

SMT Process Characterization and Financial Impact

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Abstract

Portable Electronics devices are having more functionality but the size is getting smaller. What it means to SMT is to place more, smaller and ultra fine pitch devices on PC board. This makes SMT process capability the key measure to SMT quality. A number of the companies study the process capability at the time they evaluate or purchase the equipment, or at the time they design the product to fit the process capability. But process capability is changing over time. The process/machine was capable before may not be capable now.

The paper focuses on process capability and process control. It suggests process capability study should be a routine rather than a one time work. The paper is based on the practices in our company's manufacturing environment. For placement, the Cpk measurement was trialed on some of our lines. The measurement machine problem was analyzed and a proper measurement machine that fits the requirement was chosen. The Cpk result and product yield after proper calibration were very encouraging. For printing, a DOE was conducted based on the 0.4mm pitch BGA. The significant factors related to output of paste volume and paste deposit variation were found and an optimum setting combination was suggested to production. The process characterization has been proved to have a significant financial impact.

Introduction

Wireless technology today makes it possible to integrate more functionality to portable devices, like phone, PDA, email, camera and other entertainment such as music or even movies. The nature of portable devices that they are easy to carry and use. Lighter, smaller and thinner in size and larger in display is the trend for design. The requirements bring in challenges to SMT process like 0201, ultra fine pitch BGA, leadless QFN and LGA, high density. The use of RF shields make defect detect ability harder. Lead free solder for environmental legislation makes the situation even difficult.

Before jumping to any solution, it is good to review the SMT process. If I put the major inputs of process as Printing, Placement, Profile, PCB, Paste and Part, that is 6Ps and put process design as another major input, the input would be 6Ps and 1D. These 6Ps and 1D we think are controllable inputs while some of the inputs are not controllable that are possible environment factors. Assume most companies try to keep the variation of the uncontrollable environment factors to minimum, so if 6 Ps and 1D are in control, the SMT process should be in control. For these 6Ps, the immediate factors we can control are placement and printing and profile.

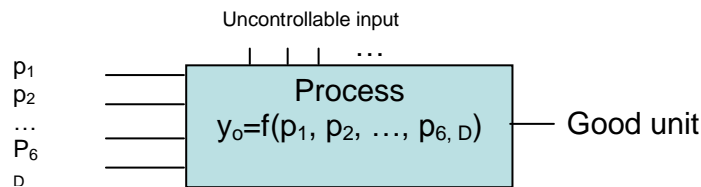


Figure 1

For each high level input there is also a lower level output of the process (shown below in Figure 2). For placement, the accuracy of part placement is considered one of the key factors to quality. For printing, the parameter setting and support setup are considered the key factors. For profile the ramping speed, peak temperature and time above liquidus. For PCB, besides design, the variation of solder mask, stretching, finishing etc are considered key parameters. Variation on paste and part will affect printing and placement accordingly.

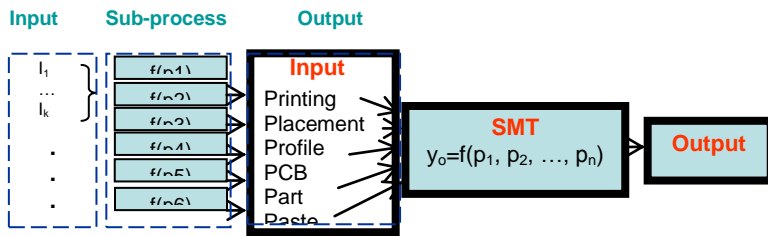


Figure 2

Process Characterization Practice

1. Placement Process Characterization

1.1. Placement process and problem

Placement accuracy is considered very important to placement quality. On most of the hand-held product, the size of the majority of the component is at the 0402 level and the BGA pitch is at the 0.5mm level. Referring to

