INFLUENCE OF SQUEEGEE IMPACT ON STENCIL PRINTING PROCESS: CFD APPROACH

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DECLARATION

I hereby declare that I carried out the reported project in School of Mechanical Engineering, Universiti Sains Malaysia (USM), under the supervision of Dr. Mohd Sharizal Bin Abdul Aziz. I solemnly declare that to the best of my knowledge, none of this report section has been submitted here or elsewhere in the previous application of degree title. All sources of knowledge used in this report have been duly acknowledged.

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ACKNOWLEGMENT

The highest gratitude goes to the God for giving me a good health and wellbeing along the venture of final year project completion. It was a tough journey and required a lot of sacrifices but by the wisdom from Him, I managed to withstand through it successfully.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Nomenclatures	**Descriptions**
PCB	Printed Circuit Board
PWB	Printed Wiring Board
SMT	Surface Mount Technology
SMA	Surface Mount Assembly
CFD	Computational Fluid Dynamics
FVM	Finite Volume Method
FEM	Finite Element Method
LBM	Lattice-Boltzmann Method
EDM	Discrete Element Method
VOF	Volume of Fluid
FSI	Fluid Structure Interaction

ABSTRAK

Peningkatan keperluan terhadap Papan Litar Bercetak (PCB) yang lebih kecil, lebih ringan, dan berprestasi tinggi dalam pempakejan elektronik telah menyebabkan penggunaan percetakan stensil secara meluas dalam proses pematerian. Percetakan stensil menawarkan prestasi proses pematerian yang baik dan konsisten serta menghasilkan ouput yang lebih besar pada masa yang singkat sehingga menjadikannya sebagai salah satu pilihan yang terbaik untuk pengeluaran berskala besar dalam Teknologi Pelekapan Permukaan (SMT). Namun, kaedah pematerian ini turut menjadi penyumbang utama kepada kecacatan pematerian berbanding dengan kaedah lain dan perlu ditangani melalui penyelidikan dan pembangunan. Salah satu daripada kecacatan biasa yang terjadi dalam proses pematerian melalui kaedah ini ialah berkaitan dengan kualiti percetakan pes pateri di atas substrat seperti Papan Litar Bercetak disebabkan perubahan parameter proses. Parameter proses yang tidak terkawal mengakibatkan kecacatan pematerian seperti penyambungan pateri yang boleh membawa kepada kegagalan produk dalam proses seterusnya di barisan pengeluaran.

Penyiasatan telah dijalankan untuk meramal pada masa sebenar terhadap proses pengisian serta kualiti percetakan pes pateri Sn96.5Ag3.0Cu0.5 (SAC305) ke dalam bukaan stensil dalam kaedah percetakan stensil dengan menggunakan pendekatan Pengiraan Dinamik Bendalir (CFD). Sebuah model percetakan stensil 3-Dimensi telah dihasilkan dan dijalankan simulasi dalam perisian FLUENT dengan menggunakan parameter bilah sapu yang berbeza dari segi sudut dan kelajuan cetakan. Eksperimen telah dijalankan untuk dibandingkan dengan sebahagian keputusan simulasi dari segi kualiti percetakan untuk tujuan pengesahan. Didapati bahawa sudut bilah sapu 60° hingga 80° berpotensi untuk mendapatkan kualiti percetakan pes pateri yang baik. Selain itu, kelajuan cetakan 35 mm/s to 95 mm/s didapati boleh menjadi pilihan kelajuan cetakan yang baik untuk mendapatkan kualiti cetakan yang sama. Akhir sekali, taburan tekanan pes pateri juga dikenalpasti berubah dengan ketara di sepanjang jarak sapuan bilah sapu untuk semua nilai parameter yang diuji.

ABSTRACT

High requirement of smaller size, lighter weight, and high performance PCB in electronic packaging has contributed to the wide application of stencil printing for soldering process. Stencil printing offers good consistency of soldering performance as well as produce larger process output at short time that make it one of the best option for high volume application in Surface Mount Technology (SMT). However, the soldering method also contributes to major percentage of soldering defect compared to other methods which is necessary to be addressed through research and development. One of the common defects due to the stencil printing is regarding to the printing quality of solder paste on substrate such as Printed Board Circuit (PCB) with respect to the variation of process parameters. Uncontrolled process parameters cause the soldering defects such as solder bridging that can lead to product failure in further processes in production line.

An investigation has been conducted to predict the real time observation of solder paste Sn96.5Ag3.0Cu0.5 (SAC305) filling process into stencil apertures as well as print quality in stencil printing by using Computational Fluid Dynamics (CFD) approach. A 3-Dimensional stencil printing model was developed and simulated in FLUENT by using different squeegee parameters which are angle and print speed. An experimental work was performed to be compared with part of the simulation results in term of print quality for validation purpose. It is found that squeegee angle 60° to 80° has potential to obtain good print quality of solder paste. In addition, print speed range between 35 mm/s to 95 mm/s also can be the good print speed option to achieve good print quality in stencil printing process. Finally, the maximum pressure distribution of solder paste also changes substantially as the squeegee travel further with respect to different values of tested parameters.

CHAPTER 1

Introduction

1.1 Overview

Stencil printing is a process of depositing a viscous fluid which is solder paste onto a bare substrate such as printed circuit board (PCB) through the aperture openings of a stencil. It is originally adapted from the screen printing process. This process is one of the widely used methods of soldering in surface mount technology (SMT) today as a solution for higher pin count and fine pitch size. This is due to the high requirement of smaller size, lighter weight, and high performance PCB in electronic packaging. The use of stencil printing for the deposition of conductive interconnects was developed during the late 1960s as companies looked to increase the densities of the products, improve assembly time and drive down production costs. This process was termed surface mount assembly (SMA) and is currently used today in at least 70% of electronic packaging. The stencil printing is commonly known in SMA as the largest contributor to soldering defect by 60% averagely [1].

In stencil printing, a thin layer of stainless steel foil is placed onto a PCB. It has laser cut configuration of apertures that will determine the basic layout of the solder paste deposits on the board. The stencil will be aligned on the top surface of the board and brought in close to or in direct contact with the surface. A squeegee is used to transfer solder paste inside the stencil apertures to deposit a required amount of solder paste on pad of the substrate [2]. For metal blade squeegee, the angle of 60° is the most suitable angle to handle the ultra fine and larger pitch size because it offers consistency of print and the closest print volume to the designed volume of solder paste. It is also mentioned that the volume of solder paste deposits is proportional to the paste pressure and the highest region of the pressure is at the edge of squeegee [3]. The squeegee provides hydrodynamic pressures in the roll of solder paste that assists the filling of paste inside the apertures by shearing as it moves over the stencil [4]. Once the squeegee is fully swiped the solder paste through the apertures, the stencil is removed out from the board leaving the small volumes of solder paste in the filled apertures on the board as deposits. Figure 1.1 below shows the schematic diagram of stencil printing process [10].

