

**THE INFLUENCE OF RECLAIMED RUBBER ON
THE PROPERTIES OF NR/SBR TYRE TREAD
COMPOUNDS**

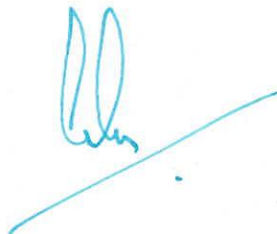
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The work describe in this thesis was carried out by the undersign at Rubber Research Institute of Ratmalana, under the supervision of Dr. W. M. Gamini Senaviratne Ph. D (UK), B. Sc.(Hons) and Ms. Dilhara G. Edirisinghe M Phil(UK), M. Sc., B. Sc., and a report on this has not been submitted to any university for another degree. Also, I certify that this thesis does not include, without acknowledgement, any material previously submitted for a Degree in any university and to best of my knowledge and belief it does not contain any material previously published, written or orally communicated by another person except where due reference is made in the text.



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ABSTRACT

The specific objective of the research was to develop a tyre tread compound, a blend with NR/SBR and reclaim having physical properties mainly, abrasion resistance, tensile strength, tear strength, hardness and rebound resilience acceptably superior to its virgin materials at an economical price. Although it is known, the usage of reclaim reduce the quality of compounds, to what extent reclaim could be incorporated to obtain tyre tread compounds having a balance cost and performance is the theme of this research.

Initially the research was carried out to study generally the effect of reclaim on NR/ SBR blends and blends were prepared using a single stage mixing technique giving higher prominence to Mooney viscosities at blending. Samples of SBR:NR, 70:30, 60:40, 50:50, 40:60 were prepared with varying percentages of reclaim (20,40,60 phr reclaim) and samples were tested for physical properties. Then the best samples were retested using different accelerator systems. Firstly, samples were prepared with MBT, where Scorch time was rather less and this was changed to a CBS accelerator system where scorch time was improved, after assuring with physical tests, properties would not compromise with the different accelerator system used.

Investigations were further extended by using different blends of filler systems (Carbon black blend of N330:N220 50:50) to see the effect on the same properties tested, basically abrasion resistance and the tensile strength. Having identified reclaim percentages could not be increase more than 20phr to obtain the required properties of tyre tread formulations, reclaim percentages in the new blends were varied from 5,10,15,20 phr reclaim ,for the best NR:SBR 60:40 blend identified.

The microscopical study was carried out with the Scanning Electron Microscope and this revealed how reclaim appears as discrete particles of varying size, like pieces of fruit in a cake. This facilitated in identifying how the properties deteriorate as reclaim percentages are increased. Further tread pattern observations, measuring the gaps between the grooves

on Akron abraded samples facilitated identifying the volume loss result in the abrasion test, with increasing level of reclaim.

In conclusion NR:SBR 60:40 blend (CBS accelerator system) appears to be a better sample having balanced cost and performance that the specific mixing cycle is used to develop the blend. The same blend (CBS Accelerator system) with C black- HAF 330 & HAF 220 combination & varying parts of Reclaim from 5phr to 20phr (5, 10, 15, 20phr) did not contribute acceptable results as to the industrial requirements. Further studies on this blend (CBS accelerator system) with C black -HAF 330 only & varying parts of reclaim from 5phr to 20 phr are necessary to give a better conclusion about the NR: SBR 60:40 blend as a whole.

