# AN INVESTIGATION OF ACRYLONITRILE BUTADIENE STYRENE (ABS) IMPACT PROPERTIES SUBJECTED TO THERMAL DEGRADATION

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## DEDICATION

This report is dedicated to my beloved parents,

Encik Mohidin Bin Musa and Puan Rabiah Binti Mohamed.

Siblings too.

# APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure and Material).

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Date : 16 JUNE 2017

**STUDENT'S DECLARATION**

"I hereby declare that the work in this thesis is the results of my own except for summaries and quotations which have been duly acknowledged"

Signature: ……………………………….

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Date : 16 JUNE 2017

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**ABSTRACT**

Nowadays, ABS can be said as one of the material that keeps enlarging its applications field especially in electronics devices. ABS is used everywhere without being acknowledge by the consumers. Due to ABS was said as a hard and tough polymers and applications of ABS were at various environmental condition, this study is conducted to investigate the impact properties effect of pure ABS after being exposed at different temperatures and times by charpy impact test method. Exposing the ABS at different temperatures and times are best known as thermally degrading the material. Therefore, this study is aim to investigate the impact energy (absorbed energy) value of ABS subjected to thermal degradation method and also characterize the morphological surface of ABS after being thermally degrade. The samples was fabricated by hot press method and cut into desired shape by referring to ASTM charpy test standard dimension for polymers materials. Samples will be heated at different temperatures under condition defined as 50$^{o}$C and 80$^{o}$C and at different times defined as 10, 30 and 50 hours in an oven. Samples at room temperature are also prepared for this experimental investigation for a reference and comparison purpose. Then, the charpy test was conducted to obtain the impact energy value, resilience and percentage of absorbed energy of thermally degrade ABS samples under constant mass, speed, angle and height for the hammer to swing. Moreover, the morphological test was conducted by SEM machine to analyse the fracture behaviour of samples under same magnification. The samples exposed at 80$^{o}$C temperature absorbed less energy before it breaks into two pieces compared to samples that was exposed at 50$^{o}$C and the longer the time the samples were heated in the same temperature, the smaller energy it absorbed to fracture the specimen. The fractographic results from SEM recognised an obvious brittle failure mode only exist in samples at 80$^{o}$C temperature heated for 50 hours by the presence of flat surface structure while others are still behaving as ductile and respectively shows ABS are good and safe to be used at low temperature environmental condition.

# *ABSTRAK*

*Pada waktu kini, ABS boleh dikatakan sebagai salah satu bahan yang terus mengembangkan bidang applikasinya lebih-lebih lagi dalam peralatan elektroniks. ABS digunakan di mana-mana sahaja tanpa disedari oleh pihak pengguna. Oleh kerana ABS sering dikatakan sebagai polimer yang kuat dan teguh dan applikasi ABS digunakan pada pelbagai persekitaran, pembelajaran ini telah dijalankan untuk mengkaji sifat hentaman ABS yang asli setelah didedahkan pada suhu dan masa yang berlainan menggunakan kaedah ujian hentaman charpy. Mendedahkan ABS pada suhu dan masa yang berlainan sesuai ditakrifkan sebagai perlakuan degradasi terma terhadap bahan tersebut. Oleh itu, pembelajaran ini bertujuan untuk mengkaji nilai tenaga hentaman (tenaga serapan) ABS bersubjek kepada kaedah degradasi terma dan juga untuk menggambarkan sifat permukaan morfologi ABS setelah dikenakan tindakan degradasi terma. Sampel telah difabrikasi menggunakan kaedah tekanan berhaba dan dipotong kepada bentuk yang ditetapkan dengan berpandukan kepada ukuran piawaian ASTM untuk ujian charpy bagi bahan polimer. Sampel akan dipanaskan pada berlainan suhu yang disifatkan sebagai 50$^oC$ dan 80$^oC$ dan juga pada masa yang berlainan yang disifatkan sebagai 10, 30 dan 50 jam di dalam ketuhar. Sampel pada suhu bilik juga telah disediakan untuk kajian eksperimen ini bertujuan untuk membuat perbandingan dan sebagai rujukan. Kemudian, ujian charpy dijalankan bagi mendapatkan nilai tenaga hentaman, ketahanan dan peratusan tenaga yang diserap oleh sampel yang telah dikenakan degradasi terma apabila ditetapkan jisim, kelajuan, sudut dan tinggi untuk pemukul melakukan hayunan. Tambahan pula, ujian morfologi telah dijalankan oleh mesin SEM untuk menganalisa tindak laku retakan sampel pada magnifikasi yang sama. Sampel yang dikenakan suhu 80$^oC$ meresap kurang tenaga dibandingkan dengan yang dikenakan suhu 50$^oC$ sebelum ianya patah menjadi dua dan makin lama masa sampel dipanaskan pada suhu yang sama, makin kurang tenaga yang diserap untuk patahkan sampel. Keputusan fraktografi dari SEM menunjukkan penampakan ketara kegagalan yang bersifat rapuh wujud pada sampel bersuhu 80$^oC$ yang dipanaskan selama 50 jam dengan melihat kehadiran permukaan struktur yang rata sedangkan sampel yang lain masih bersifat mulur dan sekaligus menujukkan ABS adalah selamat dan sesuai untuk digunakan pada kondisi persekitaran yang mempunyai suhu yang rendah.*

