Melt Flow Analysis of Novel Polymer Plate Washer Using Computational Fluid Dynamic (CFD)

by

Qurratu'aini Binti Ismail

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Mechanical Engineering)

JUNE 2010

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Melt Flow Analysis of Novel Polymer Plate Washer Using Computational Fluid Dynamic (CFD)

by

Qurratu'aini Binti Ismail

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

____

(AP Dr Bambang Ari Wahjoedi)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
JUNE 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

____

QURRATU'AINI BINTI ISMAIL

ABSTRACT

Final Year Project II is an individual research project in connection with a special engineering problem and under the guidance of a faculty member. My Final Year Project II entitled "Melt Flow Analysis of Novel Polymer Plate Washer Using Computational Fluid Dynamic (CFD)". The objective of my project is to study the melt flow process during the fabrication of polymer plate washer via the novel technique by using Computational Fluid Dynamic (CFD). The result of this analysis will be simulated by using FLUENT software. For this analysis project, the author wants to know if there is any possibility the polymer plate washers being produced by using other method instead of existing method. This procedure might be developed into novel commercial method to fabricate polymer plate washer which is much easier and less tedious, perhaps. This procedure is also important to be understood in terms of basic thermo mechanical processing. The molten flow of polymer plate washer during this novel technique will be analyzed. It is required that the flow behavior of the molten flow process is simulated by using any Computational Fluid Dynamic (CFD) software or any software that suitable.

ACKNOWLEDGEMENTS

Alhamdulillah, first and foremost I am expressing my appreciation and praise to Allah for his guidance and blessings throughout my entire final year, eventually dissertation was finally completed and finished successfully on time as the final tasks for my final year project.

I wish to thank all the people who have contributed directly or indirectly in accomplishment of this report. I would like to sincerely thank my supervisor AP Dr Bambang Ari Wahjoedi for his supervision and his support in accomplishing my final year project.

A full appreciation I give also to Mr. Mas Irfan, post graduate student for giving his concern by helping me in this final year project. Thank you for his guidance, shared his knowledge and experiences in solving problem and giving opinions.

My appreciation and gratitude is extended to Dr Azmi Abdul Wahab and Dr Patthi Hussain, my examiners throughout my final year project for their guiding, monitoring and lessons. Thanks for keeping me on the right track and offering kind of encouragement when I needed it.

My appreciation would be incomplete without giving tribute to University Teknologi PETRONAS (UTP), especially Mechanical Engineering Department who has equipped me with essential skills for self-learning. Its well-rounded graduate philosophy has proven to be useful in the industry.

I have learned so many things during my final year. Thanks all for being a part of this wonderful experience.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND STUDY

Polymer plate washers play an important role in wood and metal construction. A washer is a thin plate with a hole (typically in the middle) that is usually used to distribute the load of a threaded fastener. Other uses of washer are wear pad and locking device. Usually washers have OD (outer diameter) about twice their ID (inner diameter) [1]. Washers are typically made of metal or plastic polymer and made in round or square shapes. Square plate washers have larger surface area than round washers. Plate washers are also normally used in wood construction to prevent bolt heads or nuts from pulling into the wood.

The expansion of the plastic transforming industry in the last years has prompted the development of simulation packages, some of which combining actual rheological models with simplified computational formulations. The term melting point, when applied to polymers, suggests not a solid-liquid phase transition but a transition from a crystalline or semi-crystalline phase to a solid amorphous phase. Though abbreviated as simply T_m, the property is more properly called the crystalline melting temperature. Among synthetic polymers, crystalline melting is only discussed with regards to thermoplastics, as thermosetting polymers will decompose at high temperatures rather than melt [21].

The polymer melting mechanism has attracted much attention, especially as experimental investigations have shown that the main morphology change occurs during the melting process [22]. Comparable to experimental investigations, modeling has become another powerful and popular tool to study in detail the morphology generation during melting.

Figure 1: Soldering Rode for Heating Process

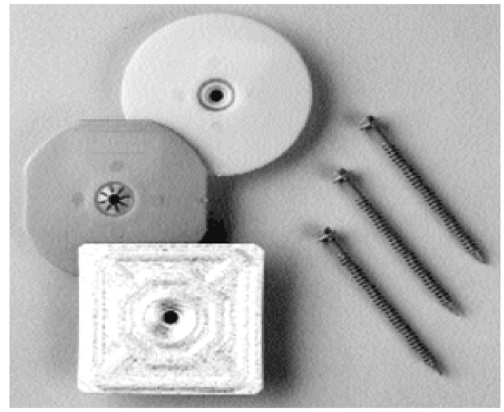

Figure 2: Plate Washer and Bolt

1.2 PROBLEM STATEMENT

Polymer plate washers are being produced by polymer processes. Two types of composite polymers are thermosets polymer and thermoplastics polymer. There are many procedures on how to process polymer such as calendaring, punching, shearing, casting, coating, blow molding and many other processes. For this analysis project, the author wants to know if there is any possibility the polymer plate washers being produced by using other method instead of existing method. This procedure might be developed into novel commercial method to fabricate polymer plate washer which is much easier and less tedious, perhaps. This procedure is also important to be understood in terms of basic thermo mechanical processing. The molten flow of polymer plate washer during this novel technique will be analyzed. It is required that the flow behavior of the molten flow process is simulated by using any Computational Fluid Dynamic (CFD) software or any software that suitable. This project typically aims to investigate the phenomena that associated with polymer melt flows.

1.3 OBJECTIVES

The objective of this analysis is to study the melt flow process during the fabrication of polymer plate washer via the novel technique by using Computational Fluid Dynamic (CFD). The result of this analysis will be simulated by using FLUENT software.

1.4 SCOPE OF STUDY

The whole project would start with the knowledge gathering and theoretical studies. Since the objective of this project is to study the melt flow analysis of novel polymer plate washer using Computational Fluid Dynamic (CFD), the result of this analysis will be simulated by using FLUENT software. Learning the FLUENT software application would be the first step in this project. After knowing the basic knowledge on how to run FLUENT software, the study of analysis will be continued by enter some data in order to get the result. Research also will keep on going on the possibility of any new technique, for this project is a novel technique that still can produce polymer washer but much easier and less tedious. Then, a methodology will be developed according to the step-by-step procedures. Meanwhile, further research and development would be continuously practiced to ensure satisfactory results are achieved.

CHAPTER 2
LITERATURE REVIEW

2.1 POLYMER

A polymer is a large molecule composed of repeating structural units typically connected by covalent chemical bonds [2]. Polymers can be divided into two major categories: thermoplastics and thermosets.

2.1.1 Thermoplastic [3]

A thermoplastic is a polymer that turns to a liquid when heated and freezes to a very glassy state when cooled sufficiently. When the polymer is cooled, it returns to its original hardness and strength, in other words, the process is reversible. Thermoplastics such as polyethylene and polystyrene are capable of being molded and remolded repeatedly. The behavior of thermoplastic depends on other variables as well as their structure and their composition. The polymer structure associated with thermoplastics is that of individual molecules that are separate from one another and flow fast one another. The molecules may have low or extremely high molecular weight, and they may be branched or linear in structure, but the important feature is that of separability and consequent mobility.

2.1.2 Thermosets[3]

A thermoset is polymer material that irreversibly cures. Thermosets cannot be reprocessed upon reheating. During their initial processing, thermosetting resins undergo a chemical reaction that results in an infusible, insoluble network [4]. Essentially, the entire heated, finished article becomes one large molecule. The cure may be done through heat (generally above 200 degrees Celsius), through a chemical reaction or irradiation such as electron beam passing [5]. Some thermosets cure at room temperature because the heat produced by the exothermic reaction is sufficient to cure the plastic such as epoxy, polyester and urethane.

2.1.3 Differences between thermoplastics and thermosets [6]

The important difference is that thermoplastics remain permanently fusible so that they will soften and eventually melt when heat is applied, whereas cured thermoset polymers do not soften, and will only char and break down at high temperatures. This allows thermoplastic materials to be reclaimed and recycled.

