THE EFFECT OF RECYCLED – ACRYLONITRILE-BUTADIENE-STYRENE (ABS) MIXING RATIO ON THE TENSILE STRENGTH OF ACRYLONITRILE-BUTADIENE-STYRENE (ABS) POLYMER

SITI NUR AIN BINTI MD SALLEH

Thesis submitted fulfillment of the requirements
for the award of the degree of
Bachelor of Engineering in Manufacturing

Faculty of Manufacturing Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2013

ABSTRACT

Plastics are widely used in industries because of the characteristic of plastics itself that toughness, high wear resistance, high impact resistance, easily processing and corrosion resistance. More plastics has been used in industries, more waste will produced. However, the lack information about recycled plastics on mechanical properties would be possible for industries to keep the good characteristic of recycled materials and make some industries produce the low qualities of products. Therefore, the main objective of this study to investigate the tensile strength of ABS, in terms of recycled ABS mixing percentage and to find the suitable percentage of recycled of ABS that can mix with virgin ABS by having the highest value of tensile test. The recycled ABS was crushed into the pallet then was mixed with the virgin ABS in certain percentage. The injection molding was used to produce the specimens. Five specimens were needed for this project of each experiment. It followed an ASTM D638 as a standard. The test that used to determine the strength of the specimen is tensile stress. The result showed there is increasing of the tensile strength when recycled ABS mixed virgin ABS at the ratio of 40% recycled with 60 % virgin.

ABSTRAK

Plastik digunakan secara meluas dalam industri kerana ciri-ciri plastik sendiri yang keliatan, rintangan yang tinggi, rintangan hentaman yang tinggi, pemprosesan yang mudah dan rintangan kakisan yang tinggi. Banyak plastik telah digunakan dalam industri, lebih banyak sisa atau pembuangan akan dihasilkan. Walau bagaimanapun, pengetahuan tentang kitar semula plastik adalah kurang mengenai ciri-ciri mekanik akan menyebabkan kesukaran bagi industri-industri untuk mengekalkan ciri-ciri yang baik daripada bahan kitar semula dan membuatkan beberapa industri akan menghasilkan produk yang berkualiti rendah. Oleh itu, objektif utama kajian ini untuk menyiasat kekuatan tegangan ABS, dari segi peratusan kitar semula ABS dan mencari peratusan ABS yang dikitar semula dengan ABS yang original dengan mempunyai nilai tertinggi untuk ujian tegangan. ABS yang kitar semula akan dihancurkan dalam bentuk palet kemudiannya bercampur dengan ABS yang original dalam peratusan tertentu.. Lima spesimen yang diperlukan untuk projek ini bagi setiap percubaan. Standar ASTM D638 digunakan dalam kajian ini. Ujian yang digunakan untuk menentukan kekuatan spesimen itu ialah ujian tegasan tegangan. Hasil kajian menunjukkan terdapat peningkatan kekuatan tegangan apabila ABS yang dikitar semula bercampur dengan ABS yang original pada nisbah 40% dengan 60%.

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LIST OF SYMBOLS

T_g	Glass Transition Temperature
T_m	Melting Point
%	Percentage
^oC	Degree Celsius
^oF	Fahrenheit
N/m^2	Newton's per Square Metre
Kpsi	Kilo-Pounds per Square Inch
Lbf/In^2	Pounds-Force per Square Inch
Pa	Pascal
MPa	Megapascal
N	Newton's
P20	Name of Steel
√	Square Root

LIST OF ABBREVIATIONS

ABS	Acrylonitrile-Butadiene-Styrene
ASTM	American Society for Testing and Materials
SEM	Scanning Electron Microscopy
UTM	Ultimate Tensile Machine
UTS	Ultimate Tensile Strength
TS	Tensile Strength
O	Oxygen
UV	UV-Stabilizations
GPC	Gel permeation chromatography
CNC	Computer Numerical Control
EDM	Electrical Discharge Machining

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

As lifestyles change, plastics will become more valuable in architecture, aerospace, communication, transportation even to medicine and the arts. Plastics have been used in household equipment and so on. This is because the characteristics of plastics itself that are easy to fabricate and light weight. Plastics also have high wear resistance, high impact resistance, easily processing and corrosion resistance.

