UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

THE DEGRADATION STUDY OF PVC/ABS AND PVC/ABS/CARBON BLENDS DURING REPEATED EXTRUSION ON MECHANICAL AND THERMAL PROPERTIES

Muhyiaddin Abdul Qadir bin Abu Bakar

Master of Manufacturing Engineering (Industrial Engineering)

2014

THE DEGRADATION STUDY OF PVC/ABS AND PVC/ABS/CARBON BLENDS DURING REPEATED EXTRUSION ON MECHANICAL AND THERMAL PROPERTIES

MUHYIADDIN ABDUL QADIR BIN ABU BAKAR

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

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

DECLARATION

I hereby, declared that this report entitled 'The Degradation Study of PVC/ABS and PVC/ABS/Carbon Blends During Repeated Extrusion on Mechanical and Thermal Properties' is the results of my own research except as cited in the references.

Signature : ………………………………………...

Name : Muhyiaddin Abdul Qadir Bin Abu Bakar

Date : 11/8/2014

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Manufacturing Engineering (Industrial Engineering).

Signature : ....

Supervisor Name : Dr. Zaleha Binti Mustafa

Date : 12/8/2014

ABSTRACT

The degradation effects on numbers of extrusion of PVC/ABS and PVC/ABS/Carbon blends to mechanical and thermal properties have been investigated. The composition of PVC/ABS blends was 80/20 wt% and PVC/ABS/Carbon was 73/23/7 wt%. The study has been focused on ultimate tensile strength, strain at ultimate tensile, elastic modulus and strain at failure for mechanical properties of the blends. Ultimate tensile strength, strain at ultimate tensile and elastic modulus have been retained by both PVC blends due to the presence of SAN phase from ABS that possess the complete retention with increasing numbers of extrusion. On the other hand, the presence of butadiene rubber (BR) phase in ABS increase the deformability of PVC blends which contributed to increase strain at failure. Increased numbers of extrusion have refined the dispersion of carbon in the blends and made stronger adhesion between carbon and the matrix that led to increase the strain at failure of PVC/ABS/Carbon. Glass transition temperature (Tg) have been obtained using differential scanning calorimetry (DSC) for thermal properties of the blends. The partial miscibility between the components of the blends was concluded from two Tg obtained from DSC test. Finally, a morphological study of the fracture surface has been completed using scanning electron microscopy (SEM). The images from SEM justify the mechanical properties of the PVC blends.

ABSTRAK

Satu kajian berkaitan kesan proses penolakan berterusan keatas campuran PVC/ABS dan PVC/ABS/Karbon telah dijalankan bagi melihat perubahan keatas sifat mekanikal dan termal campuran. Komposisi bagi campuran PVC/ABS telah ditetapkan pada 80/20 % dan campuran PVC/ABS/Karbon pada 73/23/7 %. Kajian ini akan memberi penekanan pada kekuatan tegangan puncak, terikan pada tegangan puncak, modulus anjal dan terikan putus bahan. Kekuatan tegangan puncak, terikan pada tegangan puncak dan modulus anjal dapat dikekalkan oleh kedua-dua campuran berpunca daripada kehadiran fasa SAN daripada ABS yang telah menghalang daripada berlakunya perubahan pada sifat bahan walaupun proses penolakan berterusan dilakukan berulang kali. Selain itu, kehadiran fasa getah butadiene (BR) dalam ABS telah meningkatkan kadar perubahan bentuk bahan campuran PVC yang secara tidak langsung telah meningkatkan sifat terikan putus. Penambahan proses penolakan berterusan telah mensebatikan unsur karbon dalam campuran PVC yang menyebabkan lekatan antara unsur karbon dan unsur matrix bertambah baik. Keadaan ini menyebabkan peningkatan pada sifat terikan putus bahan campuran PVC. Suhu perubahan gelas (Tg) telah direkodkan menggunakan mesin pengimbas perubahan kalori (DSC) untuk sifat termal bahan campuran. Dua Tg telah didapati pada setiap sampel yang mana telah menunjukkan bahawa bahan campuran PVC ini adalah bersifat separuh terlarut campur. Bagi mengesahkan sifat mekanikal bahan yang telah diperolehi tadi, maka akhirnya ujian pengimbasan electron mikroskop (SEM) telah dijalankan.

ACKNOWLEDGEMENTS

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Dr. Zaleha Mustafa from the Faculty of Manufacturing Engineering Universiti Teknikal Malaysia Melaka (UTeM) for her essential supervision, support and encouragement towards the completion of this Master Project 2.

Particularly, I would also like to express my deepest gratitude to Mr. Azhar and Mr. Hairul Hisham, the technicians from material laboratory Faculty of Manufacturing Engineering, for their assistance and efforts in the lab and analysis works.