CONTENTS

Acknowledgement	i
Abstract	ii
Contents	iv
1.0	
Introduction	1
1.1 General Introduction to Blends	1
Literature Review	5
1.2.1 Tyre Tread	5
1.2.2 Coefficient of rolling Friction	6
1.2.3 Rebound resilience and Hysterisis	7
1.2.4 Road holding	7
1.2.5 Tread Pattern	8
1.3 Materials	9
1.3.1 Natural Rubber	9
1.3.2 Styrene Butadiene Rubber	10
1.3.3 Reclaimed Rubber	13
1.4 A review of applications of reclaimed rubber	15
1.5 Reclaim compounding techniques	20
1.6 "Three way mixtures"- NR/SBR/Reclaim	21
Theory	24
1.7 Reinforcement of blends by fillers	24
1.7.1 Mixing of carbon black with rubber	26
1.8 Vulcanisation	31
1.8.1 Cure of rubber compounds	32

2.0

Experimental Methods 35

- 2.1 Materials & formulations 35
- 2.2 Mixing procedure 39
- 2.3 Compound preparation 40

Testing Methods 42

- 2.4 Determination of tensile properties 42
- 2.5 Determination of abrasion properties 43
 - 2.5.1 DIN Abrasion Tester 43
 - 2.5.2 Akron Abrasion Tester 44
- 2.6 Determination hardness 47
- 2.7 Determination of Rebound resilience 48
- 2.8 Analysis of Abrasion Patterns using Scanning Electron Microscopy 50

3.0

Results & Discussion 51

- 3.1 Mooney viscosities 51
- 3.2 Tensile property results 52
- 3.3 Tear strength results 57
 - 3.4.1 DIN Abrasion results 59
 - 3.4.2 Akron Abrasion results 63
- 3.5 Hardness results 64
- 3.6 Rebound resilience results 65
- 3.7 Scanning Electron Microscopy results 66

4.0

Conclusion & future work 71

References 73

CHAPTER 01

INTRODUCTION

The prime objective of the research was to develop a tyre tread compound, a blend of NR/SBR with Reclaim having performance measures, i.e. physical properties mainly, abrasion resistance, tensile strength, tear strength, hardness, rebound resilience acceptable/superior at a balanced cost.

1.1 General Introduction to Blends

More than ever before there is an increased technological interest in blending of two or more polymers together, in a view of one type of polymer alone being unable to provide all desired properties for a range of applications, two or more polymers (blends) are often used to obtain combined properties and better properties than of component polymers. (Synergism). It is required to produce a micro heterogenous blend in order to retain the individual properties of rubbers simultaneously contributes synergistically to create a macroscopic material with improved properties.

A greatest proportion of NR-SBR blends are used in the production of tyres. It is well known that NR vulcanisates in comparison with SBR vulcanisates offers higher modulus, tensile strength, tear resistance, resilience and better dynamic properties. SBR vulcanisates are better in abrasion resistance, hardness, compression set and oxidation resistance.

Under modern conditions reclaim has merit recognition in industry as an effective and versatile source of rubber hydrocarbon, since the reclaim imparts excellent and necessary compounding and processing characteristics in addition to its economic value (both lower material & volume cost).

Blends of NR and SBR with reclaim are heterogeneous systems. Further, heterogeneity is increased on addition of compounding ingredients. The mixing procedure adopted to achieve the blend and the subsequent procedure for compounding, etc. also plays a significant role. Technological problems frequently occur due to mutual incompatibilities which exist between dissimilar rubbers. Three types of incompatibilities have generally been noted:

- ***Incompatibility due to viscosity mismatch***

This has prevented or greatly delays the formation of intimate blends. Therefore it is vital important how dispersion of elastomers take place. Some of the factors to be considered are viscosity of the phases, technique and conditions of mixing or blending, proportion and type of fillers used, presence of plasticizers, etc., and the mechanical and temperature cycle, the blend has to undergo before curing is completed^(1, 9-11)

In blending of solid elastomers using either an internal mixer or two roll mill, two different techniques being generally used. In ***masterbatching*** technique the compounding ingredients are separately incorporated in to elastomers before they are blended together. In ***preblending*** technique the elastomer mix is initially obtained before compounding ingredients are incorporated into the mix. There are other techniques such as solution blending and latex blending which are quite attractive⁽³⁻⁸⁾

