



Faculty of Manufacturing Engineering

**COMPARISON OF PROPERTIES OF POLYPROPYLENE/
FIBER GLASS IN INJECTION MOULDING PROCESS
USING DIFFERENT GATE LOCATIONS**

Lorita Lawi Anak Balai

**Master of Manufacturing Engineering
(Manufacturing System Engineering)**

2018

**COMPARISON OF PROPERTIES OF POLYPROPYLENE/FIBER GLASS
IN INJECTION MOULDING PROCESS USING DIFFERENT GATE
LOCATIONS**

LORITA LAWI ANAK BALAI

**A thesis submitted
in fulfillment of the requirements for the degree of Master of Manufacturing
Engineering (Manufacturing System Engineering)**

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

DECLARATION

I declare that this thesis entitled “Comparison of Properties of Polypropylene/Fiber Glass In Injection Moulding Process Using Different Gate Locations” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name :

Date :

DEDICATION

I am dedicating this work to my beloved parents Balai Anak Ramping and Terusa Anak Blalang, who always inspire and support me with their boundless love to work hard for the things that I aspire to achieve

ABSTRACT

This project investigates the mechanical properties of polypropylene filled with fiber glass in injection molding process using single and twin gate locations. The objective of this study is to compare the mechanical properties of polypropylene filled with fiberglass having the difference gate location injected by injection molding machine using Taguchi method. The investigated mechanical properties were tensile strength, modulus strength and percentage of elongation. The effect melt temperature, holding pressure, injection time and cooling time on the mechanical properties of the material were studied. L9 orthogonal arrays with 3 replications were done with 27 totals of specimens for each gate location. The result collected was optimized using Taguchi method and P-value and R-square were calculated using analysis of variance (ANOVA). According to the result analysis, it is found that single gate location shows good in tensile strength and percentage of elongation. The significant factors that affected the tensile strength are cooling time, injection time, holding pressure and melt temperature. The significant factors that affected the percentage of elongation is melt temperature followed by cooling time, holding pressure and injection time. Meanwhile, twin gate location shows the highest modulus of strength. The significant factors that affected the modulus strength are cooling time, melt temperature, holding pressure and injection time. Thus, this result shows that in twin gate location, fiberglass in polypropylene melt penetrate in between gate location, as result modulus strength in twin gate greater than single gate. Meanwhile, in single gate location, one-way flow of fiber glass in dumbbell test specimen which resulted the tensile strength and percentage of elongation higher than twin gate location

ABSTRAK

Kajian ini adalah mengenai perbezaan ciri-ciri mekanikal penambahan gentian kaca ke dalam polipropilena di proses suntikan acuan dengan menggunakan laluan tunggal dan laluan berkembar. Jadi objektif pembelajaran ini ialah untuk membandingkan ciri-ciri mekanikal penambahan gentian kaca ke dalam polipropilena yang mempunyai laluan berbeza dengan menggunakan kaedah Taguchi. Ciri-ciri mekanikal yang dikaji adalah kekuatan tegangan, modulus kekuatan, dan peratus pemanjangan. Parameter yang telah ditetapkan untuk proses suntikan plastik adalah suhu pencairan, tekanan pegangan masa suntikan, dan masa penyejukan. L9 pelbagai ortogon dengan 3 replikasi dibuat untuk 27 jumlah sample bagi setiap laluan. Hasil ujian ketegangan seterusnya dianalisis oleh perisian Minitab 17 menggunakan kaedah taguchi dan analisis ANOVA. Hasil kajian mendapati kekuatan tegangan dan peratusan pemanjangan untuk laluan tunggal adalah lebih baik dari laluan berkembar. Manakala kekuatan tegangan modulus adalah lebih baik bagi laluan berkembar. Faktor signifikan yang mempengaruhi kekuatan tegangan ialah masa penyejukan diikuti masa suntikan, tekanan pegangan dan suhu pencairan. Faktor signifikan yang mempengaruhi peratusan pemanjangan ialah suhu pencairan diikuti masa penyejukan, tekanan pegangan dan masa suntikan. Faktor signifikan yang mempengaruhi kekuatan pegangan modulus ialah masa penyejukan diikuti suhu pencairan, tekanan pegangan dan masa suntikan. Oleh itu, keputusan ini menunjukkan bahawa di laluan kembar, gentian kaca dalam polipropilena mencairkan menembusi di antara lokasi gerbang, maka kekuatan modulus hasil dalam laluan kembar lebih tinggi berbanding pintu tunggal. Sementara itu, di laluan tunggal, satu arah aliran kaca serat dalam spesimen ujian dumbbell yang menghasilkan kekuatan tegangan dan peratusan pemanjangan yang lebih tinggi daripada laluan kembar.

