EFFECT OF PRESSURE AND DROPLET NUMBER ON SMT ADHESIVE DISPENSING

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Engineering Campus

Universiti Sains Malaysia

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed...
(NUR MAISARA BINTI MOHAMED YUSOFF)

Date ....

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NOMENCLATURE & ACRONYMS

In this section the nomenclature and acronyms used in the report are listed with the correspondent International System (IS) units.

Nomenclature

Re	Reynold number
V	Velocity (*m/s*)
ν	Kinematic Viscosity (m^2/s)
μ	Dynamic Viscosity ($N\ s/m^2$)
ρ	Density (kg/m^3)

Acronyms

SMT	Surface mount technology
CFD	Computational fluid dynamic
PCB	Printed circuit board

KESAN TEKANAN DAN BILANGAN TITIAN PADA PROSES SMT

ABSTRAK

Mesin pendispensan perekat automatik digunakan dalam proses mendispens perekat pada permukaan PCB. Kaedah pendispensan tekanan masa adalah kaedah yang paling umum digunakan dalam industri, kerana penyelenggaraannya yang fleksibel dan mudah. Titik perekat ini biasanya digunakan untuk memegang komponen tertentu. Oleh itu, projek ini akan menentukan jumlah tekanan dan titisan perekat yang sesuai dengan menggunakan Computational Fluid Dynamic (CFD) dalam perisian ANSYS Fluent. Titisan perekat juga membantu untuk menyingkirkan beberapa masalah seperti sambungan pateri yang tidak mencukupi. Dalam sistem pendispensan tekanan masa, bekalan udara yang disambungkan kepada jarum suntikan digunakan untuk menyediakan udara termampat dalam denyutan tetap untuk menolak perekat melalui jarum atau muncung jarum suntikan. Perekat mesti dipilih dengan berhati-hati untuk memastikan ia kuat dan mempunyai keupayaan yang mencukupi untuk memegang komponen di tempatnya sehingga selesai. Daripada semua simulasi, dispenser dengan satu titisan dan tekanan sebanyak 290000 Pa menunjukkan hasil terbaik.

EFFECT OF PRESSURE AND DROPLET NUMBER ON SMT ADHESIVE DISPENSING

ABSTRACT

Automatic dispensing machine is used to help the process of dispensing adhesives on the PCBs. Time-pressure (contact) dispensing method is the most common method used in industry, due to its flexible and easy maintenance. Adhesive dots are generally used to hold certain components onto the PCB during the wave soldering process. Thus, this project will determine the best pressure and droplet number of adhesive dispensing using Computational Fluid Dynamic (CFD) in ANSYS Fluent software. In time pressure dispensing, an air supply connected to a syringe is used to provide compressed air in fixed pulses to push the adhesive out through the needle or nozzle of the syringe. The adhesive must be choosen carefully to make sure it is strong and have sufficient attachment capability, to hold the components in place until cured. From all the simulations, one droplet dispenser with a pressure of 290000 Pa showed the best result.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter is discussed about the project background, the problem of the project, the objectives of the project and the project scope.

1.2 Project Background

Adhesives are widely used and play a crucial role in the assembly and packaging of electronic devices in the modern era dominated by electronic devices. Surface-mount technology (SMT) involves the mounting of electronic components onto printed circuit boards (PCBs). In SMT, electronic components are attached or glued onto a PCB using surface mount adhesive (SMA), which is dispensed by an automated dispensing machine [1]–[4]. There are several types of dispensers available in the industry such as time-pressure dispenser, auger pump, and piston pump. This process is then followed by the curing of the adhesive and reflow of the solder (solder-reflow process), which usually occurs at high temperature, to form the necessary mechanical and electrical connections between the components. Figure 1.1 shows the schematic of a typical time pressure dispensing system that will be used in this project while Figure 1.2 shows other types of SMT dispenser available in the industry

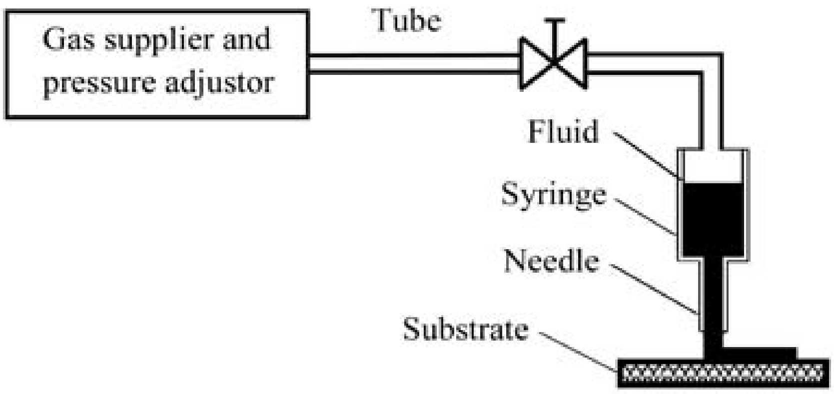


Figure 1.1 The time-pressure fluid dispensing system [5]

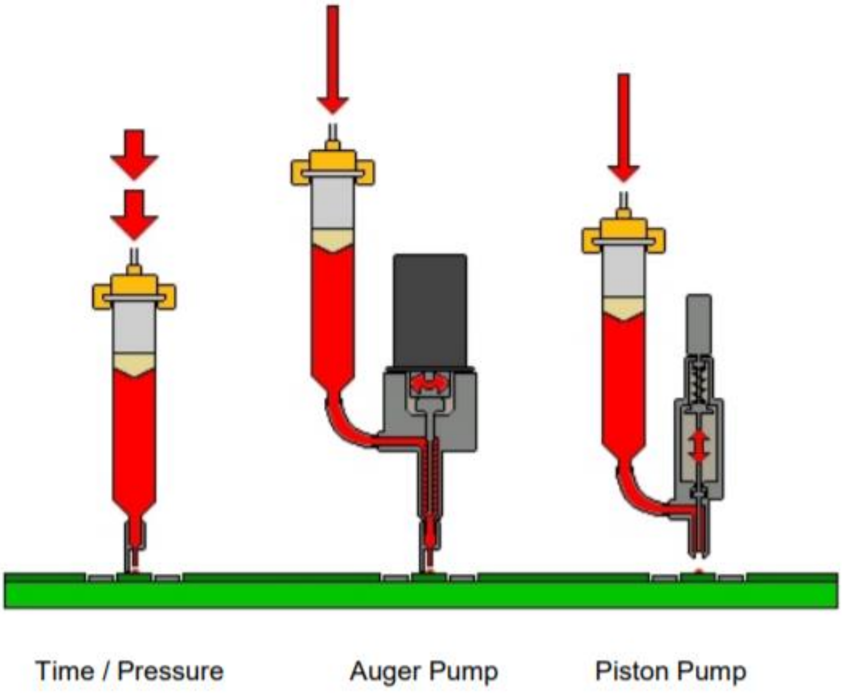


Figure 1.2 Type of SMT adhesive dispenser

The process of dispensing adhesives onto the PCBs is a highly automated process with the help of automatic dispensing machines. The most widely used dispensing method is the time-pressure (contact) dispensing method, due to its flexible and simple nature in different application situations and easy maintenance [6]. In time pressure dispensing, an air supply connected to a syringe is used to provide compressed air in fixed pulses to push the adhesive out through the needle or nozzle of the syringe. The adhesive must be strong and have sufficient attachment capability, which is also known as “green strength”, to hold the components in place until cured [7]. The cured adhesive should hold the SMD components in the correct position until wave or reflow soldered (second pass in double-sided reflow process). SMA rheology is very important in producing consistent dots with good green strength. An adhesive with poor rheological properties will exhibit lower green strength and tend to form misshapen dots that can string or slump and lose contact with components. A good understanding of the droplet generation process is also important to predict the droplet behavior. Figure 1.3 shows the stages of the droplet formation process [8].