- ***Thermodynamic incompatibility***

This prevents the mixing on the molecular scale. Interaction at the inter phase boundaries is an important factor to consider here. The extent of physical and chemical interaction at the phase boundaries will depend to great extent on the surface area available. The wetting energy available will govern the physical interaction. The entanglements of the polymer chains are an additional factor to be considered. Chemical cross-links could be established across the boundary between the two polymers and the type of cross-links and the cross linking

density would depend upon nature and concentration of curative agents present at the inter phase.⁽³⁻⁸⁾

- ***Incompatibility due to cure rate mismatch***

In order to obtain full potential and advantageous properties in blends, it is required to achieve their cure to the desired level. There are significant differences in the rate of cure of NR, SBR and reclaim with the sulphur vulcanizing systems used. For the equal partitioning of the curatives between the two phases (NR and SBR) NR needs to be cross-linked to a greater degree under similar conditions. It is possible to modify the elastic properties of vulcanisates by developing systems which can cause cure to different degrees in the two phases. The diffusion and the solubility of curatives in two phases are different and this may lead to concentration differences during blending and through subsequent processing steps. Equilibrium distribution of curatives is not likely to happen prior start nor at completion of vulcanization and migration of curatives will impact on the differences of the type of cross links obtained.⁽³⁻⁸⁾

There are several other aspects which have significant influence on preparation of an intimate polymer blend.

- ***Effect of fillers***

The distribution of filler particles between separate phases of elastomer blend is basically affected by the extent of unsaturation of elastomer, viscosity, polarity of elastomer and mixing procedure used. The carbon black distribution is uneven between the phases. The particular grade of carbon black used will have a significant influence. If the viscosities of two phases differ widely filler will mix with the lower viscosity phase initially and the viscosity of the elastomer phase is raised and as it approaches the more viscous phase, filler will be more evenly distributed.

- ***Distribution of plasticizers, antioxidants, etc..***

Diffusion of mineral oils in NR phase seems to be faster than in the SBR phase. The solubility difference is the importance here. There may be interactions between plasticizing oils and elastomers, that would benefit in compatibility of the two phases. The migration of antioxidants and other chemicals across the phase boundaries is facilitated by a zinc stearate layer, preferring the NR phase and thus migration will have a greater impact on ageing properties.

Having identified incompatibilities which occur during the blending process and subsequently in the compounding processes (vulcanization and cure) identifying the correct mixing cycle is with great importance to obtain a perfect blend. In this respect, Mooney viscosities play a major role and plot of Mooney viscosities (of all three rubbers) vs specific time intervals enables to identify suitable mixing cycle.

In tyre tread formulations the basic specifications required by the standards include physical properties such as abrasion resistance, tensile strength, tear strength, rebound resilience, hardness, compression set, etc.. Further microscopical studies will facilitate, explaining the physical characteristics identified to a greater extent at micro level.

LITERATURE REVIEW

1.2.1 TYRE TREAD

In the year 1845 when the air filled tyre was first patent by a Scot by the name of R.W. Thompson the tyre was described as a hollow, inflatable flexible tubing of leather, which was fastened around the circumference of the wheel in order to provide elasticity for the vehicle and reduce the resistance to rolling. The first car tyre was manufactured in Sweden in Gislaved in the year 1905 and this enabled the fast development of the motoring at the beginning of the 20th century. Today's tyre is a result of close corporation between car manufacturer and tyre manufacturer. Before 1970, the most dominant tyre type was the *diagonal ply tyre* but as developments has progressed this was replaced by the *radial ply tyre*. In composition of radial ply tyre it includes the following in its manufacture.