One type of plastics that commonly used in industries is Acrylonitrile-Butadiene-Styrene or known as ABS. The advantage of ABS is that this material combines the strength and rigidity of the acrylonitrile and styrene polymers with the toughness of the polybutadiene rubber. The most important mechanical properties of ABS are impact resistance and toughness. A variety of modifications can be made to improve impact resistance, toughness, and heat resistance. The impact resistance can be amplified by increasing the proportions of polybutadiene in relation to styrene and also acrylonitrile, although this causes changes in other properties. Impact resistance does not fall off rapidly at lower temperatures. Stability under load is excellent with limited loads. Thus, changing the proportions of its components ABS can be prepared in different grades.

Two major categories could be ABS for extrusion and ABS for injection molding, then high and medium impact resistance. As the used of ABS product has increased over the years, the product become waste because some company does not recycle the defect or unused product that they was made.

The ABS plastic also can be recycled. It is because the recovered polymers are compatible with virgin material and can be used for such product that are computers, office equipment, auto parts, telephones and also home appliances. The technology has proven successful in recovering the selected plastic from obsolete appliances, auto shredder residue, disassembled car parts, industrial scrap plastics and consumer electronics. For this project, dog-bone was prepared as the product recycled. Then, the product was crasher before mixed with the virgin ABS. By using injection molding, the part was produce in 5 sample based on standard ASTM. The part was tested to investigate the tensile strength using Ultimate Tensile Machine for tensile test.

1.2 PROBLEM STATEMENT

Nowadays, many people use ABS because ABS is easy to fabricate and light weight. As the use of ABS has increased over the years, it has become a larger part of waste. Unfortunately, no process is currently known for effectively and efficiently recycling ABS for subsequent use. The present process for recycling ABS in a manner permitting previously used ABS to obtain a second life. The present process employs shredding, separating and blending to recycle used ABS for subsequent use in other products, for example, substrates of decorative laminates.

The recycling ABS has been studied before but in the different scope by R. Scaffaro, L. Botta, and Di Benedetto (Physical properties of virgin-recycled ABS blends: Effect of post-consumer content and reprocessing cycle). They focus more on the how many times ABS can be re-processing and re-formed. Based on their experiment, there are only three times ABS materials or product can be recycled [1]. Even thought many researcher study about recycled of ABS, but they not totally focus on mechanical properties.

Therefore, this project was built to study the percentage of mixed ABS that suitable to recycle. So, the when it can be recycled, the waste of material can be reduce. Recycling plastics reduces the amount of energy and natural resources (such as water, petroleum and natural) needed to create virgin plastic. Recycling plastic products also keeps them out of landfills and allows the plastics to be reused in manufacturing new products.

1.3 OBJECTIVE

The objectives of this project are:

- To design the mold in produce the dog bone shape as a specimen that will be used in this study.
- To investigate the tensile strength of ABS, in terms of recycled ABS mixing percentage.
- To find the suitable percentage of recycled of ABS that can mix with virgin ABS by having the highest value of tensile test.

1.4 SCOPE OF PROJECT

The project used virgin ABS mixed with recycle ABS. This is because the ABS has a good balance of properties, toughness, strength and high quality surface. This material was melted and extruded into the form of small size which is then used to manufacture other products. Then, the material was injected into injection molding and tested using tensile test. The shape that used for testing is dog-bone shape. In designing the dog bone shape, we follow the standard ASTM-D638 tensile bar. The result will be studied is tensile strength. The test followed the ASTM D638 standard for tensile test. The location during do this project at Faculty of Manufacturing Engineering and Faculty of Mechanical Engineering Universiti Malaysia Pahang.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The large amounts of plastics produced with the recent economic growth are producing high quantities of waste. This rapid development has coincided with the equally dramatic rise of many environmental problems, and in consequence, industry has to be concerned with waste-disposal strategies. For example, a study on waste from electrical and electronic equipment has shown that it reached 6 million tons, and it is expected to double over the next decade [2]. Recycling of polymeric materials is of special interest due to the high chemical resistance of these materials, which leads to a long degradation time before their disappearance [3].