ACKNOWLEDGEMENTS

First and foremost I would like to express my gratitude to God because of His love and strength that He has given to me to complete my master project. I do thanks for His blessings to my daily life, good health, healthy mind and good ideas especially during the completion of this project.

I would like to take this opportunity to extend my deepest gratitude to my supervisor, Associate Professor Dr. Mohd Amran Bin Md Ali for his excellent cooperation and supervisions in spite of being extraordinarily busy with his daily duty. Thank you for all guidance, advices, supports and the opportunity given for me to learn and endure the experience while working on this project.

In addition, I would like to thank my beloved parents and family for their unconditional love and support; I would not have been able to complete this study without their continuous love and encouragement. Besides, I would like to express my appreciation to all assistant engineers and lecturers in Faculty of Manufacturing Engineering, UTeM for their sincere assistance and knowledge sharing regarding this project.

Special thanks go to my friend, Nur Syahirah binti Mazda@Mazdarudin for helping me through this academic exploration. Lastly, thank you to everyone who had been to the crucial parts of realization of this project

TABLE OF CONTENTS

	PAGE
DECLARATION	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	ix
LIST OF APPENDICES	xi
LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES	
xii	
CHAPTER	
1. INTRODUCTION	1
1.1 Background of Study	1
1.2 Problem Statement	2
1.3 Objectives	3
1.4 Scope of Study	3
1.4 Organisation of Report	4
2. LITERATURE REVIEW	5
2.1 Injection Molding	5
2.1.1 Injection molding machine	5
2.1.1.1 Injection unit	6
2.1.1.2 Clamping unit	7
2.1.1.3 Injection moulding mould	8
2.1.2 Process and cycle	10
2.1.3 Common defects in injection molding	11
2.2 Injection molding parameter	14
2.3 Plastics Materials	15
2.3.1 Properties of polypropylene	16
2.3.2 Properties of polypropylene filled with fibre glass	16
2.4 Tensile Testing	19
2.4.1 Stress-strain curve	21
2.5 Optimization Method	22
3. METHODOLOGY	25
3.1 Overall flow of the project	25
3.2 Selection of parameters	27
3.3 Design of Experiment	27
3.4 Injection Molding	28
3.4.1 Injection molding machine	28
3.4.2 Injection molding process	29
3.4.3 Polypropylene filled with fibre glass	31
3.4.4 Mould	32

3.5	Tensile Test	32
	3.5.1 Specimen	32
	3.5.2 Performing tensile test	33
3.6	Mechanical Properties	34
	3.6.1 Tensile strength	34
	3.6.2 Modulus of strength	35
	3.6.3 Percentage of elongation	35
3.7	Analysation of data using Design of Experiment	35
4.	RESULT AND DISCUSSION	36
4.1	Results for single gate location	36
	4.1.1 Tensile strength	36
	4.1.2 S/N response for tensile strength	38
	4.1.2.1 S/N response plot for tensile strength	39
	4.1.3 Analysis of Variance (ANOVA)	40
	4.1.4 Validation of parameter for tensile strength	41
	4.1.5 Result for modulus of strength	41
	4.1.6 S/N response for modulus of strength	43
	4.1.6.1 S/N response plot for modulus of strength	44
	4.1.7 Analysis of Variance (ANOVA)	45
	4.1.8 Validation of parameters for modulus of strength	46
	4.1.9 Result for percentage of elongation	47
	4.1.10 S/N Response for percentage of elongation	48
	4.1.10.1 S/N Response plot for percentage of elongation	48
	4.1.11 Analysis of Variance (ANOVA)	50
	4.1.12 Validation of parameters for percentage of elongation	51
4.2	Results for twin gate location	52
	4.2.1 Tensile strength	52
	4.2.2 S/N response for tensile strength	54
	4.2.2.1 S/N response plot for tensile strength	54
	4.2.3 Analysis of Variance (ANOVA)	56
	4.2.4 Validation of parameter for tensile strength	57
	4.2.5 Result for modulus of strength	57
	4.2.6 S/N response for modulus of strength	59
	4.2.6.1 S/N response plot for modulus of strength	60
	4.2.7 Analysis of Variance (ANOVA)	61
	4.2.8 Validation of parameters for modulus of strength	62
	4.2.9 Result for percentage of elongation	63
	4.2.10 S/N Response for percentage of elongation	64
	4.2.10.1 S/N Response plot for percentage of elongation	65
	4.2.11 Analysis of Variance (ANOVA)	66
	4.2.12 Validation of parameters for percentage of elongation	67
4.3	Comparison between single gate location and twin gate location	68
5.	CONCLUSION AND RECOMMENDATION	72
5.1	Conclusion	72
5.2	Recommendation	73