The reason for this is that thermoplastics relatively weak forces attraction between the chains, which are overcome when the material is heated, unlike thermosets, where the cross-linking of the molecules is by strong chemical bonds. Effectively the thermoset is one large molecule, with no crystalline structure.

Compared with thermoplastics, thermosets are generally harder, more rigid and more brittle, and their mechanical properties are not heat sensitive. They are also less soluble in organic solvents.

2.2 PROCESSING OF POLYMERS

In polymer chemistry, polymerization is a process of reacting monomer molecules together in a chemical reaction to form polymer chains.

2.2.1 Thermoforming [7]

Thermoforming is a manufacturing process where a plastic sheet is heated to a flexible forming temperature, formed to a specific shape in a mold, and trimmed to create a usable product. The sheet, or “film” when referring to thinner gauges and certain material types, is heated in an oven to a high-enough temperature that it can be stretched into or onto a mold and cooled to a finished shape.

2.2.2 Melt Blowing [13]

Melt blowing is a process for producing fibrous webs or articles directly from polymers or resins using high-velocity air or another appropriate force to attenuate the filaments. The melt blowing process is one of the newer and least developed nonwoven processes. This process is unique because it is used almost exclusively to produce microfibers rather than fibers the size of normal textile fibers.

2.3 POLYMER MELTING [22]

The polymer melting mechanism in extruders has attracted much attention especially as experimental investigations have shown that the main morphology change occurs during the melting process. Comparable to experimental investigations, modeling has become another powerful and popular tool to study in detail the morphology generation during melting.

Lee and Han [22, 23] summarized several models provided by Tadmor and co-workers [22, 24] and Lindt's group [22, 25, 26] to describe the melting process occurring in single-screw extruders, and they developed a new model to predict the deformation and movement of the solid bed surrounded by its melt in single-screw extruders. The solid fractions along the extrusion channel and the prediction showed the same trend as experiments. Understanding of the polymer melting process in extruders has improved significantly through the efforts of previous researchers. Based on the findings, we might apply the related information for this project where we want to analyze the melt flow of polymer polypropylene during the heating process. However, we still cannot model how the morphology of polymers develops inside the channel of an extruder because of our poor understanding of the melting and deformation processes.

Since the melting process in extruders is not fully understood, morphology prediction has been restricted to the molten state. A sheeting mechanism was found to be an effective way of dispersing at the initial stage of morphology generation [22, 27, 28]. Willemse et al. [22, 28] theoretically explained the rapid decrease of the sheet thickness under shear flow by using simplified equations.

To model drop size in the molten state, one method is to divide the flow into different zones according to the local flow information such as shear rate. Another method is to simplify the boundary conditions for the flow in extruders by using unwound geometries. Two basic flows are generated in extruders: shear flow and extensional flow. Shi and Utracki [22, 30] and Huneault et al. [22, 29] used this method to study the morphology development in a twin-screw extruder by incorporating drop breakup and coalescence theories for generalized Newtonian fluids under shear flow. However, a significant portion of the morphology development of polymer blends occurs during the melting process in extruders. Theories for liquid drop deformation and breakup under shear flow may not be applicable to polymer drops during melting.

In this analysis, we used Fluent software to investigate the melt flow process of a polymer polypropylene during heating process.

2.4 POLYPROPYLENE [18]

Generally, wood is preferred for chopping boards as a thick board will last for quite a long time and the food does not slide over the surface. Wood also has the advantage of not blunting knives as quickly as other materials. However, other materials such as toughened glass and propylene also can be used for chopping boards.

For this final year project, the author used chopping board materials to produce polymer plate washer. Therefore, the material of novel polymer plate washer is polypropylene.

Polypropylene or polypropene (PP) is a thermoplastic polymer, made by the chemical industry and used in a wide variety of applications, including packaging, stationary, stationary, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes. An addition polymer made from the monomer propylene, it is rugged and unusually resistant to many chemical solvents, bases and acids.

Melt processing of polypropylene can be achieved through extrusion and molding. Common extrusion methods include production of melt blown and spun bond fibers to form long rolls for future conversion into a wide range of useful products such as face masks, filters, diapers and wipes.

The most common shaping technique is injection molding, which is used for parts such as cups, cutlery, vials, caps, containers, houseware and automotive parts such as batteries. The related techniques of blow molding and injection-stretch blow molding are also used, which involve both extrusion and molding.

2.5 LAWS AND PRINCIPLES

Measuring the flow of liquids is a critical need in many industrial plants. In some operations, the ability to conduct accurate flow measurements is so important that it can make the difference between making a profit and taking a loss.

For melt flow analysis of novel polymer plate washer, there are several laws and principles that might be applicable and related to the analysis.

2.5.1 Conservation of Mass Law [14]

The law of conservation of mass also known as principle of mass conservation is one of the most fundamental principle in nature. The conservation of mass principle for a control volume can be expressed as the net mass transfer to or form a control volume during a time interval Δt is equal to the net change (increase or decrease) in the total mass within the control volume during time interval Δt. The equation can be shown as:

$$\mathbf{m_{in} - m_{out} = \Delta m \ \ (kg)} \qquad \textbf{(2.1)}$$

where: $\mathbf{m_{in}}$ = total mass entering the control volume during Δt.

$\mathbf{m_{out}}$ = total mass leaving the control volume during Δt.

$\mathbf{\Delta m}$ = net change in mass within the control volume during Δt.

Mass, like energy, is a conserved property, and it cannot be created or destroyed during a process.

2.5.2 The Bernoulli Equation [14]

The Bernoulli equation is an approximate relation between pressure, velocity, and elevation, and is valid in regions of steady, incompressible flow where net frictional forces are negligible. We derive the Bernoulli equation by applying the conservation of linear momentum principle.

The key approximation in the derivation of the Bernoulli equation is that viscous effects are negligibly small compared to inertial, gravitational, and pressure effects. Since all fluids have viscosity, this approximation cannot be valid for an entire flow field of practical interest. In other words, we cannot apply the Bernoulli equation everywhere in a flow, no matter how small the fluid's viscosity. However, it turns out that the approximation is reasonable in certain regions of many practical flows. The Bernoulli equation can be shown as:

$$\frac{P}{\rho} + \frac{V^2}{2} + gz = \text{constant (along a streamline)} \qquad \textbf{(2.2)}$$

where: $\frac{P}{\rho}$ = flow energy

$$\frac{V^2}{2} = \text{kinetic energy}$$

$$gz = \text{potential energy}$$

This is the famous Bernoulli equation, which is commonly used in fluid mechanics for steady, incompressible flow along a streamline in inviscid regions of flow. The value of the constant can be evaluated at any point on the streamline where the pressure, density, velocity, and elevation are known. The Bernoulli equation can also be written between any two points on the same streamline as:

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + gz_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + gz_2 \qquad \textbf{(2.3)}$$

The Bernoulli equation is obtained from the conservation of momentum for a fluid particle moving along a streamline. It can also be obtained from the *first law of thermodynamics* applied to a steady-flow system.

2.6 PROPERTIES OF FLUIDS [16]

A fluid is any substance which flows because its particles are not rigidly attached to one another. This includes liquids, gases and even some materials which are normally considered solids, such as glass. Essentially, fluids are materials which have no repeating crystalline structure.

The properties of fluids are included temperature, pressure, mass, specific volume and density. *Temperature* was defined as the relative measure defined as the relative measure of how hot or cold a material is. It can be used to predict the direction that heat will be transferred. *Pressure* was defined as the force per unit area. *Mass* was defined as the quantity of matter contained in a body and is to be distinguished from weight, which is measured by the pull of gravity on a body. The specific volume of a substance is the volume per unit mass of the substance. *Density*, on the other hand, is the mass of a substance per unit volume. Density and specific volume are the inverse of one another. Both density and specific volume are dependant on the temperature and somewhat on the pressure of the fluid. As the temperature of the fluid increases, the density decreases and the specific volume increases. Since liquids are considered incompressible, an increase in pressure will result in no change in density or specific volume of the liquid. In actuality, liquids can be slightly compressed at high pressures, resulting in a slight increase in density and a slight decrease in specific volume of the liquid.