Several studies have been carried out on the mechanical recycling of ABS. This is because acrylonitrile-butadiene-styrene (ABS) is an engineering thermoplastic which consists of an amorphous, heterophasic polymer with very good mechanical properties. For example, studied the recyclability of injection molded lamp-shade parts based on ABS. They found that, after regrinding and injection molding, the mechanical properties were not significantly affected, apart from a slight reduction in the notched Izod impact strength. Gel permeation chromatography (GPC) investigation showed that only slight molecular degradation occurred during the injection molding or grinding [4].

Some basic studies on multiple recycling of ABS have been carried out. For example, the effect of reprocessing condition on the mechanical properties of ABS has been evaluated by varying temperatures and dwell times [5]. In another study, an ABS material was injection molded and recovered for five cycles. During this multiple reprocessing, the strain-to-failure showed a very slightly tendency to decrease. Failure strength slightly increased after five processing cycled [6].

2.2 ACRYLONITRILE-BUTADIENE-STYRENE (ABS) THERMOPLASTIC

ABS is a well-known and widely used rigid engineering polymer. ABS is an amorphous thermoplastic blend [7]. The ABS polymers are based on three monomers: acrylonitrile (A), butadiene (B), and styrene (S). The recipe is 15-35% acrylonitrile, 5-30% butadiene and 40-60% styrene [8]. Depending on the blend different properties can be achieved. Acrylonitrile contributes with thermal and chemical resistance, and the rubberlike butadiene gives ductility and impact strength. Styrene gives the glossy surface and makes the material easily machine able and less expensive. Figure 2.1 shows some possibilities for variation in the composition of ABS.

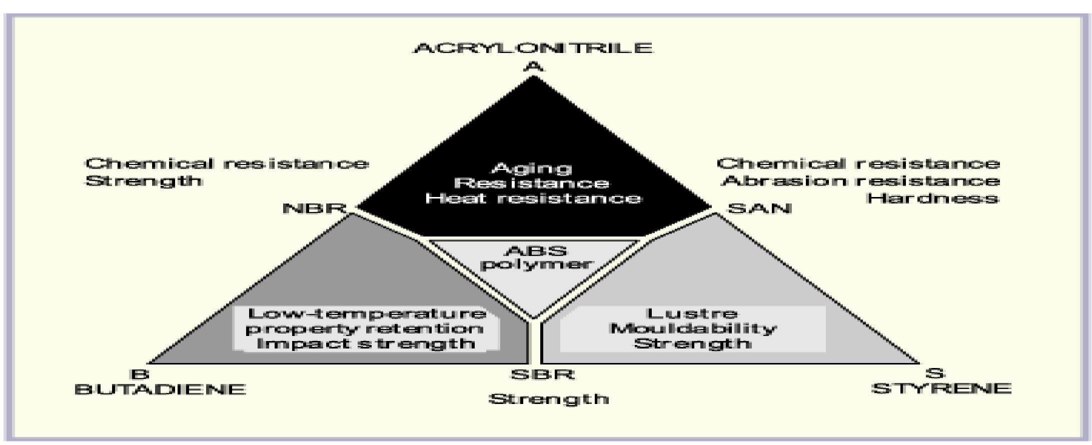

Figure 2.1: Some possibilities for variation in the composition of ABS

2.2.1 Historical Aspects

The history of ABS polymers began in the mid 1940s. In attempts to produce bulletproof plastics sheets during the last years of World War II, polymer systems were developed from special butadiene-acrylonitrile copolymers and styrene- acrylonitrile copolymers with high molecular masses. These materials had a high impact resistance on account of their low thermoplastic flow, but could only be processed with extruders. Semifinished product (i.e., predominantly sheets, profiles, and pipes) were the first molded parts to be made from ABS polymers and had dull or matt surfaces.

A drastic increase in the flow of the material allowed processing by injection molding and thus opened up the way for the production of engineering plastics. Improves processibility was obtained by the use of graft polymerization. This technique allowed the production of molded part with glossy or high-gloss surfaces. Recent developments include modification of the A, B and S monomer units as well as complex blend systems, in which the ABS polymers are components of polymer mixtures with an extremely wide range of properties.