Special thanks to all my peers, my mother, beloved father and siblings for their moral support in completing this Master Project 2. Lastly, thank you to everyone whom had been to the crucial parts of realization of this project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVEATIONS

ABS	Acrylonitrile butadiene styrene
ASA	Acrylonitrile Styrene Acrylate
AMS-ABS	α-methylstyrene-acrylonitrile- butadiene-styrene copolymer
ANOVA -	Analysis of Variances
ASTM	American Society for Testing and Materials
V-0	Burning stops within 60 seconds on a vertical specimen
BR	Butadiene rubber
DOE	Design of Experiments
$CaCO_3$	Calcium carbonate
CB	Carbon black
^oC	Degree of centigrade
DSC	Differential scanning calorimetry
DMA	Dynamic Mechanical Analysis
CPE	Chlorinated polyethylene
ε_B	Elongation at failure
EVA	Ethylene vinyl acetate
EPDM	Ethylene propylene diene monomer
ft	Foot
GPC	Gel permeation chromatography
Tg	Glass transition temperature
HCl	Hydrogen chloride
HDT	Heat distortion temperature
HDPE	High-density polyethylene
h	hour
in	Inch
J	Joule
kg	Kilogram

LDPE	Low density polyethylene
LOI	Loss on ignition
MAH	Maleic anhydride grafted
MAStVA	Maleic anhydride–styrene–vinyl acetate
Wt%	Mass fraction
m	Meter
T_m	Melting temperature
mm	Milimeter
MPa	Megapascal
NBR	Nitrile butadiene rubber
$T_{onset,m}$	Onset melting temperature
%	Percent
PC	Polycarbonate
PMMA	Poly(methyl methacrylate)
PP	Polypropylene
PPE	Polyphenyl ethers
PVC	Polyvinyl chloride
PS	Polystyrene
lbs	Pound
psi	pound per square inch
RH	Relative humidity
rpm	Revolutions per minute
T	Temperature
σ_M	Tensile strength
TiO_2	Titanium dioxide
K-value	Thermal conductivity
TGA	Thermogravimetric
TP	Thermoplastic
TS	Thermoset
TEM	Transmission electron microscopy
SEM	Scanning electron microscope
SD	Standard deviation
SAN	Styrene Acrylonitrile

SMA	Styrene-maleic anhydride
UL94	Standard for Safety of Flammability of Plastic Materials
UV	Ultraviolet
VCM	Vinyl Chloride Monomer
XRF	X-ray Fluorescence
w	Weight fraction
ZnO	Zinc Oxide

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Plastics can be divided into two groups which are thermoplastic (TP) and thermoset (TS). Thermoplastic is the type of plastic that can be repeatedly softened by heating and then solidified by cooling. Molecules in a thermoplastic are held together by relatively weak intermolecular forces. Thermoplastic can be processed several times and makes these kinds of plastics suitable for recycling. Thermosets in a soft solid or viscous state that changes irreversibly into an infusible, insoluble polymer network by curing. Curing can be induced by the action of heat or suitable radiation or both. A cured thermosetting polymer is called a thermoset.

Polyvinyl chloride (PVC) is a thermoplastic polymer. PVC is primarily an amorphous material with good durability, fire retardant, oil and chemical resistant and good mechanical properties. Many commercial polyvinyl chloride (PVC) resins contain crystalline regions ranging from 5 to 10 % of the polymer. The polymer will remain intact at temperatures well over 200 ^{o}C. The region of crystallinity with relatively narrow molecular weight distribution will help impart superior melt strength during extrusion. Another unique characteristic of polyvinyl chloride (PVC) is the amorphous nature of the polymer promotes cost effective fabrication of clear articles in thickness exceeding 0.25 in (10mm) if proper addictive selection used (Grossman, 2008).

Polyvinyl chloride (PVC) contains approximately 57 % chlorine by weight. The condition of the polymer will creates strongly polar region and make it compatible with a wide range of additives. No other commercial polymer can have its properties modified in so many ways compare to polyvinyl chloride (PVC). Beside of that, the chlorine in polyvinyl chloride (PVC) will also make the polymer flame resistance.

PVC has been use in wide range of short life and long life product application. In short life product, PVC have been processed in packaging material use in food, cleansing materials, textile, beverage packaging bottles and medical devices. In long life product, PVC have been processes into pipes, window frames, cable insulation, floors coverings and roofing sheets (Sadat-Shojai and Bakhshandeh, 2011).

1.2 Problem Statements

Every product has specific cycle time. There is a time when the product will come to their end life and the product need to be properly disposed. PVC with a wide range of products, their waste will increase with time. Thus will become a problem to the community. Today, PVC waste is dispose in landfill. However, using landfill to cater the problem is not a good solution because the area required for landfilling will increase with increasing of the waste. Beside of that, using landfilling to dispose PVC waste have potential environmental hazard because of the chlorine content of the polymer.