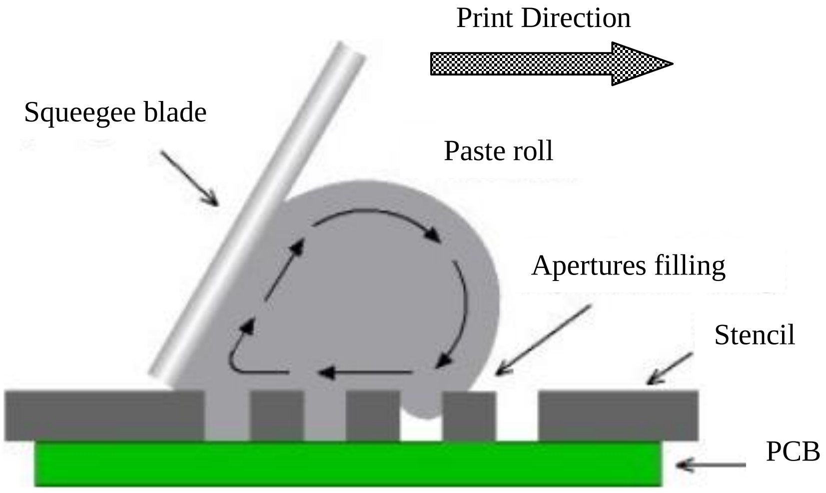


Figure 1.1: Schematic diagram of stencil printing process

One of the remarkable capabilities of stencil printing in SMT packaging is it can place millions of solder paste deposits onto a substrate such as PCB by one print stroke only. In addition, the process can be repeated thousands of times with the same stencil onto the further substrates with good consistency of soldering performance. Thus, it reduces soldering time as well as offers higher process output. More advantages about this process are it does not require large capital investment or highly skilled operators. The combination of the cost advantage with the capability to handle wide range of materials makes it in one of the top list of best option for high volume applications. Furthermore, the compatibility of the method with pre-existing equipment of printing and capability to produce solder bumps within all range of compositional spectrum such as lead-free solders have increased its reputational in SMT packaging [2].

Several aims of the project has been established to study the performance of the stencil printing regarding the print quality of the solder paste deposits due to the variation of squeegee angles and print speed. The studies are conducted through computational simulation by using Computational Fluid Dynamics (CFD) approach. In future, this finding of the project could be the guideline or fundamental idea for engineers and researchers for further development of stencil printing in electronic assembly industry. Proper angle and print speed of squeegee can be chosen to optimize the printing process to obtain good quality of solder paste distribution as well as providing real time process observation and analysis. In addition, the 3-Dimensional stencil printing simulation model also can be a useful guideline for the researchers to conduct and develop more precise and realistic stencil printing modeling in future.

1.2 Problem Statement

1.2.1 Print Quality

There are often issues always discussed in SMT industries regarding to the stencil printing performance. One of the common issues is the distribution of solder paste deposits on substrate such as PCB. A good print of solder paste in stencil printing is defined by the similarities of volume of deposited solder paste and the aperture volume but this is rarely to obtain practically [4]. Uncontrolled volume of solder paste deposits on PCB causes solder bridging due to excessive amount of solder paste or open solder joints as the result of insufficient amount of solder paste [3]. The defect is due to the incorrect amount solder paste deposited on the substrate such as PCB. The distribution of the solder paste deposits on PCB in stencil printing depends on several factors of the stencil printing components as listed below. The factors must be well optimized to obtain the correct volume of deposits distributed on the board.

1.2.1.2 Stencil

Imperfect contact of substrate and the stencil can lead to excessive amount which is larger from the designated volume of solder paste deposition on the pads even the printing parameter has been set properly [5]. Furthermore, the aperture geometry and size given by the area ratio also affect the printed volume solder paste on in stencil printing process. Incomplete solder paste deposits and stencil clogging will occur when the surface area of the aperture wall bigger than the aperture opening due to the dominant ‘sticking’ behavior of the paste to the wall than the substrate pad [6]. Stencil thickness has been proved affecting the print quality of solder paste. The increment of stencil thickness will result in increment of solder deposits area which can lead to solder bridges while reduction of stencil thickness causes decrement of aperture volume resulting to insufficient of solder deposits [7].

1.2.1.3 Solder Paste

Solder paste rheological behavior is a crucial factor in order to obtain good quality of solder paste printing. Rheological behavior of solder paste highly affect the consistency printing pattern, tack, and slump performance resulting in attributable to particle size and distribution, storage temperature, and viscosity change during the printing process [8]. Rolling of solder paste in stencil printing process gives considerable influent to the filling manner of solder paste in the apertures which could affect the print quality that subjected to the printability of solder paste [9]. Stable geometry must be maintained by the roll to obtain good printing, thus, avoiding inadequate filling of solder paste in apertures of stencil [10]. Solder paste could shear-thin until flux would separate from the metal if the pressure exerted by the squeegee is too high that could lead to further issues such as poor solderability or capability to hold components on place [11].

1.2.2 Experimental Approach

Experimental procedures have been developed by the researches in the past years to develop and optimize stencil printing process regarding to the printing quality which is related to solder paste printability. Since stencil printing is highly depending on other factors to obtain optimum printing quality, the prediction of printability becomes very difficult as well as the identification of optimum print window in manufacturing line. Real time observation during stencil printing process for defective processes correction could not be conducted since most of the established methods are visual post-print inspection. Furthermore, characterization techniques on the rheological of solder paste have been conducted in laboratory to characterize paste materials, observe print parameters, and predict product quality. Nevertheless, the connection between the rheological variables and paste printability is failed to be shown clearly in the studies that make them as infamous option in SMT line [10].

1.3 Objectives

The objectives of the project are listed below:

1) To study the effect of squeegee angles in stencil printing by using Computational Fluid Dynamics (CFD) technique
2) To study the effect of squeegee print speeds during stencil printing process
3) To perform an experimental investigation of solder paste filling in apertures for validation of simulation results

1.3 Scope of Project

A 3-Dimensional stencil printing model is developed in ANSYS Design Modeler which includes the aperture bodies and printing body for further steps of simulation. The model is built based on the exact dimension of stencil printing components where only significant dimensions are counted in the simulation. The printing body is created to have an angled part to mimic the squeegee where the slanted wall pushes the solder paste inside the body to fill the fluid inside the deposit bodies. Different angles of squeegee are simulated to analyze the changes on solder paste distribution in term of coverage area and an angle of squeegee is selected to simulate stencil printing process by using five different squeegee print speeds in FLUENT. Part of the simulation result is validated with the experimental data from stencil printing to obtain the reliability of the result by observing and analyzing the print quality.

CHAPTER 2

Literature Review

Stencil printing is one of the best method for high volume application where the time and process output are concerned. The need of high performance PCB with smaller size, lighter weight, and higher pin count has contribute to the development of fine pitch and ultra fine pitch for stencil printing applications [3]. There are various study has been conducted through the years in order to improve the performance of stencil printing in SMT technology numerically and experimentally which is the printing quality. Numerical studies have been performed to simulate stencil printing process by using Computational Fluid Dynamics (CFD) methods at macroscopic and microscopic scales by using 2-D model that involves Finite Volume Method (FVM), Lattice-Boltzmann Method (LBM), and Discrete Element Method (EDM). It is found that the volume fraction of solder paste is far lower than normal due to the unrealistic representation of spherical particles by 2-D cylinder that cause artificial blockage of fluid passage at greater volume fraction [12].