2.6.1 Bulk Elastic Properties [17]

The bulk elastic properties of a material determine how much it will compress under a given amount of external pressure. The ratio of the change in pressure to the fractional volume compression is called the bulk modulus of the material.

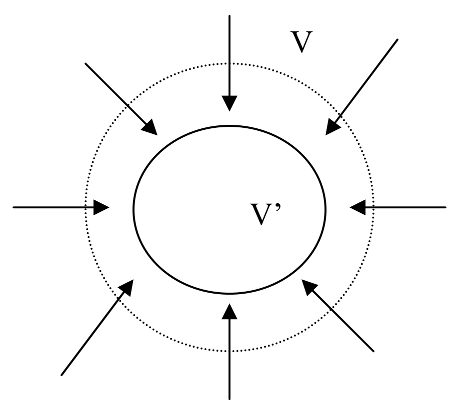

Figure 3: Representative of Bulk

The reciprocal of the bulk modulus is called the compressibility of the substance. The amount of compression of solids and liquids is seen to be very small. It is a common observation that a fluid contract when more pressure is applied on it and expands when the pressure acting on it is reduced (Figure 3). That is, fluids act like elastic solids with respect to pressure. Bulk modulus can be expressed approximately in terms of finite changes as:

$$B = \frac{\Delta P}{V/\Delta V} \quad (2.4)$$

Where **P**: pressure
V: volume

2.6.2 Standard Dimension

As a minimum, standard cut washers should be used with bolts to keep a bolt head or nut from causing crushing when tightening is taking place. If square or round plate washers are used, they must be of adequate thickness to prevent cupping and overstressing.

Table 1: Standard Dimension of Round Plate Flat washers [20]

Bolt Size	A	B	C	Weight In Pounds Per 100 Pieces
	Outside Diameter(inch)	Inside Diameter(inch)	Thickness Gauge (inch)	
3/8	2	7/16	3/16	16
1/2	2-1/4	9/16	3/16	20
5/8	2-1/2	11/16	1/4	32
3/4	3	13/16	1/4	46
7/8	3.5	15/16	5/16	79
1	4	1-1/16	3/8	124
1-1/4	5	1-3/8	3/8	193
1-1/2	5	1-5/8	3/8	184

CHAPTER 3
METHODOLOGY

3.1 ANALYTICAL MODEL DIAGRAM

3.1.1 Expected Outcome

Based on the study findings and experiment, the expected results of this analysis is the novel technique can be applied to produce polymer plate washer. This new technique is discovered to reduce time consuming while producing the polymer plate washer. The other manufacturing processes might be more applicable and suitable for the larger production of plate washers, so the cost will be higher and consumed more time and energy.

Step 1: The required equipments for this analysis are prepared. Heating rod and polymer sample are prepared to analyze the molten flow of polymer during fabrication of polymer plate washer. In this analysis, we used heating process.

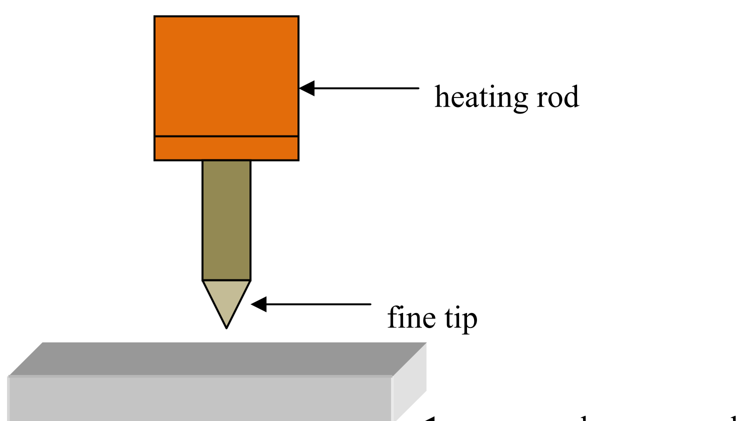

Figure 4: Molten Flow Process

Step 2: Heating rod is heated and forced into the polymer sample. The polymer is melted during the heating process.

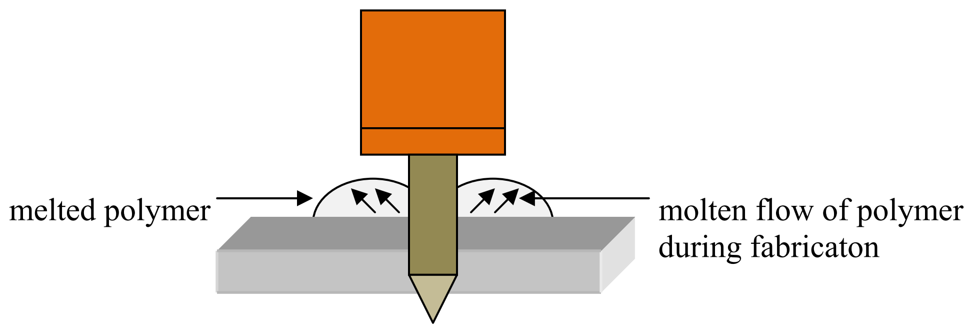

Figure 5: Molten Flow Process

Step 3: Heating rod is forced into the polymer until we get the required plate washer shape. There is some excessive molten polymer during the heating process.

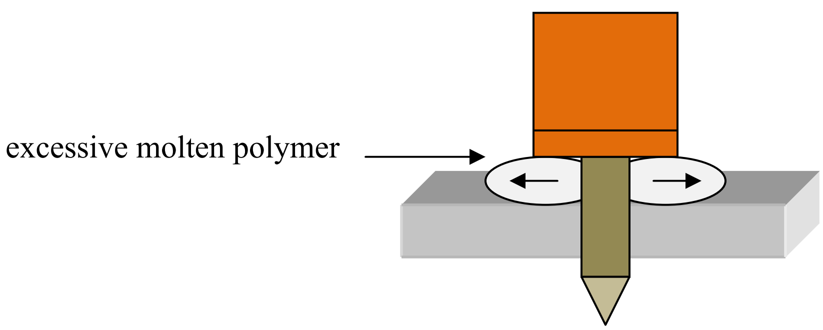

Figure 6: Molten Flow Process

Step 4: The heating process to produce polymer plate washer is done. The molten flow of polymer during the heating process is analyzed.

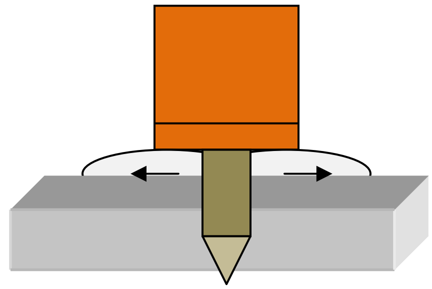

Figure 7: Molten Flow Process

3.2 COMPUTATIONAL METHOD

The whole project would start with the knowledge gathering and theoretical studies. Since the objective of this project is to study the melt flow analysis of novel polymer plate washer using Computational Fluid Dynamic (CFD), the result of this analysis will be simulated by using FLUENT software. Learning the FLUENT software application would be the first step in this project. After knowing the basic knowledge on how to run FLUENT software, the study of analysis will be continued by entering some data in order to get the result. Research also will keep on going on the possibility of any new technique, for this project is a novel technique that still can produce polymer washer but much easier and less tedious. Then, a methodology will be developed according to the step-by-step procedures. Meanwhile, further research and development would be continuously practiced to ensure satisfactory results are achieved. The recommendations are recommended to improve the results of analysis.

