# LITERATURE SURVEY ON FACTORS AFFECTING SOLDER PASTE VOLUME DEPOSITED FROM PRINTING PROCESS

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**ABSTRACT:** Manufacturing industries always giving their concern toward three main aspects, which are the quality, quantity and rework cost. Yield is the key performance index used by industries to indicate product quality. However, there are some processes cause the quality issues to the products in which will reduce the yield. Solder paste printing process is one of the critical problems to the quality issues in which 52% to 71% of the defective products are due to solder paste printing machine. In order to solve the problem, the factors that may affect the solder paste volume deposited on PCB pads have to be identified. Several studies had been made on the possible factors and these factors can be grouped into four categories, which are machine, stencil properties, environment and solder paste. Machine factor is the most favourite study by many researchers because it is controllable and less cost is required to encounter the quality issues.

**KEYWORDS**: *Surface Mount Technology (SMT), Solder paste printing*

## 1.0 INTRODUCTION

Today, electronic products are getting smaller in size, the printed circuit board (PCB) in the products is also small. This implies that small size components will have to be assembled on top of the PCB. Normal soldering method impractical to assemble small components on the PCB. Thus, surface mount technology (SMT) is required to do PCB assembly. SMT allows the assembly and soldering of electronic components onto the surface of the PCB through several steps (Zhou & Chen, 2016). The general process flow for surface mount technology is illustrated in Figure 1. First, the PCB will be delivered to the solder paste printing station in which solder paste is deposited on the PCB as shown in Figure 1(a). The process is followed by components placement as shown in Figure 1(b) where-by electronic components will be placed automatically on the pad above the PCB. Next, the PCB will be moved through reflow oven which is shown in Figure 1(c) to melt the solder paste so that the contacts between the components' leads and PCB are established. Unfortunately, to-date, a stable manufacturing yield is still a prevailing issue due to PCB defects. The defective PCBs had to be rejected for debugging and rework, further reducing the yield from the targeted number. There are studies showing that 52% to 71% of the defective products are due to the screen printing machine (Benedek et al., 2013; Pan et al., 2004).

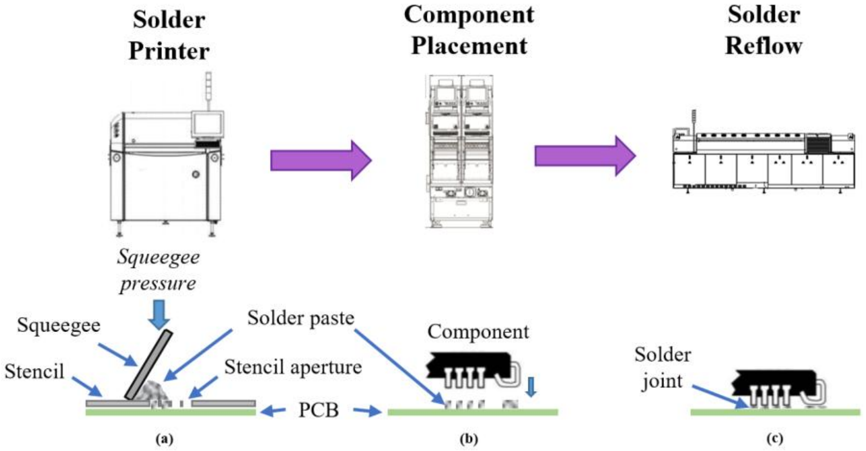

Figure 1: Process flow of surface mount technology

As so far, there is no study on the optimal value for solder paste volume to be deposited on the PCB pads before the printing process. The only study found is the method to optimize the solder paste volume after the specifications were set. As mentioned by Huang et al. (2011), different pad designs have their own optimum amount of solder paste volume. To-date, the target volume set for solder pastes is based on personal engineering experiences and observation. The improper volume of solder paste applied will cause either excessive volume or insufficient volume of solder paste on the PCB pads.

Therefore, it is very important to identify what is the possible root cause that may affect solder paste volume during the printing process. In this paper, the factors that affecting solder paste volume during the printing process will be reviewed. There are several findings by different researchers on possible factors affecting solder paste volume deposited on the PCB pads. Research on finding their optimum settings of solder paste disposition is still on-going and remain an open research problem.

## 2.0 FACTORS AFFECTING SOLDER PASTE VOLUME

This section consists of two parts. The first part will, which is Section 2.1, will discuss the findings by different researches to identify the possible factors that may affect solder paste volume deposited on the PCB pad during the printing process. Researchers had conducted a Design of Experiment (DoE) to verify those factors affecting the solder paste volume. In the second part, which is Section 2.2, will summarize all the findings from different researches and identify the gap from these researches.