Neural network approach model has been proposed to solve the fine pitch printing quality issue of the non-linear behavior stencil printing through the volume prediction of solder paste deposits. The proposed approach is determined to be effective to predict and control the printing quality in surface mount assembly such as paste volume deposited on PCB pad with small prediction errors which is less than 7% [13]. In stencil printing, the stencil experiences pressure exerted by the squeegee on its surface that might affect the behavior of the structure. The deformation behavior of stencil which can affect printing quality has been investigated by using Finite Element Method (FEM) associated with the uneven surface of Printed Wiring Circuit (PWB). Greater surface level differences between the stencil and PWB affect the stencil bending behavior that can lead to excessive solder paste deposits and solder bridges issue [5].

Furthermore, stencil printing process also has been modeled by using Finite Volume Method (FVM) to study the effect of two different characteristics of solder paste on the simulation results. The flow field and pressure distribution of the solder paste along the stencil surface are determined to be compared with non-Newtonian and

Newtonian cases. The pressure distribution of the non-Newtonian case is found to be differed from the Newtonian case substantially which means modeling the stencil printing process with Newtonian solder paste properties causes serious mistakes since solder paste is known to be a non-Newtonian fluid [14]. Moreover, the effect of squeegee speed and solder paste density variation on stencil printing process has been studied by using CFD approach through the flow characteristic of solder paste simulation. Based on the study, increment of squeegee speed can causes the shear stress to increase proportional to the increment of solder paste's shear strain [15].

Deeper investigation on the effect of different squeegee angles to the non-Newtonian solder paste pressure during stencil printing process has been conducted through numerical simulations. Two numerical methods involving Finite Element Method (FEM) model has been used to determine the true angle of squeegee regarding to the given printing forces while the pressure distribution of solder paste along the stencil has been determined by Finite Volume Method (FVM) model. It is found that the attack angle of squeegee does not varied significantly if the force changes given by the squeegee are small. In addition, pressure distribution of solder paste varies due to the difference squeegee angles that by 16% for every 5° change of angle [16].

The effect of solder paste viscosity changes on pressure along the stencil line during stencil printing has been studied by using Finite Volume Method (FVM). Different states of solder paste at fresh state and 9th print cycle are tested with respect to time gap in the study. Two different squeegee speeds are applied to test the variation of solder paste states. The pressure profile is found that the pressure change is not linear between the print speeds and the shear rate greater as closer to the squeegee blade [17] Through the years of investigating the stencil printing process by researches, it is found that there is no specific computational study to determine the effect of different squeegee angles and print speeds on the stencil printing process for real time prediction of print quality. Thus, implementing CFD approach in the project ~~is~~ the best option to solve the complex and unpredictable stencil printing problems in PCB assembly.

CHAPTER 3

Methodology

3.1 Computational Simulation Procedure

3.1.1 Model Geometry

A stencil printing model is created in 3-Dimensional by using ANSYS Design Modeler that consists of two significant components for the simulation which are aperture bodies and printing body as explained below. In this case, stencil is neglected because the stencil thickness is too thin. However, the thickness of the stencil is counted in the model preparation as the thickness of aperture bodies. Aperture bodies are drawn based on the exact dimension measured by using Alicona Infinite Focus microscope to form a complete stencil printing model as shown in Figure 3.1.

- **Printing body:** A fluid structure that has a slanted part with specific angle to mimic the squeegee in stencil printing (Figure 3.2). The slanted part is made to move across the aperture bodies.
- **Aperture bodies:** Consists of fluid structures arranged in a pattern to portray the stencil apertures (Figure 3.3). Fluid from the printing body is transferred into the bodies as the slanted part of printing body passed across them as solder paste deposits.