1. Bead Core
2. Filling rubber
3. Sealing layer
4. Cord ply
5. Sidewall rubber
6. Bead seat
7. Reinforcement strip
8. Steel belts
9. Top layer
10. Tread

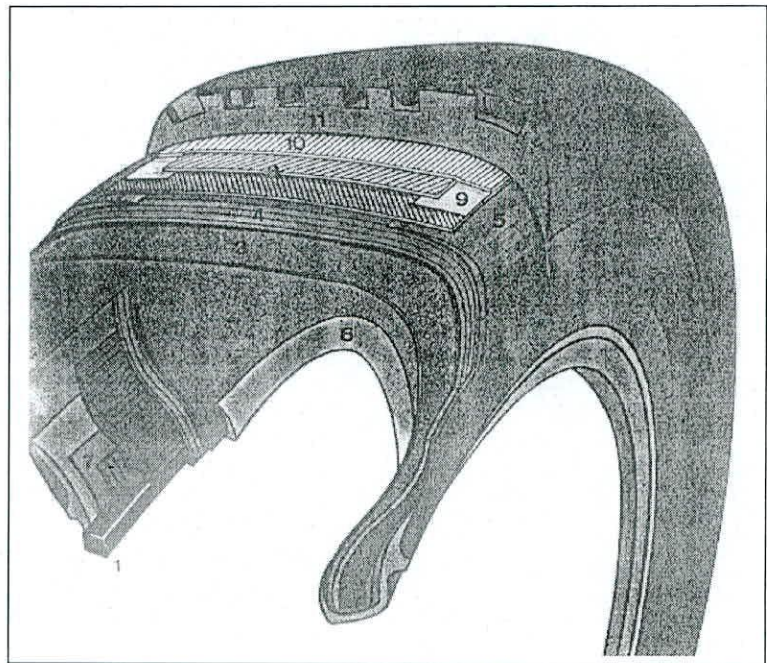


Figure - 01
The radial tyre composition

The rubber materials in the tyre vary with speeds, external stresses and areas of use which the tyre can be subjected to. Thus the rubber material in the tread has special properties which enables the tyre to be driven at very high speeds without being damaged by the build up of heat. These tread compounds must be produced so that the tyre has very good friction against the roadway in different road conditions and high wear resistance, low noise level and low rolling resistance.

1.2.2 Coefficient of rolling friction

The frictional force between the tyre and road under dry conditions is a function of the roughness and nature of the road surface, the type of rubber used in the tread and the contact area known as the contact patch. The contact patch for a typical radial car tyre is about the size of an average man's shoe sole and is greater for the radial than the cross ply.

The second factor which determines the frictional coefficient is the nature of the rubber used, and in particular the hysteresis or internal friction which occurs during deformation of the tread in contact with the road. The higher the internal friction of the tread the greater is the rolling friction and hence the greater the road holding, particularly under wet conditions.

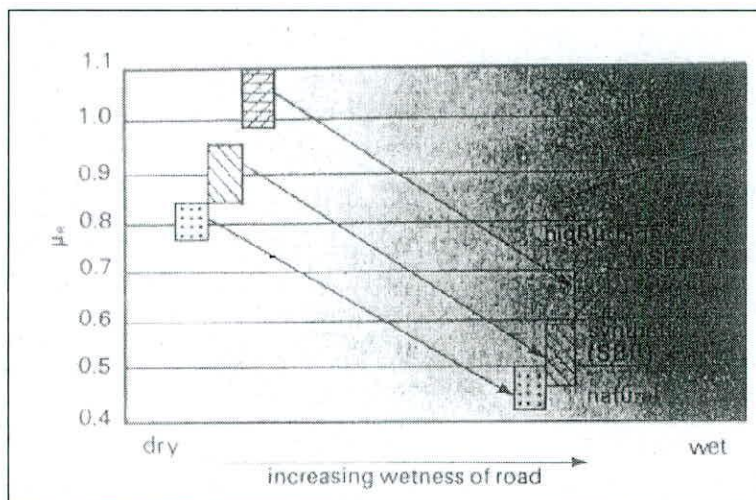


Figure – 02
The effect of road conditions on the co-efficient of rolling friction

1.2.3 Rebound resilience and hysteresis

A way to measure the hysteresis of a rubber is simply to drop a rubber ball from a fixed height on to a rigid floor. The ratio of the height to which the ball rises after bouncing to the fixed drop height is known as the rebound resilience. The value of resilience is directly related to the energy dissipated, as heat when ball hits the floor. The more kinetic energy dissipated, the lower the resilience and resilience increases with the temperature. The most resilient rubbers are NR where SBR have much lower values.