Another route to solve the increment of PVC waste is by recycle the PVC waste into another product. Thus, recycling of the PVC has gain interest for researcher in order to produce secondary materials (Sadat-Shojai and Bakhshandeh, 2011). However, recycle the PVC into similar or another product is not a straight path. Recycle PVC showed to have inferior mechanical properties (Yarahmadi et al., 2001). The recycle PVC with low mechanical properties however can be process into a low strength requirement type of product with cost conscious production. But, if the recycle PVC need to be use in another requirement type of products, the molecule properties of the material need to be alter.

One of the most popular methods to retain and increase the properties of the material is by blending the polymer with another polymer. Polymer blending has become an important field in polymer research. In this research the target was to reduce the polymer waste problem by blending the PVC with other type of polymer and make sure that the recycle blends polymer still retains an identical properties compare to the first cycle of the blends. With identical properties of the blends compare to the virgin and the recycle of the virgin, it will make the blends as an ideal replacement material to be used for consumer products. Then, by showing a slightly decrease in properties after a few recycle compare to the copolymer that show greater decrease in properties, the polymers blends will fulfil the purpose to retain the properties of the material and can be used for several times in processing. It will give a huge profit for recycle industries because the scrap from the blends can be recycle to be made into the same or different product that meet the requirement base on their properties whereas the recycle from the copolymer cannot sustain the same properties.

Beside of improving physical properties of the material, polymer blends will also benefit in low investment cost in a new material design. In this case, a cheaper material like PVC will be dilute with expensive polymer material in hope to retaining some of the high performance properties. The blends maybe homogeneous (true thermodynamic miscibility of components) or heterogeneous (phase-separated). In heterogeneous blends, components maybe thermodynamically immiscible but mechanically compatible (Elias, 2003). Many researches have blend PVC with other polymer materials such as PVC/PMMA, PVC/NBR, PVC/EVA and PVC/CPE (Grossman, 2008). Thus, the objective to minimize the cost for a new material design with improves material properties can be achieved.

Polystyrene (PS) is amorphous region material with good impact resistance high heat resistance. In theory, blending PVC with PS will improve thermal and mechanical properties of the material. But, does the properties can be retain if the blends were recycles for several times? The assumption can be made that the recycle of PVC/PS blends will give the identical outcome with slightly reduce number compare to the first cycle. Another famous amorphous region material is acrylonitrile butadiene styrene (ABS) with good impact resistance, toughness and weather ability. In theory, blends PVC with ABS will improve impact resistance, toughness and weather ability of the material (Rimdusit et al., 2012). But, does the properties can be retain if the blends were recycles for several times? Same as PVC/PS blends, assumption can be made that the recycle of PVC/ABS blends will give the identical outcome with slightly reduce number compare to the first cycle. There are very limited knowledge about the properties either PVC/PS or PVC/ABS blends when there were recycles for several times.

Blends of polyvinyl chloride (PVC) with α-methylstyrene-acrylonitrile- butadiene-styrene copolymer (AMS-ABS) show a single glass transition temperature (Tg) when observed by differential scanning calorimetry (DSC). This result indicates that PVC is miscible with AMS-ABS (Zhang et al., 2013). The research suggest that the most interesting area for further investigation is the region containing 15 – 30 wt% of AMS-ABS because within these compositions, the heat distortion temperature (HDT) and the impact strength have improved effectively without losses in tensile and flexural properties. The impact strength show gradually increase when the PVC/ABS blends below 30 wt% of ABS content and the drastic increase observed when the ABS content range from 30 to 50 wt % (Rimdusit et al., 2012). Pavan et al. (1980) show that 30 wt% of PVC/ABS blends will give the identical impact strength compare to Rimdusit et al. (2012). Thus, for this degradation study, 30 wt% of ABS will be choose to blend with 70 wt% of PVC. Although using 30 wt% of ABS will not give the highest mechanical properties compare to 50 wt% of ABS, the composition of 30 wt% of ABS is more economical to the highest composition. Then, comparison between 15 to 30 wt% of ABS show that 30 wt% will result in the highest mechanical properties. So, by choosing 30 wt% of ABS, it is the best composition to use in term of material properties and economic scale.

Effect of repeated extrusion on the properties and durability of rigid PVC scrap have been studied previously (Yarahmadi et al., 2001). The PVC scrap has been extruded for five times without adding new additives. The result shows that PVC scrap is suitable for mechanical recycling for up to three times only. The fourth recycle show the decrease in extrusion pressure cause by rheological breakdown under stress. Thus, based on the