REFERENCES	74
APPENDICES	80

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Component in the mould	8
2.2	Common defect in injection molding process	12
2.3	Processing parameter in injection molding process	15
2.4	Properties of unfilled PP	16
2.5	Summary of the optimization method	24
3.1	Process parameters	27
3.2	Orthogonal Array of the Taguchi method for tensile test for polypropylene filled with fibre glass	28
3.3	Injection moulding machine capabilities	29
3.4	Properties of Dynaglass PPG3637	31
4.1	Result of tensile strength of polypropylene filled with fibre glass using single gate	37
4.2	S/N ratio for tensile strength using single gate location	38
4.3	Response table for signal to noise ratio of tensile strength using single gate	39
4.4	Best combination of parameters	39
4.5	ANOVA computation using Minitab software for tensile strength using single gate	41
4.6	Results for Modulus of Strength of single gate location	42
4.7	S/N ratio for modulus of strength using single gate	43
4.8	Response table for signal to noise ratio of modulus of strength using single gate	44
4.9	Best combination of parameters for modulus of strength	44
4.10	ANOVA computation using Minitab software modulus of strength using single gate	46
4.11	Results for percentage of elongation using single gate	47
4.12	S/N ratio for percentage of elongation for single gate	48

4.13	Response table for signal to noise ratio of percentage of elongation using single gate	49
4.14	Best combination of parameters for percentage of elongation	49
4.15	ANOVA computation using Minitab software for percentage of elongation	51
4.16	Result for tensile strength using twin gate	53
4.17	S/N ratio for tensile strength using twin gate location	54
4.18	Response table for signal to noise ratio of tensile strength	54
4.19	Best combination of parameters	55
4.20	ANOVA computation using Minitab software for tensile strength	56
4.21	Result for the modulus of strength using twin gate location	58
4.22	S/N ratio for modulus of strength using twin gate	59
4.23	Response table for signal to noise ratio of modulus of modulus of strength	60
4.24	Best combination of parameters	61
4.25	ANOVA computation using Minitab software modulus of strength using twin gate	62
4.26	Results of percentage of elongation using twin gate location	63
4.27	S/N ratio for percentage of elongation using twin gate location	64
4.28	Response table for signal to noise ratio of percentage of elongation using twin gate location	65
4.29	Best combination of parameters	65
4.30	ANOVA computation using Minitab software for percentage of elongation using twin gate	67

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Formation of weldline	2
2.1	Injection molding machine	6
2.2	Screw zones	7
2.3	Clamping unit of injection molding machine	7
2.4	Single gate location	9
2.5	Twin gate location	9
2.6	The formation of weld line	10
2.7	Typical injection molding process	11
2.8	Sink mark in plastic part	12
2.9	Void in the moulded part	12
2.10	Excessive shrinkage in plastic part	13
2.11	Flash in the plastic part	13
2.12	Warping	13
2.13	Brittleness of the plastic part	13
2.14	Stiffening effect of the filler	17
2.15	Tensile strength for different glass fibre content in polypropylene	18
2.16	Elastic modulus for different glass fibre	18
2.17	Force vs elongation curve	19
2.18	Changes in semi crystalline structure when necking occur	20
2.19a	Example of necking if a PP specimen	20
2.19b	Fracture begins in a necked section	20
2.20	Typical shape of the tensile test of plastic specimen (dog bone or dumbbell shape)	21
2.21	Tensile testing machine	21
2.22	Stress-strain curves for 15% glass filled PP	21

