FEM Simulation on Stencil Bending Due to Squeegee Load during Solder Paste Stencil Printing Process

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LIST OF SYMBOLS

[F]	The matrix contains the boundary condition of force
[K]	stiffness matrix, which contains information about the geometry
[U]	displacement
$\vec{u}(u, v, w)$	displacement vector and a function of the coordinate (x, y, z)
$(\vec{e}_x, \vec{e}_y, \vec{e}_z)$	Unit base vectors along with the (x, y, z) coordinates.
D	flexure rigidity
$\left(\frac{\partial w_n}{\partial x}\right)^2$	displacement gradients
$g(y), f(x)$	integration functions

ABSTRAK

Dalam pemasangan papan litar bercetak, alat penyeka bergerak ke satu arah dengan penerapan beban pada alat penyeka. Ini akan menyebabkan alat penyeka melenturkan stensil dan papan litar bercetak sepanjang proses pencetakan stensil. Pemuatan ini menimbulkan lenturan mikro pada stensil dan akan mempengaruhi isi padu solder yang disimpan. FEM akan digunakan untuk mengkaji kesan beban alat penyeka pada lenturan stensil. Parameter seperti bahan alat penyeka, bahan stensil, ketebalan stensil dan ketebalan papan litar bercetak adalah kriteria utama untuk hasil simulasi lenturan stensil dan papan litar bercetak. Semakin tinggi kekuatan tegangan bahan untuk stensil, semakin rendah lenturan stensil. Bahan untuk stensil yang banyak digunakan dalam industri ini ialah Alloy Steel, AISI 4340 Steel, Annealed dan AISI 316 Stainless Steel Sheet. Bahan alat penyeka yang banyak digunakan dalam industri ialah Keluli Tahan Karat AISI 321, Baja AISI 4340, Baja Normalisasi dan Baja Aloi. Bahan dari Printed Circuit Board (PCB) yang banyak digunakan dalam industri ini adalah Epoxy, Unfilled. Semakin tinggi kekuatan tegangan pemeras, semakin tinggi pesongan stensil dan Printed Circuit Board (PCB). Semakin tinggi ketebalan Printed Circuit Board (PCB), semakin rendah pesongan stensil. Pendekatan Simulasi Statik SOLIDWORKS 2020 2-D digunakan untuk mengkaji pesongan stensil akibat pemerasan. Simulasi ini dilakukan pada tiga jenis bahan yang berbeza untuk stensil dan alat penyeka.

ABSTRACT

In the assembly of the printed circuit board, the squeegee moves in one direction with the application of load on the squeegee. This will result from the squeegee deflect the stencil and Printed Circuit Board (PCB) throughout the stencil printing process. This loading creates micro-bending on the stencil and will affect the solder paste volume that is deposited. FEM will be used to study the effect of squeegee load on the stencil bending. The parameter such as the material of the squeegee, the material of the stencil, the thickness of the squeegee and the thickness of stencil is the main criteria for the result of the simulation for the bending of the stencil and the PCB. The higher the tensile strength of the material for the stencil, the lower the deflection of the stencil. In this study, material such as Alloy Steel, AISI 4340 Steel, Annealed and AISI 316 Stainless Steel Sheet was used as they are widely used in the industry. In this study also, AISI 321 Annealed Stainless Steel, AISI 4340 Steel, Normalized and Alloy Steel was used as they are widely used in industry. The material of the Printed Circuit Board (PCB) is Epoxy, Unfilled was used as it is widely used in the industry. The higher the tensile strength of the squeegee, the higher the deflection of the stencil and the Printed Circuit Board (PCB). The higher the thickness of the Printed Circuit Board (PCB), the lower the deflection of the stencil. The SOLIDWORKS 2020 2-D Static Simulation approach is used to study the deflection of the stencil due to the squeegee. This simulation is carried out at three different types of material for the stencil and squeegee.

