

**NATURAL RUBBER/RECYCLED
CHLOROPRENE RUBBER BLENDS:
PREPARATION AND PROPERTIES**

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**NATURAL RUBBER/RECYCLED CHLOROPRENE RUBBER BLENDS:
PREPARATION AND PROPERTIES**

by

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LIST OF SYMBOLS

t_{s2}	Scorch time
t_{90}	Cure time
M_L	Minimum torque
M_H	Maximum torque
M_{L1+4}	Mooney viscosity
ΔM	Difference torque
M_{100}	Modulus at 100% elongation
M_{300}	Modulus at 300% elongation
$SW\%$	Swelling percentage
$T_{5\%}$	Decomposition temperature with 5% weight loss
$T_{10\%}$	Decomposition temperature with 10% weight loss
$T_{30\%}$	Decomposition temperature with 30% weight loss
$T_{50\%}$	Decomposition temperature with 50% weight loss
T_{max1}	Temperature for the first decomposition peak
T_{max2}	Temperature for the second decomposition peak
E'	Storage modulus
$\tan \delta$	Tan delta
T_g	Glass transition temperature
3D	Three dimensional

LIST OF ABBREVIATION

ASTM	American society for testing and materials
APTES	3-aminopropyl triethoxysilane
BSD	Backscatter electron detector
CB	Carbon black
CBS	N-cyclohexyl-2- benzothiazyl sulfenamide
Cl	Chlorine atom
CR	Chloroprene rubber
CRI	Cure rate index
CSM	Chlorosulfonated polyethylene
ENR-50	Epoxidized natural rubber (50 mol%)
EPDM	Ethylene propylene diene monomer
FTFT	Fatigue-to-failure tester
FTIR	Fourier transform infrared
GRT	Ground rubber tyre
HAF	High abrasion furnace
HCl	Hydrogen chloride
IRSG	International Rubber Study Group
JIS	Japanese Industrial Standard
MDR	Monsanto moving die rheometer
MgO	Magnesium oxide
NBR	Acrylonitrile butadiene rubber
NR	Natural rubber
NRL	Natural rubber latex

phr	Part per hundred rubber
rCR	Recycled chloroprene rubber
RRIM	Rubber Research Institute Malaysia
SE	Secondary electron
SEM	Scanning electron microscopy
SBR	Styrene butadiene rubber
TGA	Thermogravimetric analysis
TMTM	Tetramethylthiuram monosulfide
vCR	Virgin chloroprene rubber
XNBR	Carboxylated nitrile rubber
ZnO	Zinc oxide

**ADUNAN GETAH ASLI/GETAH KLOROPRENA KITAR SEMULA:
PENYEDIAAN DAN SIFAT-SIFAT**

ABSTRAK

Penggunaan produk sisa daripada sarung tangan getah kloroprena (rCR) sebagai salah satu bahan di dalam adunan getah adalah satu penyelesaian bagi mengurangkan sisa getah dalam industri. Pada siri pertama, kesan daripada dua getah kloroprena yang berbeza; asli dan kitar semula diwakili sebagai vCR and rCR di dalam adunan getah asli (NR) telah dikaji. Sifat-sifat adunan NR/vCR secara umumnya adalah lebih tinggi daripada adunan NR/rCR. Di dalam siri kedua, adunan NR/rCR diubahsuai dengan lateks getah asli (NRL) sebagai penyelesaian untuk memperbaiki lekatan antara NR dan rCR. Keputusan menunjukkan yang penambahan NRL memperbaiki sifat-sifat adunan NR/rCR terutamanya di dalam sifat-sifat mekanikal. Siri ketiga melibatkan kepelbagaian nisbah logam oksida untuk mendapatkan sifat-sifat optimum dalam adunan NR/rCR. Penambahan 4/10 (bsg/bsg) magnesium oksida/zink oksida (MgO/ZnO) ke dalam adunan getah menghasilkan kekuatan tensil optimum. Sementara itu, siri keempat melibatkan kesan pelbagai jenis dan muatan pengisi terhadap sifat-sifat adunan NR/rCR. Penambahan pengisi penguat seperti hitam karbon atau silika dengan agen gandingan; (3-Aminopropyl) triethoxysilane (APTES) telah memperbaiki sifat-sifat adunan NR/rCR. Penggunaan pengisi pada muatan yang rendah telah meningkatkan kebolehcampuran adunan NR/rCR. Penambahan pengisi tidak penguat iaitu kalsium karbonat tidak menunjukkan kesan yang ketara dalam sifat-sifat adunan NR/rCR. Di dalam siri terakhir, pelbagai getah baru digunakan bersama rCR. Keputusan menunjukkan yang

rCR adalah paling sesuai diadun bersama NR jika dibandingkan dengan getah lain; misalnya getah asli terepoksida dan getah stirena butadiena.