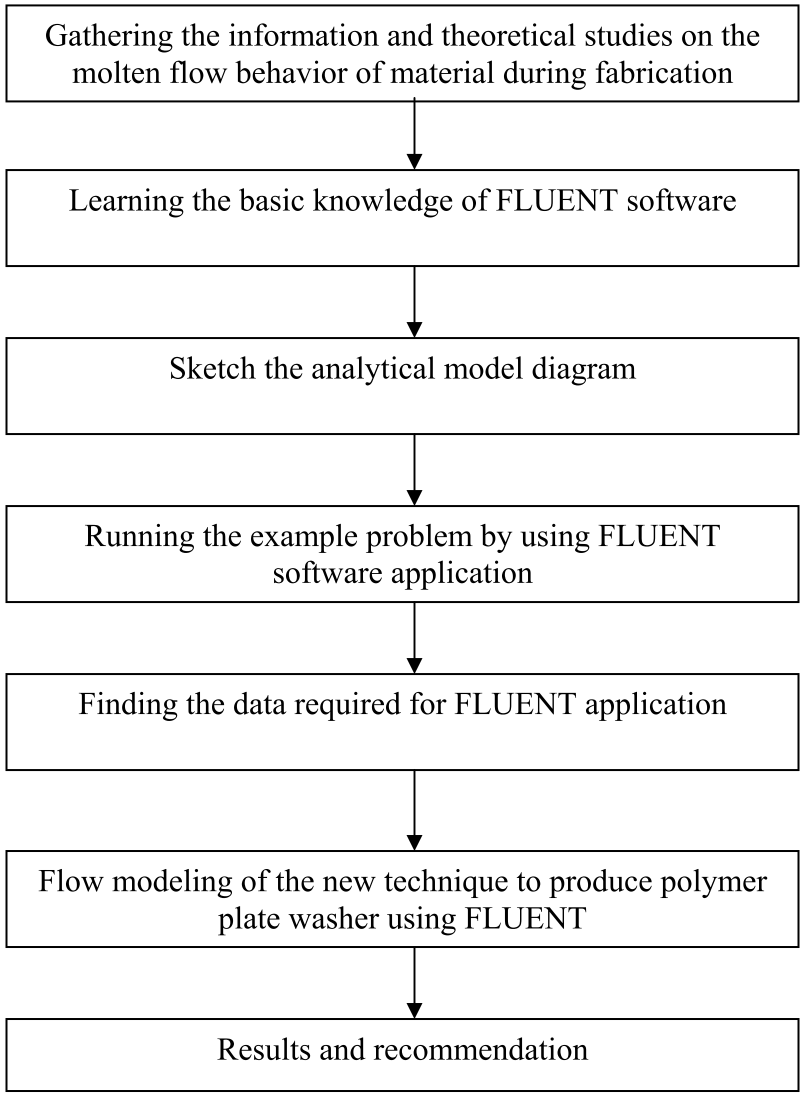

Figure 8: Flow Process of The Analysis

CHAPTER 4
RESULTS AND DISCUSSION

4.1 ANALYTICAL RESULTS

4.1.1 Data

Below are the information related to the polymer plate washer for this analysis:

External diameter of polymer washer, OD = range (12 to 15) mm
Internal diameter, ID = diameter of solder/washer hole = (5 to 6) mm
Thickness of polymer washer, t = (1 to 2) mm
Temperature of solder, T = 450°C
Speed of penetration = 3-4 s
Material = polymer
Length of solder/heating rod (excluded fine tipped part), h = 150 mm
Length of tipped part, h'= 80 mm
Length of chopping board, L = 220 mm
Width of chopping board, W = 170 mm
Thickness of chopping board, H = 6.5 mm

Calculation:

Volume of cylinder, $V = \Pi r^2 h$

$$V = \Pi \text{ x } (6\text{x}10^{-3}) \text{ m}^2 \text{ x } (150\text{x}10^{-3}) \text{ m}$$

$$V = 2.827\text{x}10^{-3} \text{ m}^3$$

4.1.2 Discussion

The early result obtained from the analysis is analyzed by using analytical method. Based on the early data and result, the heating rod will produce heat during heating process. Heating is often achieved electrically, by passing an electrical current through the resistive material of a heating element. The sample taken for polymer material is a chopping board. The material will melt during the heating process as shown in Figure 6. Heating rod is forced into the chopping board until we get the required shape of polymer plate washer. There will be some excessive molten polymer throughout the heating process. After the heating process is completed and we get the required shape, the molten flow of polymer during the heating process is analyzed.

4.2 GAMBIT AND FLUENT SIMULATION RESULT

After the analytical diagram has been modeling, the next step of this project is to simulate the melt flow analysis of polymer plate washer by using computational fluid dynamics (CFD) software which is FLUENT as related to the project. First step of simulating the melt flow analysis is by running the example problem of flat plate analysis.

The objective of this example problem is to model the flow over a flat plate aligned parallel to the freestream flow. Only the upper half of the geometry needs to be generated because of the symmetry as shown in the Figure 9 below:

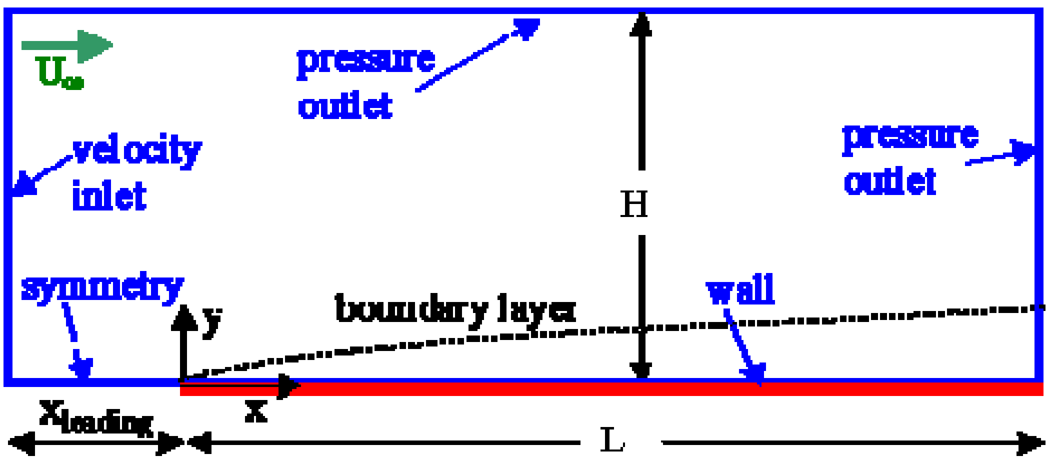

Figure 9: Sketch of The Freestream Flow Direction [19]

In the sketch, *x* is the freestream flow direction, parallel to the flat plate. Coordinate *y* lies normal to the plate. The *z* direction is out of the page. The problem is two-dimensional, so imagine that the plate extends to infinity in the *z* direction.

The length of the flat plate is L = 0.5 m, and the height of the computational domain is H = 0.40 m. The inlet is located far enough upstream of the plate so that uniform freestream flow exists. In this example, the inlet is $x_{leading}$ = 0.1 m upstream of the leading edge of the flat plate.

From Figure 10, we can see a structured mesh has been generated. We also can see how cells are nicely clustered near the leading edge of the flat plate. This will help Fluent to resolve the boundary layer along the flat plate.

