TINTVERSITY TO MOT A SPILLAN .

INVESTIGATING THE COMPETITIVENESS

OF NATURAL RUBBER LATEX-FILMS

AS A POTENTIAL SUBSTITUTE FOR COMMON THIN-FILM PLASTIC PACKAGING MATERIALS

SHALIKA ASANKA SIRIWARDHANA

DIVISION OF POLYMER TECHNOLOGY DEPARTMENT OF CHEMICAL AND PROCESS ENGINEERING FACULTY OF ENGINEERING UNIVERSITY OF MORATUWA November 2010

U....ersity of Moratuwa

(This thesis was composed as the final dissertation of the M.Sc. in Polymer technology)

16452

Declaration

Hereby I wish to declare that this research thesis is prepared from my own research work, of which a part or whole has not been submitted for any other academic qualification, or at any other institution. Information derived from published or unpublished work carried out by others has been acknowledged, cited or referred in the text.

Name of the student:

Date:

Project Supervisor:

Shalika Asanka Siriwardhana

University of ^{02nd} December 2010 Electronic Tl Dr. Jagath Premachandra 1005 www.lib.mrt.ac.lk

UOM Verified Signature

......

.....

Signature of the student:

Signature of the supervisor:

Date:

Acknowledgement

It is with heartfelt thankfulness to remember the incomparable level of support, supervision, and guidance provided by my supervisor, Dr. Jagath Premachandra, at the Department of Chemical and Process Engineering, University of Moratuwa, throughout this research project. The continuous advices and corrections he made, has been an enormous strength in making this achievement.

The invaluable support and courage I received from Dr. Shantha Walpalage, is also remembered with heartfelt gratitude. The direction he has shown, has navigated me through the research to make a highly successful outcome.

It is unforgettable to recollect the invaluable direction I received from Dr. Shantha Amarasinghe, Prof. Ajith De Alwis, Dr. Mrs Shantha Egodage, and all the staff members of the Department of Chemical And Process Engineering at the University of Moratuwa, in shaping my research to comply with the highest standards.

I am obliged for the continuous corporation and assistance extended to me, by Dr. Lakshman Nethsighe, at Dipped Products Plc, Pannipitiya, Sri Lanka, who introduced me to the polymer industry and motivated me towards innovative thinking which fuelled me in designing this research.

Finally, I am proud to recall the continuous support and encouragement given by my beloved wife, Ranmuthumalie, and my Uncle Mr. Lionel De Silva, towards overcoming various hardships and making this accomplishment.

> Shalika Siriwardhana Department of Chemical and Process Engineering Faculty of Engineering University of Moratuwa November 2010

Table of contents

Chapter One – Introduction

.1. The responsibility of a package	
1.2. Background of the issues associated with plastic packaging	4
1.3. Research on Natural Rubber Films.	5
1.4. Different applications of rubber films	6
1.5. Objectives of the Research	7

Chapter Two – Experimental

2.1. Materials used	9
2.2. Process equipment and instruments	9
2.3. Procedure for development of the packaging material	
2.3.1. Compounding formulation	10
2.3.2. Compound and process related parameters	14
2.3.3. Preparation of the main compound	18
2.3.4. Special precautions and procedural measures.	20
2.4. Physical conditions.	22
2.5. Compound management.	22
2.6. Specifications for curing	23
2.6.1. Consideration of temperature and heat, in compounding stage	23
2.6.2. Temperature in .ring	24
2.6.3. Curing and timing	24
2.6.4. Dipping process	27
2.6.5. Curing process	28
2.7. Additional Processes	29
2.8. Sampling procedure	32
2.9. Testing for Mechanical Performance of samples	34
2.9.1. Tensile Strength and Percentage Elongation at Break (% EB)	35
2.9.2. Resistance against Abrasion	35
2.9.3. Resistance Against Blade-cut.	36
2.9.4. Tear resistance.	36
2.9.5. Puncture resistance.	37

2.10. Barrier properties	37
2.10.1. Appearance of pin-holes	37
2.10.2. Air Leakage test	37
2.10.3. Water Leakage test	38
2.11. Blooming	39
Chapter Three - Results and discussion	
3.1. Outcome of test results	40
3.2. Indicative parameters in test results	41
3.3. Observations on process parameters and studies on the formulation	42
3.3.1. Extent of maturation for Prevulcanized compounds	42
3.3.2. Studying the curing pattern	44
3.3.3. Effects of the coagulant concentration	45
3.3.4. Investigation of the effects of the filler content	46
3.3.5. Effect of surface temperature of the formers.	48
3.3.6. Viscosity measurements	49
3.3.7. Studying the effects of TSC	50
3.3.8. Factors affecting the thickness	51
3.3.9. Thickness variation along the longitudinal axis of the rubber film	52
3.4. Physical performance of the product	54
3.4.1. Tensile strength	54
3.4.2. The elongation at break (% EB)	55
3.4.3. Resistance against abrasion	57
3.4.4. Blade-cut resistance	59
3.4.5. Tear resistance	61
3.4.6. Puncture resistance	63
3.5. Observations on barrier properties and blooming	64
3.5.1. Results from the air / water leakage test	65
3.5.2. Blooming and material migration	66
3.6. Analysing the overall competency of the rubber material.	67
3.7. The convenience of implementing the process	69

