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Case Study: Integrating Industry 4.0 into a Lean Six Sigma Strategy

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By Filemon Sagrero

Manufacturing technology improvements such as Industry 4.0 capability offer significant benefits in terms of productivity and enhanced quality. However, these technologies are not plug and play. Fully realizing the benefits requires strong manufacturing engineering and quality expertise. Exploiting the resulting data within a Lean Six Sigma framework can add further value. This case study looks at the implementation strategy developed by SigmaTron International's manufacturing engineering and quality team in Tijuana, Mexico.

Developing a Strong Implementation Strategy

The Tijuana facility utilizes inline 3D solder paste inspection (SPI) and 3D automated optical inspection (AOI) incorporating Industry 4.0 capabilities in its SMT lines. Industry 4.0 automated inspection technology opens the door to enhanced levels of process control by creating a closed loop system where inspection stations automatically adjust process parameters on the line based on the trends data they receive. Phase 1 of the implementation strategy focused on implementing Industry 4.0 capabilities in its SMT area. Phase 2 focused on expanding automated inspection data gathering to secondary assembly.

To fully utilize the new equipment capabilities, the team developed an accurate program validation database and a methodology for utilizing trends tracking in continuous improvement activities. In addition to the programming done as part of implementation, the machines continue to learn as they analyze trends.

In setting up the Phase 1 system, a Six Sigma Black Belt and two mechatronic technicians performed Gage R&R (GR&R) studies for repeatability and reproducibility using the Automotive Industry Action Group's acceptability definitions. CP and Cpk ratios were also calculated to measure the process capability against the Voice of the Customer (VOC) standards and requirements. The studies and calculations showed the specification limits for all 3D AOI machines were in acceptable GR&R condition and very good CP/Cpk condition. The program validation is used for machine verification every six months. Once control limits were established, programming parameters are adjusted for each printed circuit board assembly (PCBA) to assess acceptability based on the IPC-A-610 standard and customer documentation requirements.

Maximizing Results

The SMT area inspection stations communicate with the screen printer and make adjustments to paste deposition based on the defects they identify, creating a closed loop system. They also track trends data enabling the team to pareto top five defects, and where indicated, implement continuous improvement initiatives beyond process adjustments. The systems communicate to a database accessible to technical personnel via remote computers. Analysis of the trending has driven changes to stencil maintenance frequency and greater focus on monitoring pick & place machine placement variation. For example, a root cause of some defects was a fixture that had warped and was no longer seating correctly. The fixture was replaced, and fixture condition will be checked more frequently. The lines are averaging 40-50ppm defect rates in first pass yield across the facility's SMT lines. The goal in increasing automated inspection is to drop that to zero defects.

Phase 2 – Implementing Automated Inspection in Secondary Assembly Operations

Unlike the SMT area where PCBA handling, assembly and inspection operations are inline and automated, secondary assembly operations include semi-automated and manual processes plus manual handling during transit among work cells. Typical secondary assembly operations include soldering cables and components such as switches which can't be reflowed, adding rubber caps and placing QR labels.

This stage of the process introduces a higher potential for variation and associated defect opportunities, particularly in complex PCBAs. Monthly volumes are in the millions on many part numbers. The goal of utilizing 3D AOI for mass inspection following secondary assembly wasn't to implement a long-term 100 percent inspection process for every product. Instead, two 3D AOI machines have been installed in the secondary assembly area to focus on complex products with low yields. Defect data for all products built is analyzed. PCBAs showing lower yields in secondary assembly are shifted to 3D AOI inspection to better determine defect root causes and implement corrective action. When results show desired improvement levels, new products destined for continuous improvement action are shifted to inspection.

The project implementation team for this phase included a Six Sigma Black Belt, a fixture designer/continuous improvement technician, an SPI/AOI programmer/continuous improvement technician, an AOI technician associated with quality assurance and a project administrator/trainer who is also a continuous improvement assistant.

In setting up the systems, the implementation team utilized a validation process that was similar to the process utilized in Phase 1. All customer-reported failure modes for the products under study were programmed into the AOI systems. The programming process differed from the SMT setup in the number of datasets required. Setting up the 3D AOI program validation database for SMT required 16 datasets, while secondary assembly required 32 datasets for the initial products under study. As with the SMT area setup, there is a methodology for utilizing trends tracking in continuous improvement activities. Data is available real-time to correct defects immediately and can also be viewed remotely for more detailed trends analysis. The 3D AOI machines continue to learn as they analyze trends.

Two kaizen events were held to improve initial implementation assumptions related to fixturing. Analysis of initial trending indicated that the fixturing design to facilitate inspection did not have enough support for the solder side of the PCBAs and was causing board warpage. The fixture design was modified to include additional support. Additionally, the initial fixture storage setup did not make it easy enough for operators to easily identify correct fixtures. To counter this, 5S principles were implemented that segregated fixture storage by product in specially designed storage carts.

Since implementing mass inspection, customer report card data shows an over 50 percent improvement in yields on the inspected boards. Use of 3D AOI instead of manual inspection is also reducing the inspection time on the complex PCBAs while improving the accuracy of defect identification. SigmaTron's team is working with the customer on design for excellence (DFX) suggestions to further improve yields on PCBAs with manufacturability issues contributing to lower yields.

Improvements in manufacturing technology are becoming increasingly more collaborative. Use of Industry 4.0 capabilities is creating a system that auto-corrects solder deposition-related issues in real time in the SMT area, plus provides the trends data to enable the team to monitor tooling, equipment accuracy and customer design issues that may be creating defect opportunities throughout the production process. It is also providing a tool to drill down on products with higher than acceptable quality issues in the less automated processes associated with secondary assembly.

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