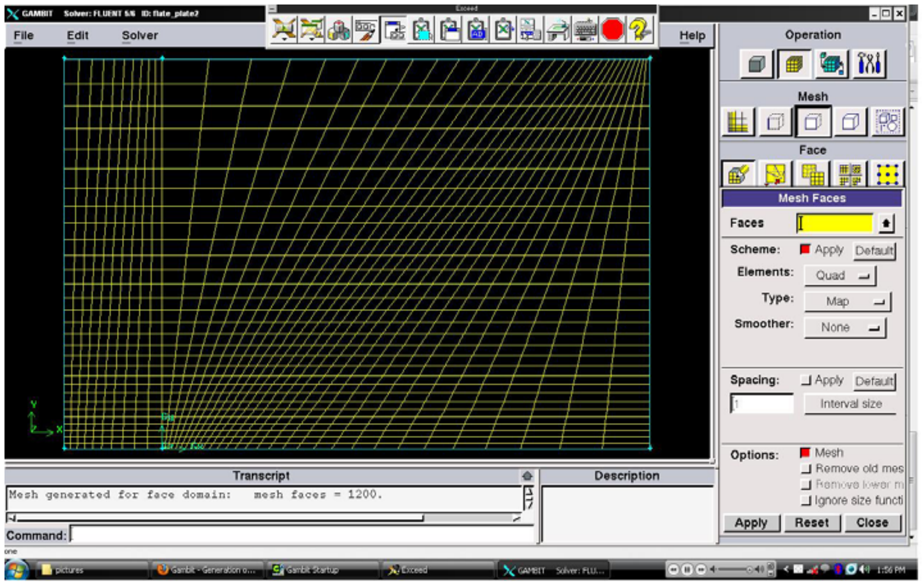

Figure 10: Mesh Generated by using GAMBIT

From Figure 11, a boundary layer profile has been generated. The boundary layer profile will be examined in detail at three locations along the flat plate, namely at x = 0.10m, 0.30m, and 0.50m. The last of these is the outlet of the domain, but lines need to be defined within Fluent for the first two.

Figure 11: Boundary Layer Profile

From Figure 12, velocity vectors are displayed by using scale at 10 to see the profiles more clearly. The velocity profile were plotted at three desired downstream locations where x = 0.10m, 0.30m, and 0.50m.

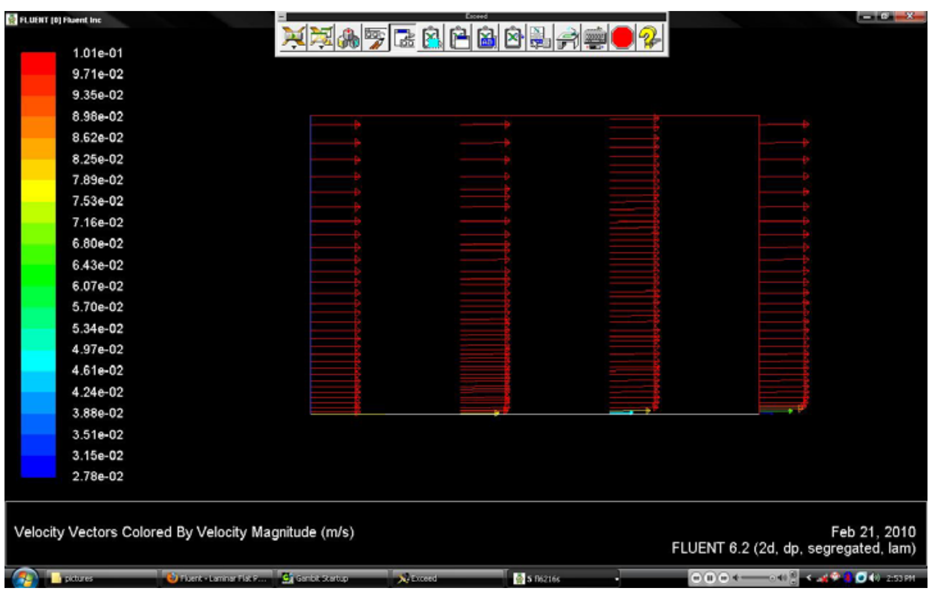

Figure 12: Velocity Vector Using Scale 10

From Figure 13, we can see there are three velocity profiles visible on the plot and the growths of the boundary layer with downstream distance are apparent.

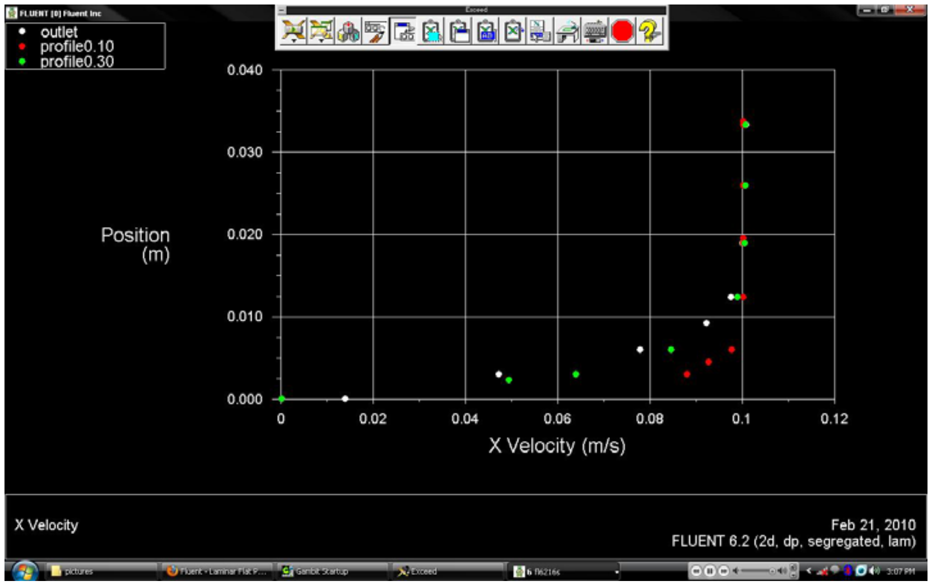

Figure 13: Velocity Profile

Then, the next step of this project after simulating the example problem of flat plate analysis is to simulate the author's project which is to simulate the melt flow analysis of polymer plate washer by using FLUENT as related to the project.

The data required to run the FLUENT software are fluid properties of polypropylene as shown in Table 2 below:

Table 2: Fluid Properties of Polypropylene

Properties	Polypropylene
Density, ρ (kg/m^3)	900
Heat capacity, c_p (J/kg-K)	2 900
Thermal conductivity, K (W/m-K)	0.4
Viscosity, μ (kg/m-s)	3.075×10^{-4}

We noticed from Figure 14, that the velocity magnitude increase when position is decrease but for position at 2 mm, the velocity magnitude is decrease until it reaches approximately 0 mm, at the outlet boundary condition. This shows the relative thinness of the boundary layer compared to the length scale of the plate. We chose the velocity inlet boundary condition at the top of our flow field, where the melt flow is flowing at the top plate and pressure outlet boundary condition on the left of the flow field.

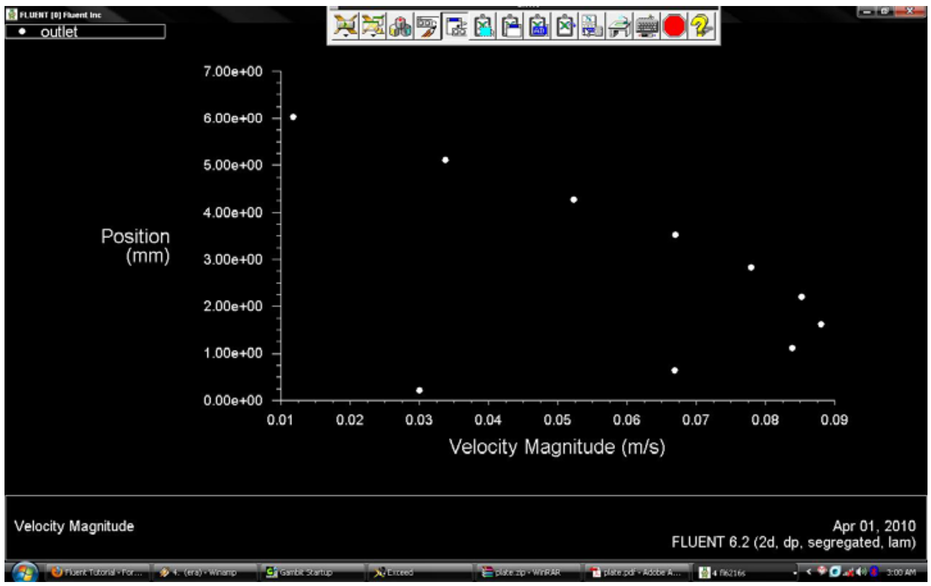

Figure 14: Outlet – Position vs. Velocity Magnitude

Figure 15 shows position versus velocity magnitude graph for the right boundary condition. We can see that velocity is increase as position is increase. This shows that the velocity is lower near the plate. In addition, the fluid is expanding near the plate because its temperature is increasing, further increasing the velocity of the fluid above it. These factors require that some mass must escape through the top of our flow field in order to satisfy conservation of mass.