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| ABS | Acrylonitrile Butadiene Styrene |
| DTA | Differential Thermal Analysis |
| DSC | Differential Scanning Calorimetry |
| FDM | Fused Deposition Method |
| MWD | Molecular Weight Distribution |
| PBT | Polybutylene Terephthalate |
| PC | Polycarbonate |
| PP | Polypropylene |
| SEBS | Styrene Ethylene Butylene Styrene |
| SEM | Scanning Electron Machine |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| E | = | Total absorbed energy by samples (J) |
| $m_{samples}$ | = | Mass of samples used in one mould = 936 g |
| g | = | Gravity acceleration value = 9.81 $ms^{-2}$ |
| $h_i$ | = | Initial height for the pendulum to swing (m) |
| $h_f$ | = | Final height for the pendulum to swing (m) |
| $\rho_{abs}$ | = | Density of ABS = 1.04 $g/cm^3$ |
| v | = | Volume dimension for mould = 900 $cm^3$ |
| $t_{cooling}$ | = | Cooling time for fabrication process = 15 minutes |
| $t_{preheat}$ | = | Preheat time for fabrication process = 7 minutes |
| $t_{press}$ | = | Pressing time for fabrication process = 10 minutes |
| P | = | Pressure on hot press machine = 50 $kg/cm^2$ |
| $m_{hammer}$ | = | Mass of hammer = 23 kg |
| $\theta_{hammer}$ | = | Angle to swing the hammer = 150° |
| $L_{span}$ | = | Span length = 42 mm |
| $\sum X$ | = | Sum of data set |
| N | = | Total number of set |
| $x_i$ | = | Sample value |
| $\bar{x}$ | = | Mean value |

# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND OF STUDY

Materials are important in the development of civilization where engineers keep them improved day by day. Material selection is a process of designing an object with a main goal to minimize the cost while meeting material performance. Systematic selection of the best material for a specified applications begins with analysing its properties. Properties can be described by how the material respond to the environment. Thus, in this case, an Acrylonitrile Butadiene Styrene (ABS) is selected to study its properties.

Generally, an ABS is a thermoplastic polymers that are hard and tough. ABS is started to be used since year 1950 (Desrousseaux, 2015) and widely applied in different field such as on electronic devices packaging, toys, automotive industries, hospitals furniture (James,1985) and much more as shown in Figure 1.1. Different applications of ABS also indicates the different environmental condition. This shows that application of ABS will experience a different environmental temperature until it has a major failure. Therefore, it is important to test ABS performance under different temperature to determine its ability.


Figure 1.1: Product made up of ABS material (James, 1985)

### 1.1.1 Polymers

Polymers material is most frequently used in the manufacturing process for industrial productions (Gan, 2009). It is widely used as a based material for most daily appliances. Polymers are constructed with relatively small molecular fragments called monomers. Polymers can be classified into two, which are synthetic polymer and natural polymer (Rich, 2011). Synthetic polymers are human made polymers that are prepared synthetically from low molecular weight compounds while natural polymers are generally obtained from nature (Anonymous, 2015). Figure 1.2 shows the classification of a polymer and its product example.

