i4.0, ARE WE REALLY READY?

Keith Bryant
Keith Bryant Consultancy
Johannesburg, South Africa
keith@keithbryant.net

ABSTRACT

The Internet of Things, as a concept, was officially named in 1999. One of the first examples of an Internet of Things was a Coca Cola machine, located at the Carnegie Melon University. Local programmers would connect by Internet to the refrigerated appliance and check to see if there was a drink available, and if it was cold, before making the trip.

The term "Industrie 4.0" was used for the first time in 2011 at the Hannover Fair. In October 2012 the Working Group on Industry 4.0 presented a set of implementation recommendations to the German federal government.

Industry 4.0" refers to the concept of factories in which machines are augmented with wireless connectivity and sensors, connected to a system that can visualise the entire production line and make decisions on its own.
Industry 4.0 fosters what has been called a "smart factory". Within modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the Internet of Things, cyber-physical systems communicate and cooperate with each other and with humans in real-time both internally and across organizational services offered and used by participants of the value chain.

So, it’s been around for a while and is well defined with the keys being connectivity and ‘smart sensors’ to monitor and feedback data, we also see that this is NOT ‘lights out factory’ as it also mentions communicating and cooperating with humans, but not at what level.

This paper will evaluate SMT production and inspection machines and attempt to define their status and potential to act as ‘smart sensors’, the first building blocks towards i4.0, this will lead to the answer to the question in the title.

INTRODUCTION

Much has been talked, written and dare I say hyped about The Internet of Things in relation to Electronics Manufacturing. Whilst there is no doubt that IoT has made huge improvements in many areas of our lives below is a great example:

Smart metering
A smart meter is an internet-capable device that measures energy, water or natural gas consumption of a building or home.

Traditional meters only measure total consumption, whereas smart meters record when and how much of a resource is consumed. Power companies are deploying smart meters to monitor consumer usage and adjust prices according to the time of day and season.

Smart metering benefits utilities by improving customer satisfaction with faster interaction, giving consumers more control of their energy usage to save money and reduce carbon emissions. Smart meters also give power consumption visibility all the way to the meter, so utilities can optimize energy distribution and take action to shift demand loads.

However, manufacturing a PCBA requires many pieces of equipment, materials and components, not to mention the multitude of variations.
IoT is well proven in many areas, Pharmaceuticals. Fleet management and many cases less complex than building boards.
So are we really ready for i4.0?

EVALUATION

Many manufacturers are using IoT to streamline their businesses, but not really in the manufacturing cycle. From inventory control using component counters and storage towers to predictive maintenance programs and intelligent programs to manage factory loading and performance. But the real challenge in our industry is in moving towards the ‘lights out factory’ where the machines themselves control production, monitor quality and change manufacturing parameters to ensure 100% acceptable end of line acceptable product.

As you can imagine this is more challenging than the other areas where i4.0 is already working well to save money, the main driver for technology advances. This is the harsh reality of the world that we work in, ROI is the major driver here and the bigger and faster the return, the easier it is to get 'buy in'.

WHERE ARE WE TODAY

Let's start by going back a little, to when this became the 'Next Big Thing' for our industry, when there was first talk of 'full automation, AI and Factories without people'. Frankly speaking most of this was hype and was used by some equipment manufacturers to try to tie in customers to a one make line, as this would make the communication 'easy'. This and other ill-informed tactics created a backlash among manufacturers to what was actually a very good thing. Thanks to much hard work by key players and standards organisations we are now in a better place, but are we there yet?

Well I have to say we are still a long way from the utopia of AI factory management, but we are moving. Smart component management, predictive maintenance and 'real-time' inventory control, plus superior ordering schedules have made great gains in PCBA manufacturers performance

These are not industry specific and often come in a 'one size fits all' box concept from software suppliers.

But this does not improve the performance of our lines or allow us to produce more with less resources. So let's start with the good news, the Hermes standard is likened to a Smart Smema I have taken the liberty to quote from the IPC directly:

'The Hermes Standard (IPC-HERMES-9852) provides the state of the art for board flow management along mixed vendor lines in SMT assembly. It is officially recognized as the next generation technology setting forth from the IPC-SMEMA-9851 standard. Where SMEMA in the late 1990s was a first important step towards board handover between machines in an SMT assembly line, The Hermes Standard introduces the full capabilities of industrie 4.0 technologies to the assembly line.'

I would take issue with the part that says, 'full capabilities of ….' As this is simply transferring data relating to the board from one machine to the next and so on, it is a big step forward but is really only data transference.

What we need is this, plus much more, the ability to monitor all the process steps in 'real time' make adjustments to any machine 'on the fly'. This takes us to the realms of 'intelligent manufacturing and into the utopian world of zero defects.

THE REALITY.