3.1	Flow chart of this project	26
3.2	Injection Molding Machine	29
3.3	Mold closed	29
3.4	Parameter setting	30
3.5	Part ejection	31
3.6	Polypropylene filled with fiber glass	31
3.7	Single gate and twin gate mould	32
3.8	Dimension of the specimen	33
3.9	Universal Testing Machine (UTM)	33
3.10	Stress-strain curve	34
4.1	Stress-strain curve of polypropylene filled with fibre glass using single gate mould	37
4.2	Main effects plot for tensile strength using single gate mould	40
4.3	Stress- strain curve for single gate location	42
4.4	Main effects plot of modulus of strength using single gate	45
4.5	Main effect plot for S/N ratio for percentage of elongation using single gate	50
4.6	Stress-strain curve for twin gate location	52
4.7	Main effect plot for S/N ratio of tensile strength using twin gate location	55
4.8	Area under the graph	58
4.9	Main effects plot for SN ratios of modulus of strength using twin gate location	61
4.10	Main effect plot for S/N ratio for percentage of elongation	66
4.11	Fracture on specimen when using (a) single gate location and (b) twin gate location	68
4.12	Comparison tensile strength of single gate and twin gate location	69
4.13	Comparison modulus of strength of single gate and twin gate location	70
4.14	Comparison percentage of elongation of single gate and twin gate location	71

LIST OF APPENDICES

APPENDIX	TITTLE	PAGE
A	Gantt Chart for Master Project 1	80
B	Gantt Chart for Master Project 2	81
C	Graphs of Tensile Result for Single Gate	82
D	Graphs of Tensile Result for Twin Gate	85

LIST OF ABBREVIATION, SYMBOL AND NOMENCLATURES

PP	-	Polypropylene
ANOVA	-	Analysis of Variance
UTM	-	Universal Testing Machine
DoE	-	Design of Experiment
FKP	-	Fakulti Kejuruteraan Pembuatan
MeT	-	Melt Temperature
HP	-	Holding Pressure
It	-	Injection Time
Ct	-	Cooling Time
Avg.	-	Average
%	-	Percentage
°C	-	Degree of Celcius
MPa	-	Mega Pascal
s	-	Second
No.	-	Number
E	-	Young Modulus
F	-	Force
L	-	Original length
A	-	Area
ΔL	-	Changes in length

CHAPTER 1

INTRODUCTION

1.1 Project Background

Injection molding is known as the most important process for processing the mass production of plastic product in the complex shape and sizes with high precision. Nowadays, the production of injection molded plastic project has been increased rapidly. This is because the plastic products are relatively easy to mold into complex shapes, low in cost, lightweight and low energy requirement for processing compare to the metal (Ciofu and Mindru, 2013). Various types of plastic materials can be used to produce plastic one of them is polypropylene (PP). PP is known as one of the most popular plastic material. PP is a thermoplastic polymer resin. PP is much preferable compare to other type of plastic material because PP is easy to be processed and consumes less cost. The example of products that has been produced from PP is packaging, household appliances, etc.

In the injection molding process, the gate location should be considered when designing the mould. According to Yatish and Nagaraja (2014), the selection of gate location will affect the manner of the material flows into the mould cavity. Besides, location of the gate also affects the quality of injection molding process. Gates have a bigger impact on the final dimension of the part and its performance. When twin gate location is used the filling pattern is much better than in single gate but, it will form the weld line in the middle of parts as shown in Figure 1.1. Formation of weld line will affect

the mechanical property of the part (Robert, 1994). Based on Gurjeet Singh et al., (2015), the other process parameters that affect the quality of injection molding are such as injection time, injection time, packing pressure, cooling time, packing time and melt temperature. The type of defects that always be found in injection molding are like warpage, surface blemish, voids, flash jetting, flow mark and weld line (Mohamed et al., 2007).