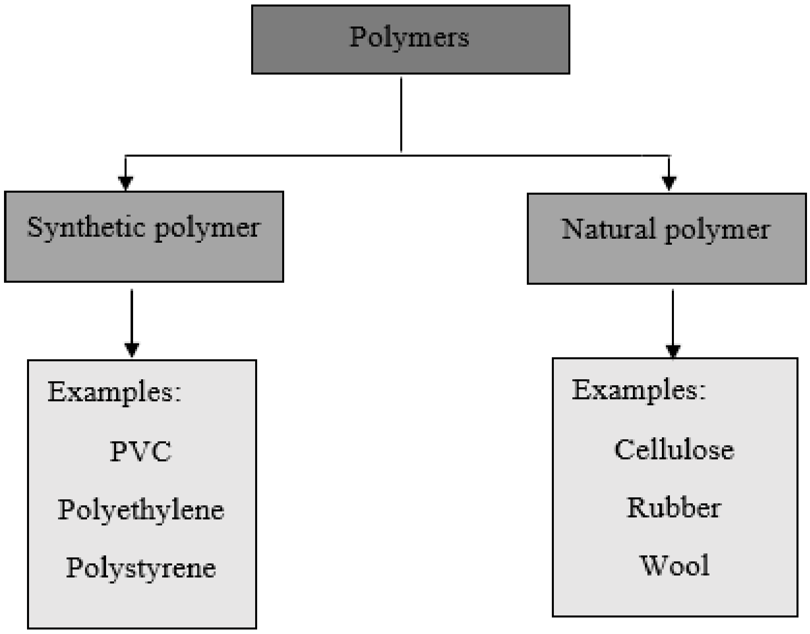


Figure 1.2: Classification of a polymer (Rich, 2011)

Polymers are widely used as adhesive in coatings, foams and packaging material in different industries. It is also used as fibres, composite, biomedical devices and electronic devices for new high technology purpose (James, 1985). The physical properties of a polymer in term of its strength and flexibility depends on its chain length, side groups, branching and cross linking. Furthermore, types of a polymers can be divided into thermoplastics and thermosetting plastic. The uses of plastic over metal material can give more advantages where plastic material is mouldable (Chanda, 1993). In addition to that, a plastic is an insulator, it will not lead to an adverse impact on material in the same way a metal would. The developments of materials that called polymer began with Rayon in 1981, Bakelite in 1907, Polyethylene in 1933, Nylon and Teflon in 1938, Polypropylene in 1954, Kevlar in 1965 (Sameer, 2012) and still continuing.

### 1.1.2 Thermoplastic

Thermoplastic can be define as materials that get soften while heating and can be remoulded in many shapes and pattern. After cooled down, it becomes solid again. This type of polymers can exist in amorphous and crystalline form. The amorphous structure acquired a bundle structure while crystalline structures of polymers contain ordered and compact arrangement (Dolgov, 2007). An Acrylonitrile Butadiene Styrene (ABS), Acrylic Plastic, Polypropylene (PP), Polyester and Polybutylene Terephthalate (PBT) are the examples of thermoplastics polymer (James, 1985).

Even though thermoplastic material has high impact towards resistance, capabilities to remoulding and reshaping, but they still higher in cost and ease to melt. Figure 1.3 shows the properties of ABS type Polylac PA-757. An ABS is on considered as a focused material in this research to study about its behaviour on impact testing.

Table 1.1: Physical properties of ABS (General ABS Polylac Characteristics PA-757, 2013)

| PROPERTIES | ASTM METHOD | TEST CONDITION | UNIT | ABS (PA-757) |
|---|---|---|---|---|
| Tensile Strength | D-638 | 6mm/min | $kg/cm^2$ ($lb/in^2$) | 460 (6 520) |
| Tensile Elongation | D-638 | 6mm/min | % | 25 |
| Flexural Modulus | D-790 | 2.8mm/min | $10^4 kg/cm^2$ ($10^5 lb/in^2$) | 2.7 (3.8) |
| Flexural Strength | D-790 | 2.8mm/min | $kg/cm^2$ ($lb/in^2$) | 790 (11 660) |
| Rockwell Hardness | D-785 | - | R-Scale | R-116 |
| Izod Izod Impact Strength (Notched) | D-256 | 1/8'' <br> 1/4'' | kg-cm/cm (ft-lb/in) <br> kg-cm/cm (ft-lb/in) | 21 (3.9) <br> 18 (3.3) |
| Vicat Softening Temperature | D-1525 | 50°C/hour | °C (°F) | 105 (221) |
| Heat Distortion Temperature | D-648 | Annealed <br> Unannealed | °C(°F) <br> °C(°F) | 95(203) <br> 85(186) |
| Specific Gravity | D-792 | 23°C | - | 1.05 |
| Flammability | Fil No E56070 UL&C-UL | - | - | 1.6mm HB |