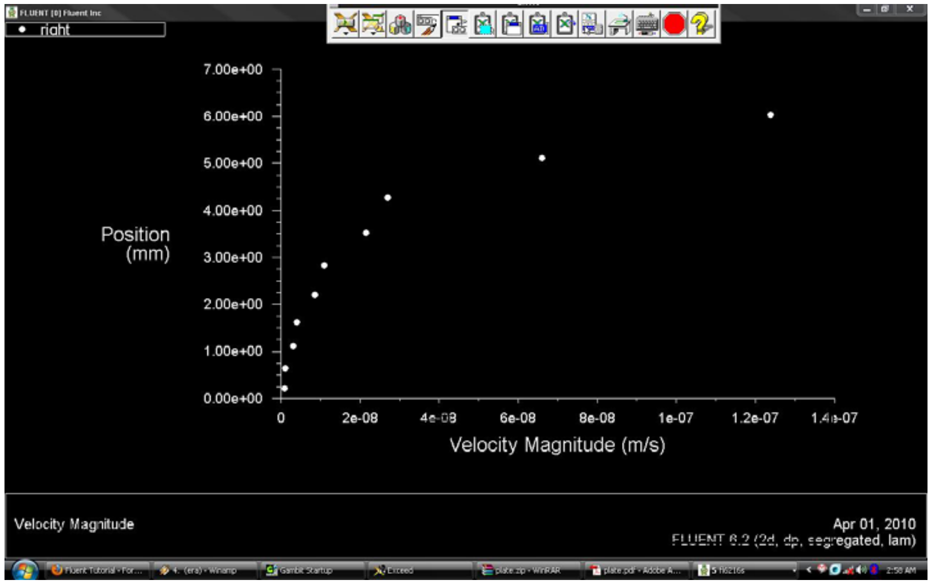

Figure 15: Right – Position vs. Velocity Magnitude

During initial heating, the viscosity remains too high for the particles to undergo significant movement, and the mass is steady. After flow begins, the sample enters a long quasi steady period, during which the mass decreases linearly with time and therefore the mass loss rate is constant with time, as the free surface of the melt flow moves back. When the free surface reaches the top of the back wall in Figure 16, the mass loss rate speeds up. As the top point of contact with the back loses height, the mass loss rate slow again, until the material has completely flowed out.

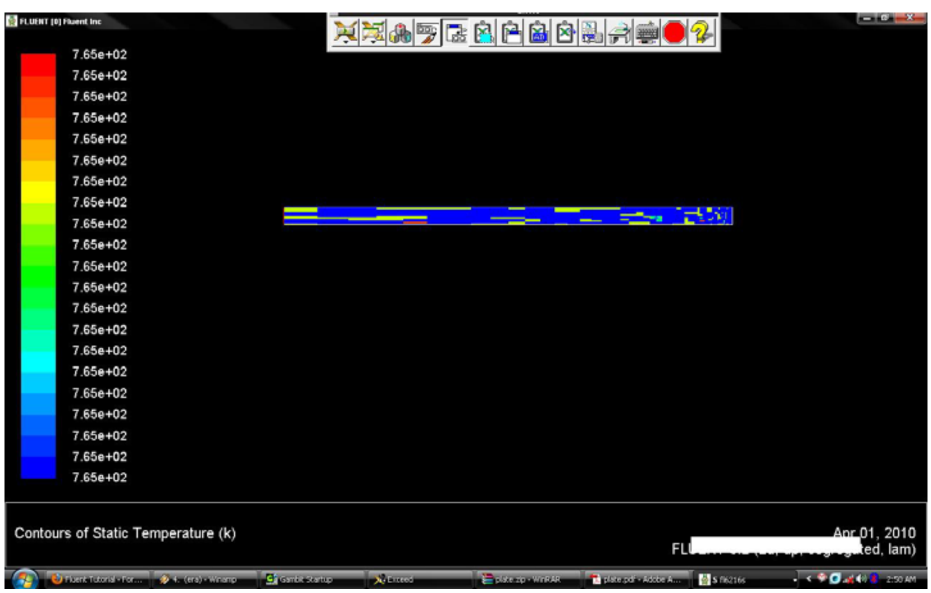

Figure 16: Contours of Static Temperature

Figure 17 shows velocity colors by velocity magnitude. Velocity vectors showing flow pattern obtained from the simulation of polymer melting flow during heating process by using soldering rod. As we can see, the temperature is increases as the heating rod goes deeper into the polymer sample. This is because the heating rod is not at its highest temperature during the rod is entered to the polymer sample. Therefore, the temperature may increase and produce more heat during the heating process is undergone.

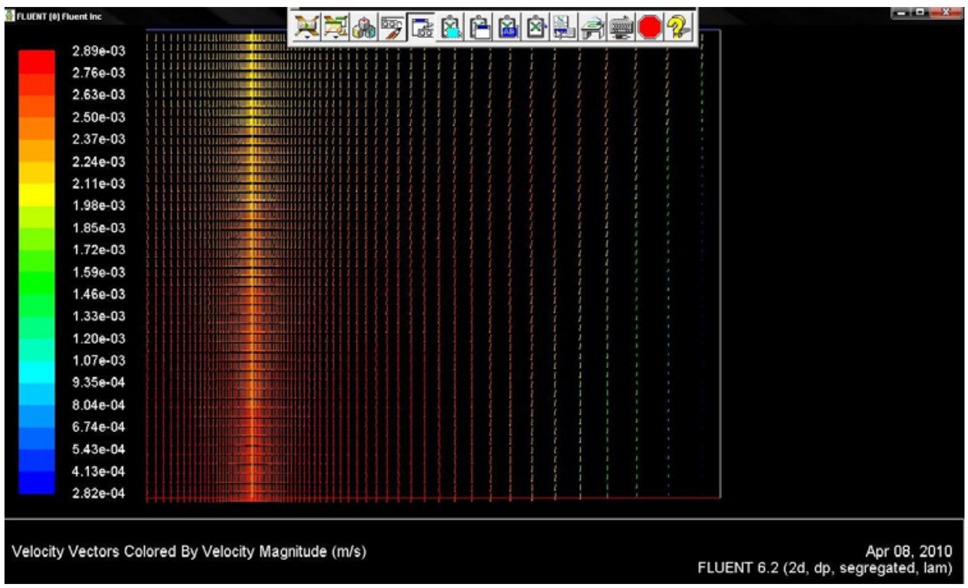

Figure 17: Velocity Colors by Velocity Magnitude

To better comprehend the velocity variation within the polymer, Figure 18 illustrates a vector plot overlaid on a contour plot of velocity magnitude with units in m/s. The contour plot shows many of the same techniques discussed with the previous figure. The contour plot employs the psychological association of the cooler (blue) colors with inactivity (lower velocities) and hot colors (red) with activity (higher velocities) by reversing the default color scale.

Figure 18 gives much more insight into the velocity variation in the polymer. Apparent from the figure, a region of acceleration occurs at the left side which for this problem, the heating process is occurring. During the process, the heating rod is forced into the polymer as we can see the left side with red hot colors. The region with cooler blue colors indicates that the polymer is not undergoing any heating process where the heat is not flowing through that region. From the figure also, we can see that flow accelerates as it enters the polymer until the heating process is done.

