



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**PROCESSABILITY AND COMPATIBILY ANALYSIS OF  
THERMOPLASTIC ELASTOMER FILLED RECLAIMED  
RUBBER**

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

by

**MOHD KHUZAIMI BIN MOHD SALLEH**

**B050810002**

**890808-11-5079**

FACULTY OF MANUFACTURING ENGINEERING

2012



# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: Processability and Compatibility Analysis of Thermoplastic Elastomer Filled Reclaimed Rubber

SESI PENGAJIAN: 2011/12 Semester 2

Saya **MOHD KHUZAIMI BIN MOHD SALLEH**

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:

**TOIBAH BINTI ABD RAHIM**

Cop Rasmi:

**JUROR PENSYARAH**  
Fakulti Kejuruteraan Pembuatan  
Universiti Teknikal Malaysia Melaka

Alamat Tetap:

26-B, KG Bukit Payong

22010, Jerteh

Terengganu

Tarikh: 6 JUNE 2012

Tarikh: 6 JUNE 2012

\*\* 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 “PROCESSABILITY AND COMPATIBILITY ANALYSIS OF THERMOPLASTIC ELASTOMER FILLED RECLAIMED RUBBER” is the results of my own research except as cited in references.

Signature : .....

Author's Name : MOHD KHUZAIMI BIN MOHD SALLEH

Date : 6 JUNE 2012

## **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 (Engineering Material) (Hons.). The members of the supervisory committee are as follow:

.....

(Principal Supervisor)

.....

(Co-Supervisor)

## ABSTRAK

Getah tebus guna terisi adunan PP/ENR adalah merupakan bahan elastomer termoplastik yang baru muncul. Kesan nisbah adunan, pemvulkanan dinamik, dan agen pematangan terhadap sifat adunan polipropilena (PP), getah asli terepoksida (ENR) dan getah tebus guna (RR) disiasat. Pemvulkanan dinamik disediakan menggunakan asid stearik dan zink oksida (ZnO) sebagai bahan tambah pematangan dan diikuti oleh penambahan sulfur. Pemvulkanan dinamik ini meningkatkan kekuatan tegangan dan sifat terma. Sebatian elastomer termoplastik ini disediakan dengan penyebatian lebur dan pengacuanan mampatan. Campuran disediakan dengan menleburkan sebatian di dalam satu pencampur dalaman, Haake Rheomix pada suhu dan laju pemutar masing-masing bersamaan 180°C dan 60 rpm. Komposisi getah tebus guna dibezakan pada 5, 25 dan 50 peratus. Pengaruh nisbah getah tebus, TMPTA dan Irganox1010 sebagai penstabil dan pengikat sebatian dikaji untuk menambahbaik ciri-ciri dan sifat-sifat mekanik adunan elastomer termoplastik. Ciri-ciri dan sifat-sifat mekanik ditentukan menggunakan ujian tegangan, ujian hentaman Izod, dan kekerasan. Elastomer termoplastik dengan 50% getah tebus guna menunjukkan kekuatan tegangan dan mekanisme penyerapan tenaga yang tinggi iaitu 7.909 MPa dan 3 J/m. Mikrostruktur spesimen menggunakan mikroskop elektron imbasan (SEM) menunjukkan peningkatan kebolehcampuran antara plastik dan getah dengan kehadiran RR. Seperti yang dijangkakan, ciri-ciri tegangan dan kestabilan haba meningkat dengan peningkatan dalam kandungan RR disebabkan ciri-ciri unggul bahan ini.

## ABSTRACT

Reclaimed rubber filled PP/ENR blend is an emerging new thermoplastic elastomer material. The effect of blend ratio, dynamic vulcanization, and crosslinking agent on the properties of polypropylene (PP), epoxidised natural rubber (ENR) and reclaimed rubber (RR) blends were investigated. Dynamic vulcanization was prepared using stearic acid and zinc oxide (ZnO) as additional crosslinking chemicals followed by sulphur curing. Design of experiment (DOE) was conceived and optimized response surface methodology (RSM). Thermoplastic elastomer compound was prepared by melt compounding and compression molding processes. Blends were prepared by melt mixing in an internal mixer, Haake Rheomix of temperature and rotor speed of 180°C and 60 rpm, respectively. Reclaimed rubber composition was introduced in 0, 25 and 50 percentage. Effect of reclaimed rubber ratio, TMPTA and Iragnox1010 as stabilizer and binder to the cure characteristics and mechanical properties of thermoplastic elastomeric compounding was investigated. The characteristics and mechanical properties of the compound had been determined using tensile, Izod impact, and hardness tests. Thermoplastic elastomers filled 50% of RR showed highest tensile strength and energy absorption mechanism of 7.909MPa and 3 J/m. The microstructure of specimen observed using scanning electron microscopy (SEM) showed good miscibility between rubber and plastic due to the presence of RR. As expected, the tensile properties and thermal stability increase with the increases RR content due to superior characteristics of this material.