There are also some problems usually encountered in the process of dispensing adhesive, therefore, a lot of factors need to be taken into consideration when dispensing adhesive onto a PCB. The factor that influences the adhesive dispensing include the pressure, droplet number, viscosity, nozzle size, and many others. Nozzle size is also very important in this process which is influenced by the nozzle head diameter. Nozzle size should theoretically form the lower bound of droplet size [9]–[11]. Hence, the present paper aims to understand the effects of pressure and droplet number on SMT adhesive dispensing.

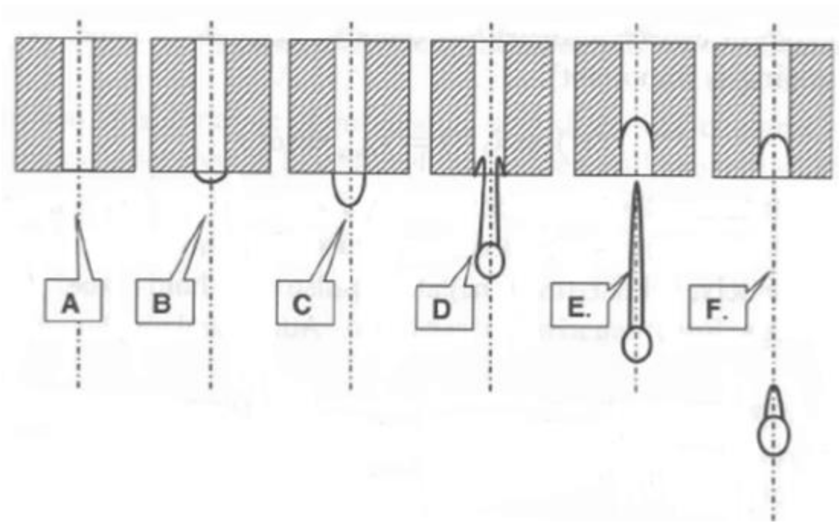


Figure 1.3 The stages of droplets formation process [9]

1.3 Problem Statement

There are a number of problems encountered in the process of dispensing adhesive. When the component is quite small, the adhesive can spread easily onto the solder pad. The most important consideration in obtaining a reliable adhesive bond is the ability of the adhesive to flow and wet the surfaces. Besides, it is very hard to observe the flow of the adhesive on the pad by naked eyes due to very small component and a small quantity of adhesive used.

1.4 Objectives

I. To investigate the effect of pressure and droplet number on SMT adhesive dispensing.

II. To simulate the fluid flow of adhesive using computational fluid dynamics.

1.5 Project Scope

From this paper, the factor that will affect the SMT adhesive dispensing will be studied. Two factors that will be focus are the effect of pressure and droplet number. Variation of pressure and droplet number of adhesive will be analyzed. Computational Fluid Dynamic (CFD) will be a main tool to be used in studying the deformation and properties change of the adhesive. Therefore, assisted by ANSYS FLUENT, the effect of pressure and droplet number on SMT adhesive dispensing will be simulated. The most suitable parameter of adhesive dispensing will be determined. The results obtain by simulation will be compared with the experimental results obtain by the previous research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will provide a review from previous researches that are related to this final year project. It includes an overview of SMT, time-pressure dispensing and wettability. This is discussed as an introductory for all the researcher done before in the past.

2.2 Overview of Surface Mount Technology

Surface Mount Technology is an area of electronic assembly used to mount electronic components to the surface of the printed circuit board (PCB) as opposed to inserting components through holes as with conventional assembly. SMT was developed to reduce manufacturing costs and also to make more efficient use of PCB space. As a result of the introduction of surface mount technology, it is now possible to build highly complex electronic circuits into smaller and smaller assemblies with good repeatability due to the higher level of automation. Sometimes, they also use a liquid adhesive to hold the component after the placement of an electronic component. The purpose of using adhesive is to prevent the shifting of SMD (surface mount device) after placement and to prevent dropping off of chips during the solder reflow process [6]. Some companies skip this part and proceed to the next process. Actually, this process plays a very important role in preparing a complete PCB board. There are many adhesive available which can be categorized based on their curing method, molecular structure, physical form, formulation, polymer type, function, or application. Adhesive dispensability is influenced by several factors such as needle size, PCB to needle stand-off height, dispense time and pressure, and temperature. Therefore, it is very important to have a basic understanding of adhesives and their properties before making any selection to prevent subsequent problems [12], [13]. Kondo [14] also reveals a dispensable adhesive benchmark program that characterizes dispensability, temperature effects, component adhesion and moisture absorption due to the need to more accurately benchmark the functional performance properties in several key areas. These tests serve as both material selection and process optimization tools. Cope [15] also found that variability actuates during the application process which is caused by many factors, significantly limits the effectiveness of the adhesive and prevent the additional increase in the performance. The evaluation of pre-applied adhesives is due to the inability for electronic component manufacturers to evaluate the performance of their components in varying designs due to variability in both manufacturing and design [15]. Figure 2.1 shows the process sequence of wave and reflow soldering.

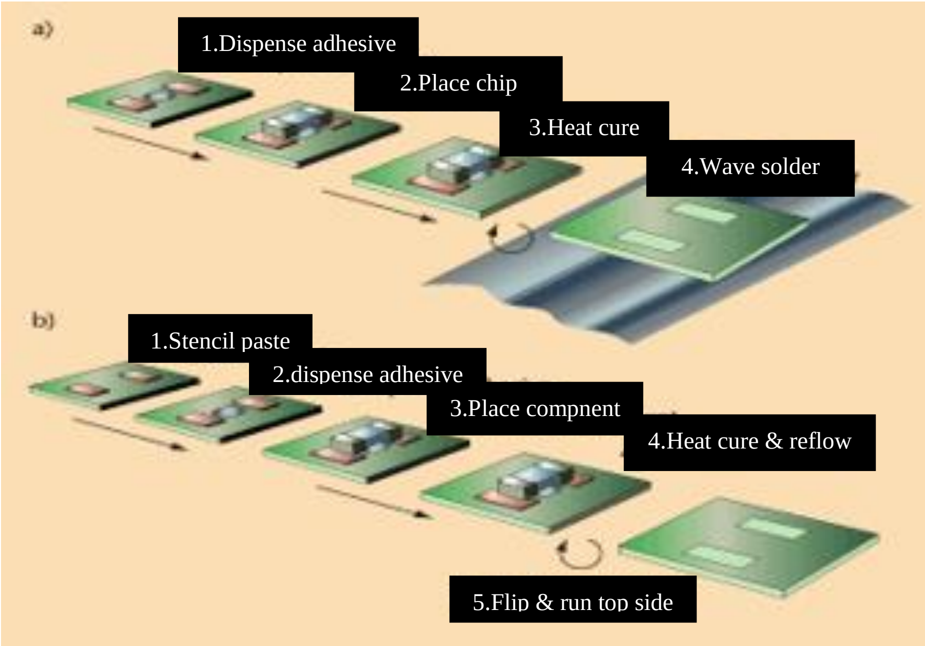


Figure 2.1 Wave and reflow soldering [5]

2.3 Time-Pressure Dispensing

The time-pressure dispensing is most widely system used in industry due to its simple operation, comparatively low cost, easy maintenance, and ability to adapt to a wide range of applications. It is estimated that about 70% of the dispensing machines on the market today use the time–pressure approach [6]. From the previous study by Brewin et al. [16], it is also found that the higher the pressure and the longer it is applied, the more the material it will dispense. Piracci [17] set up and control the machine parameters required to dispense various adhesives and then discover that there are some benefits and also limitations of non-contact dispensing in production. Toh et al. [18] studied how the manipulation of three key components in the formulation of a surface mount adhesive can affect the characteristics of the dispensed dot. Time-pressure dispensing and rheological characteristics of adhesive samples of different formulations were carried out to find the best formula that can provide perfect dots. The break-up length, dot diameter, and volume are inversely proportional to the viscosity, while the dot height showed otherwise. Figure 2.2 shows the time pressure dispenser.

