Cutting Down On False Alarms

by Ron Ellenbogen, Orbotech

AOI (Automatic Optical Inspection) machines are very effective in finding defects during the manufacturing process. Some reported defects, however, are false alarms. A reduction in false alarms will generate significant cost savings, as labour and other costs required to process the false alarms can be reduced. In Germany, the cost of a single false alarm is estimated at around 0.65 eurocents. Therefore, elimination of one false alarm per panel can result in an annual saving of more than €6,500.

Orbotech's SIP Technology, the engine behind Orbotech's new generation of AOI machines, uses advanced logic to minimize false alarms without compromising detection. The result is significant cost savings for the PCB manufacturer. Moreover, fewer false alarms reduce the chance that a real defect will be overlooked, thereby improving quality and saving additional costs.

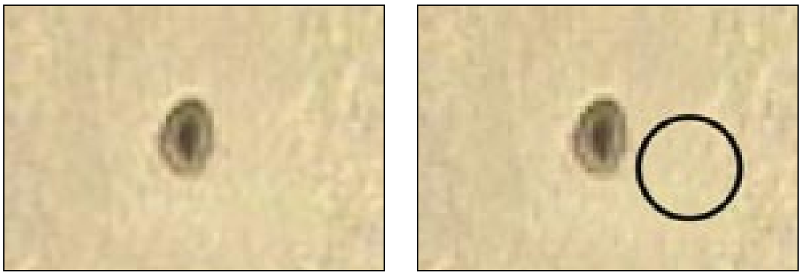


Figure 1 – Cosmetic pin hole defect inside ground area (left); critical pin hole defect in vicinity of future drill location (right)

False alarms overview

AOI has become increasingly popular over the last 20 years. AOI machines are very effective in detecting all defects on both inner and outer layers, thus providing significant cost benefits. If a defect is found on an inner layer, it can either be repaired or the faulty layer replaced. This capability allows for the manufacturing of multi-layer boards with many inner layers, even when the yield of inner layers is relatively low. Furthermore, AOI detects defects that cannot be detected by other means, such as electrical testing. A significant nick or a protrusion might not be enough to fail an electric test, but would probably affect the reliability of the board and, in turn, harm the reputation of the PCB manufacturer and his customers.

False alarms are an inherent side effect of AOI and fall into two categories: false calls and non-critical defects. A false call occurs when the AOI detects a defect even though the panel matches the CAM data or golden board. For example, oxidation can make Copper appear as a laminate and trigger a false call. A non-critical defect, such as a nick in a crosshatch area, occurs when there is a mismatch between the acquired image of the panel and the CAM data, but the mismatch does not affect the product functionality or reliability.

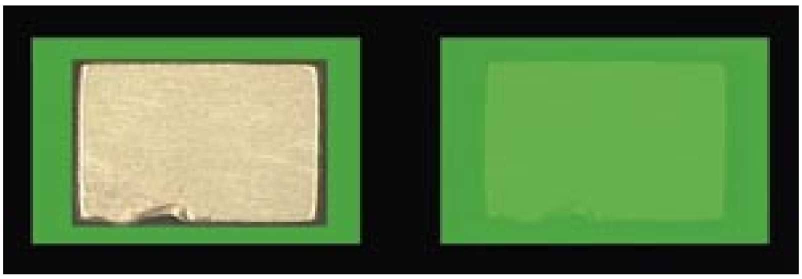
The costs of a false alarm

False alarms generate costs. Each defect reported by AOI must be verified. If the reported defect turns out to be a false alarm, then its verification effort is a cost that could have been saved, because the verification did not create any real value. False alarm verification costs include labour, capital equipment and other related costs such as maintenance and panel handling.

An analysis of false alarm verification costs will look into the work performed in verifying a reported defect. To display a defect on a verification station's monitor, the station's optical head moves to the suspected defect. When the optical head is in place, the station's operator reviews the defect and decides if it is real and critical, or not. The movement of the optical head takes between 0.8 and 1 second. The time for an operator to review a defect is estimated via observation to be between 0.3 and 0.5 seconds. Therefore, on average, a false alarm creates 1.2 seconds of additional work.