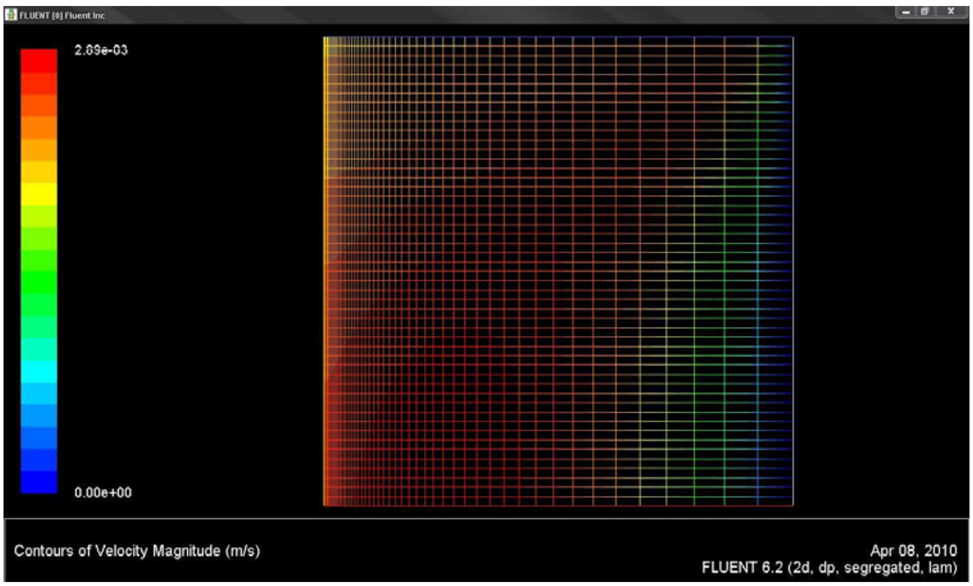

Figure 18: Contours of Velocity Magnitude

Figure 19 shows the inlet velocity where x-velocity versus position. The inlet is the velocity of heating rod during it is entered into the polymer. From the figure, as we can see the velocity is increasing starting from the surface until the heating rod exit the polymer. After the position = 0.006 m, we can see that the velocity is slightly decrease. This is might be due to the pulling back of heating rod from the polymer.

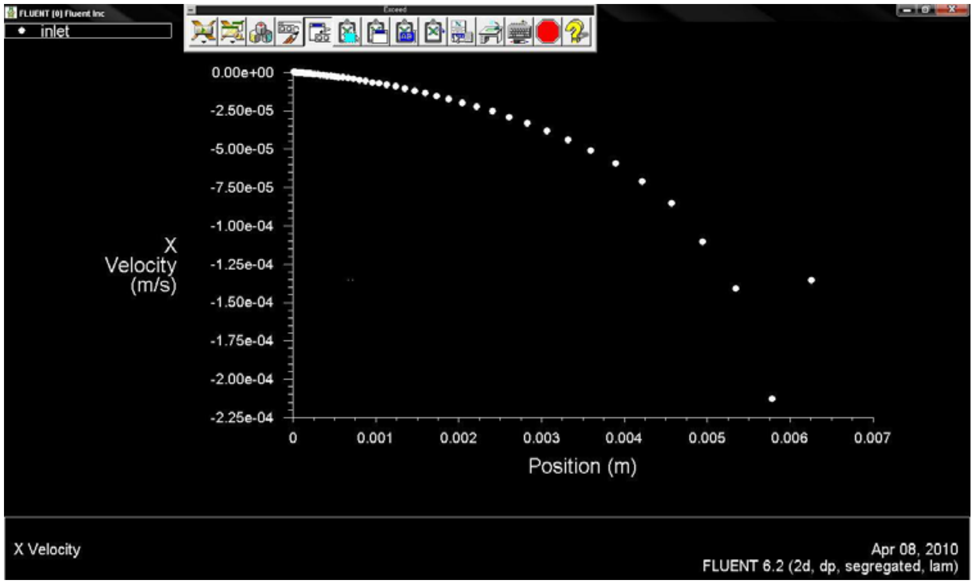

Figure 19: Inlet – X-Velocity vs. Position

Figure 20 shows the outlet velocity where velocity magnitude versus position. The outlet is the velocity of heating rod during it is pulling back from the polymer. From the figure, as we can see the velocity is decreasing in contrast with the previous figure which is increasing. The velocity is continuously decreasing until the heating process has stopped and the heating rod has reached at the end of polymer.

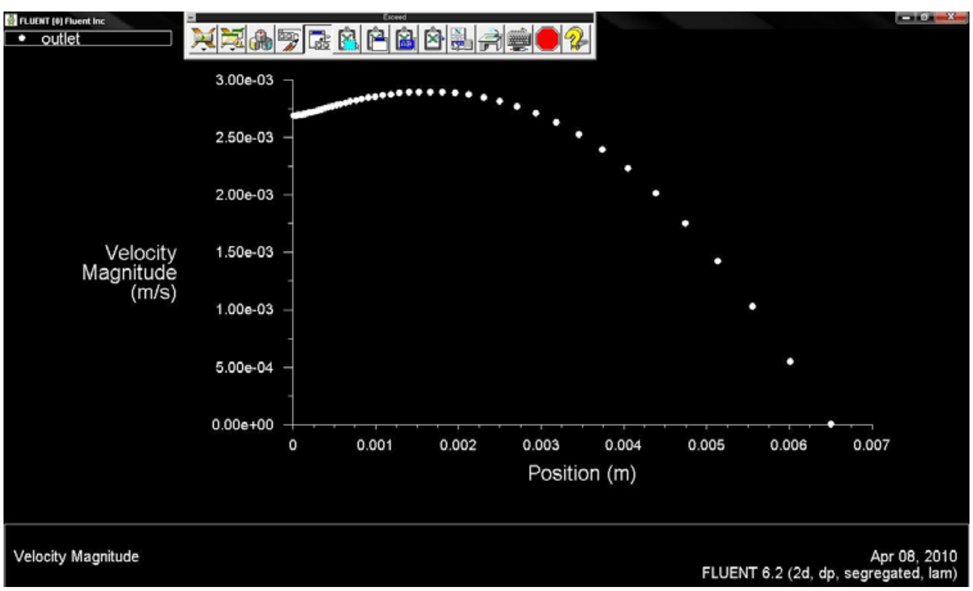

Figure 20: Outlet – Velocity Magnitude vs. Position

During the iterative solution algorithm, the imbalance in each cell is a small, non-zero value that, under normal circumstances, decreases as the solution progresses. This imbalance is called the residual. The total residual for each variable across the entire solution domain is the sum of the absolute values of the individual cell residuals. This total residual is often scaled so that the residuals of different variables can be compared or combined. The residual plot has been plotted in Figure 21 with four residuals which are continuity, x-velocity, y-velocity and energy. The residual has been iterated up to 1000 iterations until the solution no longer changes with more iteration.

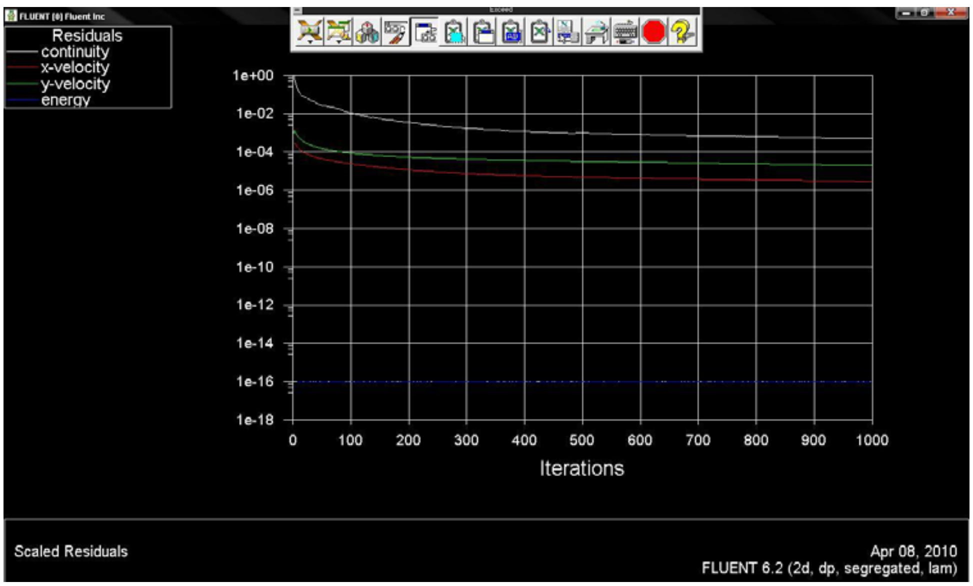

Figure 21: The Residuals Plot

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From the result, we can conclude about the flow behavior of the molten polymer during the heating or fabrication process. During the heating process, some excessive molten polymer will be produced due to the force of heating rod applied into the sample of polymer. The heated polymer was compressed in order to get the plate washer shape and this cause the excessive part is occurred.