2.2.2 Properties of ABS

Generally, ABS also has good impact strength especially at low temperatures. It has satisfactory stiffness and dimensional stability, glossy surface and is easy to machine. If UV-stabilizations are added, ABS is suitable for outdoor applications. Generally ABS would have useful characteristics within a temperature range from -20 to 80 °C (-4 to 176 °F) [9]. The final properties will be influenced to some extent by the conditions under which the material is processed to the final product. For example, molding at a high temperature improves the gloss and heat resistance of the product whereas the highest impact resistance and strength are obtained by molding at low temperature. Pigments can also be added, as the raw material original color is translucent ivory to white. The aging characteristics of the polymers are largely influenced by the polybutadiene content, and it is normal to include antioxidants in the composition. Other factors include exposure to ultraviolet radiation, for which additives are also available to protect against. Even though ABS plastics are used largely for mechanical purposes, they also have electrical properties that are fairly constant over a wide range of frequencies. These properties are little affected by temperature and atmospheric humidity in the acceptable operating range of temperatures.

ABS polymers are resistant to aqueous acids, alkalis, concentrated hydrochloric and phosphoric acids, alcohols and animal, vegetable and mineral oils, but they are swollen by glacial acetic acid, carbon tetrachloride and aromatic hydrocarbons and are attacked by concentrated sulfuric and nitric acids. They are soluble in esters, ketones, ethylene dichloride and acetone. While the cost of producing ABS is roughly twice the cost of producing polystyrene, it is considered superior for its hardness, gloss, toughness, and electrical insulation properties.

ABS is flammable when it is exposed to high temperatures or above its glass transition temperature, T_g, and below its melting point, T_m, that is approximately 105 °C (221 °F) [10] [11], such as a wood fire. It will melt then boil, at which point the vapors burst into intense, hot flames. Since pure ABS contains no halogens, its combustion does not typically produce any persistent organic pollutants, and the most toxic products of its combustion or pyrolysis are carbon monoxide and hydrogen cyanide. ABS is one of the materials that can be recycling. To recycle of the ABS, it needs to mix with virgin ABS that is one of objective this project that is to find the best percentage of recycling.

2.3 RECYCLING PROCESS

A model for recycling plastics is made to 'phase in' recycling over a given period. The recycled plastic can either replace virgin plastic or enter a new market where plastics are not normally used. The former is denoted as 'true recycling' and the latter, 'new market recycling'. It is shown that 'true recycling' will eventually reduce the amount of waste by the same amount of plastic that is recycled. On the other hand, 'new market recycling' will not reduce the amount of plastic waste and after a given period the overall result is that there is no effect on the amount of plastic waste generated. This is due to the fact that plastics in general have a finite lifetime [12].

In industry for example in the automotive industry, there is a growing move towards reuse and reprocessing of ABS polymer for economic, as well as environmental reasons, with many praiseworthy examples of companies developing technologies and strategies for recycling of ABS polymer.

Currently, a large number of companies consider recycling of material as an opportunity to minimize profit and to reduce the environmental impact generated by this material after they are disposed. It also encourages their greater applicability and reduces use of virgin materials during the production process [13]. According Domingo et.al[14], it defined that three main points to evaluate the quality of recycle material that are composition, the state of degradation and the level of contaminants for example additives, fillers and others. He also reported that some factors hinder the separation and reuse of material during the recycling process, including difficult of materials identification, few researches in the area of recycling processes to assess the composition, structure and properties of recycled materials, presence of aggressive components in their composition, poor development of the characterization technique aim at evaluating their recyclability, lack of standardized recycling methods.

Based on Callister [15], he described that the material goes through several steps known as life cycle of materials, including their extraction, processing, use and disposal. The recycling process is not always considered during the first stages of the life cycle. Figure 2.2 shows the life cycle of material [16].

