

**CORRELATION OF OUTDOOR EXPOSURE AND
ACCELERATED WEATHERING TEST FOR STUDY OF SERVICE
LIFETIME OF PLASTIC CARDS**

Thamrong Chansawang

A Thesis Submitted in Partial Fulfilment of the Requirements
for the Degree of Master of Science
The Petroleum and Petrochemical College, Chulalongkorn University
in Academic Partnership with
The University of Michigan, The University of Oklahoma
and Case Western Reserve University

2011


I 28374800


Thesis Title: Correlation of Outdoor Exposure and Accelerated Weathering Test for Study of Service Lifetime of Plastic Cards
By: Thamrong Chansawang
Program: Polymer Science
Thesis Advisors: Asst. Prof. Hathaikarn Manuspiya

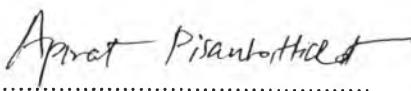
Accepted by The Petroleum and Petrochemical College, Chulalongkorn University, in partial fulfilment of the requirements for the Degree of Master of Science.


..... College Dean
(Asst. Prof. Pomthong Malakul)

Thesis Committee:


.....
(Asst. Prof. Hathaikarn Manuspiya)


.....
(Asst. Prof. Thanyalak Chaisuwan)


.....
(Asst. Prof. Apirat Pisankittichot)

ABSTRACT

5272030063: Polymer Science Program

Thamrong Chansawang: Correlation of Outdoor Exposure and Accelerated Weathering Test for Study of Service Lifetime of Plastic Cards

Thesis Advisor: Asst. Prof. Hathaikarn Manuspiya 106 pp.

Keywords: Degradation of plastic materials / outdoor exposure / accelerated weathering test

A number of commercial plastic card materials, such as polyvinyl chloride (unplasticized) (PVC), polycarbonate (PC) and polyethylene terephthalate glycol (PETG), are widely available for using as smart card body. Usually, the degradation of plastic materials is concerned because the life time of smart card is required to specify. The study of plastic card degradation by moisture, light, and temperature with outdoor exposure and accelerated weathering test in Thailand has to the authors' knowledge never been studied. Therefore, this study aims to correlate the outdoor exposure condition with the condition in accelerated weathering tester or QUV. The outdoor exposure periods were set at 1, 2, 3, 4, 5, and 6 months. Accelerated weathering test was performed by QUV accelerated weathering tester. QUV accelerated weathering tester was operated with both UV-B lamps irradiance and dark light at 0.48 W/m^2 340 nm for 4 hours at 37° . The results show that introduction of outdoor exposure and accelerated weathering test causes changing in gloss at 60° , total color different value, thermal properties and mechanical properties. Finally, the results were summarized for correlation condition between the outdoor exposure and the accelerated weathering test.

บทคัดย่อ

ธีรารัตน์ จันทร์สว่าง : การศึกษาความสัมพันธ์ของอายุการใช้งานของบัตรพลาสติก ในการใช้งานกลางแจ้ง กับในเครื่องเร่งสภาวะอากาศ (Correlation of Outdoor Exposure and Accelerated Weathering Test for Study of Service Lifetime of Plastic cards) อ.ที่ปรึกษา : ผศ. ดร. หทัยกานต์ มนต์ปิยะ 106 หน้า

วัสดุที่นิยมใช้ทำบัตรพลาสติกสำหรับทำบัตรอสังหาริมทรัพย์ที่มีจำหน่ายทั่วไปมีหลายชนิดเช่น โพลีไวนิลคลอไรด์ โพลีคาร์บอเนต และ โพลีเอทิลีนเทเรฟทาเลตไกลคอล การเสื่อมสภาพของบัตรพลาสติกจากปัจจัยของสภาพแวดล้อมทั้งความชื้น อุณหภูมิ และแสงแดด เป็นเรื่องสำคัญที่ต้องคำนึงถึง เนื่องจากการเสื่อมสภาพของบริเวณพลาสติกมีผลโดยตรงต่ออายุการใช้งานของบัตรอสังหาริมทรัพย์ ประกอบกับงานวิจัยที่เกี่ยวข้องกับการเสื่อมสภาพของบัตรพลาสติกในประเทศไทยยังไม่มีผู้ใดทำการศึกษา ดังนั้นหัวข้อวิจัยเรื่องนี้จึงมีเป้าหมายในการศึกษาความสัมพันธ์ของอายุการใช้งานของบัตรพลาสติก ในการใช้งานกลางแจ้ง กับในเครื่องเร่งสภาวะอากาศ โดยช่วงเวลาของการใช้งานกลางแจ้งคือ 6 เดือน เก็บตัวอย่างมาทำการทดสอบสมบัติต่างๆทุกเดือน ผลการทดสอบที่ได้จะถูกนำมาเปรียบเทียบและหาความสัมพันธ์กับผลการทดสอบบัตรพลาสติกที่ถูกใช้งานในเครื่องเร่งสภาวะอากาศ ตามจำนวนของรอบการทดสอบด้วยเครื่อง QUV accelerated weathering tester โดยหนึ่งรอบของการทดสอบบัตรพลาสติกจะถูกฉายรังสียูวี ชนิดบี ด้วยความเข้ม 0.48 วัตต์ต่อตารางเมตรเป็นเวลา 4 ชั่วโมง และอยู่ในสภาวะที่มีความชื้นแบบไร้แสง เป็นเวลา 4 ชั่วโมง โดยควบคุมอุณหภูมิไว้ที่ 37 องศาเซลเซียส ผลการทดลองจากการตากไว้กลางแจ้ง และการตากไว้ในเครื่องเร่งสภาวะอากาศ ทำให้บัตรพลาสติกมีการเปลี่ยนแปลงในเรื่องของความมันวาวที่มุม 60 องศา การเปลี่ยนแปลงของสี สมบัติทางความร้อน และสมบัติทางกล สุดท้ายนำผลการทดลองที่ได้มาสรุปความสัมพันธ์ของสภาวะการใช้งานกลางแจ้ง กับในเครื่องเร่งสภาวะอากาศ