Figure 3, if we look at 0402 part geometry, the size of terminal is 0.5mm x 0.25mm, according to IPC standards. If the part is offset by 50% of the pad which is 0.125mm, it is considered misaligned. This is also applicable for 0.5mm pitch BGAs. 50% of 0.25mm is 0.125mm and if the offset is more than 0.125mm it is considered misalignment. It is very reasonable to use +/- 0.12mm as specification to measure the process capability. If standard of $Cpk \geq 1.33$ is applied to the capability study, it means that we have a very high confidence the process is capable for the placement. The +/-0.120mm was the specification we used on machine in RIM to test the placement machines. Very surprisingly we saw almost all Siplace machines failed the test. They all below the threshold of $Cpk \geq 1.33$ either in X or Y coordinate.

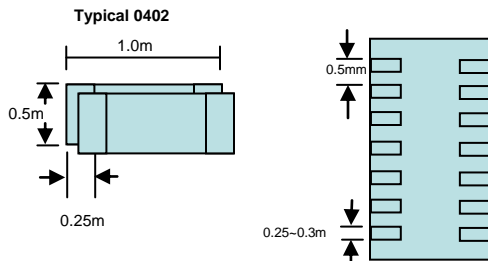


Figure 3

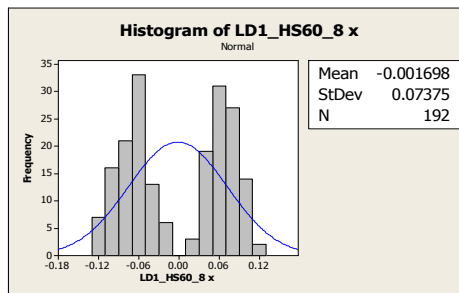


Figure 4

To investigate the causes behind this bad result, the distribution of the deviation of one of the machine was plotted. Obviously the distribution is Bimodal as showed above. Figure 4. Continuing to investigate the deviation of placement by each gantry was plotted. The distribution of each gantry was normally distributed but with an overall offset: two gantries shifted to left while the other two shifted to right. That was the reason that the distribution of the machines is not normal. When our investigation came to this conclusion that the machine needs calibration, the regular calibration was performed, but the result was not encouraging. Machine service was consulted. Another calibration called “Final calibration” was performed. This calibration brought the machine deviation data distribution to normal, and brought the Cpk to greater than the 1.33 threshold. Further investigation lead us to the knowledge that the two levels of calibration have difference focuses. Regular calibration focuses on segment calibration with the segment smaller shown in blue color. But it does nothing about gantry offset. Fine calibration focuses on gantry offset. Fine calibration checks the offset for each gantry and then the offsets are corrected to close to zero. (See Figure 6 Function of fine calibration).