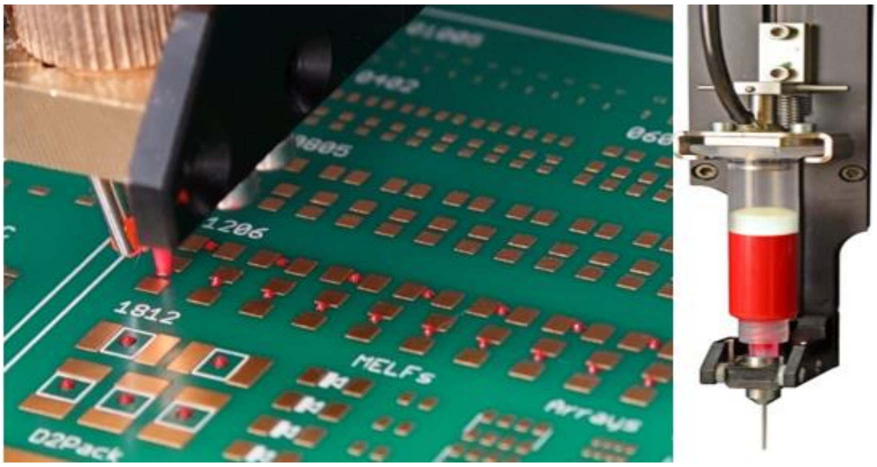


Figure 2.2 The actual time-pressure dispenser [2]

2.4 Dispense Condition

SMT PCB pad for the component is designed for either adhesive deposition or screening of solder paste. The pad spacing for the 0603 resistor is around 1.512mm. The amount of glue applied is very small, of the order of 0.0002 to 0.005 cc [7], depending on the component.

Standard of 0.4mm internal diameter needle is used for 0603 and 0805 components while 0.5mm or 0.6mm internal diameter needle is used for the1206 component. But we can also choose any needle sizes and standoffs as long it is compatible with our component and pad spacing. The diameter of the dispensed dot is usually double the size of the internal diameter of the needle [8]. The diameter of the needle chosen for this project is 0.6mm.

Dispense time also plays a very important role in this process as it controls the volume of the adhesive to be dispensed. The standard dispense time in the industry which yield stable dot size and shape is in the range of 10ms to 90ms [8].

Air pressure also determine the volume of the adhesive dispensed. The pressure used in industry is normally between 25 and 50 psi. Tip heating is another parameter that is important in this process because it makes the viscosity of the adhesive easier to dispense. The optimal process temperature for adhesive is 25°C [8].

2.5 Wettability

The adhesive must always have enough strength which is also known as wet or green strength to hold the SMD in position until cured [19], [20]. Wetting is the ability of a liquid to maintain contact with a solid surface, resulting from intermolecular interactions when the two are brought together and are extremely important in maximizing the coverage area and minimizing the voids in the bond lines. The higher the coverage area the better for the component to stick onto the PCB board. The criteria for a good adhesive is that the adhesive drop diameter on the board should be twice the size of the nozzle tip.Yuan & Lee [21] studied about the measurement of contact angle and wetting properties, the degree of wetting is usually determined by a force balance between adhesive and cohesive force and it is measured by the equilibrium contact angle, θ. It shows that for good wetting, the angle should be less than 90° [22]. Figure 2.3 shows wetting vs non-wetting while figure 2.4 shows the contact angles formed by liquid drops on a smooth surface. It can be seen that the wettability is inversely proportional to the contact angles. Cheng & Lin [23] studied that the surface tension and mass of each droplet form through the dispenser and found out that the surface tension is between 0.025 N/m to 0.043 N/m.

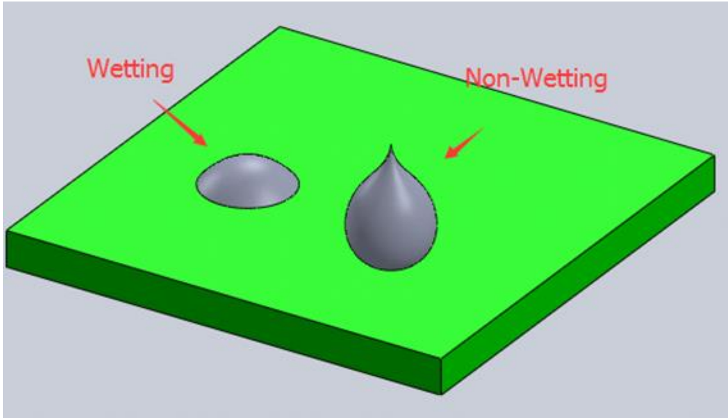


Figure 2.3 Wetting vs non wetting [21]

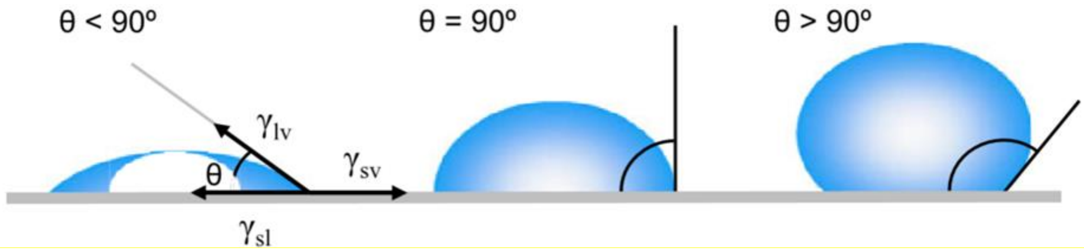


Figure 2.4 Illustration of contact angles formed by liquid drops on smooth surface [21]

2.6 Failure Related to SMT Adhesive Dispensing

The most common failure that usually occurs during SMT adhesive dispensing is the missing of the components after the wave or reflow (bottom side) soldering process can be caused by insufficient, misaligned, or missing adhesive dots. Some of the factors of missing adhesive are often caused by trapped air in the adhesive cartridge, very high standoff distance between the nozzle and PCB, and the most common factor is caused by the clogged or partly clogged nozzle. One of the reasons why adhesion to the mask is very poor is that the surface of the solder mask is contaminated. The mask usually looks oily or very shiny. A typical sign indicating this problem is that the adhesive is always attached to the removed component and never to the PCB mask. Be aware that a poor curing process can also result in missing components after the wave soldering process.

The second failure is the open joints which can be the result of misaligned adhesive dots, stringing or tailing. If the adhesive is dispensed onto or partly onto the solder pads and pressed further out by the placed component, wave soldering cannot be performed. Adhesive dispensed onto the solder pads could be a machine accuracy problem or wrong setting leaving too much adhesive on the PCB surface. Adhesive stringing or tailing can be caused by several factors such as poor adhesive thixotropic behavior, poor PCB surface condition, wrong machine set-up parameters, static electricity, and incorrect dispense nozzle. Figure 2.5 shows the image of a stringing dot. For time-pressure and auger systems, a too large amount of adhesive dispensed compared with the nozzle inner diameter and standoff height will result in stringing and a large variation of transferred dot volume. The access adhesive simply sticks to the nozzle tip due to larger surface tension and then leaving a tail when retracted.