ACKNOWLEDGEMENTS

The author would like to acknowledge Smartrac Technology LTD (Thailand) for supporting the thesis work and all plastic cards and also acknowledge the Thai Meteorological Department for weathering data and radiation data.

The author would like to acknowledge the Petroleum and Petrochemical College; and National Excellence Center for Petroleum, Petrochemicals, and Advance Materials, Thailand for the instrument support and their kindness.

Moreover, I gratefully acknowledge Asst. Prof. Hathaikarn Manuspiya, Asst. Prof. Thanyaluk Chaisuwan, Asst. Prof. Apirat Pisankittichot and Smartrac Technology research and develop team for their kind advice for the suggestion of the experiment and discussion of thesis

This thesis work is funded by the Petroleum and Petrochemical College; and the National Center of Excellence for Petroleum, Petrochemicals, and Advanced Materials, Thailand.

Finally, I would like to thank all of my friends and my family who have been encourage and support me to complete this work.

TABLE OF CONTENTS

	PAGE
Title Page	i
Abstract (in English)	iii
Abstract (in Thai)	iv
Acknowledgements	v
Table of Contents	vi
List of Tables	ix
List of Figures	xi
CHAPTER	
I INTRODUCTION	1
II LITERATURE REVIEW	3
III EXPERIMENTAL	20
3.1 Materials	20
3.2 Equipment	20
3.2.1 QUV Weathering Tester	20
3.2.2 Colorimetric Spectrophotometer	20
3.2.3 Universal Testing Machine	20
3.2.4 Haze-Gloss Tester	20
3.2.5 Thermogravimetric Analysis	20
3.2.6 Atomic Force Microscope	21
3.2.7 Fourier Transformation Infared Spectroscopy	21
3.3 Experimantal Procedures	21
3.3.1 Samples Preparation	22
3.3.2 Samples Exposure	22
3.3.3 Effect on Sample	22
3.3.4 Characterization of Exposed Samples	22

CHAPTER	PAGE
3.3.5 Correlation of the Result	23
IV DEGRADATION OF PLASTIC CARDS	24
4.1 Abstract	24
4.2 Introduction	24
4.3 Experimental	25
4.4 Results and Discussions	26
4.5 Conclusions	46
4.6 Acknowledgements	47
4.7 References	47
V CORRELATION OF THE SERVICE LIFETIME OF PLASTIC CARDS	49
5.1 Abstract	49
5.2 Introduction	49
5.3 Experimental	50
5.4 Results and Discussions	51
5.5 Conclusion	58
5.6 Acknowledgements	58
5.7 References	58
VI CONCLUSIONS AND RECOMMENDATIONS	59
REFERENCES	61
APPENDICES	64
Appendix A Data of mechanical properties of plastic cards	64
Appendix B M-file from MATLAB application	78
Appendix C The goodness of curve fitting in MATLAB application	90

CHAPTER	PAGE
Appendix D The daily integral UV radiation in Bangkok	91
CURRICULUM VITAE	105