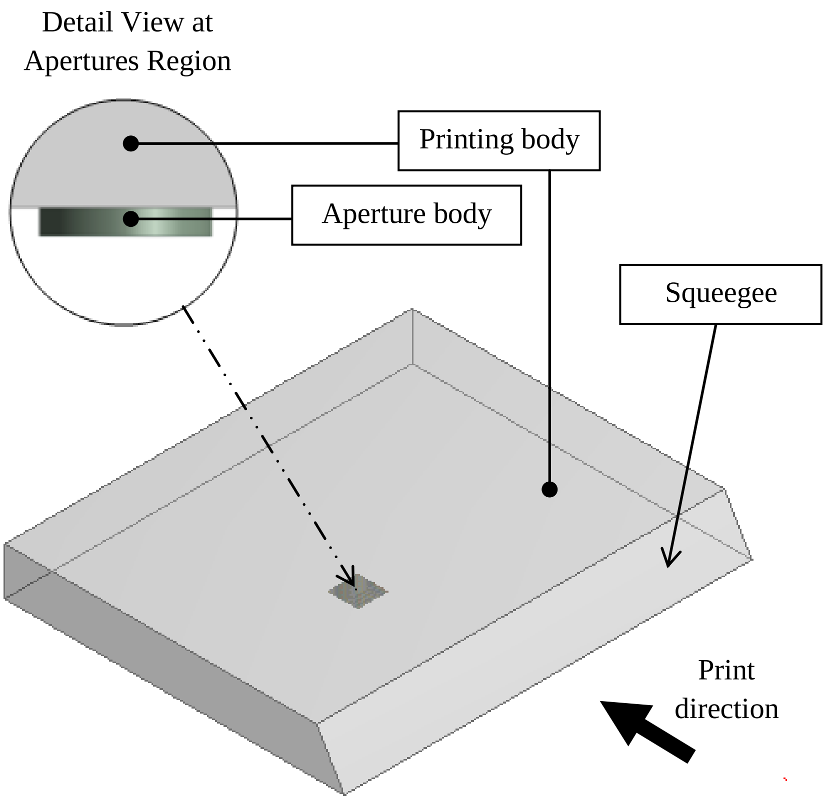


Figure 3.1: 3-Dimensional stencil printing model

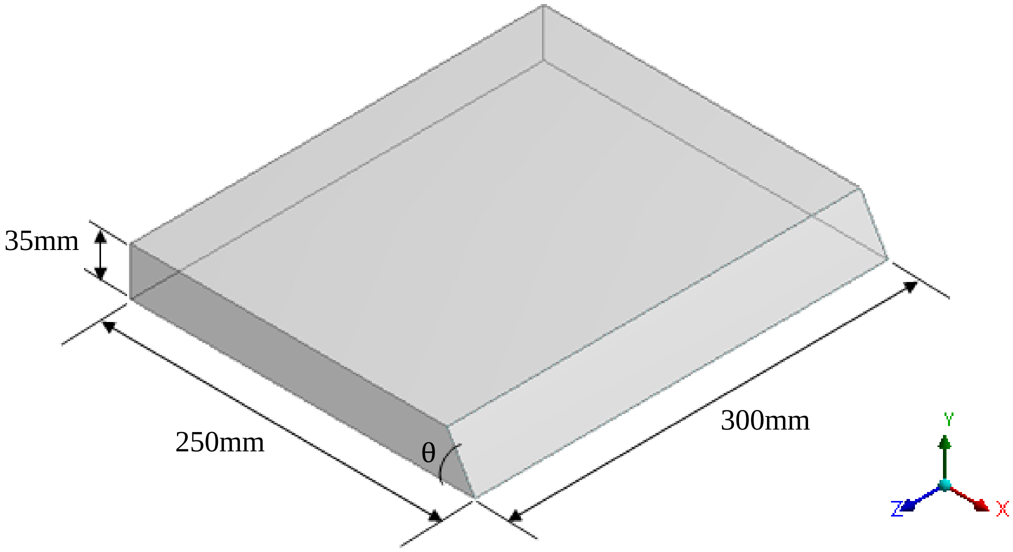


Figure 3.2: Printing body dimension of stencil printing model

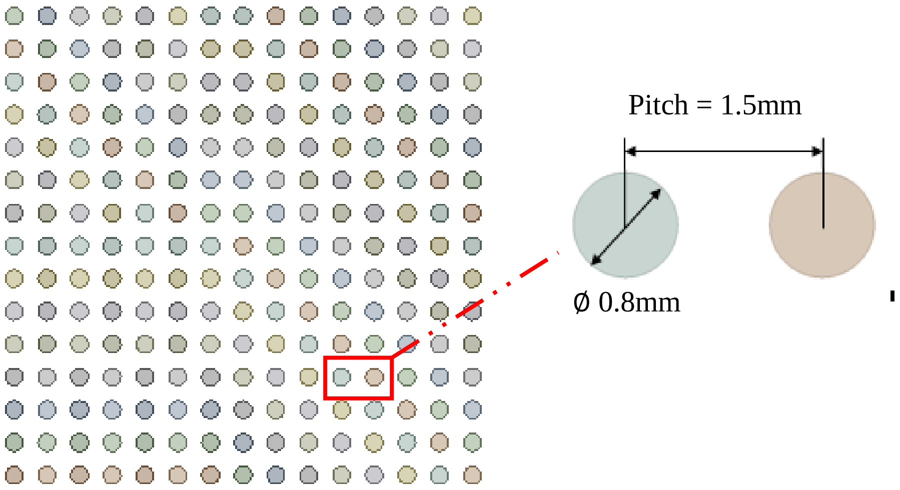


Figure 3.3: Design of aperture bodies and dimension

The thickness of the aperture bodies are the same due to the adoption of stencil thickness that are assumed as constant and perfect (thickness = 0.1 mm). The printing body is made to have a slanted part as the squeegee where the angle is the variable parameter to be tested in the simulation. The angles tested in the simulation are 50°, 60°, 70°, and 80°. The specification of the selected apertures design is 225 I/O; 1.5 mm PITCH. The design has 225 individual aperture bodies by pitch distance 1.5mm to each other.

3.1.2 Meshing and Boundary Condition

All the fluid bodies are meshed with structured elements consists of hexahedral and wedges for both aperture and printing bodies as shown in Figure 3.4. For the printing body, the bottom surface is declared as fluid interface while others are declared as wall. The walls of the printing body are further used in dynamic mesh setting. The interior of the printing body is the zone where solder paste and air are placed together inside it. Furthermore, the top surface of the aperture bodies is declared as fluid interface while others are set as wall. The aperture bodies also have interior zone where fluid from printing body is filled in it. The surface contact of fluid interface between printing and aperture bodies formed fluid connection between the bodies in simulation.

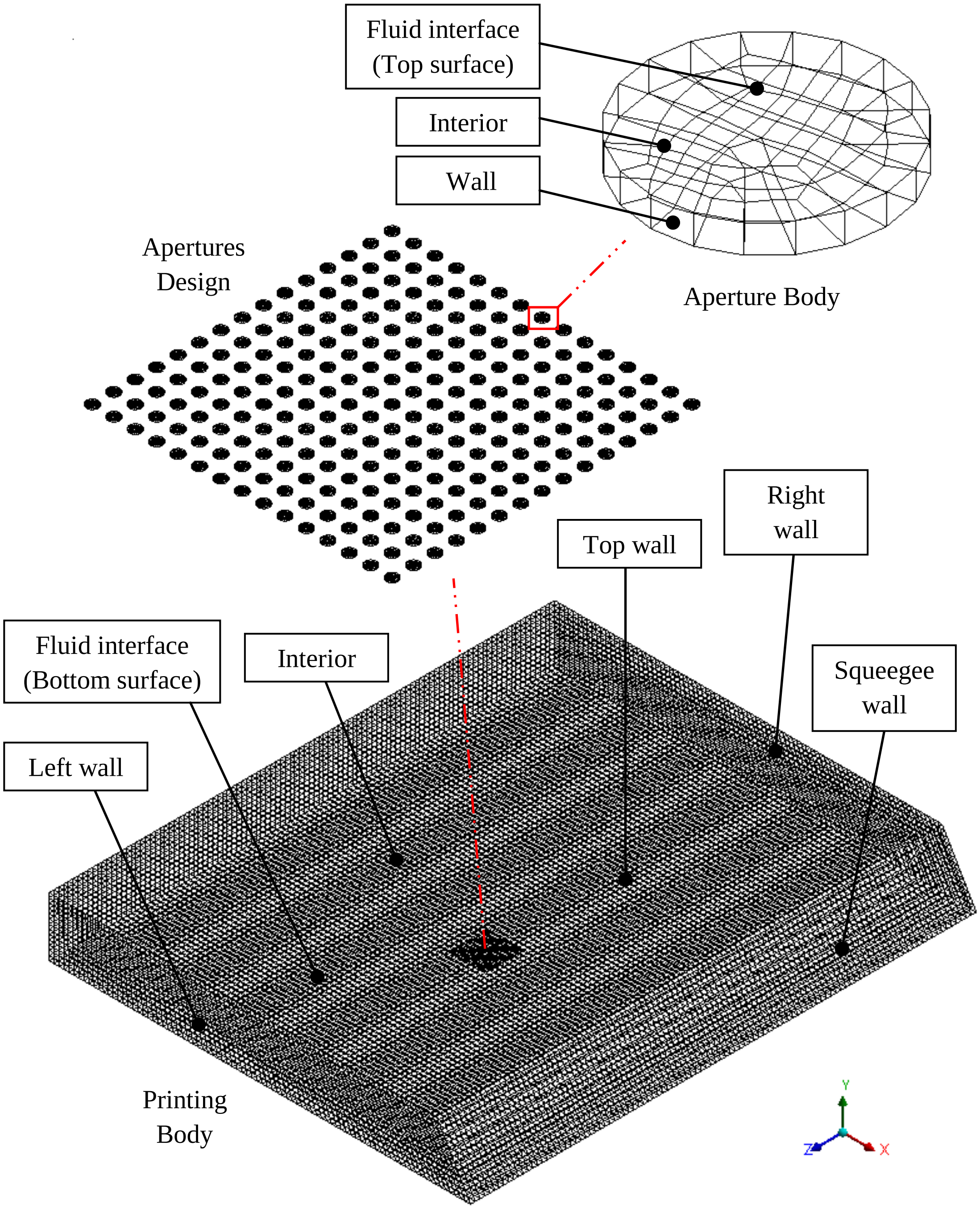


Figure 3.4: FLUENT structured meshed model and boundary conditions

3.1.2.1 Grid Dependency Study

Grid dependency study was performed to determine the optimum mesh size to reduce computational time and error during the analysis by using different element sizes as shown in Table 3.1 below. Five element sizes were tested in the simulation to obtain suitable element size for the simulation while maintaining the structured element type used in the test; which are hexahedral and wedges.

