



**Faculty of Manufacturing Engineering**

**IMPROVEMENT ON TEAR RESISTANCE OF  
RUBBER MOULDED MAT BY VARYING  
FILLER AND ACCELERATOR CONTENTS**

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**Engineering Doctorate**

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**IMPROVEMENT ON TEAR RESISTANCE OF RUBBER MOULDED MAT  
BY VARYING FILLER AND ACCELERATOR CONTENTS**

**SOH TIAK CHUAN**

**A thesis submitted  
in fulfilment of the requirements for the degree of Engineering Doctorate**

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**2016**

## DECLARATION

I declare that this thesis entitled “Improvement on tear resistance of rubber moulded mat by varying filler and accelerator contents” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

## **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 Engineering Doctorate.

Signature : .....

Supervisor Name : .....

Date : .....

## **DEDICATION**

To my beloved mother, father and wife.

## ABSTRACT

An industrial baby product, rubber moulded mat, produced in Rubber Leisure Products Sendirian Berhad has encountered with tear problem at the complicated shape of suction cups when it is manually stripped after moulding process. Its tear resistance has been improved in this work to reduce the high rejection and reworking rates in production by focusing on the two parameters of fillers and accelerators. The effect of fillers was focused on the content of precipitated silica and calcined clay whereas the effect of accelerators was studied by using mercaptobenzothiazole disulphide (MBTS), Zn-2-mercaptobenzo thiazole (ZMBT) and diphenyl guanidine (DPG). Phase 1 of this research involved the analyses of different ratios and combinations of fillers and accelerators. Phase 2 involved the analyses of tensile strength and tear strength of vulcanizates with 5 levels of fillers and 4 levels of accelerators by using statistical factorial design of experiment. Phase 3 focused on the test mechanism of hot-tear-strength, mass production validation and benefit-cost analysis. A scorch-safe filled masterbatch added with silane coupling agent was formulated. Multiple-stage melt mixing method can disperse effectively the fillers into the smaller aggregated structure. The combination of accelerators MBTS:DPG:ZMBT enhanced better the rubber tear resistance than the conventional MBTS:DPG system. An optimum formulation was produced with the levels of fillers:accelerators at 0.65phr:1.77phr and reduced the content of calcium carbonate from 40 phr to 20 phr which have imparted better tear resistance. The finely dispersed and uniformly distributed fillers, optimum crosslink density and predominantly polysulphidic crosslink type improved primarily the rubber tear resistance especially on hot-tear-strength. The new formulation did not deteriorate the end-use function and colour aesthetic of the finished product as well as did not increase the product manufacturing cost.

## ABSTRAK

*Pelapik getah teracuan, suatu produk bayi buatan industri yang dihasilkan oleh Rubber Leisure Products Sendirian Berhad menghadapi masalah koyakan pada bahagian rumit mangkuk sedutan apabila ditanggalkan secara manual selepas proses pengacuanan. Rintangan koyakan telah ditingkatkan dalam kajian ini bagi mengurangkan kadar buangan dan baikpulih yang tinggi dalam pengeluaran dengan memfokus kepada dua parameter iaitu bahan pengisi dan bahan pencepat. Pengaruh pengisi difokuskan kepada kandungan silika termendak dan lempung terkalsin manakala pengaruh pencepat dikaji menggunakan mercaptobenzothiazole disulfide (MBTS), Zn-2-mercaptobenzo thiazole (ZMBT) dan diphenyl guanidine (DPG). Fasa 1 kajian melibatkan penganalisan ke atas nisbah dan gabungan pengisi dan pencepat yang berbeza. Fasa 2 pula melibatkan analisa kekuatan tegangan dan kekuatan koyakan vulkanisat bagi 5 tahap pengisi dan 4 tahap pencepat menggunakan eksperimen rekabentuk faktor statistik. Fasa 3 memfokus kepada ujian mekanisma kekuatan koyakan-panas, penentusahan pengeluaran pukal serta penganalisan kos-faedah. Suatu sebatian utama berpengisi yang dicampurkan dengan agen pengkupel silana diformulasikan. Kaedah percampuran lebur berbilang peringkat dapat menyerak pengisi secara berkesan kepada struktur agregat yang lebih halus. Gabungan pencepat MBTS:DPG:ZMBT meningkatkan rintangan koyakan getah berbanding sistem konvensional MBTS:DPG. Suatu formulasi optimum dengan tahap pengisi:pencepat pada 0.65phr:1.77phr dan pengurangan kandungan kalsium karbonat daripada 40 phr kepada 20 phr telah memberikan ringtangan koyakan yang lebih baik. Penyerakan halus dan pengisi tertabur seragam, ketumpatan sambung silang optimum dan sambung silang didominasi polisulfidik telah meningkatkan ringtangan koyakan khususnya kekuatan koyakan-panas. Formulasi baru tidak menjejaskan fungsi penggunaan dan kecantikan warna produk akhir serta tidak menambahkan kos penghasilan produk.*

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## LIST OF ABBREVIATIONS

NR	-	Natural rubber
EPDM	-	Ethylene propylene diene terpolymer
SBR	-	Styrene butadiene rubber
ENR	-	Epoxidized natural rubber
TSR	-	Technically specified rubber
PS	-	Precipitated silica
ClCy	-	Calcined clay
CaCO <sub>3</sub>	-	Calcium carbonate
CB	-	Carbon Black
ZnO	-	Zinc oxide
TiO <sub>2</sub>	-	Titanium dioxide
KBr	-	Potassium bromide
TESPT	-	Bis(triethoxysilylpropyl)tetrasulphide
MBTS	-	Mercaptobenzothiazole disulphide
ZMBT	-	Zn-2-mercaptobenzo thiazole
DPG	-	Diphenyl guanidine
PEG	-	Polyethylene glycol
A/S	-	Accelerator to sulphur ratio
phr	-	Part per hundred rubber
EV	-	Efficient vulcanization
CV	-	Conventional vulcanization
FTIR	-	Fourier transform infrared
ATR	-	Attenuated total reflectance
T <sub>2</sub>	-	Scorch time
T <sub>90</sub>	-	Optimum 90 % cure time
CRI	-	Cure rate index
M <sub>L</sub>	-	Minimum torque
M <sub>H</sub>	-	Maximum torque