Chapter four - Conclusions and suggestions

4.1. Conclusions	70
4.2. Suggestions for future developments	71
4.2.1. Applications and commercial considerations	71
4.2.2. Curing system and vulcanization ingredients	71
4.2.3. Fillers	71
4.2.4. Other additives	72
4.2.5. Former design	72
4.2.6. Dipping facilities	72
4.2.7. Latex Production, supply and quality	72
4.2.8. Industrial Collaborations	73
4.2.9. Regulations	73
Bibliography	74



University of Moratuwa, Sri Lanka. Electronic Theses & Dissertations www.lib.mrt.ac.lk

List of Figures

Figure N	0	Page
Figure 1.	The global packaging consumption, by region, 2003-2009	4
Figure 2.	Dipping tank used for pilot-scale production runs.	11
Figure 3.	Ceramic formers being used in the preparation of rubber sacks	12
Figure 4.	Standard MST measuring Instrumentation and set-up.	14
Figure 5.	Effects of movements in the pH towards the behaviour of the compound	15
Figure 6.	The Experimental set-up for Viscosity Measurement, using a Ford-Cup.	18
Figure 7.	Set-up for the preparation of compounds in temperature controlled tanks	23
Figure 8.	Temperature profile of the curing oven, used for the research.	24
Figure 9.	The flow chart which illustrates the sequence of steps involved in the preparation of rubber articles for packaging applications.	26
Figure 10.	The mechanism of supplying hot air to the dipped formers, to cure the gelled rubber films formed on flat ceramic formers	28
Figure 11.	The air leakage test apparatus used to measure the existence of pin-holes of the rubber sack.	38
Figure 12.	The apparatus used to observe water leakage from the rubber sack.	39
Figure 13.	Effect of the swelling index on the tensile strength of the films in Toluene	43
Figure 14.	Effect of the swelling index to the Elongation at Break	43
Figure 15.	Variation of the Tensile Strength vs. curing time in the oven.	45
Figure 16.	Variation of the film-thickness against the concentration of Coagulant	45
Figure 17.	Effect of the filler content on the tensile strength	46
Figure 18.	Effect of the filler content on the resistance against tear	47

Figure 19.	Effect of the filler content on the resistance against blade-cut	47
Figure 20.	Variation of the time for sedimentation of dispersions against the average viscosity of the compound,	49
Figure 21.	Variation of the thickness of the film, depending on the dwell time of the formers in the compound	51
Figure 22.	Variation of the average thickness of the film, with the change in the withdrawal time	51
Figure 23.	Variation of the thickness of the dipped article, along its profile	52
Figure 24.	Variation of thickness of the rubber sack along its profile as a result of 3 different withdrawal speeds.	53
Figure 25.	Comparison of the tensile strength of the rubber material, with that of other common polymeric materials used as thin-film general purpose packaging materials. Sri Lanka.	54
Figure 26.	Comparison of Elongation at Break (% EB) for few common thin-film packaging materials.	55
Figure 27.	Variation of the Percentage Elongation at Break, for the rubber material, with different phr values of filler being used	55
Figure 28.	Comparison of the resistance against abrasion, for commonly used films.	57
Figure 29.	Analysis of the average blade-cut cycles and the average Blade-cut Index exhibited by four thin-film materials	59
Figure 30.	The tear resistance of various materials compared with rubber, while taking different thickness values into consideration.	61
Figure 31.	Comparison of puncture-resistance of some commonly used as flexible packaging materials along with the NR latex film	63
Figure 32.	Illustration of percentages of instances where pin-holes appeared, against the concentration of Surfactant used in the coagulant.	65

List of Tables

Table 1.	Basic Formulation for the compound used for dipping	19
Table 2.	Formulation for the same dipping compound but, specially presented to be used with the Curing Dispersion Master batch.	19
Table 3.	Formulation for the Calcium-based coagulant	27
Table 4.	Basic criteria for EN388 Physical testing for protective gloves, which is the closest analogy to the product profile.	35
Table 5.	Parameters tested for the final product and its significance for the research.	41
Table 6.	Variation of compound properties with the changes in swelling index as a measure of the extent of prevulcanization of compounds.	42
Table 7.	The effect of concentration of the coagulant on the film-thickness and its characteristics, (timing and other parameters were kept constant)	45
Table 8.	Effects of temperature of the former surface on the properties of dipped films	49
Table 9.	Effect of Percentage TSC on the nature and behaviour of compounds	50
Table 10.	Comparison of the average tear resistance against their thickness, for the rubber film, along with some major polymers used for flexible packaging.	61
Table 11.	Effect of the surfactant in the coagulant, on the possibility of creating pin-holes and the quality of the rubber film.	64
Table 12.	The percentage of instances where water leakage and air leakage was observed for five different contestant materials most commonly used in thin-film packaging.	65