## 2.1 LITERATURE SURVEY ON FACTORS AFFECTING SOLDER PASTE VOLUME

Li et al. (2008) had performed the Define, Measure, Analyze, Improve and Control (DMAIC) method with the intention to improve the SMT solder printing process. An experiment was conducted through DMAIC approaches to identify eight possible factors that affect the solder paste thickness which gave significant effects to solder paste volume. The eight factors were shown in *Table 1* with each factor tested with three different settings. The experiments used orthogonal array $L_{18}$ to form 18 different combinations of control factors. After went through ANOVA analysis, factors D, E, H, M, N and O gave significant effect to solder paste thickness.

Luxnanan and Kittithreerapronchai (2016) also employ the DMAIC approach to identify factors to reduce the defective rate on the flexible printed circuit board (FPC). Failure Mode and Effect Analysis (FMEA) methodology applied by Luxnanan and Kittithreerapronchai (2016) had helped to identify the three possible causes of solder paste strain defects; human error, machine error and cleaning routine. Five potential factors were investigated to identify their significant effect on the defect. Two levels were set for each control factors and the controls factors tested were summarized *Table 1*. Findings from the experiment showed control factors J and K have significant effects on solder paste strain on FPC pads.

Another method used by Su et al. (2017) to obtain the optimized solder paste volume on the printed circuit board was through operating window experiment. Five control factors were involved in this experiment and listed in *Table 1*. The unique part did by Su et al. was involving noise factor in their experiments which were relative humidity (e.g. 40%, 45% and 50%). The orthogonal array of $L_{18}$ ($2^1 \times 3^7$ experiments) was employed to reduce the number of running experiments. The experiment was to identify the critical squeegee pressure value at which solder open started, $y_{\text{open}}$ and at which the solder bridge started, $y_{\text{bridge}}$. Each experiment was tested at every humidity condition. With the measurement obtained, the signal-to-noise ratio for the operating window, $\eta_{OW}$ was calculated using Equation (1).

$$\eta_{ow} = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_{\text{open}}^2\right) - 10\log\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_{\text{bridge}}^2}\right) \tag{1}$$

where $n$ is the number of levels used for humidity factor. ANOVA analysis had been done to the signal-to-noise ratio. The results show that factors D, E, G, and H are the significant factors.

A similar experiment to Li et al. (2008) was conducted by Huang (2018) to identify the optimum control settings for stencil printing process on the quad flat package (QFP) component. The experiment tested out with six control factors and they were listed out in *Table 1*. A total of 18 sets of experiments (orthogonal array of $L_{18}$) had been designed. The measurement made was to the solder paste thickness gauge. Signal-to-noise (SNR) ratio had been calculated. The ANOVA analysis is done to SNR results and it showed that the decisive factors to the solder paste thickness gauge were squeegee pressure, cleaning frequency and stencil cleaning method.

Taguchi-Grey approach was used by Liu et al. (2018) to obtain optimize parameter of solder paste deposition. An experiment had been set up to identify the significant effects of squeegee pressure, squeegee speed and separation speed to the solder paste volume. Each control factor had three different settings to be set up in the solder paste printing machine of model DEK Horizon-iX. Solder paste inspection (TR7006A model) was used to inspect the volume of solder paste deposited on the PCB. There are other variable values fix throughout the experiment such as type of solder paste, squeegee material, squeegee angle, aperture width and stencil thickness. A total of nine experiments which based on Taguchi orthogonal array, $L_9$ with each experiment was tested with 20 sample PCBs. The S/N ratio for volume, area and height of solder paste were calculated for further interpretation. The ANOVA analysis showed that separation speed was significant factors to solder paste volume.