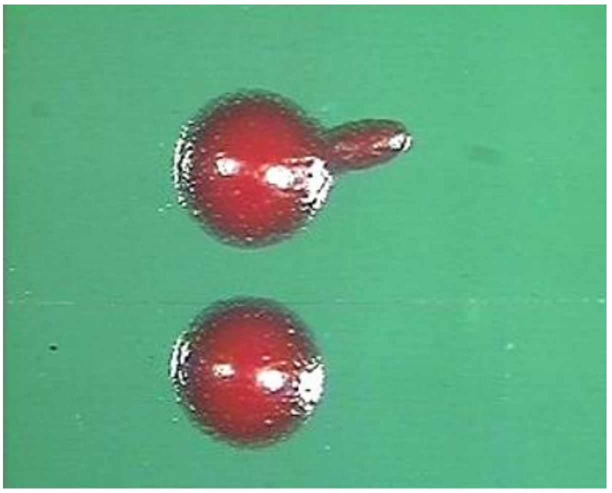


Figure 2.5 The-of stringing dot [14]

2.7 CFD Application to Droplet Formation

Due to the tiny space and very small component size used, the process is very hard and extremely difficult to observe and analyze. Computational fluid dynamics can also be used to calculate flows in the time-pressure dispenser. Computational fluid dynamic is a better method to simulate the process which can obtain qualitative results with the less complex approach. The analysis of different factors will be useful in understanding the dispensing mechanism and thus allow for performance improvement [11]. So far, it is still difficult to have a highly consistent dispensing. As the development of surface-mount technology (SMT) continues, dispensers are expected to achieve higher speed and increased accuracy. Modeling and control of fluid dispensing have been studied by using a simple model-based approach to obtain a proper operating condition for the parameter estimation. It can be seen that the disturbance from the fluid variation is finally reduced and the dispensing consistency also had been improved from the simulation and experiment conducted [5], [24], [25].

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this project, several processes has been carried out and were included in the research methodology. The analysis will be conducted by using ANSYS FLUENT software because simulation can overcome the experimental limitation. The processes consist of the study is finding the dimensions and properties of fluid and nozzle respectively , design the nozzle tube and PCB using Design Modeler in ANSYS 2018 software, meshing and setting up the suitable boundary conditions for the simulations in ANSYS Fluent, running the simulation repeatedly for five more different pressure at nozzle inlet using the same design. After analyzing the most suitable pressure, the project is continued by using varies number of nozzle. The fluid solver used was ANSYS Fluent.

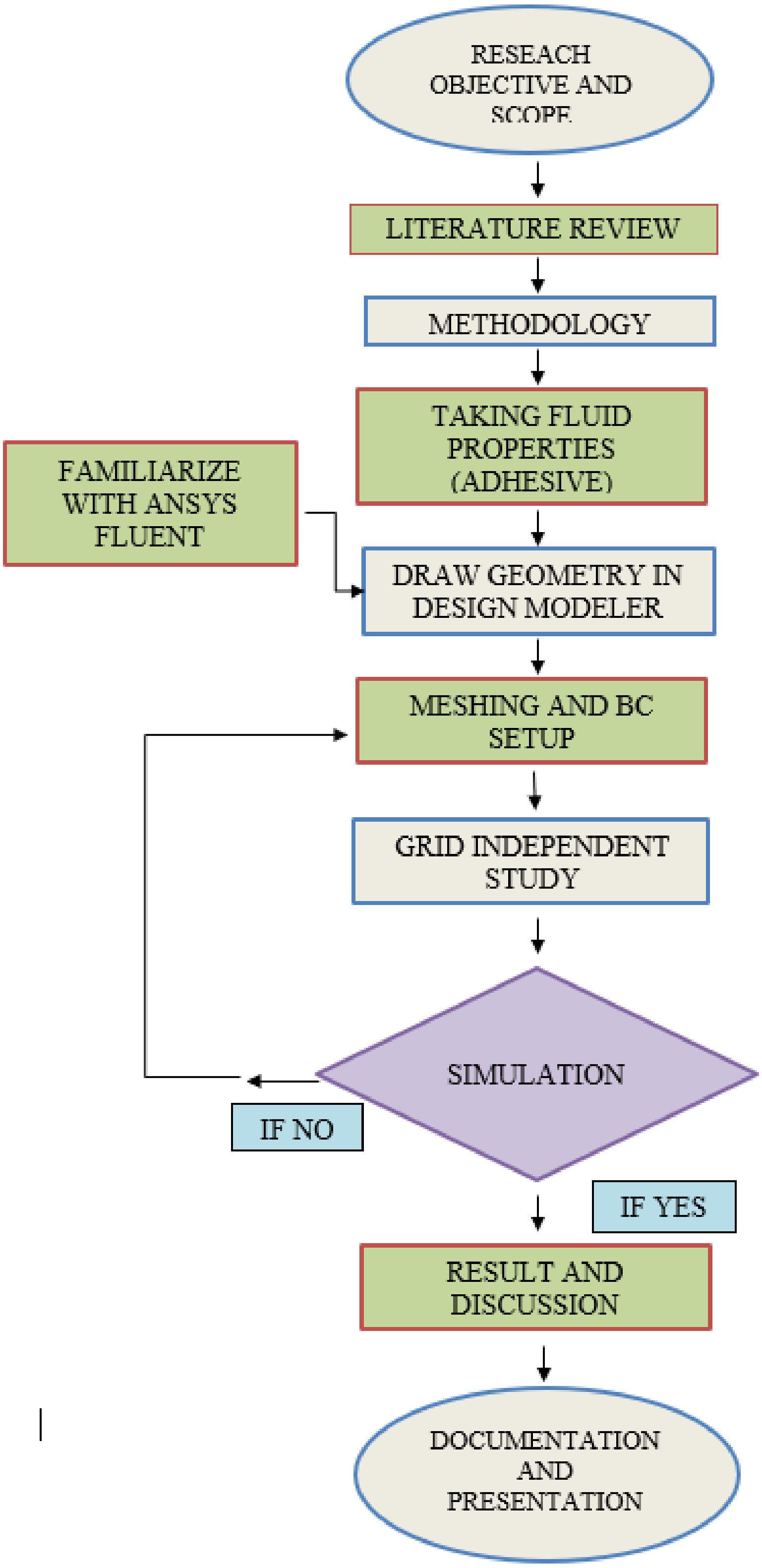


Figure 3.1 Steps taken in methodology

For this project for CFD solution, ANSYS Fluent is used for fluid solver. A CFD analysis consists of five main steps:

I. Computational domain (geometry) definition;
II. Meshing: the division of the domain in a number of points where the solution is calculated;
III. Fluid properties and boundary conditions definition;
IV. Solution of the discretised representation of the model;
V. Post processing and validation of results.

In this study a finite volume method solver called ANSYS Fluent was used. Fluid characteristics, such as velocity, pressure and flow rate, are defined at nodes and both accuracy of solution and its calculation time are strictly related to the grid (mesh) quality and its fineness. ANSYS Fluent can be used to solve the equation of continuity (1) and the Navier-Stokes equation (2) for incompressible steady flow:

$$\nabla . \upsilon = 0 \qquad (1)$$

$$\upsilon \nabla . \upsilon = -\frac{1}{\rho} \nabla \rho + \frac{\mu}{\rho} \nabla^2 \upsilon + F \qquad (2)$$

where υ, ρ, μ, and F represent the kinematic vicosity , the density, the dynamic viscosity, and body forces, respectively. Based on Celestica company in Penang, the adhesive used was Loctite 3621. Figure 3.2 show the simplified model of the dispenser. Pressure was applied at the nozzle inlet. The non-slip condition (i.e. zero normal velocity at the wall) was imposed on the nozzle and PCB surface. Simulations were carried out using a personal computer which is Asus Vivobook. PC specification are shown in Table 3.1

Table 3.1 PC specification

Device specifications

Device name	maisarayusoff
Processor	Intel(R) Core(TM) i5-8250U CPU @ 1.60GHz 1.80 GHz
Installed RAM	8.00 GB (7.88 GB usable)
Device ID	50BBE20F-E5FB-49FB-BE4B-DCC8FA2E9790
Product ID	00327-30221-47672-AAOEM
System type	64-bit operating system, x64-based processor
Pen and touch	No pen or touch input is available for this display

