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Collaboration Efforts to Develop AI-powered Smart Assembly Processes

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In electronics manufacturing, automated production has undeniably revolutionized the industry, enabling the creation of high-quality products at an unprecedented scale. However, it comes with its own set of challenges, particularly the potential for specific failures that need human intervention. The rapid advancements in technology, such as the Industrial Internet of Things (IIoT), big data analysis, cloud computing, and artificial intelligence (AI), have ushered in the era of Industry 4.0, promising more intelligent manufacturing processes. Smart manufacturing, a pivotal part of this transformation, relies on real-time decision-making based on operational and inspectional data, seamlessly integrating the entire manufacturing process into a unified framework. This digital transformation of cyber-physical systems enables proactive responses to uncertain situations while ensuring heightened efficiency.

In the context of printed circuit board assembly (PCBA) with surface mount technology (SMT) lines, IIoT technology accelerates data collection on equipment status and production quality. Data-driven solutions, powered by AI and machine learning algorithms, can diagnose abnormal defects, and adjust machine parameters on the fly in response to unexpected changes during production. Collaborating with various SMT industry partners, researchers at the State University of New York at Binghamton (Binghamton University) have developed a groundbreaking framework based on AI-based closed-loop feedback control and parameter optimization. This innovation promises to implement a smart manufacturing solution in the PCB assembly, with a focus on improving yield and throughput. This AI-based framework holds the potential to pave the way for data-driven process control in SMA.

Binghamton University Collaboration

Since 2016, Koh Young Technology and the Smart Electronics Manufacturing Laboratory (SEMLab) at Binghamton University's Integrated Electronics Engineering Center (IEEC) have been collaborating on several key research initiatives to improve the assembly process in electronics manufacturing using AI integration. The aim of the SEM Lab is to develop smart electronics manufacturing solutions using data science and AI principles to manufacture sophisticated printed circuit board assemblies with a focus on advanced robotics to revolutionize the electronics manufacturing process with improved yield and productivity. With automatic optimization, real-time intelligence techniques, and the implementation of advanced analytical approaches to the data collected from the equipment, the smart systems can deliver fewer defects, higher productivity, and increased reliability with cost-efficient results.

The team from Binghamton University including Dr. Seungbae Park, Dr. Daehan Won, Dr. Sangwon Yoon, and Benson Chan have helped deliver several beneficial studies that helped drive Koh Young to further refine and deliver award-winning AI-based solutions. The research envelops developing closed-loop control and optimization modules using self-optimization and AI-based diagnostics for process enhancement in the Printed Circuit Board Assembly. This research is clearly advancing PCBA with innovative artificial intelligence and machine learning techniques.

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Machine Intelligence in PCBA

In printed circuit board assembly (PCBA), each step significantly affects the final quality and throughput of the PCB product. The solder printing process, for instance, is a critical operation that causes upwards of 80 percent of PCBA soldering defects. Printing faults, characterized by an inadequate volume of solder paste on PCB pads, can lead to board failures and substantial rework costs. The component mounting process, encompassing expensive machine investments and extended production times, is another high-cost procedure. Meanwhile, in the reflow process, the quality and reliability of solder joints are contingent upon reflow oven temperature and related settings. Consequently, inspection machines, such as solder paste inspection (SPI) and automated optical inspection (AOI) can enhance PCBA. Specifically, integrating two independent, but linked AOIs in the PCBA line before and after reflow can detect component defects.

As electronics components shrink (e.g., 0201M components), PCBA-related failures increase. The SEMLab has the tools in place to help find solutions: solder paste printers, component mounters, and a reflow oven, as well as Koh Young SPI and AOI machines. Extensive testing on over 8,000 PCBs revealed that numerical methods based on physical properties may have practical limitations in explaining the behavior of small-scale components. This is often due to unknown environmental factors like temperature, humidity, machine calibration, measurement inaccuracies, and vibrations, which can influence PCBA quality. Research demonstrates that AI-based methods can enhance product quality by up to 35 percent and reduce scrap rates compared to traditional approaches. This suggests data-driven intelligent process control can advance PCBA significantly.

Intelligent Inspection Modules

The goal of smart PCBA is to maintain optimized settings both offline and online. AI and data analytics solutions can optimize PCBA process parameters before production (offline control) and during production (online control). A printing advisor module uses sophisticated data-driven methodologies to improve the printed circuit board quality and increase process robustness. Reinforcement learning approaches developed a printing optimization module to achieve intelligent control of printing parameters. Also, a printing diagnosis module will reduce the operational costs and potential failures by identifying and preventing the root causes.

Using deep learning models like convolutional neural network and recurrent neural network, we can detect a potential anomaly in the PCBA to ensure high operation reliability and smart process control. Yet, beyond print process advancements, the collaboration is also helping drive component mounting improvements. Testing is underway on modules designed to identify optimal component placement positions by predicting post-reflow positions based on data collected by SPI, Pre-AOI, and Post-AOI machines, as well as offering adaptive placement adjustments during production.

Preliminary results show an 18 percent reduction in misalignments compared to conventional placement methods. Moreover, the module uses operational and AOI inspection data to trace the root causes of mounter defects and prevent future failures, achieving an 84.50 percent accuracy in finding known root causes. These efforts not only save time and labor but also enhance the automated PCBA process. The innovative electronic manufacturing solutions from this project will promote the sustainable success of the electronics manufacturing and improve the competitive advantage with efficient manufacturing decision making, improved product quality, and increased profitability, while advancing Industry 4.0 development for PCBA.

Summary and Conclusion

The increasing complexity of PCBA, driven by the demand for small-scale electronics products, requires innovative solutions. With AI and big data harnessed from various inspectional operations, PCBA can become intelligent and adaptable in response to dynamic environmental conditions. By maintaining the ideal process parameters throughout the processes, AI-powered tools can help manufacturers improve quality and yield without sacrificing production speed. Automated, smart systems open the door to the next level of electronics manufacturing, by utilizing data from end-users to facilitate customized product manufacturing with enhanced efficiency for high-mix/low-volume production. This not only expands the possibilities for design variations but also accelerates delivery times, ushering in a new era for electronics manufacturing.

To learn more about the Koh Young efforts to streamline the journey to a smart factory using our True3D inspection solutions visit us at www.kohyoungamerica.com or through these FREE downloads from Koh Young:

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- ***The Companion Guide to..SMT Inspection: Today, Tomorrow, and Beyond*** [eBook]
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