CHAPTER 1

INTRODUCTION

1.1 Overview

Electronic products are improving and becoming increasingly sophisticated, intelligent and compact. Improvements must follow this progress in the production of electronic components. Surface mount technology (SMT) is a manufacturing method used in the electronic industry for electronic board assembly. This method involves a succession of processes through the PCB with its electronic components. The solder paste is placed on the solder pad using a squeegee and a stencil in the stencil printing step of the SMT process. The solder paste is swept into the designated aperture using a squeegee that moves at a specific angle. This process contributes 60% of the overall defects in the SMT products. The cost of designing and testing the stencil process experimentally is high in terms of both money and time[1]. Numerical simulation, particularly computational fluid dynamics (CFD), is a promising alternative for researching solder paste stencil printing[1]. One of the most important procedures in the reflow soldering of electrical components and Printed Circuit Boards (PCB's) is stencil printing of solder paste using the Surface Mount Technology (SMT) technique. In general, the stencil printing technique must deposit precise and consistent amounts of solder paste onto the PCB pads.

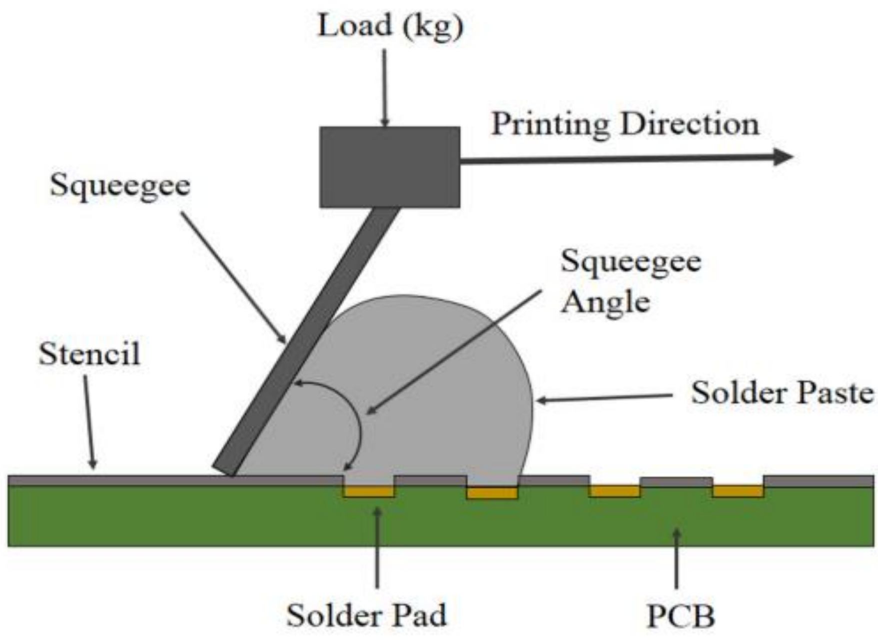

Figure 1.1 Solder Paste Stencil Printing Process.[2]

After that, the components are soldered onto the PCB, then run through an infrared reflow oven to finish the process [3]. Based on Figure 1.1, the squeegee moves in one way when a load is applied to it during the stencil printing process. This loading causes micro bending on the stencil, which affects the amount of solder paste deposited. The influence of squeegee load on stencil bending will be investigated using FEM. The material of stencil, the material of squeegee, thickness of stencil and the thickness of PCB affect the deflection of the stencil. A wide thickness of stencil used in industry is in the range of 0.1 to 0.3mm[4]. The wide thickness of PCB used in industry is 0.78mm, 1.57mm, and 2.36mm[5]. Researchers have used AISI 4340 Steel, Annealed and AISI 4340 Steel, Normalized as the material of stencil and squeegee respectively[6]. In this project, the material for the stencil and squeegee tested in the simulation is Alloy Steel, AISI 316 Stainless Steel Sheet and AISI 321 Annealed Stainless Steel with high tensile strength. The material of the PCB used in this simulation is Epoxy, Unfilled[7]. Solidworks 2020 2-D Static Analysis simulation approach is used to study the deflection of the stencil and the PCB due to the squeegee load is also as the result of the material of the squeegee, the material of the stencil, the thickness of the stencil and the thickness of the PCB. This 2-D simplification analysis is used to shorten the time in running the simulation rather than using the 3-D simplification that might take longer time to run the simulation[8]. The grid dependency test is important to know the right number of elements for meshing on the assembly of the stencil, squeegee and PCB. The amount of solder applied to the PCB is critical for achieving satisfactory soldering quality. The simulation method has proven to be a viable alternative for solder paste printing.