Table 3.1: Different element sizes for grid dependency test

Mesh	Element size(mm)
I	3.2
II	3.0
III	2.8
IV	2.7
V	2.6

Figure 3.5 shows that the relationship between the elements sizes and the average volume fraction based on volume-weighted average at full swipe of the aperture bodies. It was found that the element sizes of 2.8 mm to 2.7 mm showed similar volume fraction which was at 1. Decrement of average volume fraction was occurred as the element size is bigger than 2.8 mm or smaller than 2.7 mm which was unreliable to be adopted in the simulation. Hence, 2.8 mm element size was selected compared to 2.7 mm element size since it was more reasonable for shorter computational time.

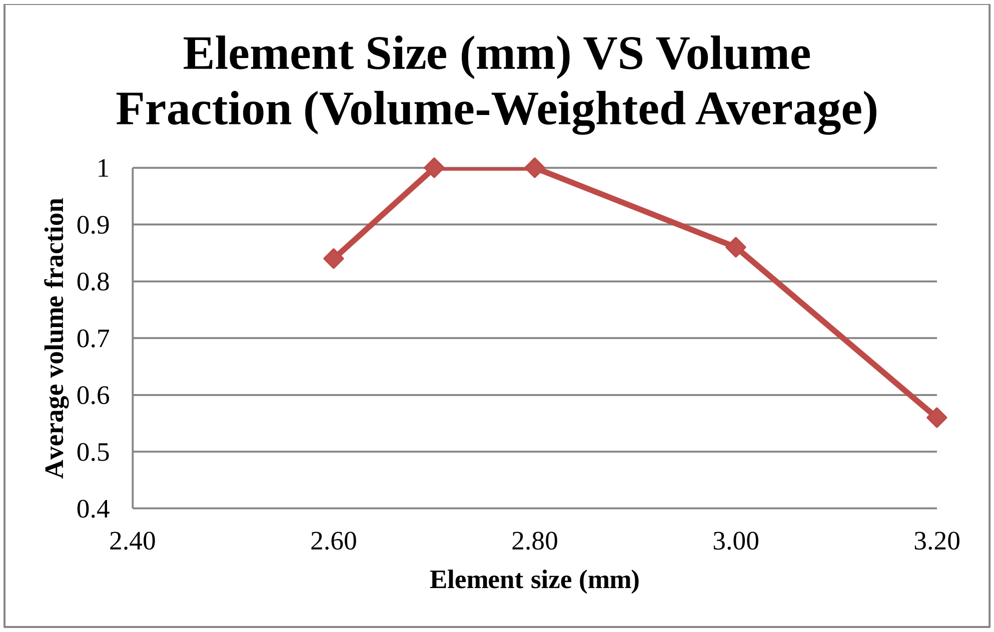


Figure 3.5: Element size vs. average volume fraction (volume-weighted average based)

3.1.3 Fluid Modeling

The filling of solder paste inside the solder deposit bodies by the angled squeegee is simulated in FLUENT where only fluid is the main concern. Area of solder paste deposits are observed and analyzed as the result of printing process due to the variation of squeegee angles and print speeds. The squeegee is set to travel for 140 mm across the 'virtual stencil' until it is fully swiped all the solder deposit bodies by using 0.01 time step regardless of all the tested parameters. Assumptions are made for the model simulation due to few limitations as listed below.

Assumptions:

- Pressure exerted by the squeegee is neglected.
- Stencil is perfectly attached on PCB during printing process. Thus, solder paste is well-contained inside the apertures.
- The fluid bodies are in atmospheric condition [15].
- The model is isothermal, no heat loss to atmosphere [17].

3.1.3.1 Model Setup and Parameters

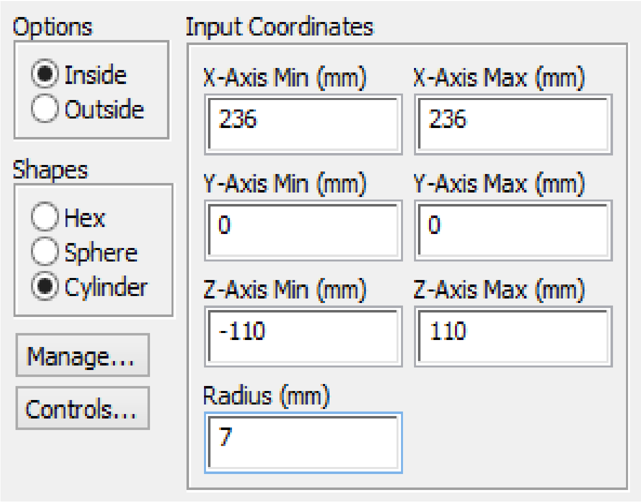
The model is set to run with transient/unsteady calculation in the simulation. Due to the presence of air and solder paste, Volume of Fluid (VOF) model is selected with implicit formulation. Furthermore, the model is also set to be a viscous model due to the high viscosity of solder paste where turbulent is absent in the flow. Other parameters are also included which are the gravitational acceleration, $\mathrm{g_y} = -9.81\ \mathrm{m/s^2}$ that acting towards negative direction of Y-axis while temperature, T is at ambient (default).

3.1.3.2 Material Selection

For this simulation, Sn96.5Ag3.0Cu0.5 (SAC305) is selected as the solder paste to be presence with the air. Solder paste is a non-Newtonian fluid which the apparent viscosity is depended on the shear strain rate. Thus, a Carreau model is chosen to model the non-Newtonian solder paste with the parameters shown in Table 3.2 while the air properties are set to be default [17]. Furthermore, density of the solder paste is set to $8410\ \mathrm{kg/m^\wedge 3}$ while the air is maintained at default value $1.225\ \mathrm{kg/m^\wedge 3}$ [18]. The solder paste is patched in the interior of printing body in front of the squeegee wall. The patch region of solder paste is shown in Figure 3.6 which is the approximate placement dimension of solder paste on stencil during experiment.

Table 3.2: SAC305 Carreau model parameters

Viscosity at zero shear rate, μ_0	38000
Viscosity at infinite shear rate, μ_∞	33
Time constant. K	445
Power factor, m	0.36


Options

● Inside
○ Outside

Shapes

○ Hex
○ Sphere
● Cylinder

Input Coordinates

X-Axis Min (mm): 236
X-Axis Max (mm): 236
Y-Axis Min (mm): 0
Y-Axis Max (mm): 0
Z-Axis Min (mm): -110
Z-Axis Max (mm): 110
Radius (mm): 7

Figure 3.6: Patch region of solder paste SAC305

3.1.3.3 Dynamic Mesh Setup

In the modeling case, dynamic mesh is applied where the squeegee wall of the printing body is made to move at constant tested print speeds which are 15 mm/s, 35 mm/s, 55 mm/s, 75 mm/s, and 95 mm/s. Smoothing-diffusion method with boundary-distance 0 is used because it is the best applicable method to simulate the squeegee movement without errors and to obtain realistic flow of solder paste. The dynamic mesh zones setup of the model are explained and displayed in Figure 3.7 below.

Dynamic Mesh Zones

Squeegee wall

- The wall is set as rigid body due to free region of deformation
- A movement profile of the moving wall is imported into the FLUENT as shown below.

Movement profile of squeegee wall:

```
((squeegee transient 2 0)
(time   0        15)                       //movement duration
(v_x    -0.035          -0.035)            //velocity at X-axis
(v_y    0        0)                        //velocity at Y-axis
(v_z    0        0))                       //Velocity at Z-axis
```

- *Note that -0.035 is the printing speed towards negative direction of X-axis of the model coordinate*

Top wall

- The wall is set as deforming due to the region of mesh distortion.
- In geometry definition, plane is selected; the point on plane Y is set to 35 mm while X and Z are 0. The plane normal Z is set to 1 while X and Y are 0.
- Meshing default is left to be default.