3.2 Geometry

During the first phase of simulations, four different pressure were applied at the pressure inlet with only one nozzle used. In the second phase, simulation is repeated as in the first phase using double and triple nozzle. The diameter of the nozzle used in both phase is 0.6mm and the height the nozzle is around 1.00mm which is correspond to 1.25e-10 mm^3 of adhesive. The standoff height is set to 0.2mm and the PCB thickness is around 0.5mm

a. Single nozzle

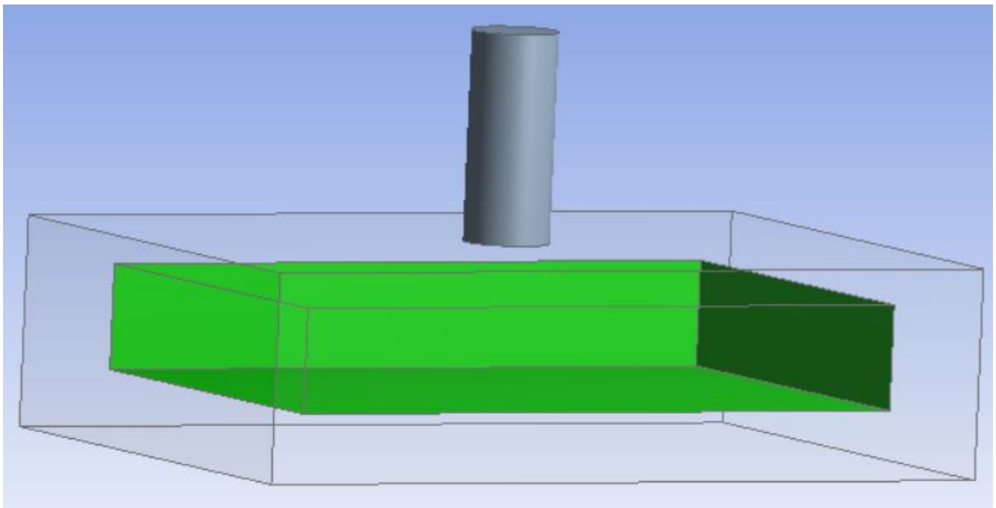


Figure 3.2 Front view of single nozzle

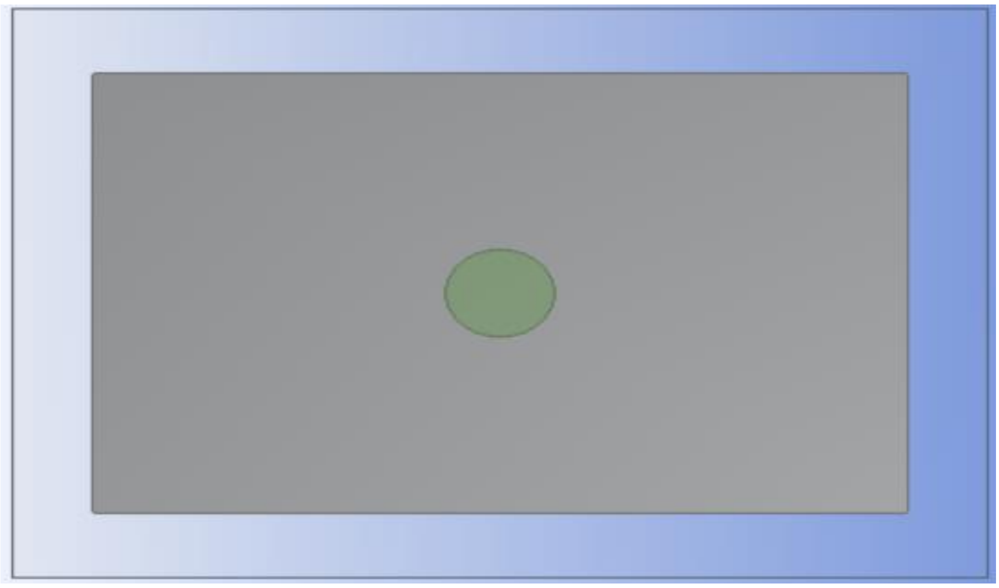


Figure 3.3 Top view of single nozzle

b. Double nozzle

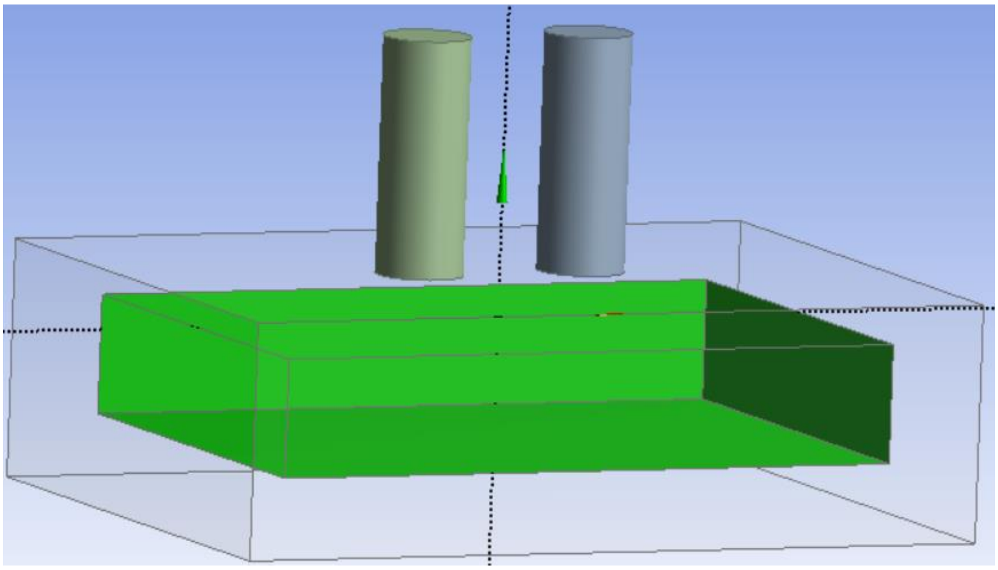


Figure 3.4 Front view of double nozzle

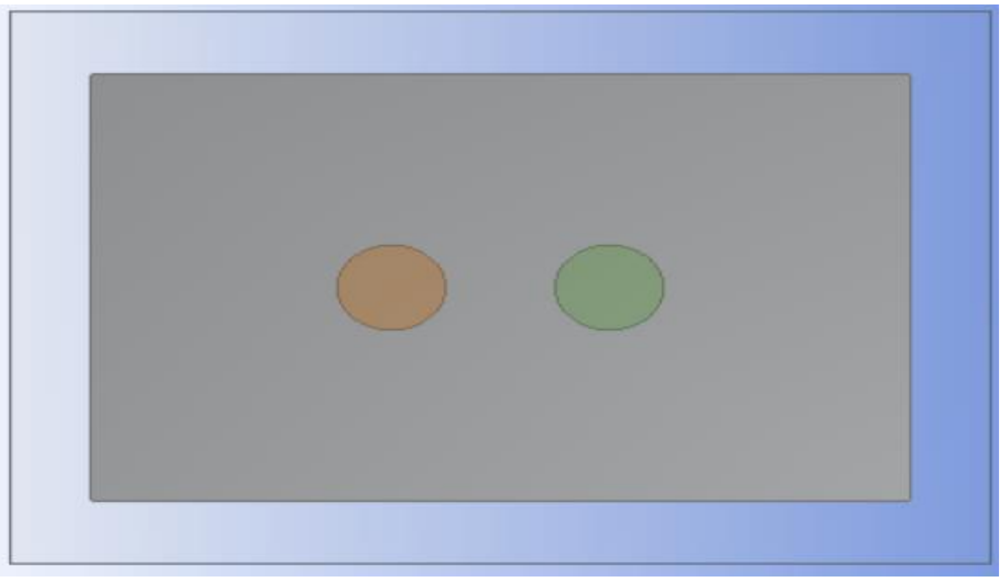


Figure 3.5 Top view of double nozzle

c. Triple nozzle

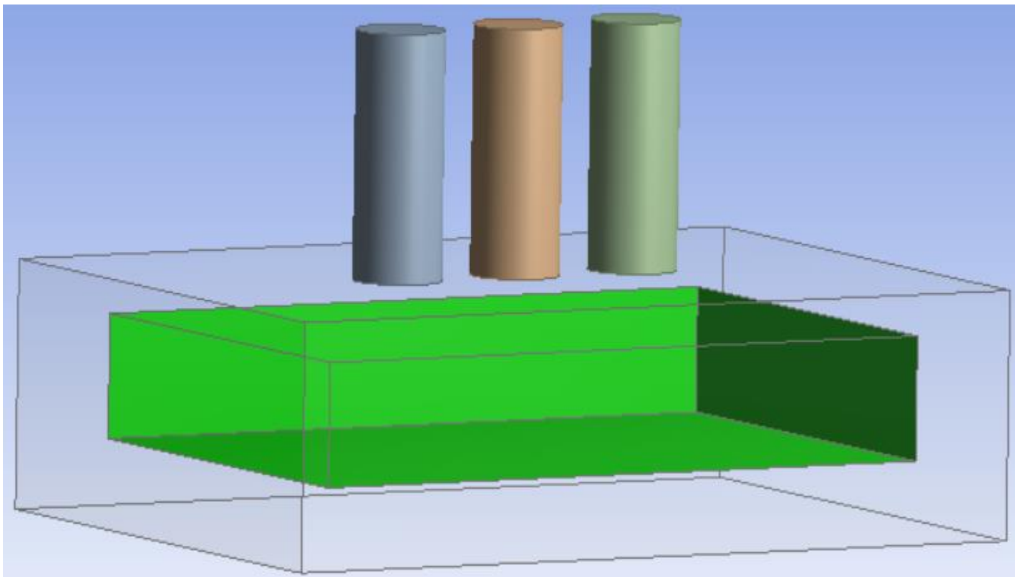


Figure 3.6 Front view of triple nozzle

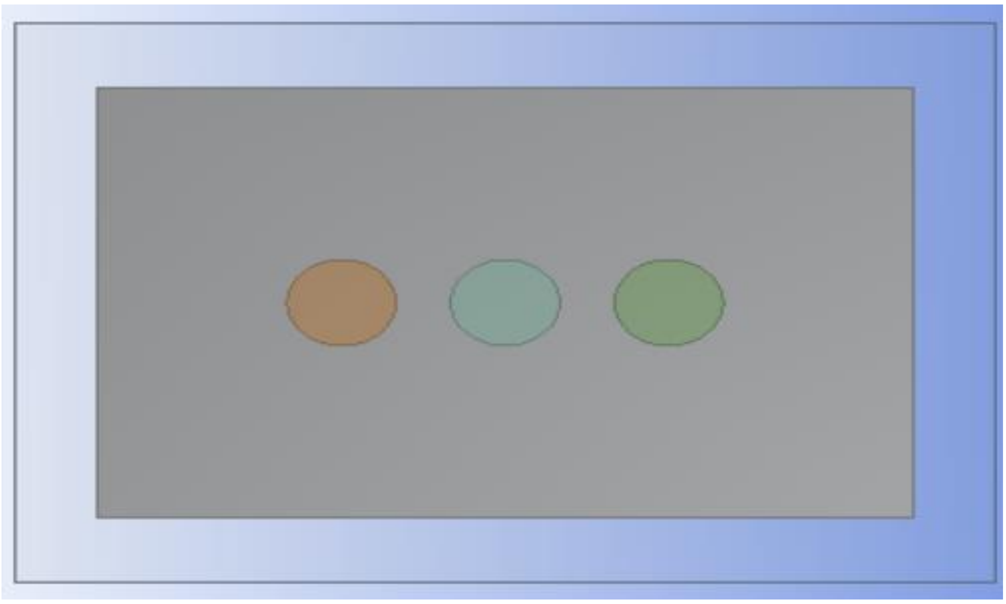


Figure 3.7 Top view of triple nozzle

3.2.1 Fluid Properties

It is important to define the flow properties of the adhesive. The adhesive is considered as a non-compressible and Newtonian fluid. A Newtonian laminar flow does not need a very refined mesh but able to reproduce the physics accurately. In the case of turbulent flow, the grid must be generated in accordance with the turbulence model used to perform the simulation. The type of flow can be defined by the value of Reynold’s number (Re). Laminar flow is when the internal flow have the value lower than 2300. If it is between 2300 and 4000, then the flow is considered as transitional. Finally, if