1.2 The Aim of The Project

The objective of this study is to:

a) Investigate and study the effect of squeegee load on the stencil.
b) Effect of different types of material to the squeegee, stencil material, stencil and PCB thickness.

1.3 Problem Statement

Surface mount technology has been utilized widely to mount electronic parts to PCB. Solder paste printing is a part of the Surface Mount technology process. The squeegee gives load in the roll of solder paste that fills the paste at the stencil opening. When the stencil bends critically, the solder paste will be insufficient and will not distribute uniformly on the PCB. Thus, the main objective is to investigate the right type of material for the squeegee, stencil, and stencil and PCB thickness.

1.4 Scope of The Project.

A stencil printing model is created by using SOLIDWORKS 2020 software consisting of three significant components for the simulation: squeegee, stencil, and

PCB. SOLIDWORKS 2020 Statics 2-D Simplification Analysis is used to simulate the bending of the stencil. In the simulation, the squeegee will deflect the stencil and the PCB. The material of the squeegee, the material of the stencil and the thickness of the PCB are parameters. The constant parameter is the dimension of the squeegee, the material of the PCB.

CHAPTER 2

LITERATURE REVIEW

2.1 Experimental Works on Stencil Printing

Minimise the horizontal velocity component of the paste to ensure that the paste fills the aperture vertically and raise the vertical velocity component of the paste to reduce the gap-filling time to produce sufficient and uniform paste deposits. Solder pastes are still commonly used to connect components and printed circuit boards electrically and mechanically. In SMT PCB assembly, solder paste is used. Many academics have looked into employing a squeegee blade to stencil/screen-print solder paste for SMT. Suppose the paste flow inside the chamber is entirely dependent on the frictional force between the paste and the stencil at the slot. In that case, the paste does not fill vertically into the aperture, according to the research [3]. When the stencil is dragged away from the PCB during stencil printing due to uneven solder paste thickness or other PCB defects, a large amount of solder paste is deposited, and solder bridges are formed during reflow soldering. Even if the stencil printing circumstances are ideal, an excessive amount of solder paste can be deposited on the pads if the gasket between the stencil and the PCB is insufficient. Gaps between the stencil and the PCB might be caused by uneven solder paste height or identifying decals on the PCB. In these cases, if the distance is great, as shown in Figure 2.1.

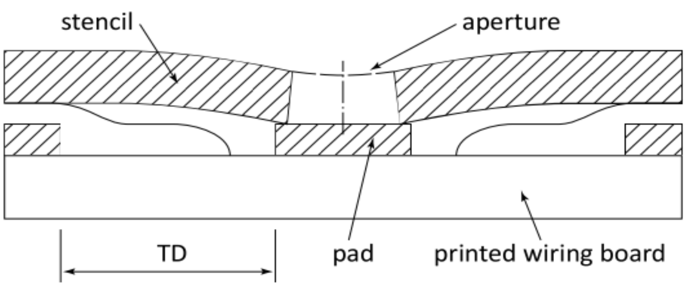

Figure 2.1 The technological distance to get the stencil to be able to bend down to the PCB.[6]

Because there is no data on how the uneven height of the PCB affects the stencil printing process and hence reduces soldering failures, our purpose was to investigate stencil deformation during stencil printing. The load is applied to the stencil via the fixed micrometre clock's measuring probe, and the clock measures the stencil bending, as shown in Figure 2.2.