## **DEDICATION**

This thesis is gratefully dedicated to my family, all my friends, my supervisor, Puan Toibah Binti Abd Rahim and my co-supervisor Dr Noraiham Binti Mohamad. Thank you for all your supports, guidance, help and co-operation, directly or indirectly.

## ACKNOWLEDGEMENT

Bismillahirrahmanirrahim, I would like to thank to Allah for His blessing because I have accomplished this research. Firstly I would like to extend my heartiest gratitude to Puan Toibah Binti Abd Rahim and Dr Noraiham Binti Mohamad as my supervisor and co-supervisor who had given me guidance and support during the research. Not to be forgotten to other lecturers, my friends and other person whose name is not mention here.

Secondly, I want to thank my loving mother and father for supporting me to continue this study. With prayers and moral support from both of them, I have gained strength to endure this study. I also want to thank to UTeM especially for Faculty of Manufacturing Engineering for giving me the opportunity to gain experience and knowledge during my studies.

Finally, I sincerely thank to all people who directly or indirectly helped to finish my final year project.

Thank you.



# TABLE OF CONTENT

Abstrak	i
Abstract	ii
Acknowledgement	iii
Table of Content	iv
List of Tables	vii
List of Figures	viii
List of Abbreviations	ix
List of Symbols	x
<b>1. INTRODUCTION</b>	<b>1</b>
1.1 Research Background	1
1.2 Problem Statement	3
1.3 Objective	4
1.4 Scope	5
<b>2. LITERATURE REVIEW</b>	<b>6</b>
2.1 Introduction	6
2.1.1 Thermoset Elastomer (TSE)	7
2.1.2 Thermoplastic Elastomer (TPE)	8
2.1.2.1 Properties Of Thermoplastic Elastomer	10
2.1.2.2 Applications of TPEs	10
2.1.2.3 Thermoplastic	12
2.1.2.4 Polypropylene (PP)	14
2.1.2.5 Elastomer	14
2.1.2.6 Natural Rubber (NR)	15
2.1.2.7 Epoxidized Natural Rubber (ENR)	15

2.1.2.8	Reclaimed Rubber (RR)	16
2.1.3	Current Development of Thermoplastic Elastomer	20
2.1.3.1	Polypropylene / Nitrile Butadiene Rubber (PP/NBR)	20
2.1.3.2	Polypropylene / Natural Rubber (PP/NR)	20
2.2	Compounding process	21
2.2.1	Melt Mixing	21
2.2.1.1	Internal Mixer	22
2.2.1.2	Twin-Screw Extruder	24
2.2.1.3	Two Roll Mill	25
2.2.2	Solution Blending	26
2.2.3	Latex Blending	27
2.2.4	Compression Molding	27
2.3	Vulcanization/Curing Process	28
2.3.1	Peroxide Vulcanization	28
2.3.2	Sulphur Vulcanization	29
2.3.3	Mixed Vulcanization	30
2.4	Fabrication	30
2.4.1	Hot Press	30
2.4.2	Isostatic Press	31
2.5	Testing and Analysis	32
2.5.2	Mechanical Test	32
2.5.1.1	Tensile Test	32
2.5.2.2	Flexural Test	34
2.5.2.3	Hardness Test	35
2.5.1.4	Impact test	36
2.5.2	Fourier Transform Infrared	37
2.5.3	Thermal Analysis	38

