FLEXURAL TEST ON VIRGIN AND RECYCLED HDPE SPECIMEN

MUHAMMAD SHAHMI BIN RAZAK
B051310004

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
2016

B051310004 BACHELOR OF MANUFACTURING ENGINEERING (MANUFACTURING PROCESS) (HONS.) 2016 UTeM

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FLEXURAL TEST ON VIRGIN AND RECYCLED HDPE SPECIMEN

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) (Hons.)

by

MUHAMMAD SHAHMI BIN RAZAK
B051310004
920206-11-5367

FACULTY OF MANUFACTURING ENGINEERING
2016

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **FLEXURAL TEST ON VIRGIN AND RECYCLED HDPE SPECIMEN**

SESI PENGAJIAN: **2015/16 SEMESTER 2**

Saya **MUHAMMAD SHAHMI BIN RAZAK**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

Disahkan oleh:

Alamat Tetap:
3011, KG SURAU HAJI DAUD,
21070, KUALA TERENGGANU,
TERENGGANU DARUL IMAN

Cop Rasmi:

Tarikh:

Tarikh:

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled ―FLEXURAL TEST ON VIRGIN AND RECYCLED HDPE SPECIMEN" is the results of my own research except as cited in references.

Signature :…………………………………………….

Author‘s Name :MUHAMMAD SHAHMI BIN RAZAK

Date :……………………………………………

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons.). The member of the supervisory is as follow:

………………………………
(DR. MOHD AMRI BIN SULAIMAN)

ABSTRAK

Kertas kerja ini mengemukakan kajian tentang ujian lenturan terhadap spesimen asli dan kitar semula *HDPE*. Kekuatan lenturan *HDPE* telah dikaji. Ujian lenturan dijalankan dengan menggunakan *Universal Testing Machine (UTM)*. Ujian eksperimen telah mengikuti kaedah *ASTM D790*. Keputusan spesimen asli dan kitar semula *HDPE* telah dibandingkan. Hasil kajian telah dibandingkan dengan teori dan *Finite Element Analysis (FEA)* untuk pengesahan. Kekuatan lenturan spesimen ‗HDPE' asli adalah lebih tinggi daripada kitar semula *HDPE*, kira-kira 50%. Oleh itu, kitar semula *HDPE* boleh menggantikan *HDPE* asli dalam sesetengah aplikasi. Kedua-dua keputusan eksperimen telah disahkan dengan ralat yang kurang daripada 5%. Perbandingan antara hasil eksperimen (*HDPE* asli) dan teori (*ASTM D790*) adalah 0.05%. Perbandingan antara hasil eksperimen (*HDPE* asli) dan simulasi (*FEA*) adalah 0.8%.

ABSTRACT

This thesis presented the flexural test on virgin and recycle HDPE specimen. The flexural strength of HDPE was investigated. The flexural test was conducted by using Universal Testing Machine (UTM). The experimental test was followed ASTM D790 method. The results of the virgin and recycled HDPE were compared. The theoretical and Finite Element Analysis (FEA) was used to validate the experimental results. Flexural strength of virgin HDPE was higher than recycled HDPE, about 50 %. Thus, recycled HDPE can replace virgin HDPE in a certain application. Both of the experimental result verified that error less than 5 %. The deviation between experimental (Virgin HDPE) and theoretical (ASTM D790) result was 0.05 %. The deviation between experimental (Virgin HDPE) and simulation (FEA) result was 0.8 %.

DEDICATION

To my beloved family, friends and that accompanying me along the difficult pathway in my university life, thanks for your help and support.

ACKNOWLEDGEMENT

Alhamdulillah, grateful to Allah S.W.T. for giving me the strength and patience to completed and finished my project and gained an experiences during the process to complete this project. I would also like to thank my family especially my beloved parents for their never ending support and courage in terms of financial and emotion as well as their prayers in order to provide me with better education for a better and brighter future.

First and foremost, I would like to thank to my supervisor, Dr. Mohd Amri bin Sulaiman for his endless supports and ongoing guidance throughout the course of this project ever since the first day until the project have been completed. I have acquired so much knowledge and experience from him. Besides, special thanks to all my friends Zuraimi Ramli and Mohd Amirhafizan. They had giving me advice, ideas, comments and sharing their time without any difficulties to completed my project.

I would also like to thanks each and every one in Faculty of Manufacturing Engineering; the lecturers, staffs and technicians for the cooperation in sharing their experiences and knowledge as well as their time and energy. Their views and tips are useful indeed. The obstacles, the sleepless nights, the impossibilities and the arguments, are definitely worthwhile once I have completed this valuable project.