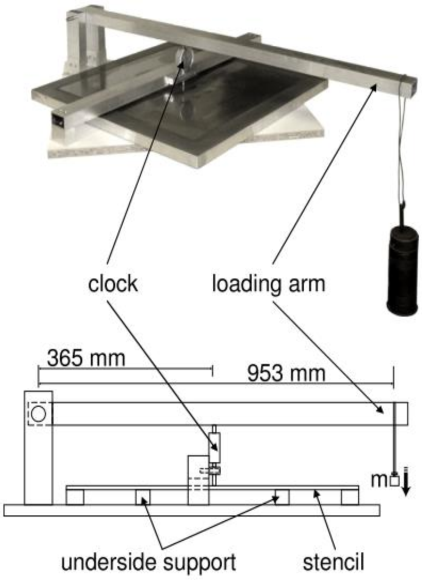

Figure 2.2 The equipment to measure the elastic properties of the stencil.[6]

Measuring tool for determining the mechanical properties of the stencil. To assess the elastic characteristics of the 175 m thick stainless-steel stencil, an instrument was built to load it and measure its bending, as a result, shown in Figure 2.3.

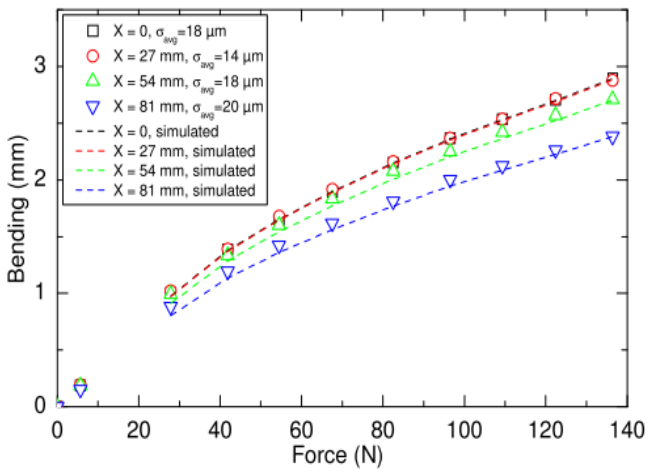

Figure 2.3 The load-strain curve of the 175 μm thick stencil[6].

A stencil printing solder pad for the stencil printing experiment, the DEK248 printer, was employed, which has a positioning precision of 25 m. The printing speed was 30 mm/s, the separation was six mm/s, and the squeegee force for the 300 mm long blade was 92 N in the experiment[6]. This is a measure that influences the print quality and efficiency of circuit sheets. Stencil cleaning activity is influenced by cycle characteristics such as printing speed, printing weight, and gap form. This research aims to create a sophisticated model for controlling stencil cleaning dynamics to minimise measures of failure, such as in SPP, as its name implies, follows three distinct stages as shown in Figure 2.4. In this investigation, the stencil cleaning technique is treated as a subsequent identification issue.