*Table 1: Summary of review on factors affecting solder paste volume by researches*

| Category | Factor | Li et al. (2008) | Luxnanan et al. (2016) | Su et al. (2017) | Huang (2018) | Liu et al. (2018) |
|---|---|---|---|---|---|---|
| Solder Paste | A. Solder paste stirring time | | | | ✓ | |
| Environment | B. Operating temperature | ✓ | | | | |
| | C. Humidity condition | | | ✓ | | |
| Machine Control Factors | D. Squeegee angle | ✓ | | ✓ | | |
| | E. Squeegee speed | ✓ | | ✓ | ✓ | ✓ |
| | F. Squeegee pressure | | | | ✓ | ✓ |
| | G. Snap off distance | | | ✓ | ✓ | |
| | H. Separation speed | ✓ | | ✓ | | ✓ |
| | I. Down-stop | | | ✓ | | |
| | J. Cleaning roller direction | | ✓ | | | |
| | K. Cleaning speed | | ✓ | | | |
| | L. Vacuum | | ✓ | | | |
| | M. Cleaning frequency | ✓ | ✓ | | | |
| Stencil Properties | N. Solder area to pad area ratio | ✓ | | | | |
| | O. Aperture shape | ✓ | | | | |
| | P. Aperture size | ✓ | | | | |

## 2.2 Summary of Factors Affecting Solder Paste Volume on PCB Pads

From all the available researchers' studies, different researches are investigating on different factors that affecting solder paste volume, which may cause defects such as tombstone, dewetting, soldering bridging and insufficient solder. Luxnanan and Kittithreerapronchai (2016) investigated machine recipe, but they were focusing on cleaning process parameters, such as cleaning roller direction, cleaning speed and so on. Liu et al. (2018) were also identified the machine recipe towards the solder paste volume effect, but in term of process control parameters, such as squeegee speed, squeegee pressure and separation speed. Su et al. (2017) investigated the same factors as Liu et al. (2018) but the method of data measurement is different. Su et al. (2017) changed the pressure exerted on the stencil to the condition where solder open and solder bridge happened. These pressure values are then used to calculate signal to noise ratio. The relationship between multiple types of controls, such as machine recipe, stencil designs and environments were investigated by Li et al. (2008) and Huang (2018). Differ from these two investigations, Huang (2018) was focused on quad flat package (QFP) component with a pin pitch of 0.4 mm. There are only a few common objectives that researchers are trying to achieve. The objectives are to increase the quality of products, to reduce the manufacturing costs of rework and to improve product yields. There are several types of factors which will affect the solder paste volume, including machine, stencil, solder paste and environment. They are summarized using a cause-and-effect diagram (fishbone diagram) as shown in Figure 2.

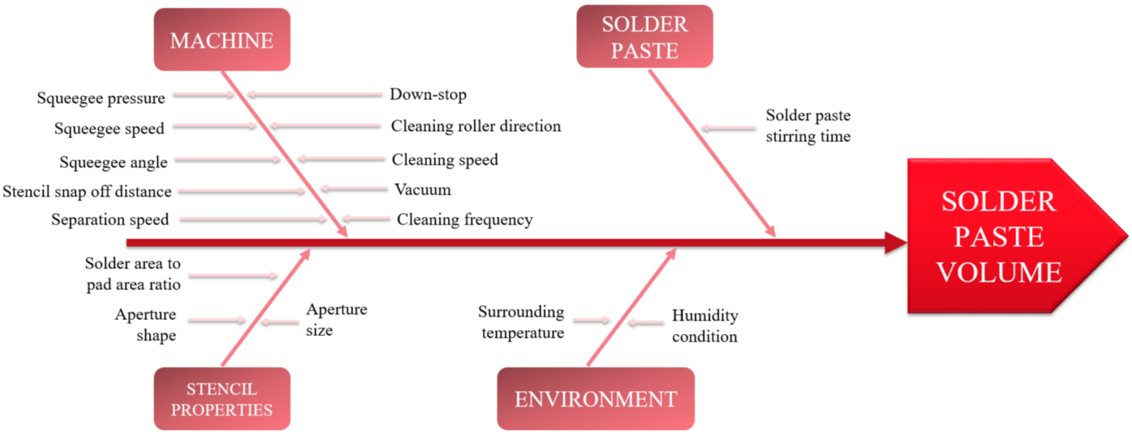

Figure 2: Cause-and-effect diagram showing the factors affecting the solder paste volume

## 3.0 CONCLUSION

The yield is the most important key aspect in the mass production of an industrial company in order to achieve profit margin. The development of SMT provides a substantial benefit in making PCB assembly, in particular, the product can be manufactured within a shorter time without sacrificing quality. However, without a proper setting in the process, material design and control, the high yield target would be hindered by the defects occurring. Therefore, it is important to understand the possible factors that may result in defect failure to a product. Throughout several reviews from the researcher's findings, it can be concluded that there are four categories of factors that may affect solder paste volume. They are machines, stencil properties, solder paste and environments. Among these four factors, machines factors are the easiest factor to be controlled and required less cost to solve the problems.

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