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Advances in Automatic Monitoring of Stencil Printing Processes

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Abstract

The electronics assembly industry has long wished for and made great advancements toward developing a true, closed-loop automatic print verification and process monitoring technology. While significant progress has been made, many hurdles remain to be overcome. Recent developments in on-board inspection technology, however, have pushed the "lights-out" printing concept even closer to becoming reality.

This paper will present data on a novel print verification technology that uses a series of sensors to capture the full board image, analyze the data and accept or reject the print – all in real time. The system compares the actual print to that of the PCB's Gerber data to assess accuracy and paste presence/absence, among other print components, and can be integrated with additional machine performance tools to make the printing platform even more intuitive. By enabling the print and inspection processes to run concurrently and deliver 100% verification at full line speed, production rates can be maintained and throughput is exponentially improved. The technology can have a profound impact on cost reduction, as faulty boards are isolated and removed from the line at the printing phase instead of traveling fully downstream to final assembly. Additionally, integrating such high-speed and powerful inspection technology onto the printing system eliminates the requirement for a dedicated, in-line SPI machine, and saves even more resource including training and floor space.

The inspection component of this next-generation technology can also be combined with verification and traceability tools to confirm all print inputs and outputs and trace materials, boards and processes to origination. This is a requirement for many high-value applications such as medical, defense and aerospace and has tremendous benefit for traditional EMS and OEM assembly operations as well.

These details along with future closed-loop printing platform developments will be presented.

Introduction

Once, every part of a stencil printer's set up had to be performed manually. But this historic reality arguably pre-dates most of today's assembly line operators. Modern automatic print platforms typically read the required machine settings directly from the product's software file as it is uploaded – often using quality assurance technologies like bar-coded boards – and will make machine settings adjustments automatically before printing begins. However, operators remain responsible for other aspects of the process and they must ensure that these are correct. Even before printing commences, obvious checks that a printer cannot be expected to monitor itself need to be performed, like verifying that the correct type of solder paste and stencil are being used (although both can be bar-coded for easier validation).

During the manufacturing run, as production progresses, operators still typically many manage aspects of the process. For instance, they must continually monitor solder paste usage to effect timely replenishment, or check post-print inspection results to catch defective boards and identify process flaws.

Increasingly, operators depend on automated systems to assist in monitoring and keeping the “process in control”. However, what typically happens in the capital equipment product development cycle is a tendency to develop individual tools, solutions and options that address different aspects of process monitoring and process control. The clear goal of various process-monitoring, verification and traceability systems is always to help maintain or increase productivity. But as each new tool most likely either developed or evolved separately, the operator ends up being responsible for consistently collecting and interpreting the results from each separate system, and for implementing the appropriate corrective action. The problem here is that a large number of individual process-monitoring tools and systems, while perfectly well automated in their own right, become cumbersome and therefore difficult to manage.

A better way to evolve these diverse tools is to integrate them into a unified system that can then benefit from effective software control. Advances in user-interface technologies help to make this a reality, so now it is possible to create an efficient tool to safeguard productivity and reduce the operator’s workload – which itself delivers tangible benefits by eliminating another potential source of error.

The Inspection Boom

One process area where a process tool can be integrated into the heart of a printing system is post-print inspection. Traditionally, the technology is applied to samples of boards at regular intervals. The procedure provides alerts that enable operators to identify and perhaps even pre-empt print defects such as bridging, aperture blockage or paste-to-pad misalignment. Automated vision tools such as 2Di inspection facilities deploy cameras that look down onto the board. These can be programmed to issue an alert when a preset threshold is reached. Often, this requires the operator to take emergency action, such as manual activation of an understencil cleaning cycle or verifying stencil alignment.

Traditional post-print inspection systems like 2Di collect detailed, quantitative information at regular intervals. Another approach to safe-guarding yield and hence productivity is to deploy a faster technique that offers a straightforward Good-Board/Bad-Board indication, and which does so for every board while operating at the full line beat rate – so it doesn’t impair productivity by impacting on throughput. The ability to check 100% of printed boards automatically has arrived recently, partly due to improved vision system processor performance. Such systems can also detect paste bridging at the line beat rate, or can be programmed to perform quantitative inspection on selected areas of each board. They deliver reports to the operator in real-time.