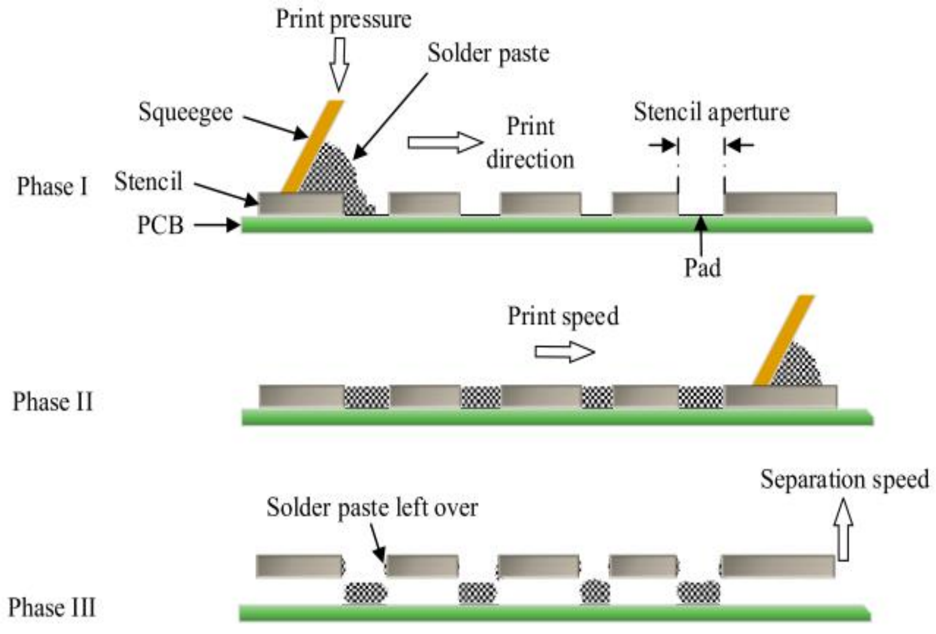

Figure 2.4 Three phases of a typical solder paste printing process[9]

A new element space is provided by observing at the value proportions of printed verifiable sheets, such as solder paste volume and the number of deformities. An angle boosting model is utilised to determine the stencil cleaning choice. Various phase is described in the trial test to ensure that the suggested model is suitable. The proposed cleaning dynamic model is compared to other models for conditions of workmanship and information mining. The proposed boosting-based astute model outperforms existing models and can provide appropriate cleaning recommendations even if the board design is later changed.[9]

2.2 Simulation Works on Stencil Printing

The stencil FEM model, as shown in Figure 2.5, was built to align with the testing results.

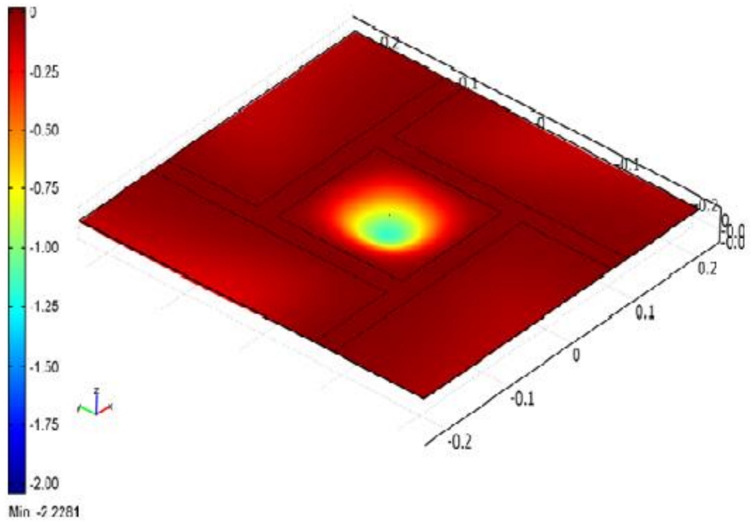

Figure 2.5 The FEM model of the stencil with 16x16 cm underside support.[6]

A 22 N to 131 N range of loads was tested in the experiment, whereas the FEM model used loads where the stencil's load-strain curve is linear, as shown in Figure 2.6[6].

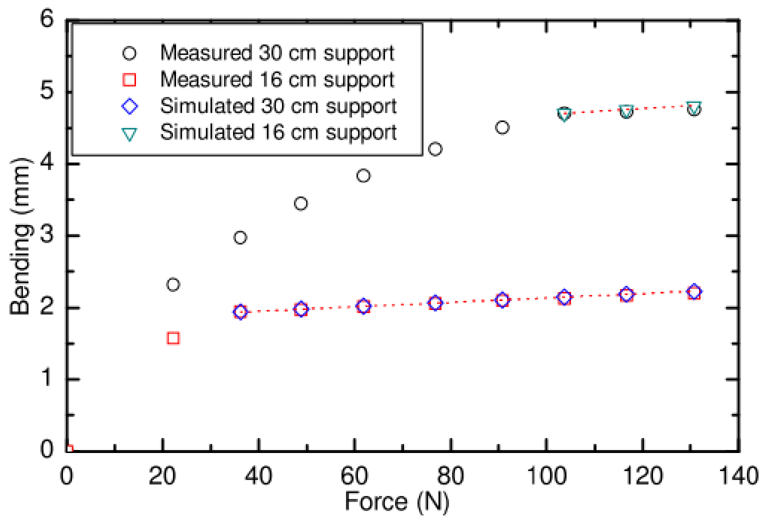

Figure 2.6 The load-strain curve of the 175 µm thick stencil.[6]

Figure. 2.6 shows that the simulation findings are consistent with the pilot model bending values, as demonstrated in Figure 2.5[6].