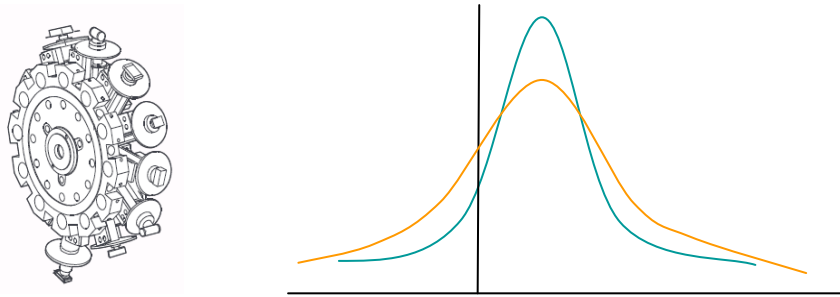


Figure 5 Segment and function of regular calibration

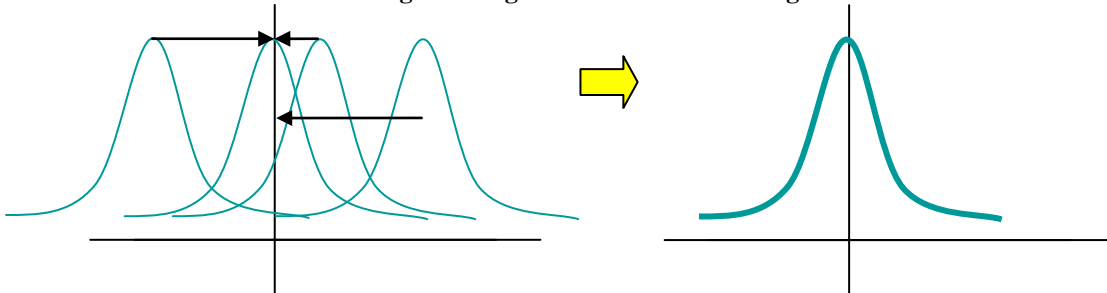


Figure 6 Function of fine calibration

1.2. Measurement system selection

In the following weeks we saw the fine calibration was working well to correct gantry offset. But the “Fine Calibration” needs a long time which impacts production output. Deploying fine calibration in a busy manufacturing environment on a monthly basis may be a costly activity. To shorten the Checking or Calibration time, several methods were tried. Using AOI machine was tried. It was found that the accuracy of the AOI machine was not good enough to carry out the activity although the GR&R was good. Using an offline CMM machine and CeTaQ machine was tried too. For the placement Cpk check in particular, CeTaQ was considered the proper machine. The methodology of CeTaQ and “Fine calibration” are identical. Both using a grid glass plate which has a 3 um accuracy across the board (as shown in

Figure 7). Test components are placed close to the Dot (in the space among the 4 Dots) on the glass board. When measuring, the machine camera looks for the Dot(s) as a local fiducial(s) of which the coordinate is given. So the accuracy of the measurement pretty much relies on the accuracy of the glass board.

As mentioned the accuracy of the glass board is within 3 um across the board. To precede with the checking process, each gantry on each machine has been assigned with a number of placements to calculate the accuracy of the gantry. These components are then measured by the measurement machine offline without affecting production. The software provides detail information for segment and gantry. The calculated offset, if any, can be fed back to the machine data to make the machine pass the Cpk test.

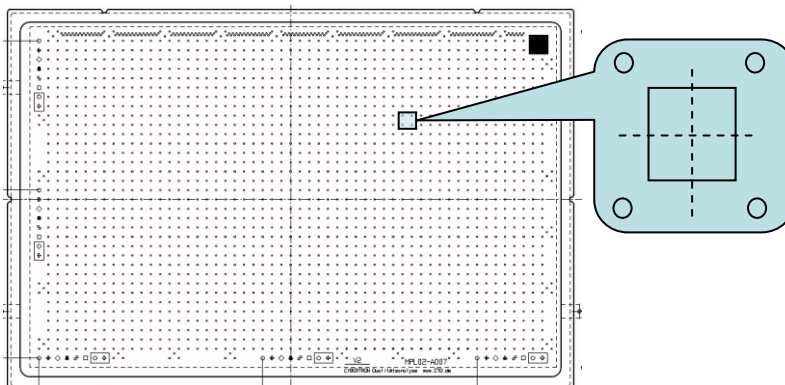


Figure 7

2. Printing Process Characterization

2.1. Printing Problem

With more IO integrated a smaller package size is requested making the BGA have a smaller pitch. The problem we encountered was with the Ultra fine pitch BGA.

When the BGA was used on product, we saw insufficient solder (

Figure 9) and excessive solder (Figure 8) on same BGA. When we measured the solder deposit volume after printing process, it is found that the variation was very large. (Figure 11).