It is hard to thank everyone personally in this report, therefore thanks to everyone who has directly or indirectly been supportive and helpful throughout this project until the end of it.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ASTM	-	American Society for Testing And Materials
DENT	-	Double-Edge-Notched Tensile
EPA	-	European Psychiatric Association
FEA	-	Finite Element Analysis
FEM	-	Finite Element Method
HDPE	-	High Density Polyethylene
ISO	-	International Standards Organization
LDPE	-	Low Density Polyethylene
PET	-	Polyethylene terephthalate
UT	-	Uni-Axial Tensile
σ	-	Stress
D		Midspan deflection

CHAPTER 1
INTRODUCTION

This chapter defines the introduction of the study and briefly explains the problem statement, objectives and scopes of the project.

1.1 Background of Project

Today, plastics are one of the most used polyvalent materials and are an important part of the economy. They provide multiple applications in a wide range of sectors, from the packaging market, which represents 39.4% of the demand for plastics, to the building and construction sector, the automotive industry and other examples, such as home appliances or medical products (PlasticEurope, 2005). According to PlasticsEurope, which has accompanied life-cycle inventories on some plastics end applications such as HDPE bottles, the common of the energy and emissions related to the production of various plastics applications is due to the production of the resin itself. Injection molding is known as an efficient process for mass production of plastic parts with complicated forms and high dimensional precision. In the method of injection molding process, high pressure fluid polymer is injected into the cavity to desired form. After that, fluid is solidified under high pressure. During the process, plastic materials are under high pressure and temperature. Finally, materials are cooled to get required form. Injection molding process can be distributed into four stages: (i) Plasticization, (ii) Injection (iii) Packing (iv) Cooling.

Achilias et al. (2008) stated that the consumption trends of the plastics state that its consumption in the form of High Density Polyethylene (HDPE) is about 11%.

HDPE is a thermoplastic material comprised of carbon and hydrogen atoms joined together forming long-chain high-molecular-weight products. The arrangement of the molecular chains and the number and size of side chains will be depend on the properties of HDPE. These structures determine the mechanical properties such as density, stiffness, tensile strength, flexibility, hardness, brittleness, elongation and creep characteristics (Jones et al 2005).

In this research, to replace the virgin HDPE, the recycled of HDPE is invetigated. HDPE is a multipurpose thermoplastic because of its mechanical, physical properties, cost and environmental inertness, for which product and market development continue to open new applications (Ramírez-Vargas et al 2006). It is generally used in products and packaging such as milk jugs, detergent bottles, margarine tubs, garbage containers and many other things.

El-Khair et al. (2013) stated that in the long time ago with the increasing use of polymeric materials the disposal of the used material became a serious problem. As polyethylene is one of the commonly used polymers in many applications, it represents a significant amount of the total municipal waste of thermoplastic materials. So, the recycling process of polyethylene is a subject which needs more investigation.

The best flexural strength value of the experiment which are virgin and recycled HDPE specimen are compared with the standard formula that use that is ASTM D790 standards. ASTM D790 stated that to calculate the flexural strength, the formula that use is same with the formula to calculate the maximum stress. The comparisons are then valid by use the FEA method in SolidWorks software. FEA is used to determine the strength of the material in a numerical method and traditionally which is a branch of Solid Mechanics. Nowadays, FEA is a commonly used method for multiphysics problems (Zamani, 2010).

1.2 Problems Statement

Notwithstanding all the qualities of HDPE, its use postures serious limitation owing to many aspect which are: (i) HDPE are constructed from natural supplies and all plastic manufacture exhaustions 8% of the world's oil manufacture. So recycling the plastics will maintain nonrenewable fossil fuel. (ii) Landfills and plastic burning generate toxic emanations and greenhouse gases such as carbon dioxide etc. So, recycled plastic can reduce energy consumption by one third and cut the production of dangerous gases. (iii) Many plastics that are used not be recyclable or destroy very slowly in our mother earth, this not only occupies important space but it is a waste of the plastic resource that might be recycled into other useful products (Khan et al., 2010). Through this problem, recycling of plastics not only reduce the demand of natural resources but also can reduce energy consumption and greenhouse and provides a solution to the plastic waste disposal. Efforts have been made to recycle the post-consumer plastics in order to reduce the environmental impact and consumption of virgin plastics. In this study, analysis and determine the optimum condition for HDPE material both virgin and recycled by using flexural testing method.

1.3 Objectives

The objective of this study is:

i. To study the mechanical property on virgin and recycled HDPE specimen through flexural testing.
ii. To analyze the difference percentage in flexural strength between virgin and recycled HDPE specimen.
iii. To determine the validation of experimental value through theoretical calculation and FEA simulation.