2.5.3.1	Differential Scanning Calorimetry	38
2.5.4	Physical testing	39
2.5.4.1	Density test	39
2.5.4.2	Melt Flow Indexer	40
2.5.5	Morphological Study	41
2.5.5.1	Scanning Electron Microscopy (SEM)	41
<b>3.</b>	<b>METHODOLOGY</b>	<b>42</b>
3.1	Characterization of Raw Material	44
3.3.1	Polypropylene	44
3.3.2	Epoxidized Natural Rubber	45
3.3.3	Reclaimed Rubber	46
3.2	Preparation of the samples and process.	47
3.2.1	Blending of PP/ENR Blends in Internal Mixer	48
3.2.2	Pelletizing	49
3.3	Hot Pressing	50
3.3.1	Compression Molding Process	50
3.4	Testing and Analysis	52
3.4.1	Tensile Test	52
3.4.2	Hardness Test	54
3.4.3	Impact test	55
3.5	Physical Test	56
3.5.1	Melt Flow Index (MFI)	56
3.5.2	Density Test	57
3.5.3	Morphological analysis	58
3.5.3.1	Scanning Electron Microscopy (SEM)	58
3.7.4	Thermal Analysis	59
3.7.5.1	Differential Scanning Calorimetry	59

<b>4. RESULT AND DISCUSSION</b>	<b>62</b>
4.1 Introduction	62
4.1.1 Testing and Optimization of Mixing Parameter via RSM	63
4.2 Properties & Analysis	64
4.2.1 Tensile Properties	64
4.2.2 Elongation at Break	70
4.2.3 Hardness test	74
4.2.5 Impact test	79
4.2.6 Melt Flow Index	84
4.2.7 Density Analysis	88
4.2.8 Young's Modulus	92
4.2.9 DSC test	95
4.3 Optimization of Mixing Parameter via Response Surface Methodology	96
4.4 Microstructure	99
4.4.1 Fracture Surface Morphology of Tensile specimen	95
<b>5. CONCLUSION AND RECOMMENDATION</b>	<b>104</b>
5.1 Conclusion	104
5.2 Recommendation	105
<b>REFERENCES</b>	<b>106</b>

## LIST OF TABLES

Table 2.1	Common thermoplastic elastomeric materials	10
Table 2.2:	Technical specification of reclaimed rubber	20
Table 3.1:	Compound formulation used in TPEs blend recycled rubber	33
Table 4.1	Tensile properties of PP/ENR/RR blend	62
Table 4.2	ANOVA for the Selected Factorial Models Tensile Properties	64
Table 4.3	Observed Responses and Predicted Tensile Values	65
Table 4.4	ANOVA for the Selected Factorial Models Elongation at break	69
Table 4.5	Observed Responses and Predicted Values of Elongation break	70
Table 4.6	ANOVA for the Selected Factorial Models hardness Properties	73
Table 4.7	Observed Responses and Predicted Values of hardness	75
Table 4.8	ANOVA for the Selected Factorial Models Impact properties	78
Table 4.9	Observed Responses and Predicted Values of impact	79
Table 4.10	ANOVA for the Selected Factorial Models (MFI)	83
Table 4.11	Observed Responses and Predicted Values (MFI)	84
Table 4.12	ANOVA for the Selected Factorial Models density	87
Table 4.13	Observed Responses and Predicted Values of density	88
Table 4.14	The glass transition temperature of samples.	93
Table 4.15	Optimization Criteria of PP/ENR/RR blends.	95
Table 4.16	Solution formulation	95

## LIST OF FIGURES

Figure 2.1:	Repeating unit of polypropylene	14
Figure 2.2:	Rubber product for motor vehicles	18
Figure 2.3:	Schematic illustration of the reactor for the product of reclaimed rubber.	18
Figure 2.4:	Continuous recycling process for the product of reclaimed rubber.	19
Figure 2.5:	Stress-strain curves of crosslinked rubbers.	19
Figure 2.6:	Internal mixer machine	24
Figure 2.7:	A co-rotating twin screw extruder.	25
Figure 2.8:	Counter-rotating screws	26
Figure 2.9:	Two roll mill machine	27
Figure 2.10:	Schematic compression molding process	28
Figure 2.11:	The mechanism of peroxide vulcanization	29
Figure 2.12:	Standard tensile specimen with circular cross section	33
Figure 2.13:	Schematic illustration of a tensile load	34
Figure 2.14:	Schematic 3- point flexural test	35
Figure 3.1:	The flowchart of overall processing method, testing and analysis	45
Figure 3.2:	Polypropylene(PP)	47
Figure 3.3:	Reclaimed rubber	48
Figure 3.4:	HAAKE RHEOMIX OS Internal Mixer.	49
Figure 3.5:	Crusher machine.	50
Figure 3.6:	Hydraulic hot press machine.	51
Figure 3.7:	The small piece of compound is flattened onto the mold.	51
Figure 3.8:	Sheet form of the specimen.	52
Figure 3.9:	Universal Testing Machine	53
Figure 3.10:	The plot of area underneath the stress-strain curve.	54
Figure 3.11:	Rockwell Hardness Testing machine	55