Figure 1 – Post-print inspection with built-in analysis and Good-board/Bad-board signaling.

Figure 1 illustrates the results of high-speed post-print inspection performed at the line beat rate by analyzing images streamed at up to 1,700mm^2 per second. The system quickly compares detected paste coverage for each pad with programmed thresholds to generate color-coded results, highlighting pass, fail or warning indications that are easily interpreted.

By imaging at speeds up to 36,000mm^2 per second with leading-edge machine-vision technology, it's possible to perform paste-on-pad, bridging and alignment inspection concurrently with paste deposition, without increasing cycle time. In addition, using the appropriate hardware tools, failing boards can be identified and isolated automatically in real time, preventing defective products from moving to downstream processes, where repair or rework costs increase by an order of magnitude.

Thinking Ahead to Boost Productivity

But automated integral inspection is only part of the armory. Modern tools allow more proactive verification of correct process setup, reducing the incidence of operator errors that can lead to bad boards. Identification technology, such as bar-coding as already mentioned, is a significant capability enabler. Operators scan items such as the stencil, solder paste and squeegee blades during set up to confirm their identities before they are fitted. The print platform immediately compares this data with the identities specified in the product file. If there's a mismatch, an error flag can be used to halt the machine until the mistake is rectified, essentially eliminating human errors at setup as a cause of printing defects. It also expedites the setup operation by saving laborious manual cross checking.

In addition, linking individual board identity with process-verification data from these procedures provides the detailed level of traceability required by manufacturers serving markets such as medical, automotive or military. The data can then be time-stamped and linked with the stored verification data and any other information required, such as measurements of environment variables like temperature or humidity. Such data offers comprehensive detail on the prevailing process parameters at the point of manufacture. Similarly, a record of successful boards and reject counts provides manufacturers with accurate data of assembly process performance and management.

A number of real-time status-monitoring systems have also evolved to provide operators with further detailed and timely information about the performance of the current print process. These include tools to monitor the height of the paste roll on the stencil when printing with squeegees in order to alert the operator when replenishment is required. This helps to maximize productivity by allowing solder paste to be replenished without interrupting the all-important continuous operation of the printer, and to avoid 'insufficient-paste' defects in printed boards. Similar paste monitoring capabilities are available for enclosed-head print systems.

The ability to integrate and collate other data sensed in real-time, like paste-roll height, also allows the print platform to initiate appropriate corrective actions, such as automatic paste dispense, thereby completely relieving the operator of many low-level process-management tasks. A warning or report can be issued to the operator for information purposes.

Widespread adoption of verification and traceability techniques such as these has provided a significant boost to stencil-printing productivity. In combination with post-print verification and process-monitoring such as paste-roll sensing, these tools provide effective assistance for operators, and help to achieve higher levels of productivity more quickly than previously possible.

The Bigger Process Picture

Particularly for manufacturers taking a longer-term, strategic view of their processes, other initiatives exist that complement these process management tools and procedures. Initiatives like investment in operator training and bespoke equipment maintenance programs. One such program is DEK's Performance Services, which has successfully helped customers manage, maintain and optimize large numbers of printers – sometimes installed across several global locations – to benchmark and continuously improve machine performance and productivity. But this demands a cultural commitment by equipment owners.

Other aspects for consideration in the productivity safeguarding argument include evaluating the inherent self-sustaining capability of the print platform. Platform developers continuously increase the on-board intelligence of automated, in-line printers, which augments the Performance Services and has been successful in securing additional improvements in productivity. One example is the adoption of field bus technology, in particular using the Controller Area Network (CAN) protocol, in the design of the platform. Field bus-based wiring infrastructure permits the machine's central controller to send actuation commands and collect diagnostic information from subsystems, such as positional and motion-control mechanisms. These infrastructures enable individual printers to prompt their owners when routine maintenance like print rail re-alignment becomes necessary. Advantages include a better-optimized maintenance schedule and reduced emergency downtime, both of which naturally boost productivity.