To demonstrate the cost model for false calls, data from Germany is used. In Germany, the annual cost per verification operator is €30K-€35K. €32K will be used as a rough average figure. On average, an operator works 225 days a year, 8 hours

Figure 2 - Critical nick in SMT located in opening in solder mask (left); cosmetic nick in SMT covered with solder (right)



aday. The hourly cost of an employee is therefore €18, and 1.2 seconds of labour costs 0.6 cents. Taking into account depreciation and the maintenance cost of the verification station, the total cost for a false call is estimated at 0.65 cents.

The average throughput of an AOI machine scanning 4 mil panels is around 170 panels per hour. Therefore, assuming that the machine is utilized 75% of the time, a single additional false alarm per panel translates to an additional 1,009,800 false alarms per year, an annual cost of €6564 per panel. The model is linear – for two additional false calls per panel the cost will be double, and so on.

This model can be expanded to include the cost of handling a panel that has zero real defects to the verification station. Moreover, the higher the percentage of false alarms out of total reported defects, the higher the chance that a verification station operator will miss a real defect. The probability of missing a real defect and the cost of having a bad layer in later stages of production, or even in the end product, can also be used in the model.

SIP technology eliminates false calls

SIP Technology, or Simple, Intelligent, Powerful Technology, is the engine that powers Orbotech's new generation of AOI machines. SIP introduces a new approach to panel inspection. The idea behind SIP technology is that in order to repeatedly achieve complete and precise results, the AOI machine must rely on an in-depth understanding of the panel rather than heuristics to find defects. SIP Technology identifies the various elements on the panel. It then compares each line, pad, SMT, and so on, in the acquired image with its matching element in the reference. In essence, it checks whether each feature, such as line or pad, in the inspected panel adheres to its specification defined by the reference.

One major benefit of SIP Technology is that it eliminates false calls

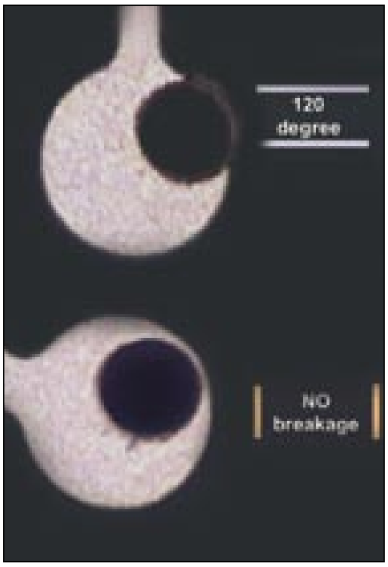


Figure 3 - Pad displaying breakage (top) and non-defect (bottom)

without compromising detectability. SIP Technology performs this feat by utilizing full panel understanding; a specific algorithm for each feature; independent measurement of each feature; and the elimination of oxidations

Full panel understanding

The purpose of full panel understanding is to correctly identify the features on the panel. One benefit of this identification is an improved ability to separate critical from non-critical defects. Panel understanding is multi-dimensional: horizontally, SIP uses a large area in order to correctly classify the features on the panel to lines, pads, SMTs, power and ground areas and crosshatch areas. Vertically, SIP uses drilling and solder mask layers to distinguish between critical and non-critical defects.

The incorporation of future drills allows for the separation of critical defects from non-critical ones. For example, a pin-hole inside a ground area is critical if the pin hole is near a future drill location – indicated by a black circle (Figure 1, right), but only cosmetic if no drill is in its vicinity (Figure 1, left).

Incorporating a solder mask allows critical and cosmetic defects in SMTs to be separated. For example, there is a nick in the SMT in the examples in Figure 2. In the left picture, the SMT is located in an opening in the solder mask while on the right the SMT is covered by solder. Consequently, the nick on the left will be identified as critical, while the one on the right will be cosmetic.