Figure 3.12:	shows the 3-point flexure test.	56
Figure 3.13:	A pendulum swings( Izod impact apparatus).	58
Figure 3.14:	scanning electron microscope	60
Figure 4.1	Half-normal plot Tensile strength for the screening factors.	63
Figure 4.2	Tensile properties of samples.	66
Figure 4.3	Half-normal plot % elongation break for the screening factors.	68
Figure 4.4	The elongation break of samples.	71
Figure 4.5	Half-normal plot hardness strength for the screening factors.	73
Figure 4.6	The Hardness of samples.	76
Figure 4.7	Half-normal plot impact strength for the screening factors.	78
Figure 4.8	The Impact strength of samples.	80
Figure 4.9	Half-normal plot melt flow index for the screening factors	82
Figure 4.10	The melt flow index of samples	87
Figure 4.11	Half-normal plot density for the screening factors	87
Figure 4.12:	The density of samples.	89
Figure 4.13	Young's modulus of samples.	90
Figure 4.14	Half-normal plot Young's modulus for the screening factor	91
Figure 4.15	Histogram the desirability of formulation.	96
Figure 4.16 :	SEM fractographs using secondary electron at 500x magnification	98
Figure 4.17	SEM fractographs using secondary electron at 1000x magnification	100

## LIST OF ABBREVIATIONS

ASTM	-	American Standard Test Method
TPNR	-	Thermoplastic natural rubber
SEM	-	Scanning Electron Microscope
TPNR	-	Thermoplastic natural rubber
NBR	-	Nitrile butadiene rubber
PP	-	Polypropylene
RSM	-	Response surface methodology
SEM	-	Scanning electron microscopy
DSC	-	Differential scanning calorimetry
FTIR	-	Fourier transform infrared
TPO	-	Thermoplastic polyolefin
TPV	-	Thermoplastic vulcanizate
TPE	-	Thermoplastic elastomer
RR	-	Reclaimed Rubber
TMPTA	-	Trimethylolpropane triacrylate
ENR	-	Epoxidized Natural Rubber
Irganox1010	-	Phenolic Primary Antioxidant



# CHAPTER 1

## INTRODUCTION

### 1.1 Research Background

Thermoplastic elastomers (TPEs) have emerged as a highly demanding class of polymeric materials and already started replacing many other conventional materials in various applications. With the exception of their dual characteristics of vulcanized elastomer and thermoplastic properties, the possibility of adjusting their properties by different routes has caused TPEs to be a versatile class of materials. TPEs have low cost and attractive properties such as superior mechanical strength, light weight, corrosion resistance, applicability at elevated temperatures, ability to be tailored for specific engineering applications are some of the properties of TPEs which may not be found in any other materials. The most important feature of TPEs is the repeated recyclability up to several times without significant loss of properties (Naderi *et al.*, 1999).

Basically, TPES consists of at least two polymeric phases. A hard thermoplastic phase combined with a softer elastomer phase, and the properties of the resultant TPES will be derived from the properties of each of the two phases individually and from the extent of interaction between these phases (Arnold and Rader, 1992). There are many possible combinations of plastics and elastomers of TPEs that could be developed in accordance with the expected properties of the final material. Polypropylene (PP) is a linear hydrocarbon polymer and the typical density of PP is 0.9 g/cm<sup>3</sup>. The products based on PP are very significant commercially due to the advantages of being low in both density and the cost. Additionally, its crystalline structure and high melting point results in

resistance to solvent and high temperature (Holden, 2000). The importance of recycling of waste materials (reclaimed rubber) generated from industries worldwide has become significantly important in the recent past mainly due to environmental reasons. The rubber manufacturing industry also faces a major challenge in this regard. A study to find the satisfactory ways and means to deal with the enormous quantity of waste rubber goods generated by the industry which may lead to severe environmental problems unless they are disposed properly. Reclaimed rubber wastes are usually generated during the processing of the products and from the disposal of post-consumer products.