LIST OF TABLES

TABLE		PAGE
CHAPTER IV		
4.1	The average gloss value at 60° of plastic cards after exposure in QUV accelerated weathering tester	26
4.2	The average gloss value at 60° of plastic cards after outdoor exposure	27
4.3	The average total color different of plastic cards after exposure in QUV accelerated weathering tester	29
4.4	The average total color different of plastic cards after outdoor exposure	30
4.5	The average Young's modulus of plastic cards after exposure in QUV accelerated weathering tester	32
4.6	The average Young's modulus of plastic cards after outdoor exposure	33
4.7	The average tensile strength of plastic cards after exposure in QUV accelerated weathering tester	34
4.8	The average tensile strength of plastic cards after outdoor exposure	35
4.9	The average toughness of plastic cards after exposure in QUV accelerated weathering tester	36
4.10	The average toughness of plastic cards after outdoor exposure	37
4.11	T _d degradation content (weight loss) of plastic card	38
CHAPTER V		
5.1	Monthly integral UV radiation at Bangkok (Lat. 13 40' N, Long. 100 37' E, Elev.60m)	51
5.2	Monthly integral UV-B radiation at Bangkok (Lat. 13 40' N, Long. 100 37' E, Elev.60m)	52

5.3	QUV integral UV-B radiation, Joule/m ²	52
5.4	Correlation equations	53
5.5	correlation of period between outdoor exposure and QUV accelerated weathering tester	57

LIST OF FIGURES

FIGURE		PAGE
CHAPTER II		
2.1	PVC structure.	4
2.2	PVC card's composition.	4
2.3	ABS structure.	5
2.4	PC structure.	5
2.5	PC card's composition.	6
2.6	PETG structure.	6
2.7	PETG card's composition.	7
2.8	Direct phototransformation of PC at short wavelength in the absence of oxygen.	17
2.9	Gemdimethyl side-chain photo-oxidation of PC.	18
2.10	Probable mechanism of ring oxidation.	19
CHAPTER III		
3.1	Separation procedure flow diagram.	21
CHAPTER IV		
4.1	The average gloss value at 60° of plastic cards after outdoor exposure.	27
4.2	The average gloss value at 60° of plastic cards after outdoor exposure.	28
4.3	The average total color different of plastic cards after exposure in QUV accelerated weathering tester.	29
4.4	The average total color different of plastic cards after outdoor exposure.	30
4.5	The average Young's modulus of plastic cards after exposure in QUV accelerated weathering tester.	32

4.6	The average Young's modulus of plastic cards after outdoor exposure.	33
4.7	The average tensile strength of plastic cards after exposure in QUV accelerated weathering tester.	34
4.8	The average tensile strength of plastic cards after outdoor exposure.	35
4.9	The average toughness of plastic cards after exposure in QUV accelerated weathering tester.	36
4.10	The average toughness of plastic cards after outdoor exposure.	37
4.11	T _d degradation content (weight loss) of plastic card.	38
4.12	Typical topography in 3D-profiles of the surfaces of PVC cards before exposure.	39
4.13	Typical topography in 3D-profiles of the surfaces of PVC cards after exposure in QUV accelerated weathering tester for 15 cycles.	39
4.14	Typical topography in 3D-profiles of the surfaces of PVC cards after outdoor exposure for 5 months.	40
4.15	Typical topography in 3D-profiles of the surfaces of PC cards before exposure.	40
4.16	Typical topography in 3D-profiles of the surfaces of PC cards after exposure in QUV accelerated weathering tester for 15 cycles.	41
4.17	Typical topography in 3D-profiles of the surfaces of PC cards after outdoor exposure for 5 months.	41
4.18	Typical topography in 3D-profiles of the surfaces of PETG cards before exposure.	42
4.19	Typical topography in 3D-profiles of the surfaces of PETG cards after exposure in QUV accelerated weathering tester for 15 cycles.	42
4.20	Typical topography in 3D-profiles of the surfaces of PETG	

	cards after outdoor exposure for 5 months.	43
4.21	FTIR spectrum of PVC cards, (a) FTIR spectrum before exposure (b) FTIR spectrum after exposure in QUV accelerated weathering tester for 12 cycles (c) FTIR spectrum after outdoor exposure for 6 months.	44
4.22	FTIR spectrum of PETG cards, (a) FTIR spectrum before exposure (b) FTIR spectrum after exposure in QUV accelerated weathering tester for 12 cycles (c) FTIR spectrum after outdoor exposure for 6 months.	45
4.23	FTIR spectrum of PC cards, (a) FTIR spectrum before exposure (b) FTIR spectrum after exposure in QUV accelerated weathering tester for 12 cycles (c) FTIR spectrum after outdoor exposure for 6 months.	46

CHAPTER V

5.1	Curve fitting of the results of tensile strength of PC cards after outdoor exposure.	54
5.2	Curve fitting of the results of tensile strength of PVC cards after exposure in QUV accelerated weathering tester.	54
5.3	Curve fitting of the results of tensile strength of PVC cards after outdoor exposure.	55
5.4	Curve fitting of the results of tensile strength of PVC cards after exposure in QUV accelerated weathering tester.	55
5.5	Curve fitting of the results of tensile strength of PETG cards after outdoor exposure.	56
5.6	Curve fitting of the results of tensile strength of PVC cards after exposure in QUV accelerated weathering tester.	56