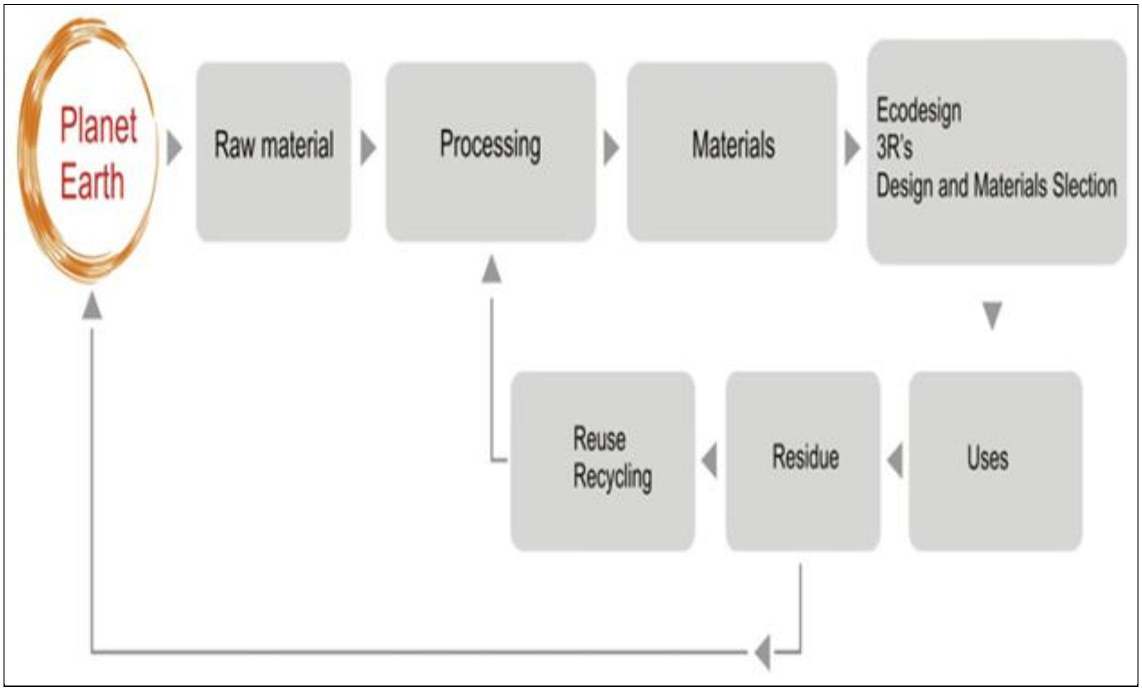

Figure 2.2: Life cycle of material

Nowadays, there are four main approaches to polymer recycling, primary recycling, secondary recycling, tertiary or chemical recycling, and quaternary recycling or energy recovery. According to A.Arostegui, et al [17], a new method based on the dissolution of polymer is being developed. Solvent-based processes include cutting the waste into smaller pieces, treating it with an appropriate solvent, filtrating the solution to remove any insoluble contaminant and additives, and finally, recovering the polymer by re-precipitation and drying. Separating and recycling polymers by this method appear to be technologically feasible and of considerable commercial interest for the following reasons:

- ABS polymer waste is converted into an acceptable form of manufactured goods.
- Insoluble contaminants and additives can be removed by passing the ABS polymer solution through a far finer mesh screen, leaving pure polymeric material. Moreover, additives can be re-used.
- Solvent-based processes can separate plastics from other types of waste and can deal with mixture of polymers of different chemical nature and polymer blends.

The scheme followed to recycle ABS material is shown in Figure 2.3[18].