Let us start at the beginning of the standard process of PCB Assembly, the humble screen printer

Below are comments that I have canvassed from renowned industry experts:

- 50% of SMT Assembly faults are caused by solder paste printing……
- 60% of SMT Assembly faults are caused by solder paste printing……
- 65% of SMT Assembly faults are caused by solder paste printing……
- 70% of SMT Assembly faults are caused by solder paste printing……

Whilst they may not agree, if we assume that between 50% and 70% of end of line faults come from this area, it would seem to be a good place to improve. But now we start to run into problems, printing is a complex process with many possible errors, despite its simple nature.

Let us look at a single error seen at the SPI system straight after the printer

- • Solder Paste too dry
- Stencil apertures blocked
- Not enough paste on stencil
- Squeegee pressure too low

- Board to stencil gasket poor
- Co-planarity issues
- Paste too cold
- Stencil needs cleaning
- And I am sure a few more…….

So how can an algorithm which needs one solution resolve this issue? The SPI probably would have a default response to this:

Insufficient Paste = not enough squeegee pressure or not enough paste on stencil or any one of several others. This may make things better or if it's the wrong call it will make things worse!

Adding paste to an already fully loaded stencil will create other issues, increasing squeegee pressure if its already correct will cause extra paste to be pushed through the stencil leading to smearing and bridging. So you can quickly see that this is not a simple solution, however, there are potentially things which can be done. Industry 4.0 relies on data and feedback, this in turn requires sensors to monitor the process and feedback to a central Management Information System, what is going on in 'real time'.

So, let's go back to our insufficient paste problem, if we knew the weight of the paste on the stencil, we would know the volume and know if it was correct, 4 piezoelectric crystals, one under each corner of the frame would do this. They could also detect co planarity issues and monitor squeegee pressure, so adding to the level of feedback.

Horticulturalists use soil monitors to check for Ph and wetness, they cost a few dollars only. Sticking one in the solder paste after every 20 prints will find out if the paste is drying out on the stencil or if it is losing volatiles (reducing flux activity) as the Ph will change when this happens.

Two simple sensors and now we have reduced the guesswork dramatically, I could go on, but I think you get the point.

We are currently not in a position to move to full i4.0 as we do not have the sensors to give enough feedback to allow accurate analysis of what is happening.

GOOD NEWS

There is one area of electronics manufacturing where we have some very good sensors, they do not work together, but they are accurate, repeatable and mostly work in 'real time'. This is in the area of in-line inspection, to be exact, in line x-ray and 3D AOI. Both produce reasonable results but have weaknesses.

A limitation of 3D AOI is being an optical inspection system it cannot see underneath any black devices, BGAs, etc.

Therefore, it does not allow the system to make a conclusive decision if the solder joints of the black devices are still acceptable despite co-planarity or warpage issues.

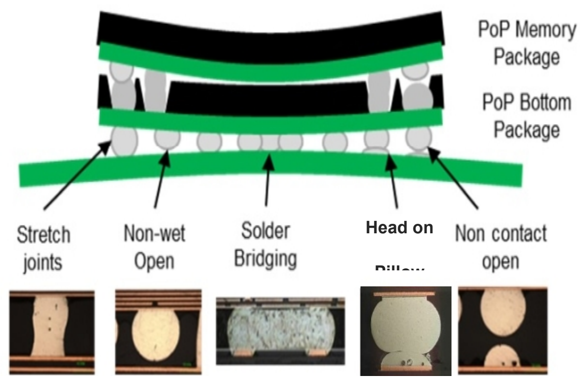

Figure 1, Issues with 3D AOI

In line X-ray has been around a long time and struggles with the speed and complexity of some of todays advanced manufacturing Head on Pillow (HoP) defects have become more prevalent since BGA components have been converted to lead-free alloys and lead-free solder.

This results in a solder joint with enough of a connection to have electrical integrity, but lacking sufficient mechanical strength.

The in-line x-ray inspection systems try to find HoP defect by looking at BGA balls in at least 3 different positions – the PCB Pad slice, the BGA Mid-ball slice and The Package Slice.

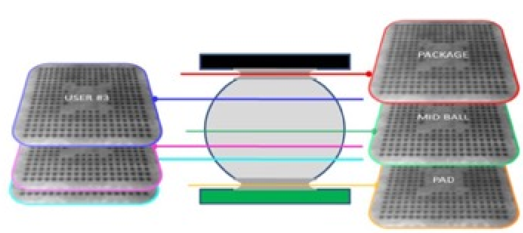

Figure 2. In-Line x-ray slices

This can lead to the following assumption, the ball is small and round, therefore it has not reflowed, this is a dangerous leap and can lead to unnecessary rework and scrap.

Both 3D AOI and in line x-ray are good technologies and despite their weaknesses are the backbone of volume manufacturing. But what if we can use i4.0 to make them Smarter and overcome their weaknesses?