Fluid interface (bottom surface)

- The wall is set as deforming due to the region of mesh distortion.
- In geometry definition, plane is selected; the point on plane Y is set to 0 mm while X and X are 0. The plane normal Z is set to 1 while X and Z are 0.
- Meshing default is left to be default.

Left wall

- The wall is set as deforming due to the region of mesh distortion.
- In geometry definition, plane is selected; the point on plane Z is set to 125 mm while X and Y are 0. The plane normal Z is set to 1 while X and Y are 0.
- Meshing default is left to be default.

Right wall

- The wall is set as deforming due to the region of mesh distortion.
- In geometry definition, plane is selected; the point on plane Z is set to -125 mm while X and Y are 0. The plane normal Z is set to 1 while X and Y are 0.
- Meshing default is left to be default.

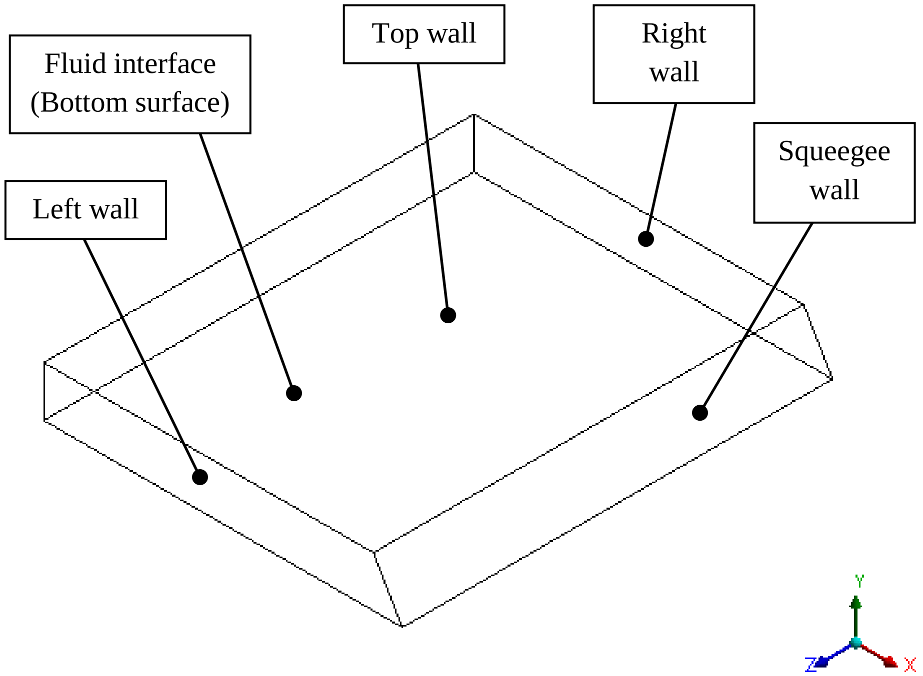


Figure 3.7: Dynamic mesh zones on printing body

3.2 Experimental Procedure

3.2.1 Experimental Preparation

An experimental procedure for validation purpose of the simulation result was conducted in SMT laboratory regarding to the stencil printing process by observing the print quality. The printing process was performed by hand which is the manual method of stencil printing process as shown in Figure 3.8. The experiment was performed at ambient temperature and pressure which was approximately 25℃ and 1 atm. The tools and materials used in the experiment are listed in Table 3.3 below.

Table 1.3: Materials and tools for experimental setup

Materials	Tools
• Solder paste Sn96.5Ag3.0Cu0.5 (SAC305)	• Laser cut aluminum stencil
• 35mm × 35mm copper plate	• 60° metal blade squeegee
• Sand paper	
• Acetone	