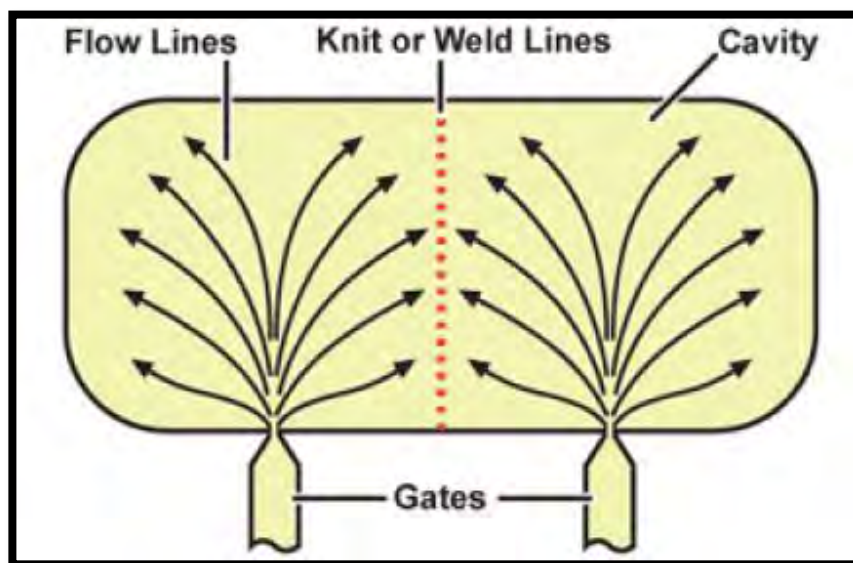


Figure 1.1: Formation of weldline (Robert, 1994)

1.2 Problem Statement

In injection molding process, the quality of product and the proper working of the mold are significantly affected by the gate location. The gate location will influence the manner of the polymer flows into the mold cavity (Shen et al., 2007). Gate location is one of the causes that affected the mechanical properties of the plastic products (Yatish and Nagaraja, 2014). The product quality can be improved by determining the better gate location. Hence, in this study the differences of gate location between single gate and twin gate are investigated. The flow front of molten plastic meets together can cause weld line

marks in twin gate as compare to the single gate. Formation of weld line will affect the mechanical property of the part (Robert, 1994). Therefore, the tensile test will be used to compare the mechanical properties of single gate and twin gate location. Type of material is going to be used is polypropylene filled with fiber glass. By addition of other material such as fiber glass to the polypropylene, the mechanical properties of polypropylene may be changed.

1.3 Objectives

The main objective of this study is to compare the mechanical properties of polypropylene filled with fiber glass having the different gate location injected by injection molding process using Taguchi method

There are three sub objectives of this study, which are:

1. To investigate the effect of all responses such as tensile strength, tensile modulus and percent of elongation on each gate location.
2. To identify the most important injection molding process parameters such as melt temperature, holding pressure, injection time and cooling time on mechanical properties using analysis of variance (ANOVA).
3. To validate the optimised mechanical properties result through run of optimum parameters using Taguchi method.

1.4 Scope of Study

The scope of this study will cover on the analysis of the mechanical properties of plastic part by using injection molding process. Universal Tensile Strength machine is used to investigate the mechanical properties of the injected plastic part. The material selected for this study is polypropylene filled with fiber glass. The limitation of this project is the

analysis for the gate location is only conducted by using twin gate and single gate location only. For optimization process, design of experiment (DOE) using Taguchi method and analysis of variance (ANOVA) are used to find the optimum parameters for the output responses.

1.5 Organization of the report

This master project report consists of several chapters to be completed. Chapter 1 until chapter 3 need to be completed in Master Project 1 meanwhile chapter 4 and 5 will be completed in Master Project 2. In chapter 1, introduction of the project such as background, objective and scope of study is discussed. Then, chapter 2 discusses the literature review of the study such as introduction of injection molding, mechanical properties, tensile testing, etc. Chapter 3 discusses the methodology of study which elaborates in details about the parameters selected and the procedures needed to carry out the experiment. Chapter 4 presents the data and results obtained through the experiment. Lastly, chapter 5 concludes the findings of study and recommendations for the future improvement.

CHAPTER 2

LITERATURE REVIEW

2.1 Injection Molding

Injection molding is a process of manufacturing the plastic parts based on the required specification by melting the plastic pellets and forcing it under certain pressure into sprue, runner, gate and reach to mold cavity. According to Shakkarwal and Yadav (2013), over 32% of plastic parts is produced by the injection molding process. This is due to the ability of injection molding in producing complex geometry shape with accurate dimension

Jain et al., (2003) stated that injection molding is widely used in industries such as medical, automotive and electronic sector to manufacture large amount of the plastic part. Besides, plastic injection molding also able to produce good dimensional intricate shape of the part and can be produced in finished state. Thus, injection molding process indirectly provide many advantages such as short product cycle, good mechanical properties, light weight, high quality part surfaces and low cost. Hence, it is becoming increasingly in today's plastic production industries

2.1.1 Injection molding machine

Typical injection molding as shown in Figure 1 consists of five major elements which are an injections unit, hydraulic system, mold system, clamping system and control system.

