institute of Standards Technology (NIST). To determine if the inspection system was measuring within the specified limits, it was used to measure the same NIST-traceable target 30 times. The measurement data was analyzed to determine the mean reading and process variation (sigma), i.e., to what extent the measurements fell within the specified upper (USL) and lower limits (LSL) above or below the know true value.

Finally, CPk for height was calculated by using this formula:

CPk = minimum of either (USL - mean)/ 3 sigma of all samples or (LSL - mean)/ 3 sigma of all samples.

Height Accuracy and Calibration Target Repeatability (Table 1).

- Number of samples: 30
- Nominal height: 0.004"
- Specification for typical components: ±0.00019"
- Specification for CSPs, 0.008 to 0.018" diameter: ±0.00031"
- Qualification criteria for CPk: CPk >1.66.

Off-line Production PCB Sampling. With the machine still in off-line mode, boards were taken from the production line and run through the inspection system to verify that the program data generated for these assemblies was executing correctly.

In-line Installation. In-line installation of the 100 percent solder paste inspection system** (replacing a sampling inspection system) was accomplished in approximately four hours. Installation involved removing a 1 m section of conveyor, positioning the inspection system, and connecting upstream and downstream SMEMA communications. A network connection was provided so that programs generated off-line could be downloaded easily to the in-line system.

In-line Operation. Initial in-line operation consisted of adjusting conveyor width for production assemblies, loading pre-existing programs and executing them. Gross defects were introduced on some assemblies by manually removing solder paste to assure that the inspection equipment was detecting all failures.

In-line Speed Testing. Initial in-line speed testing was performed on the company's paste printing test board. A 6 x 7" paste printing test vehicle containing 312 components and 4,027 pads was inspected in 26 seconds. This inspection time was well within the company's production cycle time for this board. Later tests run on a complex telecommunications motherboard containing 64 CSPs also demonstrated acceptable inspection times.

Payback Calculation and Analysis. A standard return-on-investment (ROI) spreadsheet[2] calculated the amount of time required for the inspection system to pay back its initial investment. The first step in a financial justification is to define typical production scenarios and costs. Key elements are initial yield, solder paste defect rates and test/labor costs.

Data or estimates for the typical production scenario were used to calculate the annual cost of solder paste-related defects. By estimating the percentage of defects that potentially could be eliminated by doing 100 percent inspection, the projected annual cost savings was determined. This cost savings is composed of reduced labor for rework, lower test cost and reduced scrap.

Using the total cost of ownership figures and the projected savings figures, payback time, rate of return and net present value was determined. After plugging internally collected data and estimates into this spreadsheet, pay back was shown to be just under a year, meeting the company's expectations.

Results Show 30 Percent Yield Improvement. During initial runs on the modified SMT line equipped with the new machine, 30 percent ICT yield improvements were reported for a high-density, high-complexity PCB with 20,000 apertures on the top side. SMT

TABLE 1

CPk Test Results

Pad Diameter (on target with BGA and CSP pads)	Cpk Height: High-resolution Mode	Cpk Height: High-speed Mode
0.008"	3.81	4.43
0.010"	4.28	6.05
0.012"	9.19	6.94
0.014"	9.35	8.77
0.016"	7.45	9.60
0.018"	6.26	17.78
0.020"	2.94	9.90
0.025"	2.85	12.65

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** CyberOptics SE 300.

REFERENCES

[1] Detailed information about the GR&R procedure and results can be found on CyberOptics' Web site, www.cyberoptics.com.

[2] The Microsoft Excel spreadsheet used to calculate ROI is available upon request. Contact info@cyberoptics.com for more information.

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