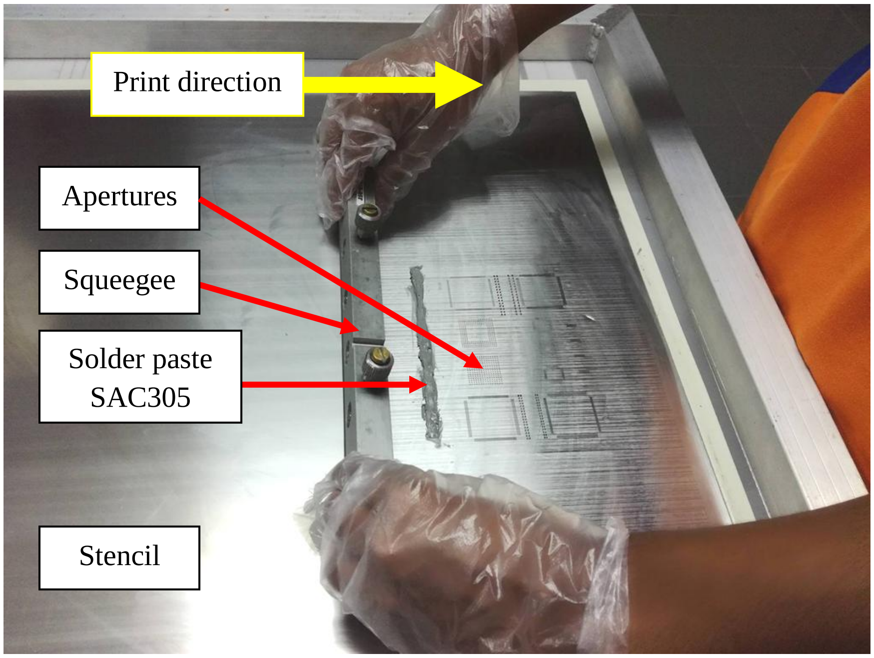


Figure 3.8: Experimental procedure of stencil printing

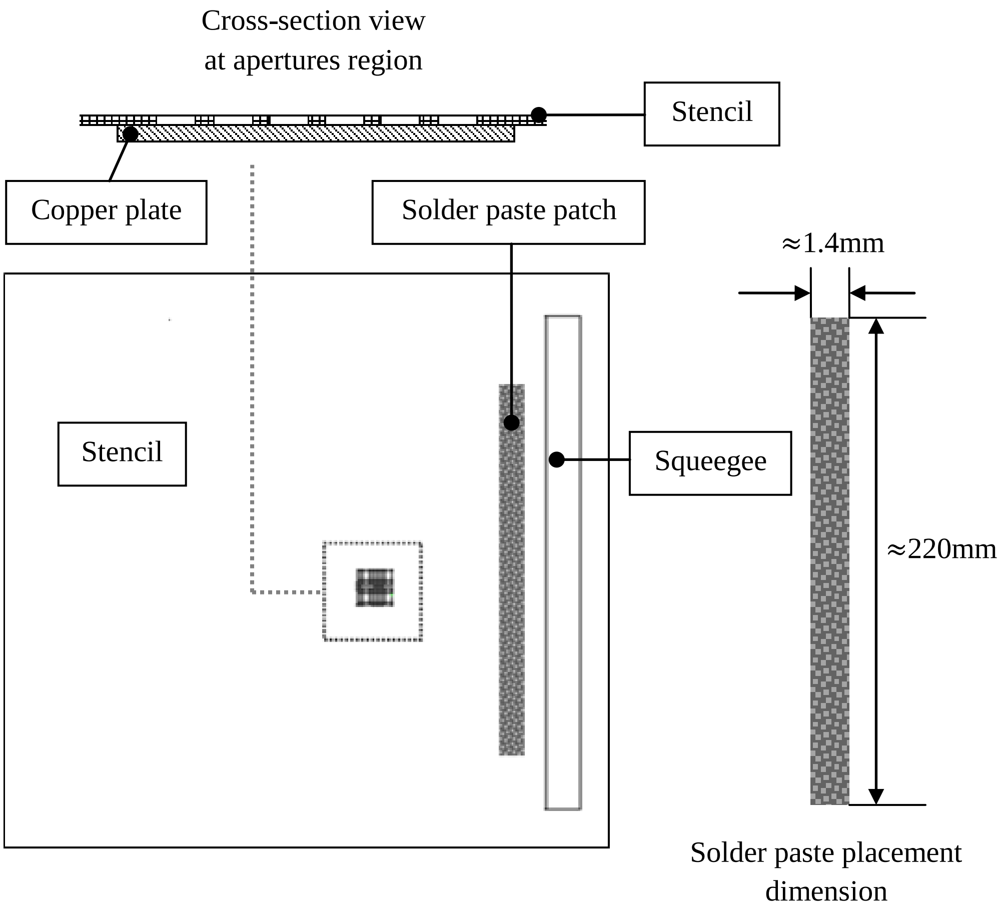


Figure 3.9: Schematic diagram of actual experimental setup from top view

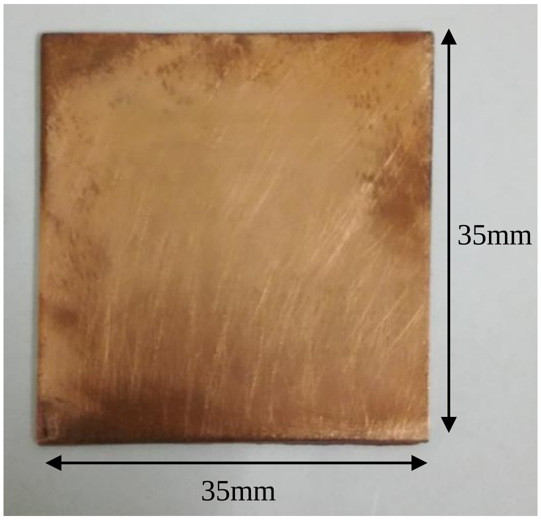


Figure 3.10: 35mm × 35mm copper plate

A thin 35mm × 35mm copper plate is used in the experiment as shown in Figure 3.10. The plate was polished by using sand paper and cleaned by acetone to have better surface finish. Before stencil printing can be done, the selected apertures design was ensured to be on the top surface of copper plate by placing the aluminum stencil on it and solder paste SAC305 is placed lengthways on the stencil near to the apertures with approximate specified dimension of solder paste placement as shown in Figure 3.9. Next, a 60° metal blade squeegee swiped the solder paste on the stencil through the apertures manually by hand. The copper plate was taken out as the product of the printing process and examined for further analysis of the research.

3.2.2 Experimental Analysis

A TM-1000 Tabletop microscope (Figure 3.11) is used to observe and analyze the quality of the deposited solder paste on the copper plate as the product of the stencil printing process. 60° squeegee angle and 35 mm/s squeegee print speed simulation result is chosen for the comparison to experimental results regarding to the print quality. Four different solder paste deposits on the plate of the selected apertures design were observed and analyzed for validation purpose based on the targeted location as shown in Figure 3.12. The parameter of validation was the coverage area of each of the selected solder deposits which were captured by the microscope. The images of solder deposits are transferred into ImageJ software to calculate the coverage area and compared with the simulation result.

Figure 3.11: TM-1000 Tabletop microscope

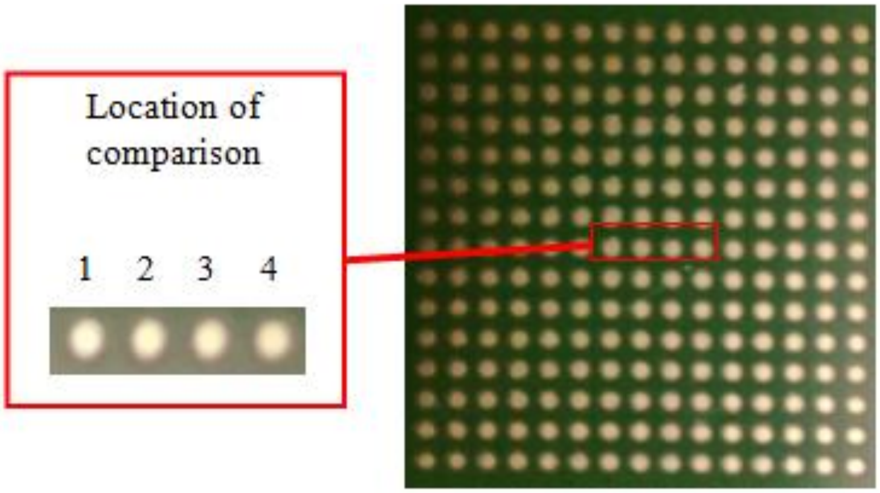


Figure 3.12: Inspection location for validation (represent by PCB)

CHAPTER 4

Result and Discussion

4.1 Experimental Validation

Figure 4.1 and 4.2 show the comparison of solder deposits coverage area between simulation and experimental results. It is found that the experimental solder deposits coverage area at all comparison locations are greater than simulation at 100% filling stage; squeegee print speed 35mm/s and angle 60°. This indicates the area of paste deposition on the copper plate is bigger than the size of the apertures. In addition, solder deposits coverage area in simulation are similar at all locations which are fully covered the apertures. The highest percentage difference of coverage area is at location 3 by 7.62% while the lowest is at location 1, 2.65% as shown in Figure 4.3. This is due to the experimental procedure that has uncontrolled parameters such as printing speed due to manual printing process compared to the simulation. However, the percentage differences for all locations are within 10%. Thus, simulation results generated by FLUENT in the prediction of print quality in stencil printing it is fairly acceptable.