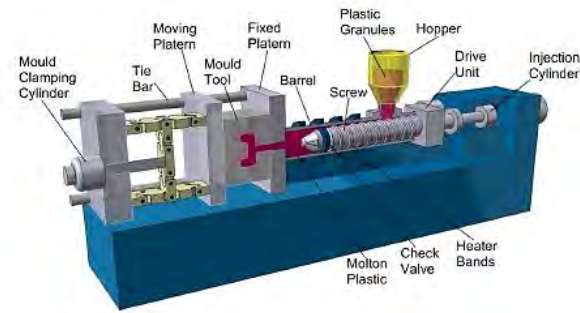


Figure 2.1: Injection molding machine (Rutland, 2007)

2.1.1.1 Injection unit

Injection unit basically consists of hopper, screw, barrel and injection nozzle (Teklehaimanot, 2011).

a) Hopper

- In the injection molding process the plastic materials are supplied in the form of a small pellet. Hence, hopper is used as the holder for the plastic pellets. After that, the pellets are gravity fed to the barrel

b) Barrel

- The main function of the barrel is to give support to the screw

c) Reciprocating screw

- Reciprocating screw is used for compressing, melting and conveying the plastic pellets. Generally, the screw is divided into three zones which are feeding zone, transition zone and metering zone. In feeding zone, there will be no changes made to the plastic pellet. Then pellets will be transferred to

the transition zone. In the transition zone melting process of the pellet will be occurring and the molten plastic will be transferred to the metering zone. In metering zone the molten plastic is ready for injection. Figure 2.2 shows the three zones in screw.

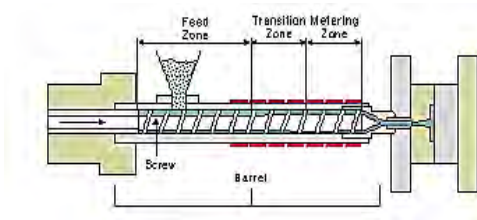


Figure 2.2: Screw Zones (Ruthland,2007)

d) Nozzle

- The nozzle is used in connecting the barrel to the sprue bushing to form a seal between the mold and barrel. The nozzle temperature must be set to the melt temperature.

2.1.1.2 Clamping unit

Clamping unit is the part of machine that carries, closed and open the mould. It provides the force required keeping the mould closed during the injection phase and it ejected the moulding plastic part once the mould is opened. The clamp unit consist of three plates or platens (Robert, 1994):

- I. A stationary platen on which is mounted the half of the mould that contain runner and sprue bush.
- II. A moveable plate on which is mounted the other half of the mould (the one that contains the ejection system.)
- III. The tail plate.

The tie bars are used to connect all three platens together.

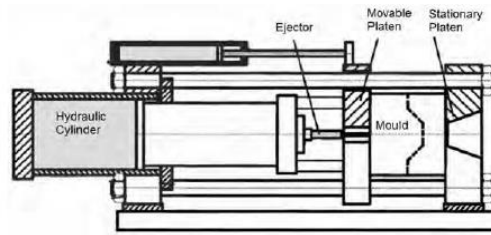


Figure 2.3: Clamping unit of injection moulding machine (Funda, 2014)

2.1.1.3 Injection Molding Mould

In the injection moulding process the mould is usually in form of cavity whereby the molten polymer is injected and solidified. Basically, mould comprises of two halves which is known as stationary half and movable half. These two halves were mounted to the mould of the clamping unit of the injection molding machine. The movable half is to eject finish part. Mould is placed in between stationary plate and the moveable plate. There are two types of mould in injection molding which are two-plate mould and three-plate mould (Osswald et al., 2008).

Table 2.1: Component in the mould (Osswald et al., 2008)

Component	Function
Cavity	Cavity is molded by eradicating the metal from the mating surfaces of the two halves. The moulds can have a single cavity or multiple cavities.
Sprue	Sprue is used to lead the melt material from the nozzle into the mould. Basically the sprue is act as the inlet channel to transfer molten material from the heating chamber into the runner system.
Runner	Runner is used to lead the melt material from the sprue to the multiple mould cavities. Runner is used as the channels to connect the sprue bush to the cavity gates. There are two types of runner system which are cold and hot.
Gates	The gate is the melts' point of entry into the mold cavity. When the injection pressure is removed, gate is used to prevent the material from flowing out.
Ejection system	Ejection system is used to eject the moulded part from the cavity. When the mould is open, the ejector pins that built into the movable plate are used to push the part out of the mould