Recently, the importance of recycling waste materials has been increasing for all industries worldwide. For rubber products, the automotive and transportation industries are the biggest consumers of raw rubber. Rubber waste is usually generated during the manufacturing process of products for these industries and by disposal of post-consumer (retired) products, mainly including scrap tires. For example, in Japan, about one million tons of scrap tires are generated annually. Blending the reclaimed rubber with another polymeric material to form a blend is one of the most effective methods of utilizing the reclaimed rubber for any industrial applications. Among various thermoplastic elastomers (TPEs), blends based on polypropylene are an important class of engineering materials (Rajalekshmi *et al.*, 2005). Therefore this study is focused on the development of a new class of TPES material by blending PP, ENR and reclaimed rubber with different composition ratio generating from rubber manufacturing industry. It is hopeful at the end the final product developed would find useful applications in the automotive and rubber industries. The blending of PP, ENR and reclaimed rubber looks to be a very attractive as a way to obtain new TPEs with good mechanical properties and easy processability, these blends are found to be highly compatible. To improve the properties of TPES blends is to introduce crosslinks in the rubber phase of the blend. This can be done by vulcanization of the rubber phase through dynamic vulcanization

## 1.2 Problem Statement

Prior to the existence of thermoplastic elastomers (TPES), there were individual recyclable thermoplastic and non-recyclable elastomers. Nowadays, thermoplastic elastomers are getting encouraging response due to its unique properties, combining individual properties of plastic and elastomer, characteristics of vulcanized elastomer and thermoplastic properties. They exhibit the properties of both plastics and rubbers. The unique properties of both materials exist because TPES materials are created only by physical mixing of a thermoplastic and elastomer and no chemical or covalent bonding exists between the two. Thermoplastic elastomers have become a significant part of the polymer industry. Further research of thermoplastic currently lies on the polypropylene (PP), epoxidised natural rubber (ENR) involving the effort to reuse the reclaimed rubbers that had been vulcanized. This kind of rubber could reduce the manufacturing cost and contribute to greener environment due to the reclaimed rubbers used. The latest TPEs blend filled reclaimed rubber present good mechanical strength and compatible performance like other thermoplastic elastomer properties. The compatibility of recycled rubber to be the constituents of thermoplastic elastomers obviously could cut the production cost.

### 1.3 Objectives

The main focus of this study is to develop a new thermoplastic elastomer (TPEs) using polypropylene (PP), epoxidized natural rubbers(ENR) and reclaimed rubber and thereby to find a suitable solution to the existing problem of disposing the reclaimed rubber waste material generated from rubber based product industries.

The objectives of this study are :-

- a) To prepare TPE filled reclaimed rubber using melt compounding and dynamic vulcanization technique.
- b) To characterize the physical, mechanical and thermal properties of thermoplastic elastomer filled reclaimed rubber.
- c) To identify the compatibility between thermoplastic, epoxidised natural rubber and reclaimed rubber.

## 1.4 Scope of Project

This study focuses on to produce a new thermoplastic elastomer material with blending of polypropylene (PP), epoxidised natural rubber (ENR) and reclaimed rubber (RR). It investigated the effect of blend ratios and some process modification such as dynamic vulcanization (with sulphur, stearic acid and zinc oxide) and additional of TMPTA and Irganox1010 as stabilizer and binder. The effect of ratio on blends is evaluated from characteristic and properties of PP/ENR filled reclaimed rubber, zinc oxide and stearic acid are used as activator, then sulphur act as curing agent. The melt compounding process involved materials in pallet form were blended together in an internal mixer to produce compound at operating temperature of 180 °C and rotor speed of 60 rpm. Crusher machine is used to crush compound into smaller particle size before placed into a mold (Hydraulic hot moulding machine) for compression molding process. Lastly, the sample materials were cut into specific size for mechanical testing, physical testing, thermal testing, composition and morphology analysis.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

Since the beginning of the plastics industry, it has been recognized that blending yields materials with property profiles superior to the features of the individual components. The blending of polymers provides a means of producing new materials, which combine the useful properties of all of the constituents (Utracki, 2002). The technology of blending is now advancing at a rapid pace. The ability to combine existing polymers into new compositions with commercial utilities offers the advantage of reduced research and development expense compared to the development of new monomers and polymers to yield a similar property profile. An additional advantage is the much lower capital expense involved with scale-up and commercialization. Another specific advantage of polymer blends versus new monomer polymer compositions is that blends often offer property profile combinations not easily obtained with new polymeric structures. Blending technology is more useful in the field of plastics recycling. It is estimated that about one third of all commercially produced polymer materials are blends of two or more polymers.