If the stencil does not achieve perfect contact with the PWB, an excessive amount of solder paste can get onto the pads, even if the stencil printing circumstances are ideal[10]. When a gap exists between the stencil and the board, the volume of solder paste deposited may be larger than desired, as shown in Figure 2.7.

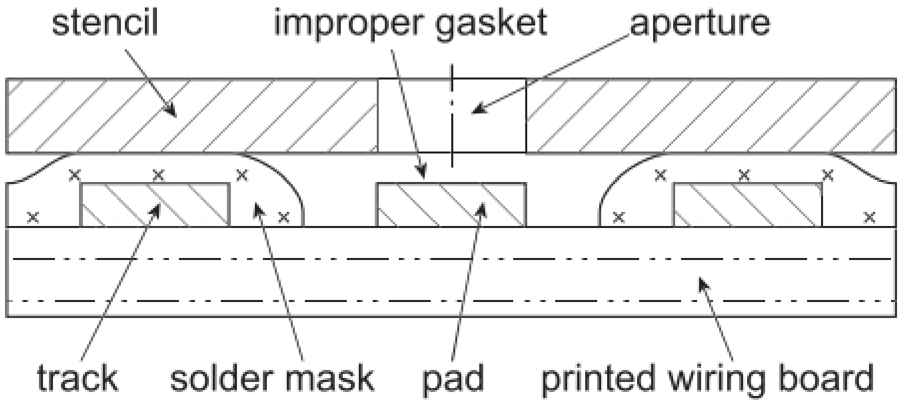

Figure 2.7 Incomplete contact between the stencil and the PWB due to uneven solder mask thickness[10]

When it comes to stencil foil, there is a minimum distance that should be maintained between a soldering pad's stencil aperture and the stencil step to avoid printing problems caused by the difference in stencil levels—the critical technological distance for optimum stencil contact with the PWB. PWB surface level fluctuations were modelled as geometrical parameters in the FEM, and simulations were done for various stencil foil thicknesses to estimate the distances needed to achieve complete stencil contact with the PWB. The FEM's performance was proven by comparing simulation results to stencil printing experiment results. The stencil foil is commonly tensioned to the stencil frame with a stainless-steel mesh, which changes the deformation measurements of the stencil foil. If a pad is too close to the thickened area, the height of the deposited solder paste is the sum of the stencil thickness and the difference between the height of the reduced size and the pad's height. If a pad is far enough away from the thickened area, the stencil can bend to the PCB, and the thickness of the deposited solder paste is equivalent to the stencil thickness. The stencil can bend to the PCB. FEM simulations of the required technological distance for different level differences and stencil foil thicknesses, FEM simulations of the necessary technical length for various level differences and stencil foil thicknesses were performed as shown in Figure 2.8. Because of the thickness of the stencil foil, we may give an expression to compute the required distance as a function of stencil thickness and step height[10].