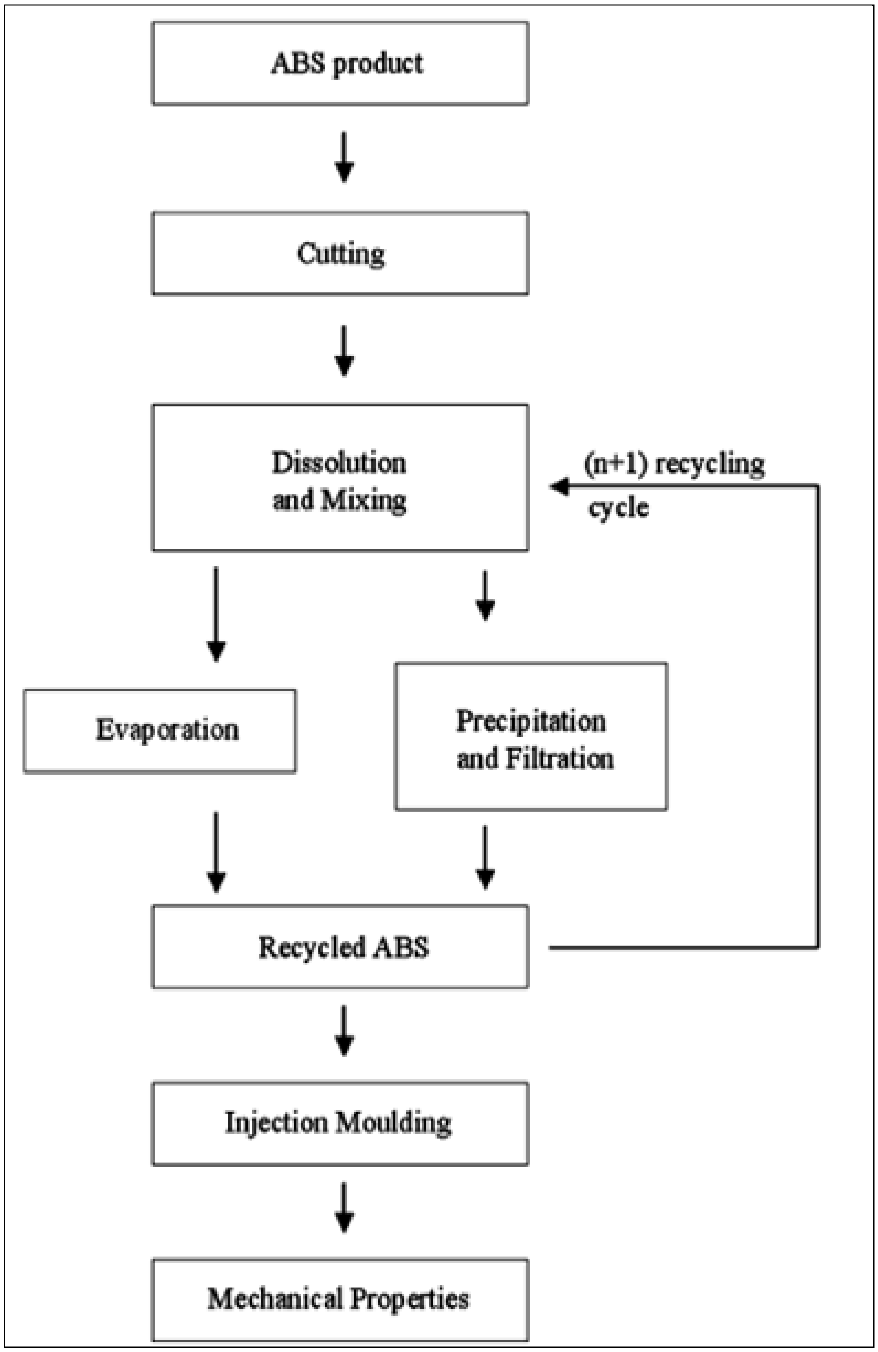

Figure 2.3: Dissolution-based recycling of ABS

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

For the methodology process, they are a few stages that have been involved in this project such as experimental preparation, experimental design, material preparation, injection molding and part testing. In order to choose the material, the ABS has been chosen in this study because of properties itself. ABS has good mechanical properties such as good balance properties, toughness and strength.

Beside that, it easy to molded. Below is the list of ABS properties:

- Maximum temperature : $176^oF(80^oC)$
- Minimum temperature : $-4^oF(-20^oC)$
- Melting point : $221^oF(105^oC)$
- Tensile strength : 4300 psi