NATURAL RUBBER/RECYCLED CHLOROPRENE RUBBER BLENDS: PREPARATION AND PROPERTIES

ABSTRACT

The utilization of rejected rubber product from chloroprene rubber glove as a part of ingredient in rubber blend is a solution to reduce rubber waste in industry. In the first series, the effect of two different chloroprene rubbers; virgin and recycled denoted as vCR and rCR in natural rubber (NR) blends was studied. The properties of NR/vCR blends are generally higher than NR/rCR blends. In the second series, the NR/rCR blend is modified with natural rubber latex (NRL) as a solution to improve the adhesion between NR and rCR. The result showed that the addition of NRL improved the properties of NR/rCR blends especially the mechanical properties. The third series involved the variation of metal oxides ratios in order to obtain the optimum properties in NR/rCR blends. The addition of 4/10 (phr/phr) of magnesium oxide/zinc oxide (MgO/ZnO) into the rubber blend showed an optimum tensile strength. Meanwhile, the fourth series involved the effect of various types and loading filler on the properties of NR/rCR blends. The addition of reinforced fillers such as carbon black or silica with coupling agent; (3-Aminopropyl) triethoxysilane (APTES) has improved the properties of NR/rCR blends. The addition of filler at lower loading improved the miscibility in NR/rCR blends. The addition of non-reinforced filler which is calcium carbonate did not show significant effect in properties of NR/rCR blends. In the last series, different virgin rubber is used together with rCR. The result revealed that rCR is the most suitable to be blended with NR as compared to other rubbers; for example epoxidized natural rubber or styrene-butadiene rubber.

CHAPTER ONE

INTRODUCTION

1.1 Rubber and rubber waste

The natural rubber (NR) ever since its first discovery has been given much convenience to daily life of humankind and major development of modern civilization. The earliest record for NR used was summarized to be rubber balls or ritual tributes in ancient times. The other earliest application of natural rubber latex (NR) is as a waterproof for clothing and footwear. Then, the elasticity and waterproofing ability of the material attracted attention of the scientists to explore the potential of NR. Since then, there have been great advances of rubber usage in diverse applications.

Then, due to the World War II, the development of synthetic rubber (SR) became important because the shortage of NR which is a necessity for the rubber industry to develop a substitute (Holden and Wilder, 2000). The successful invention of SR brings an improved rubbers resulting from better properties which can easily be tailored to meet the properties requirement in comparison to NR. The development in rubber research and technology to improve the properties of rubber assist the growth of rubber as the primary raw materials in various rubber-based products. The main application of rubber remains in automobile industry where the production of tyre is the most important rubber consumption. The expansion of rubber products is included in other fields such as in clothing, agriculture, building, aerospace, marine and also latex goods.

Based on the history, the demand for both rubbers; NR and SR in production, consumption and trade prices are expected to increase due to the growth of economy and population across the globe. The latest world rubber industry outlook from International Rubber Study Group (IRSG) as listed in Table 1.1 shows the consumption of rubbers is increase every year although 2014 showed a slight slump in SR consumption. Positive increment in demand for both rubbers is forecast in future. The consumption of rubbers are estimated to be 12.9 million tons in 2016 and expected to increase and contribute 16.5 million tons for NR in 2023 and SR demand is increase to 21.5 million tons in 2023 from 16.8 million tons in 2016 (<http://www.rubberstudy.com/default.aspx>). According to a comprehensive global report on chloroprene rubber from Global Industry Analysts, the forecast on chloroprene rubber is to reach about 445.3 thousand metric tons by the year 2017 driven by increasing demand from end-use industries such as industrial rubber products, adhesives and automobiles especially in Asia (Rubber World Online 2017)

Table 1.1: Worldwide rubbers consumption (International Rubber Study Group Online 2016)

Year	Types of rubber (million tons)	
	Natural rubber (NR)	Synthetic rubber (SR)
2011	11.2	14.5
2012	11.3	15.5
2013	11.8	16.4
2014	11.9	16.1
2015	12.3	16.8
2016	12.9	17.5
2023	16.5	21.5

Figure 1.1 gives an overview of general life cycle of rubbers. The figure reveals that the rubber waste can be obtained from three different resources. The first of rubber is found from the waste of unvulcanized rubber compound from the