the Re is greater than 4000, the flow is turbulent. The Re number is calculated using the characteristics length of the geometry used. This is a value usually known a priori, and in this study, it is the internal diameter. This number includes also fluid properties such as the velocity, the kinematic viscosity and the density of the fluid used. Figure 3.8 shows the type of fluid flow.

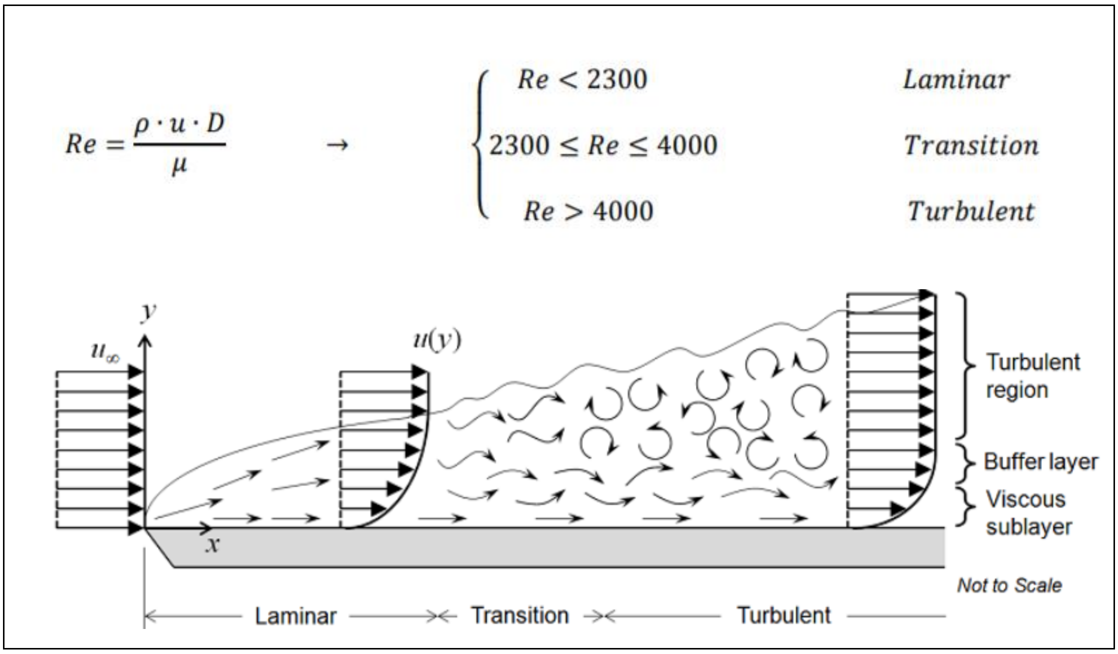


Figure 3.8 Type of fluid flow

The Reynold number for adhesive dispensing is greater than 2300. This would imply the necessity to solve the CFD problem using a turbulence model. Depending on the fluid model employed, a different mesh with different properties was required. The adhesive used in this project is Loctite 3621 which has viscosity and density of $3\ Pa.s\ and\ 1160kg/m^3$ respectively. The reference state chose was 25°C.

3.2.2 Meshing

Since the properties of fluid are known, meshing can be done accurately. This is because the characteristics of turbulent flow are very different from laminar flows. The main differences are near the wall where strong gradients related to the dependent variable will add the computational cost of the analysis.

Once the mesh was created, the mesh dependence study was performed in order to choose the best possible grid to be used for the simulation. Five different mesh with a various number of elements as shown in the table below were used for this study. Then the simulation was run and calculated. After the calculations completed, the area of adhesive deposited onto the PCB was analyzed as shown in figure 3.9 below.