2.2. DOE and process optimization

Digging into detail, there are two problems: one is the unstable printing process, another is the solder paste volume. Without stabilization of the process, any effort on stencil design change will not help the situation. So first we tried to reduce the variation and to get the process stable. With the input from paste manufacturer and printer supplier and also from process engineers, a DOE (Figure 12 DOE of printing process Average and Standard deviation) of 8 factors was planned to screen and optimize the factors. The output chosen are *Average* and *Standard Deviation* of the solder paste deposit volume. The *Average* is used to check the release performance of the paste. The *Standard Deviation* is used to check the stability of the process. The higher the volume average, the better the release performance. The smaller the standard deviation, the more stable the process.

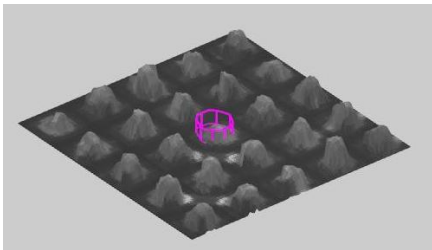


Figure 9

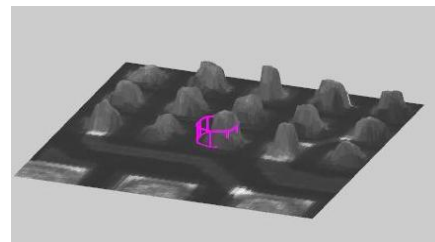


Figure 10

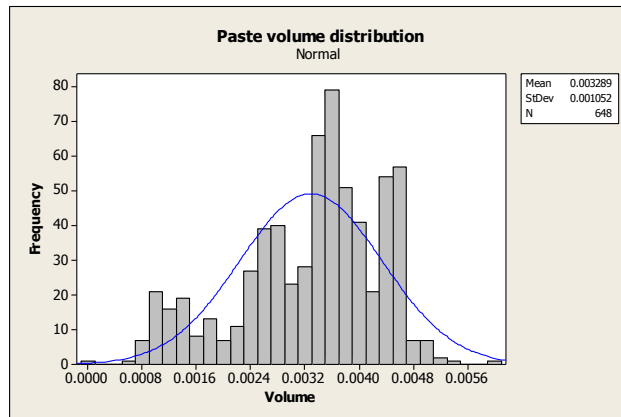


Figure 11

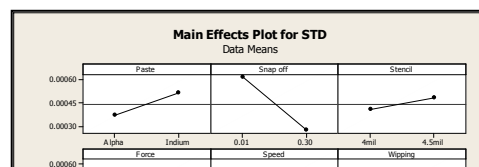
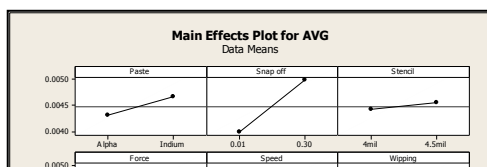


Figure 12 DOE of printing process Average and Standard deviation

The DOE result suggests that the PCB-stencil separation speed is the most significant factor. Stencil thickness, aperture design and printing speed etc. have an impact on the output measured. But look at chart of interaction below. When PCB-Stencil separation speed is set at the higher end of 0.3 inch per second, the difference on other factors (except for Aperture) tends to be flat on the chart. In other words, the difference from these factors is minimized.

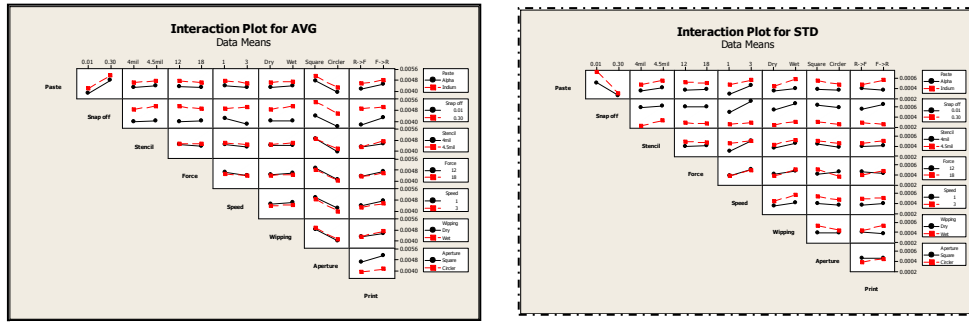


Figure 13 Interaction of between factors

The confirmation run after the DOE also confirmed the result from analysis. In figure 13 the top left chart shows the same as in Figure 10. The bottom left chart is a 4 mil stencil with the best optimization. The distribution is narrow and tall. On real production, the defect of insufficient solder has been eliminated, but the solder short defect still exists. Further improvement involves aperture redesign and other factors.