Polymer blend could be defined as a mixture of at least two macromolecular substances, polymers or copolymers, in which the ingredient content is higher than 2 wt% (Utracki,1998).Preparation of polymer blends can be done by melt mixing, latex blending, solution blending, partial block or graft polymerization as well as interpenetrating polymer network (IPN) technology. Melt mixing is the most widespread

method of polymer blend preparation in practice. It is important that the size of the dispersed phase be optimized, considering the final performance of the blend (Horak *et al.*, 2007).

Polymer blends can be classified with many parameters such as number of components (binary, ternary etc), type of constituent (thermoplastic, thermosetting or elastomer), nature of the polymer architecture (graft or block polymer), compatibility among the constituent (compatible, incompatible), and method of producing (physical or chemical blending). Among the listed parameters, type of constituent is the most commonly used indicator. The polymer blends is classified into three main categories that is plastics-plastics blends, elastomer- elastomer blends, plastics elastomer blends As this study is more about the plastics elastomer blends.

### **2.1.1 Thermosetting Elastomer (TSE)**

Thermoset is a polymer that is cured by heat or chemical reaction and becomes infusible and insoluble material. Thermoset polymers possess a cross linked molecular structure and are formed in two stage polymerization. The first stage is formation of a polymer with linear chains. The second stage of polymerization results in final cross linked structure. The end product can be made rigid or flexible. The Polymerization is controlled to result in heavily cross linked short chains for hard product and lightly cross linked long chains for soft and flexible products (Kear, 2003). Thermosetting polymers are network polymers (Callister, 2000). They become permanently hard during their formation, and do not soften upon heating. Thermosets have been chemically linked chains by covalent bonds during polymerization or by subsequent chemical or thermal treatment during fabrication. Others thermosets (such as epoxy, polyester, and urethane) cure at room temperature, because the heat produced by the exothermic reaction is sufficient to cure the plastics (Kalpakjian and Schmid, 2006). The high density of crosslinking between the molecules makes the thermosetting material stiff and brittle and has better stability (Osswald and Menges, 2003). Thermoset is a polymer that is

cured by heat or chemical reaction and becomes infusible and insoluble material. Thermoset polymers have a permanent irreversible polymerization. It is form permanent crosslinks between chains when cured and are comparatively strong and stiff but can't be recycled (Callister, 2006). Thermoset useful physical property of a thermoplastic is its glass transition temperature at which it begins to soften. Glass transition temperatures of different thermoplastics can be seen in (Legge, 1987).

### **2.1.2 Thermoplastic Elastomer (TPEs)**

Holden (2000) and Walker (1986) have both shown that thermoplastic elastomers (TPEs) have become a technologically important class of material in recent past years. TPEs have many of the elastomeric physical properties of rubbers such as softness, flexibility, resilience but they are processable as thermoplastics. TPEs can be able to process using conventional thermoplastic processing techniques such as injection molding, extrusion. TPEs can also be completely reprocessable without any considerable loss in properties or processing characteristics due to recyclability of their scrap and rejects. Charles (2002) state that thermoplastic elastomers one of synthetic rubber aren't crosslinked, however. They can be molded and remolded again and again. Thermo- means "heat", and plastic means "moldable". Elastomer is just a fancy word that means "rubber." So a thermoplastic elastomer is a rubber that can be molded when it is heated.

Abdullah and Dahlan (1998) classify TPEs are a new of material that combine the properties of vulcanized rubbers with the ease of processability of thermoplastics Thermoplastic elastomers can be prepared by blending thermoplastic and elastomers at high shear rate. Thermoplastics, for example, polypropylene (PP), polyethylene (PE) and polystyrene (PS), and elastomers, such as ethylene propylene diene monomer (EPDM), natural rubber (NR) and butyl rubber (BR), are among the materials used in thermoplastic elastomer blends.