Table 3.2 Number of element for each mesh

Mesh	Relevence Center	Smoothing	Element number
Mesh 1	Fine	High	195703
Mesh 2	Fine	Low	195339
Mesh 3	Medium	High	132230
Mesh 4	Coarse	Low	132131
Mesh 5	Coarse	High	132306

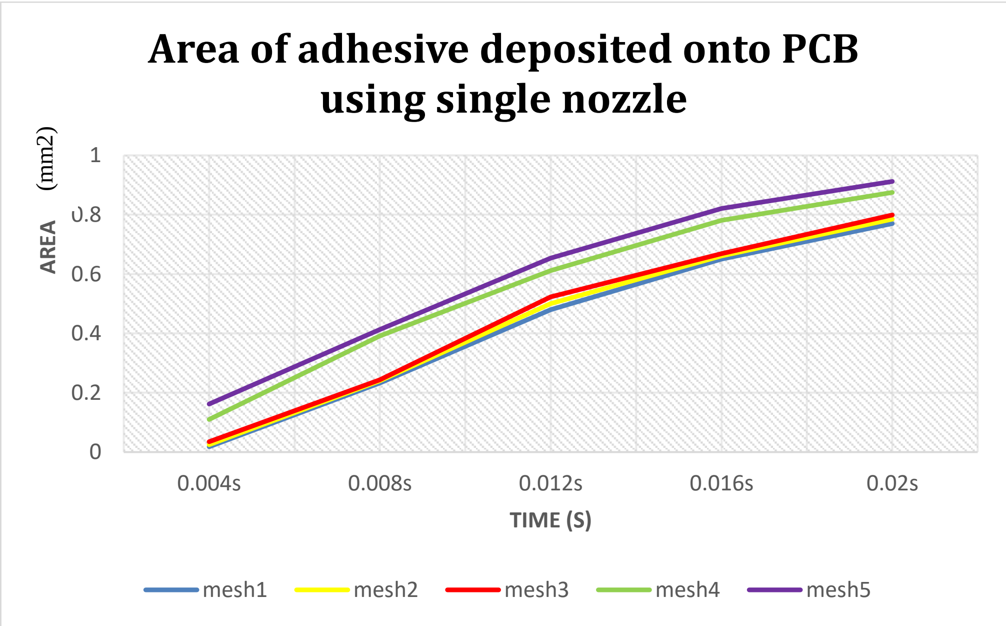
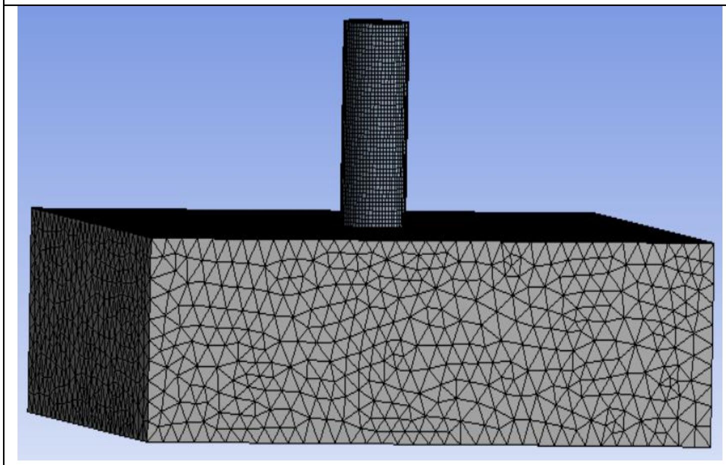
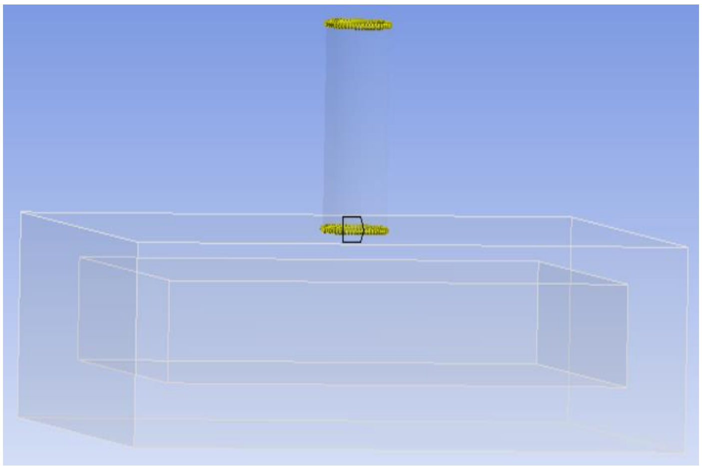
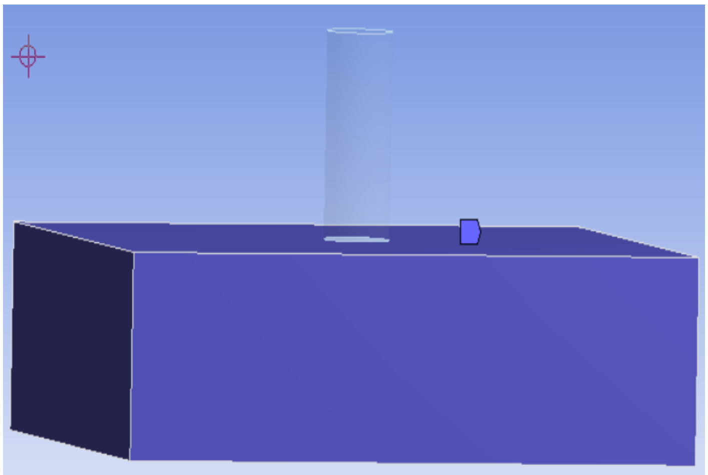
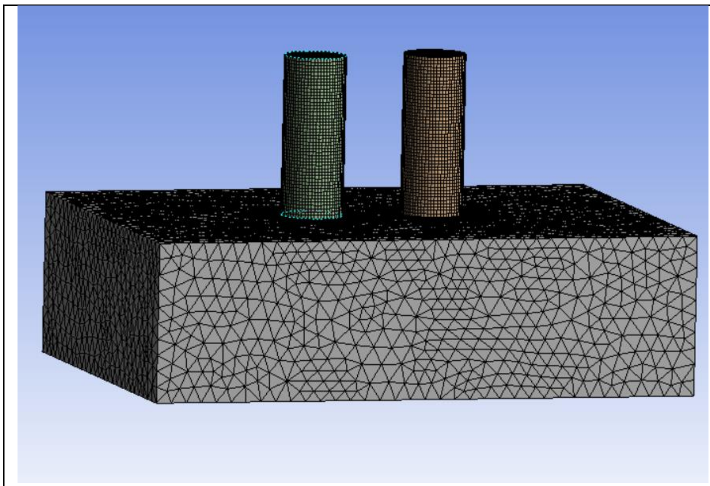
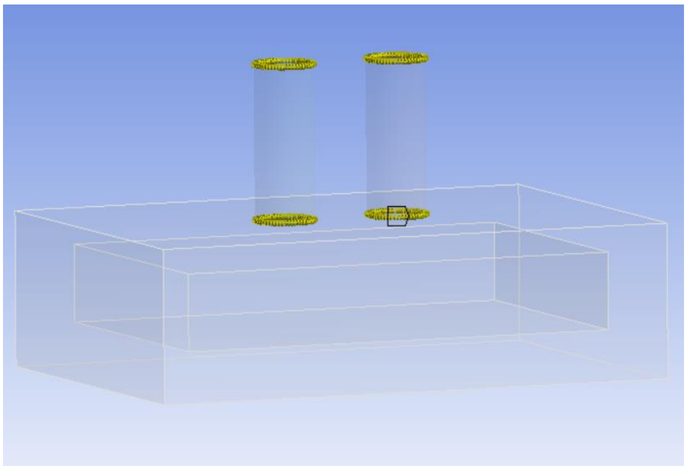
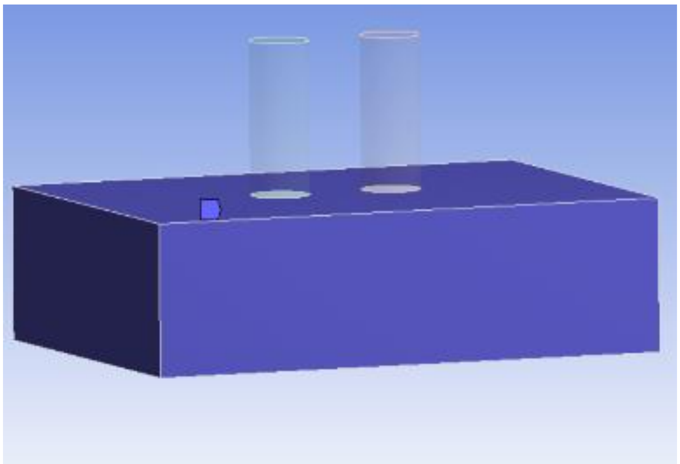