1.4 Scope of Project

This research is focused on the testing method for HDPE specimen that is flexural testing method according to the suitable parameter of injection molding process that making both virgin and recycled HDPE material. The corrensponding molding parameters are melt temperature (^{0}C), hold pressure (MPa), injection pressure (Mpa), holding time (s), injection time (s) and cooling time (s). This testing method is use in the third point bending configuration and of moulded specimens. This testing method is planned for HDPE specimen that is not longer than 160 mm. The parameter for flexural testing are referred to the ASTM D790. The method also can be used for a recycle HDPE specimen. There are 22 test must been ran for virgin HDPE specimen and 22 test for recycle HDPE specimen. Each test includes different parameter of injection molding. Each test is also conducted for 5 specimens that stated in the ASTM standards to take the average reading of the test. Then, all results are scanned and select the highest from virgin and recycle HDPE to be compare with the formula flexural strength in ASTM standards. Lastly, valid the results by using FEA in SolidWorks software.

CHAPTER 2

LITERATURE REVIEW

This chapter elaborates the meanings and information regarding the project where it informs on the details of the project. The idea, data and information are collected from various resources in order to understand the concept and useful information or knowledge for the project.

2.1 Plastic Injection Molding

Kavade et al. (2012) stated that the machine that widely used in plastic industry is injection molding machine. Injection molding is technique for shaping the thermoplastic material through the concept of molten the material and put them into mold until it solidifies. The process is very useful to create a product in high production rates. Although the shape of product is complex, but the result for the qualities of product that produce are very good.

The injection molding processes consist of heating a thermoplastic material until its melting and push them into the mold cavity and it will be solidified. Injection molding machine can be divided to a several part which is injection unit, mold system and lamping unit as shown in Figure 2.1.

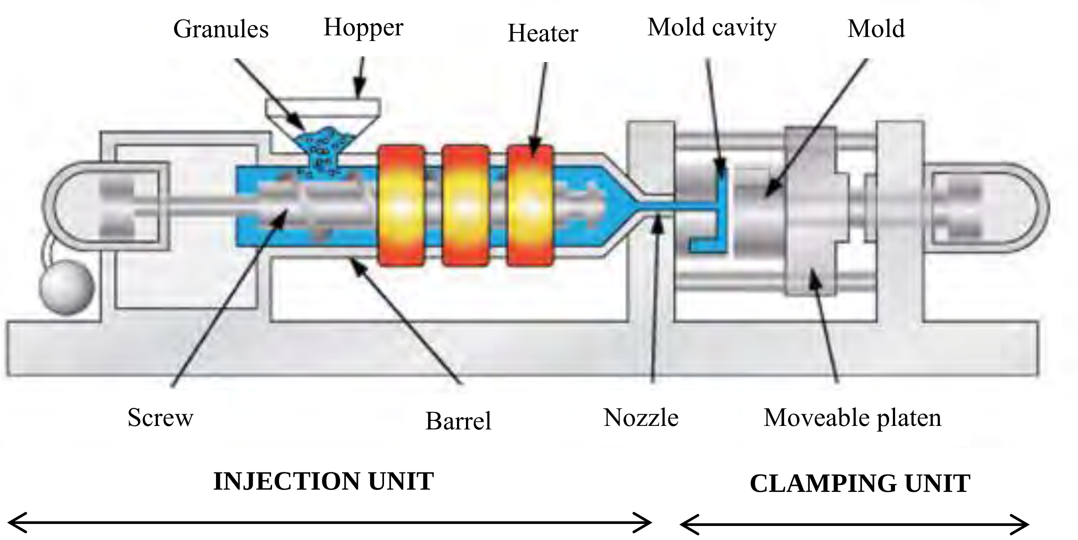

Figure 2.1: Schematic of thermoplastic Injection molding machine (Svečko et al., 2013)

2.2 Process of Injection Molding

The process of injection molding can be described as the method of filling water in a mug and put into the refrigerator. It will change to the ice condition and the shape will follow the mug shape. This situation is same as injection molding which is its fill with molten polymer and inject to the mold and then become a part. This process normally runs in between 2 seconds and 2 minutes that contains of four stages:

i. Clamping unit
ii. Injection
iii. Cooling
iv. Ejection

Clamping unit is a press unit, closed by a hydraulic or mechanical toggle system. There are two parts of the mold and clamp each other. This unit performs the following essential function. Holds the mold, closes the mold and keep the mold closed during injection under pressure. Next, the clamping unit will be open to eject the finished parts. Big machine of injection molding will need more time to close and clamp the mold.