Specific algorithm per feature

A specific algorithm works on each feature in the panel. Each algorithm uses different logic to detect defects and distinguish between real and cosmetic defects. An algorithm for pads, for example, must take into account the location of the drill when analyzing each pad. Therefore, SIP first identifies the binary edge between Copper and laminate. Based on the edge, SIP builds a model of the pad. The model contains the centre of the pad and its radius. Using the binary edge, the algorithm also builds a model of the drill – centre and radius. Using the two models and user supplied thresholds, the algorithm can distinguish between the breakage on top, and the non-defect on the bottom (Figure 3).

Independent measurement of features

With the bitmap system technology AOI systems were traditionally based on, the operator had to trade between detection and false calls. For example, in the line image (Figure 4), there are three nicks in the line. However, only the ones on the left are significant as the line width is considerably reduced. In bitmap, the operator had to set the contour tolerance, thereby either detecting all three nicks (false alarms), or not detecting any (misdetection).

With SIP Technology, the system firstly identifies the feature as a line before operating a line-specific algorithm. This algorithm reports a defect if, and only if, at some location in the line the width is less than the specification for that line, taking into account a user supplied tolerance. In this case, only for the place where the two small nicks are adjacent, thereby reducing the line width significantly, will a defect be reported. The trade-off between detection and false calls is eliminated. Furthermore, not only is the algorithm tailored to a feature, so too are the tolerances. The threshold/tolerance for lines of different width can be different. The user can specify that the tolerance for 2 mil lines is ±5% whereas for 4 mil lines it is ±10%. This ensures that detection will be stricter in locations where a nick might have greater impact on reliability.

Elimination of oxidations

Oxidations are a major cause of false calls. SIP Technology uses the raw data from the image sensor to eliminate false calls created by oxidations. In Figure 5 the line algorithm detects a nick defect (top). The AOI will now use a different threshold (bottom) on the raw data to check whether the nick is due to a Copper shortage or oxidation.

Figure 4 - Line image displaying 3 nicks - the two to the left are significant as the line width is considerably reduced

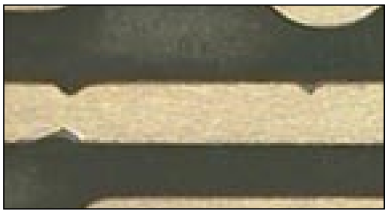
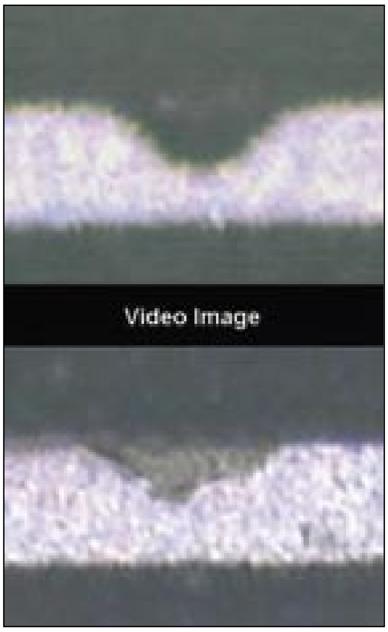


Figure 5 - Line algorithm detects nick defect (top); AOI uses different threshold to check reason for nick (bottom)



It is important to note that the system is conservative – when there is a doubt over whether a nick is a defect or oxidation, the system will prefer to report a defect, filtering it out. This ensures that detection is not compromised.

Repeatability of results

On AOI machines based on traditional image processing technologies such as bitmaps or ray analysis, the operator could set up the machine so that it would produce only a small number of false alarms. However, the user had to be an expert in the image processing algorithms and a large number of trial and error cycles were required. Even then, the operator had to trade between detection and false alarms. Consequently, the machines would work well in evaluations, reporting a low percentage of false alarms, but fail to deliver the same results in normal production. SIP technology overcomes this problem. By understanding the panel's geometry and matching each feature with the right algorithm, the technology eliminates the complicated manual setup. With SIP Technology it therefore takes just a single day to train operators to reach consistent results.

Increase in savings and quality

When assessing AOI machines, special care must be taken when considering the amount of false alarms generated in each panel. As demonstrated by our model, each additional false alarm per panel results in a significant additional annual cost. An AOI machine that can repeatedly produce fewer false alarms without compromising detection will provide savings and increase quality for the PCB manufacturer.