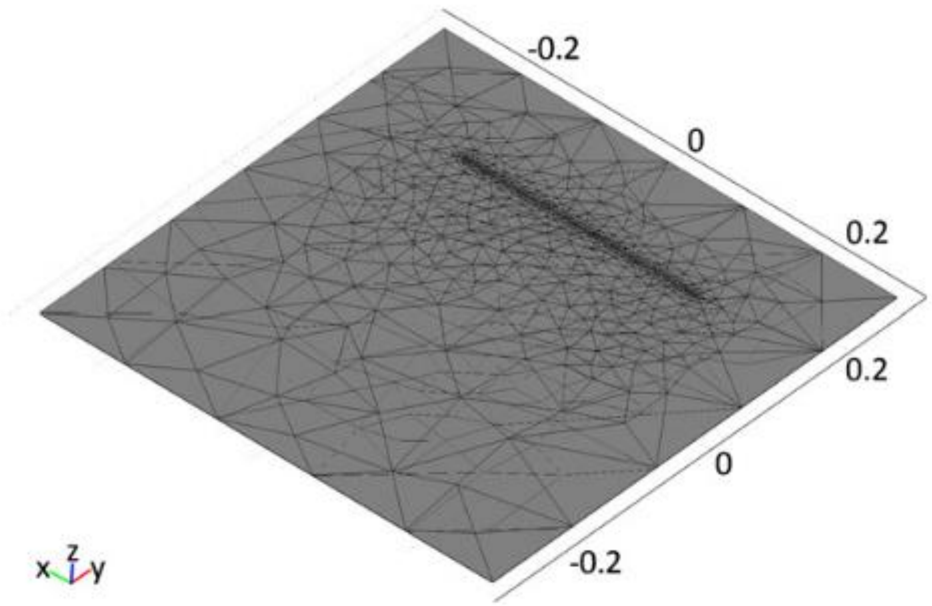

Figure 2.8 Meshed stencil; the mesh is finer at the pressed working area of the squeegee[10].

The knowledge of the thermal features of a reflow oven, PCB and solder joint assists the engineer with maintaining and controlling the standard of the solder joints in the reflow soldering measure[11]. Once more, the knowledge of the thermal features of a reflow oven, the PCB and the weld joints assists the designer with maintaining and controlling the standard of the solder joint in the reflow soldering measure[11]. A few methodologies, for example, stacked solder, double bump technology, stretched solder, and ceramic column grid array were accounted to rise the standoff height and adjust the shape of a solder bump connection. For the steady solder volume and cushion size, hourglass-shaped solder joints had the best standoff height, trailed by column and barrel moulded solder joints[11]. A few factors, for example, reflow profile, thermal conditioning, longer time above liquidus, thermal aging, volume and type of solder may impact the development of IMC[11]. Lately, nanoparticle supported solder materials have been widely explored by analysts[11]. Replacement for lead-free solder, for example, SnAgCu, SnZn or SnBi weld, were perceived as substitutes for the common toxic SnPb solder[11]. The inclusion of nanoparticles to solder alloys may improve soldering joint mechanical and material features, subsequently rise the solder joint reliability[11]. The ramification of the nanoparticle solder ball and solder paste will create a more extensive research gap in the scope of reflow soldering process, environment concern, fabricating cost and solder joint quality[11]. Solder paste printing is a procedure for dispersing solder paste on a bound cushion utilising a squeegee and a stencil. A squeegee is utilised in stencil printing to move solder paste inside the stencil gaps and store the ideal measure of solder paste on the substrate cushion[2]. Ansys Workbench was used to create and mesh a 3D model of a stencil printing system. The ANSYS FLUENT mesh file was then transferred and simulated as shown in Figure 2.9[2].

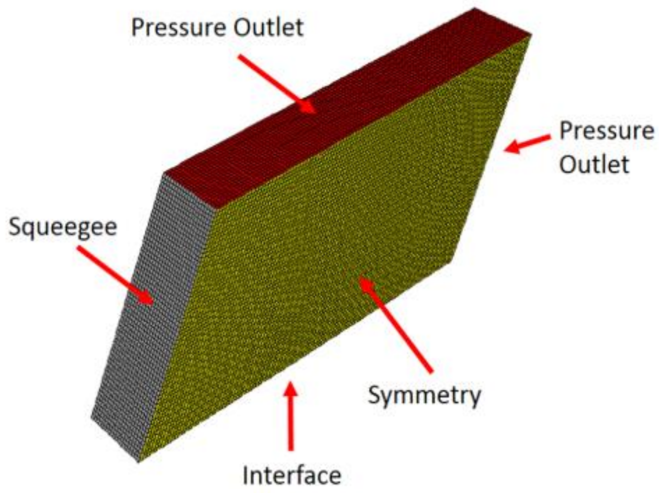

Figure 2.9 Mesh and Boundaries Conditions[2].