3.1.1 Flow Chart for Methodology

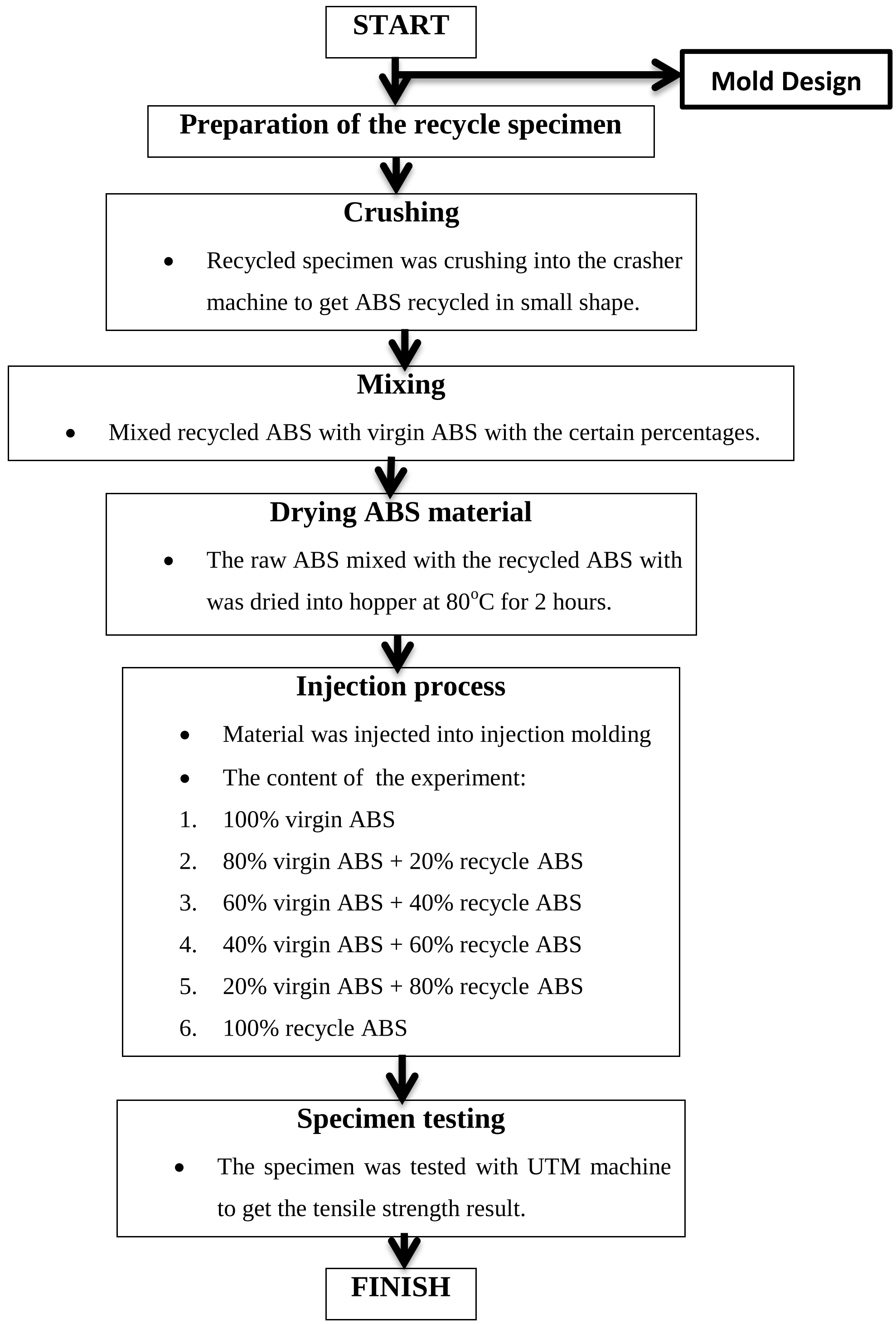

Figure 3.1: Flowcharts for methodology

3.2 EXPERIMENTAL DESIGN

In doing this experiment, five samples for each experiment was prepared in order to obtain the average for the result based on ASTM requirement. This because the result that we get more accurate. The method for testing part is followed the ASTM D638 standard. Then, the sample was tested at UTM (Universal Testing Machine). There is the list of experiment that was tested:

i. Experiment 1: Contents 100% virgin ABS
ii. Experiment 2: Contents 80% virgin ABS + 20% recycle ABS
iii. Experiment 3: Contents 60% virgin ABS + 40% recycle ABS
iv. Experiment 4: Contents 40% virgin ABS + 60% recycle ABS
v. Experiment 5: Contents 20% virgin ABS + 80% recycle ABS
vi. Experiment 6: Contents100% recycle ABS

3.3 EXPERIMENTAL PREPARATION

The steps that involved in this experimental preparation such as mold design and also mold preparation. In order to make mold for dog-bone shape, we choose P20 steel plate because P20 pure steel quality due to vacuum degassing treatment and screwing die is formed by forging, and the flat steel and round steel are formed by rolling at a high ratio of deformation. It is compact in structure, suitable for making the plastic molds requiring polish or etches machining.

P20 is chrome-moly tool steel made specifically to fill the requirements for the machined cavities and forces used in zinc die casting and plastic molding. It is delivered fully quenched and tempered to approximately Brinell 300. Other hardness levels may be obtained through additional heat treatment. Table 3.1 shows the properties of P20 steel plate.