The temperature is increases as the heating rod entered the polymer sample. This is because the heating rod is not at its highest temperature during the rod is entered into the polymer sample. Hence, the temperature may increase and produce more heat during the heating process is undergone. For that reason, it causes the polymer melting and forms a flat plate when it gets compressed by the flat surface of heating rod.

The ability of the FLUENT to model thermoplastic polypropylene melt flow has been tested by modeling the flow of polymeric material out of the heated/back extruded sample during heating/back extrusion process. Although it requires further experiment and analysis, the results show that during the modeling process under study the thermoplastic polymer exhibits melt non Newtonian flow behavior.

5.2 RECOMMENDATION

For the recommendation, the author should do more example problem by using GAMBIT and FLUENT. The author will have a better knowledge when facing a different problem by using the software required.

The author should improve the result of melt flow analysis by doing more simulation but on different discipline of FLUENT. The result also can be improved by doing more studies and research on the similar problem by other authors. By doing this, the author may discover more new solution for the simulation.

CHAPTER 6
REFERENCES

1. Plate washer.<http://www.absoluteastronomy.com/topics/Washer_(mechanical)>. Accessed 2009 Aug.
2. Polymer.<http://wapedia.mobi/en/Polymer>. Accessed 2009 Aug.
3. Thermoplastic. <http://en.wikipedia.org/wiki/Thermoplastic>. Accessed 2009 Aug.
4. Plastic.Chemical compound. <http://www.britannica.com/EBchecked/topic/463684/plastic/82463/Thermoplastic-and-thermosetting>. Accessed 2009 Aug.
5. Thermosetting plastic. <http://en.wikipedia.org/wiki/Thermosetting_polymer>. Accessed 2009 Aug.
6. Differences between thermoplastics and thermosets. <http://www.ami.ac.uk/courses/topics/0210_pt/solutions/sol_01.html>. Accessed 2009 Aug.
7. Serope Kalpakjian, Steven R. Schmid. Manufacturing Engineering and Technology, Pearson Prentice Hall 8th Edition, (2006).
8. Polymers and polymer composites in construction <http://books.google.com.my/books?id=8SqmyiZz6GIC&pg=PA12&lpg=PA12&dq=what+is+polymer+calendering+process&source=bl&ots=aVnxh10dKR&sig=2ow79dtxTidwiLbWV9S-9rZu6HA&hl=en&ei=h4OmStryM5eNkAXjiqmMCQ&sa=X&oi=book_result&ct=result&resnum=5#v=onepage&q=what%20is%20polymer%20calendering%20process&f=false>. Acessed 2009 Sept.

9. Polymer calendering process <http://images.google.com.my/imgres?imgurl=http://www.aipma.net/info/pp14.gif&imgrefurl=http://www.aipma.net/info/plasticprocess.htm&usg=__UwuW0R3BudQS-AZ7xpBqIsq-KXA=&h=354&w=500&sz=23&hl=en&start=35&tbnid=zk0OJ2jZzZtkKM:&tbnh=92&tbnw=130&prev=/images%3Fq%3Dpolymer%2Bcalendering%2Bprocess%26gbv%3D2%26ndsp%3D20%26hl%3Den%26sa%3DN%26start%3D20>. Accessed 2009 Sept.
10. Punching process <http://www.custompartnet.com/wu/sheet-metal-shearing#punching>. Accessed 2009 Sept.
11. Calendaring process <http://www.achooallergy.com/allergy-relief-bedding-uncovered.asp>. Accessed 2009 Sept.
12. Typical calendar line<http://www.geomembrane.com/PGI%20Tech%20Bull/86-05.htm>. Accessed 2009 Sept.
13. Melt blown technology <http://www.engr.utk.edu/mse/pages/Textiles/Melt%20Blown%20Technology.htm>.Accessed 2009 October.
14. Yunus A. Cengel, John M. Cimbala. Fluid Mechanics Fundamentals and Applications, McGraw Hill International Edition (2006)
15. Navier-Stokes equation <http://en.wikipedia.org/wiki/Navier–Stokes_equations>.Accessed 2009 October.
16. Properties of fluids <http://www.tpub.com/content/doe/h1012v3/css/h1012v3_24.htm>.Accessed 2009 October.
17. Bulk Elastic Properties <http://hyperphysics.phy-astr.gsu.edu/hbase/permot3.html>.Accessed 2009 October.
18. Polypropylene <http://en.wikipedia.org/wiki/Polypropylene> Accessed 2010 February.
19. Generation of Grid for a Flat Plate Boundary Layer <http://www.mne.psu.edu/cimbala/Learning/Fluent/gambit_flatplate.htm> Accessed 2010 February.

20. Standard dimension of round plate flat washers <http://www.portlandbolt.com/products/washers/index.html> Accessed 2010 February.
21. Polymer <http://en.wikipedia.org/wiki/Polymer> Accessed 2010 May.
22. Modeling of polymer melting, drop deformation and breakup under shear flow <http://findarticles.com/p/articles> Accesses 2010 May.
23. K. Y. Lee and C. D. Han, Polym. Eng. Sci., 30, 665 (1990).
24. Z. Tadmor, I. Duvdevani, and R. T. Klein, Polym. Eng. Sci., 7, 198 (1967).
25. B. Elbirli, J. T. Lindt, S. R. Gottgetreu, and S. M. Baba, Polym. Eng. Sci., 24, 988 (1984).
26. J. T. Lindt and B. Elbirli, Polym. Eng. Sci., 25, 412 (1985).
27. U. Sundararaj, Y. Dori, and C. W. Macosko, Polymer, 36, 1957 (1995).
28. R. C. Willemse, E. J. J. Ramaker, J. V. Dam, and A. P. D. Boer, Polymer, 40, 6651 (1999).
29. M. A. Huneault, Z. H. Shi, and L. A. Utracki, Polym. Eng. Sci., 35, 115 (1995).
30. Z. H. Shi and L. A. Utracki, Polym, Eng. Sci., 32, 1834 (1992).

CHAPTER 7

APPENDIXES

Table A1: Gantt Chart for FYP 1 Semester July 2009

No.	Activities	Week No / Date													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of the Project Topic														
2	Preliminary Research Work														
3	Submission of Preliminary Report					21/8									
4	Project Work														
5	Submission of Progress Report								8/9						
6	Seminar								11/9						
7	Project Work Continues														
8	Submission of Interim Report Final Draft														26/10
9	Oral Presentation										2/11 - 6/11				

Table A2: Gantt Chart for FYP 1I Semester January 2010

		WEEK NO / DATE													
NO.	ACTIVITIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Progress Work 1														
2	Submission of Progress Report 1					22/2									
3	Simulate the example of FLUENT														
4	Submission of Progress Report 2								22/3						
5	Seminar								24/3						
6	Simulate the project by using FLUENT														
7	Seek SV / GA for any help														
8	Simulation Work Continues														
9	Poster Submission											12/4			
10	Project Work Continues (smooth and finish)														
11	Submission of Dissertation Draft														3/5
12	Oral Presentation	During Study Week (10/5 – 14/5)													
13	Hardbound Dissertation	During Exam Week (17/5 – 21/5)													