The process where the molten materials are fed into the hopper as raw materials is called injection unit. In this section, the material will cross into the reciprocating screw and melting to some temperature by heat and pressure that apply on the machine. Then, the material will go to injection unit to fill into the mold cavity.

After that, the molten plastic will be solidified and follow the shape of the mold. During the cooling of material, there are some defect will occur such as shrinkage due to the some disturbance or incompatibility parameter. After the cooling time has elapsed, the mold can be open and ejector the part. The mold can be clamped shut for the next shot to be injected. The mold closes again and the cycle repeats. Lastly, the part that finish from ejector will goes some finishing. It will be trimming the overbalance from the process using cutter. The waste part can be recycled for the next shot.

2.3 Parameters of Injection Molding

There are many various types of parameters that must be recognized to succeed appropriate injection molding for plastic part. All of this parameters fall within four major as shown in Figure 2.2. All the parameters are related to each other. If some parameters are change in one it may have a major effect on another. To determine the parameter are not easy. In this case, it all depends on the material that we used and how complex the shape that is going to be use. Hence, investigate the parameter will be necessary.

To the problem solver, all of these are consequential but the pressure and temperature areas are the most one commonly considered during the troubleshooting process. Predicated at the fundamentals of any particular plastic material, the pressure must be sufficient to inject the plastic material and to hold the mold closed. In integration, the maintenance of the temperature in the injection plastic and mold must be correctly.

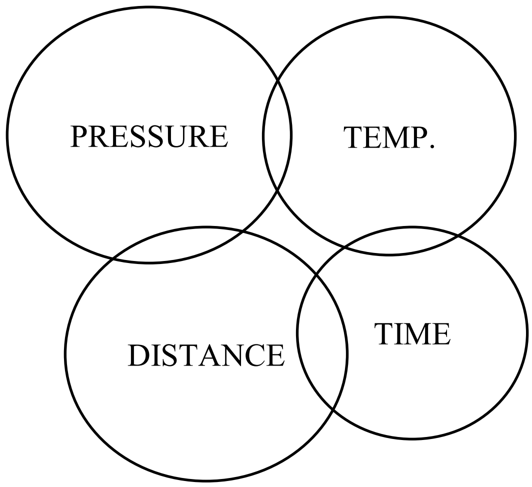

Figure 2.2: Four parameter areas (Bryce, 1999)

2.4. Parameter Effects

The property of the part will be change if the parameter of the injection molding machining changed during the process running. Table 2.1 below shows the interaction between the parameter change and what will be occurred if we adjusted the parameter by plus or minus change in some of common injection molding parameters.

Table 2.1: Parameter Change vs. Property Effect (Bryce, 1999)

Parameter	Property Effect
Injection pressure (+)	Low shrinkage, high gloss, less warp, hard to eject
Injection pressure (-)	More shrinkage, less gloss, more warp, easier to eject
Back pressure (+)	Higher density, more degradation, fewer voids
Back pressure (-)	Lower density, less degradation, more voids
Melt temperature (+)	Faster flow, more degradation, more brittle, flashing
Melt temperature (-)	Lighters flow, less degradation, less brittle, less flushing
Mold temperature (+)	Longer cycle, higher gloss, less warp, less shrinkage
Mold temperature (-)	Cycle fast, lower gloss, greater warp

The table above shows that how the properties of material is effected by the parameters of the injection molding. In short, ―less shrinkage" is obtain by increasing the injection pressure and ―less degradation" is achieved by decreasing pressure as well as decreasing melt temperature. By referring and understanding the relationship between the parameter and effect, the possibility in minimizing the number of adjustment are required in making the correction due to the unexpected change of the process (Qureshi et al., 2012).

2.5 High Density Polyethylene

According to Azarsa and Mostafapour (2013) stated that among the most important and versatile of the hundreds of commercial thermoplastics is polyethylene. Moreover, polyethylene is utilized in a wide variety of industrial applications because, based on its natural structure, it can be easily produced in many different forms. There are many members that are important and useful in polyethylene. HDPE and LDPE are the two popular materials that use for packaging products. But the family also includes Ultra High Molecular Weight Polyethylene that can be known as the most popular plastic in the world with annual production of 80 million metric tons are the polyethylene family.

On the other hand, the three plastics which are HDPE, LDPE and PET are the most popular uses in the world. According to the EPA report, Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2008, these three plastics accounted for nearly half of all plastic waste generated in 2008 (EPA, 2009). Emission factors are been calculated for a mixed plastics category, based on the relative occurrence of each of the plastic types in the recovery stream. Table 2.2 shows that the data that recorded for the three type of plastics in the United States country.