The volume of solder paste stores is identified with paste pressure, with an essential pressing factor at the squeegee's edge. The squeegee makes the hydrodynamic power in the solder paste move, which helps fill the openings by shearing the paste as it disregards the stencil[2]. As shown in Figure 2.10, the simulator results demonstrate that the aperture E (pre-printing) filled before the printing process began and then reached its total capacity once the procedure was done. The illustration shows that the whole volume of the aperture is taken up by SAC387, with some residual space in the four corners. This simulation shows the capabilities of CFD for printing solder paste[2].

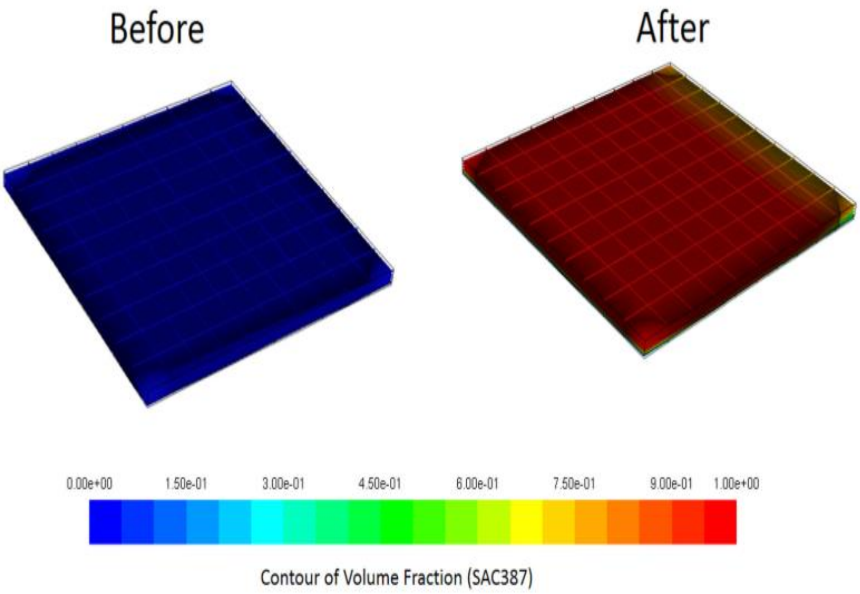

Figure 2.10 Aperture E before and after the printing process.[2]

Moving solder paste into the stencil printing measure essentially affects the filling method of the solder paste in the openings as shown in Figure 2.11, which can influence the printing nature of the exposed solder paste[2].

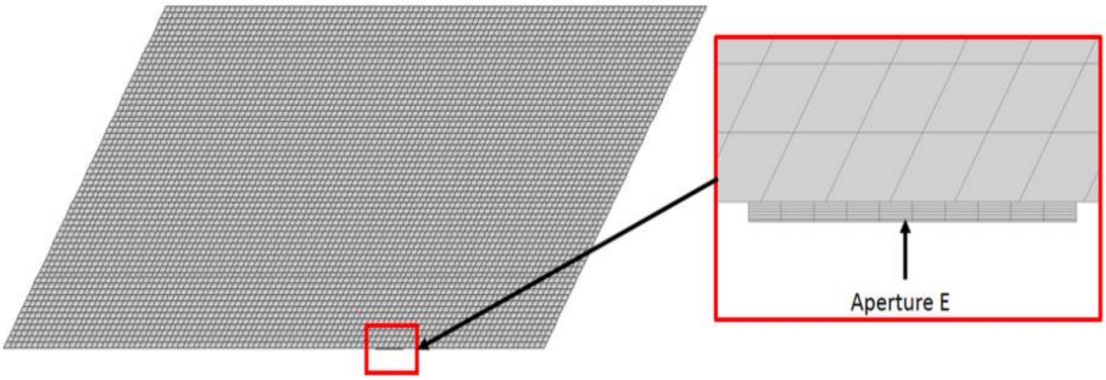

Figure 2.11 Cross-section plane showing Aperture E location and mesh[2].

Due to the costly expense of solder paste and the time needed for experimentation, CFD is a practical option for examining the solder paste stencil printing measures. Solder paste with a lower consistency improves flowability and,