Controlling Process Variables

A key issue with getting the "process in control" is the huge number of variables that come into play and potentially influence the results that can be achieved with solder paste stencil printing. Maintaining consistently high levels of accuracy and precision requires absolute attention to detail in setting up all aspects of the process, including the printer platform and its related hardware & software options, the materials, process parameters and procedures. Errors or inaccuracies can significantly reduce the numbers of good boards produced, which equates directly to lower productivity. The fishbone diagram at Figure 2 below visually details the huge number of factors that influence the stencil printing processes on a modern print platform.

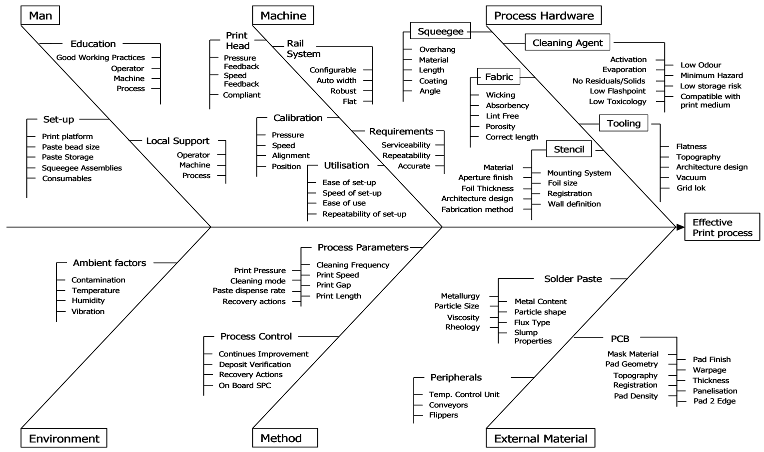

Figure 2 – Factors governing print-process control; all have a strong influence on productivity.

Make it Easy for the Operator

Given that operators still need to observe and control a number of process variables, even with new technologies delivering higher levels of automation and integration, a desirable objective is to make that control as easy as possible. From iPods and smartphones to automotive dashboards and airliner 'glass cockpits', presenting complex, sophisticated and continually changing data graphically is proven to make comprehension clearer. Likewise, the most operator-efficient print platforms take advantage of recent advances in user-interface technology by using large, color TFT-LCD displays to present information in a clear and intuitive format.

Such technology enables manufacturers to increase productivity through improved ergonomics and the easy addition of extra graphical features like "Time to Go" for consumables, thereby aiding real-time management of the print process. It also simplifies setup and eliminates another source of human error (Figure 3). Using menu-driven guidance, on-board video tutorials, and error-recovery assistance lets operators complete complicated setup procedures quickly and confidently, without enduring the highly specialized training traditionally expected. This also facilitates more flexible utilization of staff and skills resources, which helps manufacturing organizations to raise efficiency and become more responsive to customer demands to improve competitiveness.

Figure 3 – The DEK Instinctiv V9 user interface provides a portal for multiple productivity-enhancing tools.

Menu-driven user interfaces like this, which provide rich graphics and on-board help for operators, provide an ideal platform for converging and integrating productivity-safeguarding features. Coupled with large, color displays capable of supporting multiple concurrent windows, new tools can be deployed that combine data from verification and traceability modules, automatically preventing printing until the detected problem is rectified, yet offer intuitive setup and reporting. The DEK Sentinel system is an example of a fully integrated productivity-safeguarding tool that unifies automatic verification, traceability, real-time process management and inspection capabilities to enable future generations of print platforms to produce even greater numbers of good boards per hour.

Conclusion: The Platform for Productivity Growth

Operators and developers of capital equipment such as stencil printing platforms have identified increased automation and closed-loop automatic print verification and process monitoring technology as the optimum path to realize ever-greater process performance, quality, repeatability and productivity. A number of innovative features have successfully eliminated many potential sources of error at setup and during the print process runtime. But many of these features still work in isolation, and astute equipment specifiers and purchasers increasingly recognize the danger in systems that offer too many disparate tools being unmanageable by operators, negating their potential benefit to productivity. Now is the time to unify these systems by taking advantage of advances in user-interface design and enhanced inspection capabilities. The technologies now exist to create a concurrent and seamless environment that safeguards productivity all the way from product setup to high-speed, high-volume production of verified, known-good boards.

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