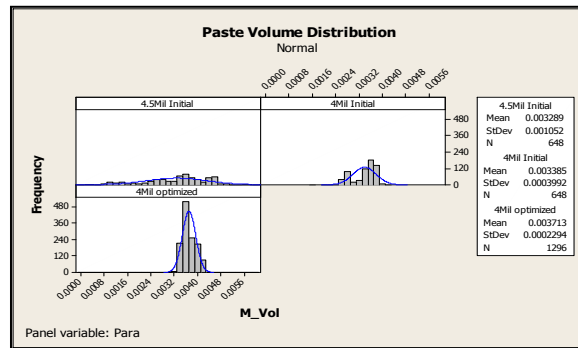
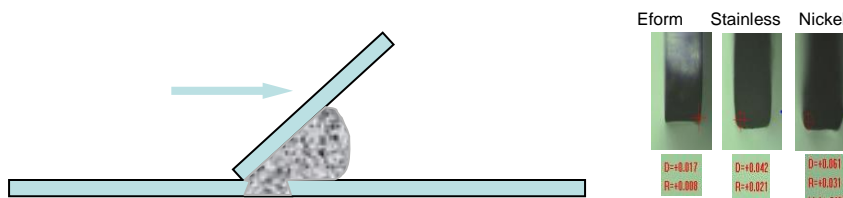


Figure 14 Printing result comparison

2.3. Other factors

Besides optimization of printing parameters, other factor have been investigated: material of squeegee blade, stainless steel Vs. Eformed, PCB shrinkage and stencil stretching. The experiment shows the Eformed squeegee blade has a better result comparing to the stainless steel one. The reason would be the edge of the Eformed blade is sharper: it help in cutting process when printing. The surface of the blade is smoother which helps solder paste rolling on the stencil.



PCB shrinkage is another factor that affects the printing result. Although the shrinkage can be compensated in some degree in PCB manufacturing process by adding scale factor to the process, PCB shrinks further with every reflow. The worst case is that PCB is shrinking while the Eform stencil is stretching. With ultra fine pitch BGA, the process window for alignment is smaller than the stack of the tolerance. Efforts need to be made to get the PCB and stencil in control.

3. Reflow

To some people reflow process may be considered very simple, but it is a very important process. Quality of the soldering is relying upon the process. Also some other defects may take place on this process too. Profile is a common character that every manufacturer controls. Normally the profile is done at very beginning. Each company has set a frequency to check the consistency of the profile. Physically running a profiler every day may be very expensive to some busy companies. We installed a KIC system to every oven to sample check the profile every hour for consistency. The variation can be read whenever it is needed. Any out of spec event generates a warning on the machine computer. Another important characteristic is the smoothness of the chains which are used to convey the board through oven.

If the smoothness of the chain movement is not good it may cause components movement when the solder become liquid. This is especially true for heavy components. Lubrication of chain should be treated as a important item for maintenance.

Summary

The financial impact through the process characterization was calculated with quality data and repair process analysis. The direct impact on yield was significant. The annual financial impact is on the million-level.

For any volume production, Characterization is the most effective way to improve the process quality and can have a direct financial impact. Without knowing the key parameters for the process and direction of adjustment, any effort on them could make the process worse. That was one of reason we saw that the process personnel kept adjusting the parameters every day but with the result that process varies over time.