Figure 3.9 Graph of mesh study

From the graph obtained, we can see that the the medium and fine mesh grid type Mesh1-Mesh3) are close to each other and almost the same, while mesh 4 and mesh 5 differ from the other 3 meshes. This 3 meshes are suitable and accepted to be used in this project. Therefore, medium type will be selected in this simulation due to fewer time will be needed to complete the simulation.

Meshing	*Description*
	Size function: Proximity Relevance center: fine Nodes: 47952 Elements: 132230
	*Edge sizing* Geometry: 2 edges Type: number of division Number of division: 60
	*Face sizing* Geometry: 6 faces Type: element size Elemet size: 0.1mm
Single Nozzle	

	Size function: Proximity Relevance center: medium Nodes: 80961 Elements: 180090
	*Edge sizing* Geometry: 4 edges Type: number of division Number of division: 60
 *Double Nozzle*	*Face sizing* Geometry: 6 faces Type: element size Elemet size: 0.1mm

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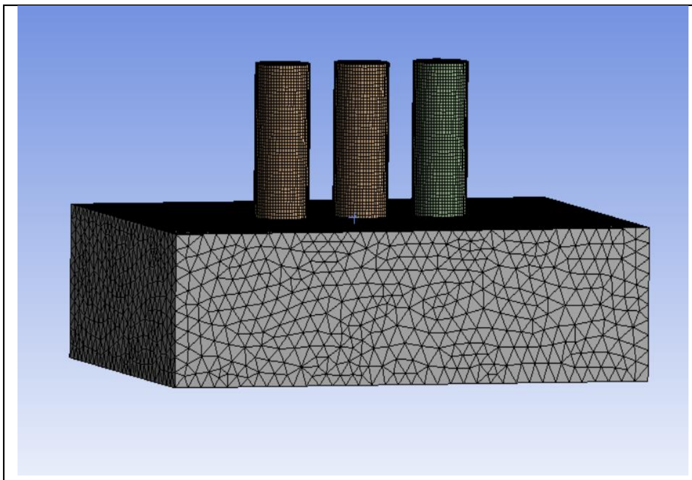
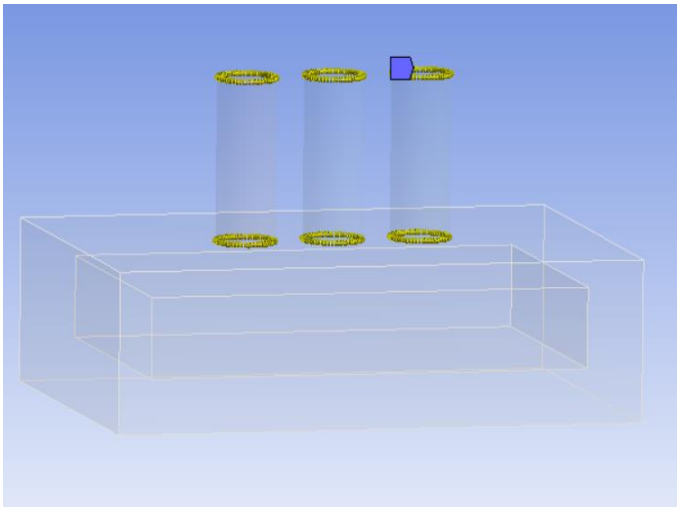
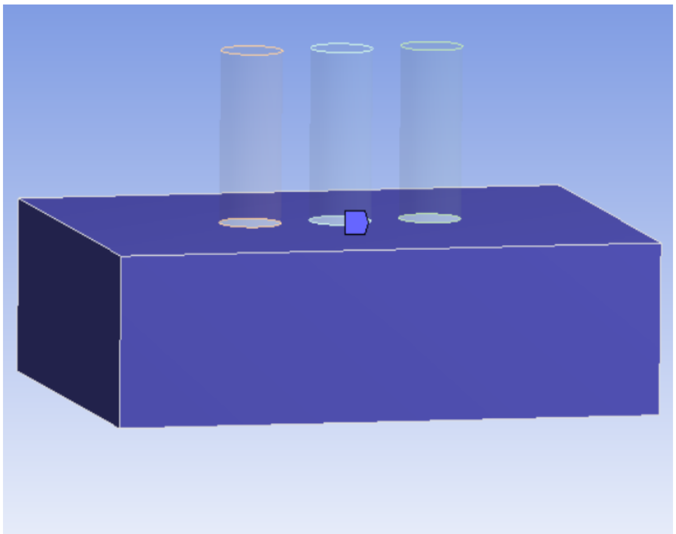
<tr><td>


<u>Triple_Nozzle</u></td><td>Size function: Proximity
Relevance center: medium
Nodes: 107163
Elements: 217565

Edge sizing
Geometry: 4 edges
Type: number of division
Number of division: 60

Face sizing
Geometry: 6 faces
Type: element size
Elemet size: 0.1mm</td></tr>
</table>

Figure 3.10 Meshing of the design model

Figure 3.9 illustrates the meshing process of the single nozzle, double nozzle, and triple nozzle. For the single nozzle, double nozzle and triple nozzle, the size function chosen for this simulation was proximity. 60 number of division was selected for the edge sizing and 0.1mm of element size was selected for the face sizing. The total number of element obtained for single nozzle was 132557 while the number of nodes obtained was 48398. For the total number of element obtained for double nozzle was 180090 while the number of nodes obtained was 80961. For the triple nozzle, the total number of element obtained was 217565 while the number of nodes obtained was 107163.

3.3 CFD Setup

For the setup in ANSYS Fluent, the flow selected was transient flow. The transient simulation includes all the cross term and higher order terms dealing with time. The Volume of Fluid was used for the multiphase in implicit manner. The two types of fluids adressed in the design were air and adhesive.

K-epsilon Model was used for the viscous model. The adhesive was added as fluid and its properties were also included. The k-epsilon is a model that guarantees strong stability and is considered the standard model for industrial applications. Accuracy and robustness are peculiarities of this model, which is based on the wall-function approach and is able to predict many different flows in engineering contexts. However, there are some cases in which other models could give more accurate solutions and are able to better simulate the fluid dynamics. For instance, k-epsilon the model is not able to solve low turbulent Re number computations properly. Moreover, to model the area closest to the wall using k-epsilon it is necessary to use damping functions, which are incorporated in ANSYS FLUENT, refining the grid resolution appropriate.

In boundary condition, the inlet was set as pressure-inlet and the value of pressure at the inlet was also included. For adhesive under the pressure-inlet, in multiphase tab, the volume fraction was changed to 0. In Solution Method, choose SIMPLE. The implicit method for pressure-linked equations (SIMPLE) algorithm deals with the pressure terms in the momentum equations and use the iterative procedure in which the solution to the discretized equations is obtained. All the convergence boxes under Residuals were unticked. Gravity of -9.81 m/s was also added at the solution initialization (acts as Gravitational pull)

Then, the setup was initialized and the adhesive was patched. Finally, the simulation was run at 1000 iteration for a time step of 0.00002 s.