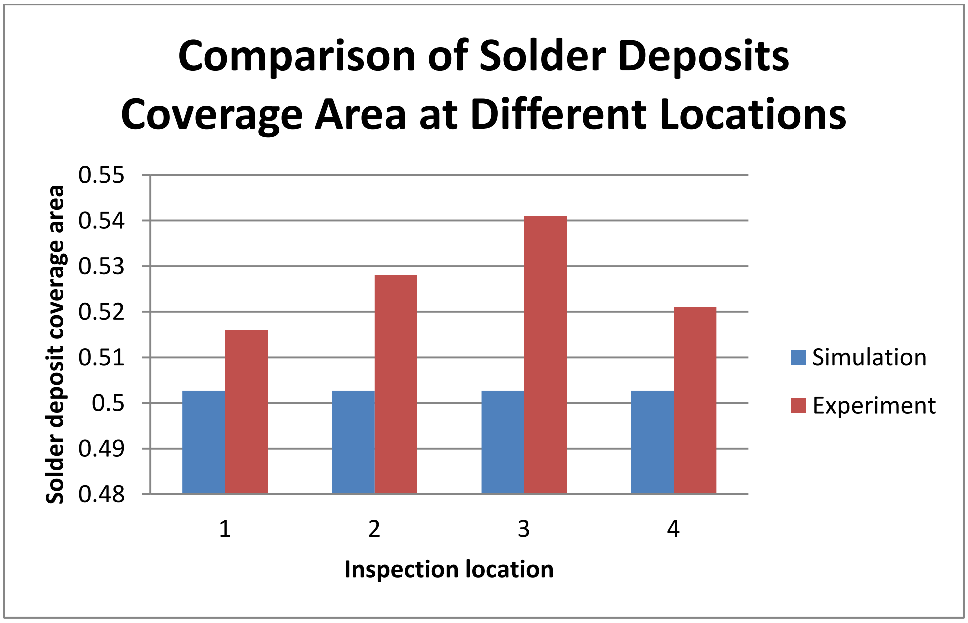


Figure 4.1: Comparison of solder deposits coverage area at different locations

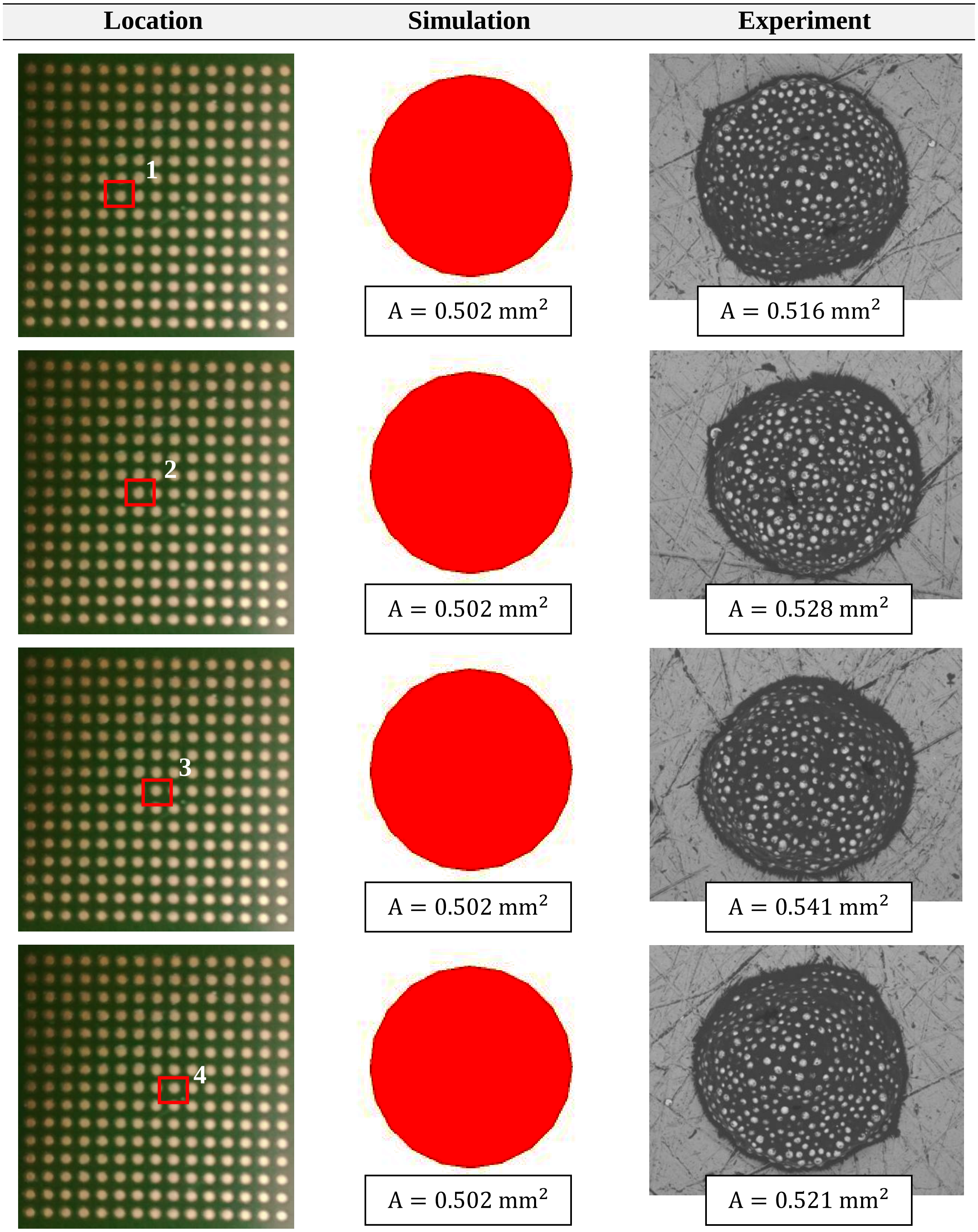


Figure 4.2: Observation of solder deposits coverage area, A at different locations

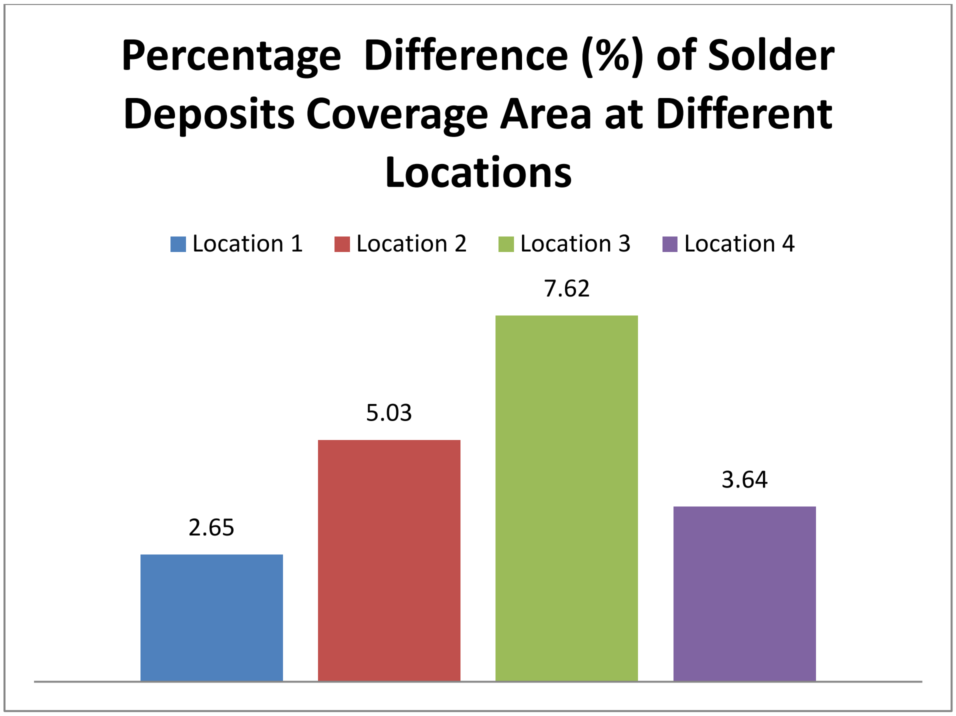


Figure 4.3: Percentage difference of solder deposits coverage area at different locations