### 1.1.3 ABS

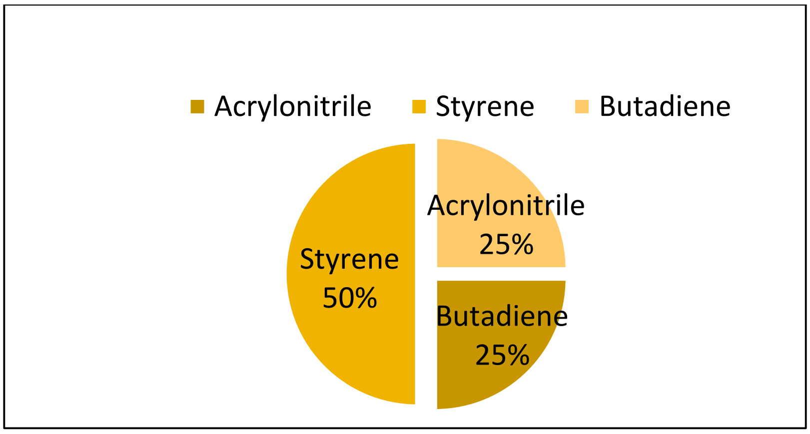


Figure 1.3: Composition of an ABS (Hashim, 2013)


Figure 1.4: Pellets of ABS

ABS is an oil based filament that is opaque and translucent. As shown in Figure 1.3, an ABS is a copolymer comprised of polymerized styrene and acrylonitrile with polybutadiene (Hashim, 2013). Based on application, half styrene with balance divided equally between butadiene and acrylonitrile are generally used in industries. Figure 1.4 shows the ABS pellets used in this study. This is a low cost engineering products that is easy to machine and fabricate. ABS can be fabricated by injection moulding or hot press technique (Jose, 2001). A virgin ABS seems to be expensive, thus the virgin ABS can be blended with recycled ABS which is economically attractive, while preserving high quality. Because of its non-toxic and recyclability characteristics, ABS is recommended compared to acrylic plastic where it is also a lightweight material and have high impact resistance (Perez, 2010).

## 1.2 PROBLEM STATEMENT

ABS is widely used in daily life. Application of ABS such as toys, car parts and on electrical device are used in different environmental condition either hot or cold, indoor or outdoor and days or night. Changes in temperature always influence the material performance in toughness properties because temperature effect may change the microstructure of the material as well as the ability to absorb energy. Therefore, it is significant to study the impact force at pure ABS material subjected to thermal degradation.

For better understanding, a modern refrigerator is one of the major applications of ABS where it is used in the making of the door liners of this device (ABS- Acrylonitrile Butadiene Styrene, 2013). This device can be used as an example of cases. The door liners is expected to receive an extreme force during opening and closing of the device. Moreover, the door liners of the refrigerator will also experience a heat transfer from the device to its surrounding. Therefore, it is significant to study the impact force of ABS material subjected to thermal degradation.

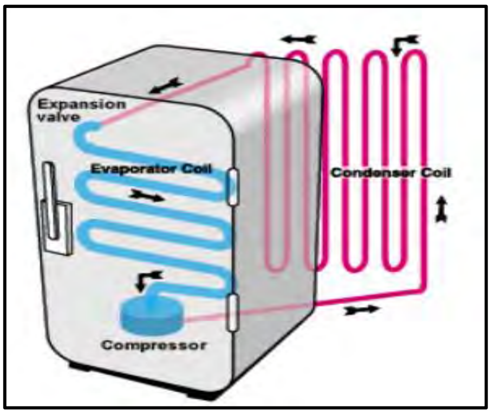


Figure 1.5: Illustration of heat transfer in refrigerator
(source from http://refrigeratorillustration )

## 1.3 OBJECTIVES

This study is aim to investigate the impact properties of ABS subjected to thermal degradation. Thus, the objectives of this project are:

i. To investigate the absorbed energy (absorbed energy) of ABS subjected to thermal degradation.
ii. To characterize the morphological surface of ABS subjected to thermal degradation.