So here it is, a technology which works like this: any height measurement of a BTC which the in-line 3D AOI "fails" is relayed to the At- Line X-ray and evaluated by its operator using all the technology at his disposal including ICT which gives a detailed view of all hidden joint interface

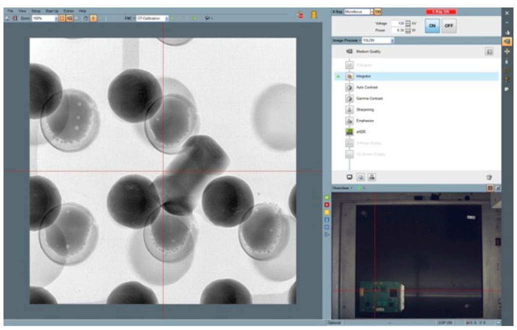

Figure 3. At-Line X-ray Image

The result and images are then fed to a Management Information System where a technician can review the SPI data, the 3D AOI data and the x-ray results, in real time on the same monitor. He can now use his judgment to accept or fail the board, can review historic data trends to fine-tune the AOI height limits and continuously improve the process by Intelligent Feedback. The use of a brain to filter the algorithms and images to ensure maximized yields and reduced rework and lower costs. This data can then be archived and shared with other lines, other factories or even with customers.

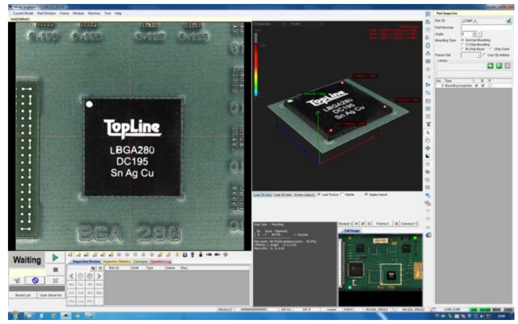

Figure 4. The image shows the 3D AOI screen

So, the At-Line X-ray does an AQL inspection and also checks all of the potential height failed BTC's, so it is a fast and accurate tool and the 3D AOI is now doing a much better job. By simply scanning the bar code of the suspect panel all the potential fail sites are checked concurrently with the x-ray system moving to them automatically and displaying the data from the 3D AOI to aid the operator. The resultant images and data are returned to the 3D AOI and shared with the Management Information System. So, there you have it, Intelligent Feedback and much more. Limits on machines will be adjusted, based on a complete set of data and the interpretation of a technician, who could be managing multiple lines.

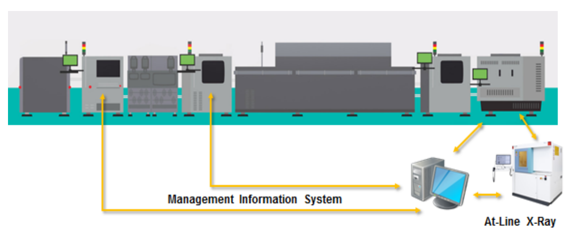

Figure 5. How it works

These improvements can easily be shared with copy exact factories around the world, for a really joined up solution. Reports can be made available to senior managers and customers showing the results of this Process Management as improved yields and reduced rework. In short, a process fully under control and utilizing the application of knowledge, tools and systems to measure, control, report and improve processes with the goal to meet the customer requirements profitably.

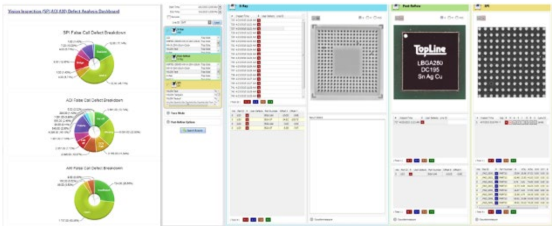

Figure 6. Management Information Screen

RESULTS

At the factory where this system was tested, the following observations were made

- ✓ The number of PCBs from regular production workflow that needed an additional manual inspection and verification with microscope, ICT or offline X-ray was approx. **10%**
- ✓ The average time spent on this manual inspection and verification was **30 min**
- ✓ During the test period of the ProLoop solution we measured an average time of the verification at **4.6 minutes** per PCB, inclusive of loading, start-up of the system and unloading
- ✓ This means that the verification process became at least **6,5 times** more effective, 85% of time and relevant costs can be saved
- ✓ We accepted that human error in at-line X-ray inspection could be 5%, a number that is unrealistically high, but will serve to illustrate the next point
- ✓ This means that the first-time pass yield of the line has gone from an average of **90% to 99.5%** and that is even with an unrealistically high percentage for human error.

CONCLUSION

While some areas of PCBA manufacture are moving towards i4.0 there are some major obstacles to overcome before we get to a full lights out factory.

By combining In-Line and At-Line inspection we are able to improve first time pass yield and monitor line build quality in ‘real time’, this reduces costs and improves efficiency. However operators and technicians are still required for the process, but they are used very efficiently and make a significant contribution to the cost down.

As there is still a strong drive from the customers and the equipment companies i4.0 will move closer to full implementation, but currently the linking of in-line and at-line technologies gives us the biggest ROI in this arena.

ACKNOWLEDGEMENTS

- Yxlon International, for the x-ray images and for allowing me to share the test results.
- Mirtec, for the 3D AOI images and data.
- Mr R Vaga of Yxlon International for working with me on this project.