## 1.4 SCOPE

A proper guideline need to be construct to ensure this project can be finished smoothly and satisfied the scope. The scopes of this project are to conduct literature on ABS impact properties subjected to thermal degradation. Journals, articles or any materials regarding this project were reviewed to assist the studies. The plates are prepared using hot press machine. Next, conduct experimental test under different condition by varying its temperatures and times in oven. Each sample will be give an impact test on it. Then, undergoes a morphological study of ABS by using SEM (Scanning Electron Microscope). All results gain from experiments in laboratory will be recorded and the morphological surface structure of an ABS that undergoes thermal degradation and impact test will also be analysed. After that, data analysis will be done and interpret in the form of figures, tables and graphs. Finally, a complete report writing will be conducted to accomplish this study.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 ABS

ABS has a big molecular mass with its formula $(C_8H_8{\cdot}C_4H_6{\cdot}C_3H_3N)_n$ shows a long carbon chain that consist of monomers acrylonitrile, butadiene and styrene. The atomic components includes carbon, hydrogen and nitrogen where carbon is the dominant atom in this structure. With the presence of two double bond (C=C) in butadiene monomers, the butadiene structure can be very reactive. Butadiene will contributes to the toughness and impact resistance in ABS compound. ABS loss its strength due to loosen in butadiene carbon-carbon double bond. The double bonds in the elastic rubber phase in butadiene monomers will decrease the toughness of ABS in response to long term heat effect (Joseph, 1986).

Campo et. al, in this study described an Acrylonitrile Butadiene Styrene (ABS) as a polymeric material. Chemical structures of ABS made up of three substances as shown in Figure 2.1 below. This journal stated that an ABS is tough and good impact resistance material through the contribution of butadiene monomers. Because of its individuality towards morphological analysis, more products have been produced in industries. ABS performance are stated to be well in usage of alloys and blends because the combination of plastics enhanced a positive features. Table 2.1 shows the typical applications of ABS that is used by humans (Campo, 2007).

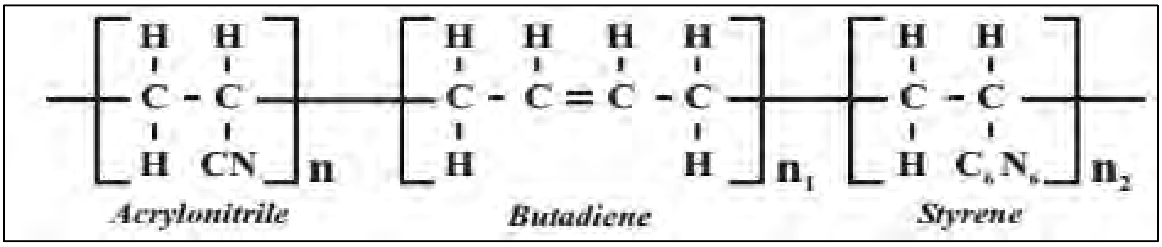


Figure 2.1: Chemical structure of ABS (Joseph, 1986).

Table 2.1: Typical application of ABS (Eric, 2016)

| APPLICATION | DESCRIPTION |
|---|---|
| Refrigerators | Doors and food liners for the interior wall, shelves, evaporator part trays and breaker strips. |
| Automotive Appliances | Seat belt retainers, headlight, mirror housing and armrest. |
| Home appliances | Hair dryers, blenders, vacuum cleaners and coffee makers. |
| Recreational | Motorcycles moulding, sailboats, airplanes, campers and picnic cooler liners, |
| Other applications | Briefcase, cosmetic cases, toys, photographic equipment and household packaging |

Gorski et. al, study on utilizing an Acrylonitrile Butadiene Styrene (ABS) as the tested material define that different angle of orientation in fabricating samples gives a different strength results. The fabrication of the ABS specimen has been carried out by using fused deposition modelling (FDM) and injection moulding method in order to determine its mechanical strength ability and will presents the results of impact strength test. Samples are