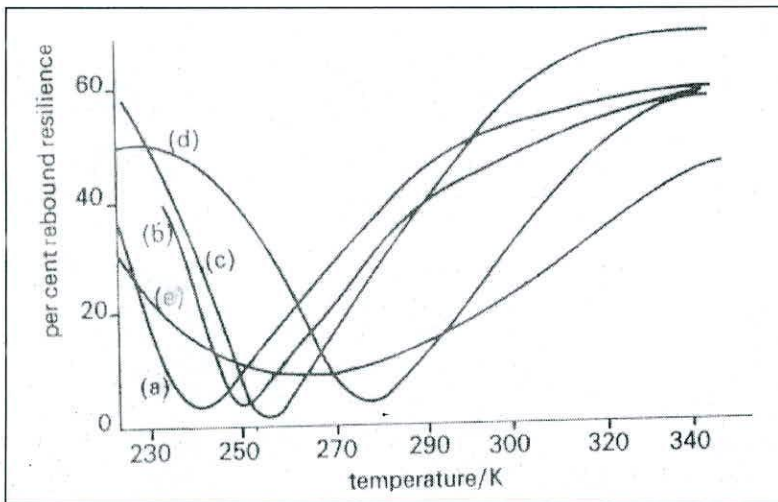


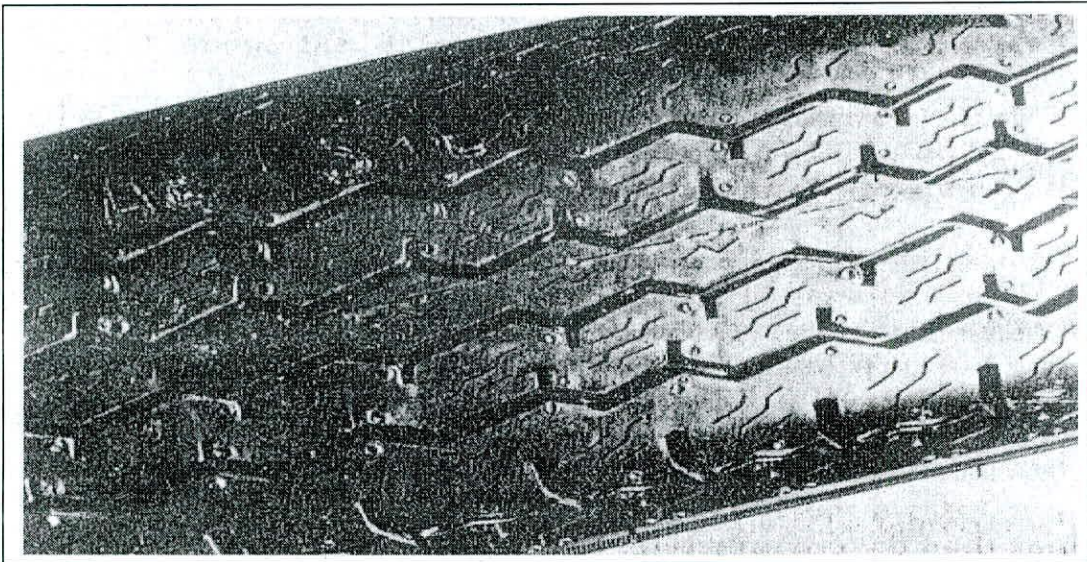
Figure – 03
Rebound resilience as a function of temperature

- a) Natural rubber
- b) SBR
- c) Neoprene
- d) Butadiene-acrylonitrile
- e) Butyl rubber

1.2.4 Road Holding

Having established, high hysteresis rubber such as SBR is desirable for the tread to achieve a high coefficient of rolling friction, the effect of other variables to be concerned are the constraints on the design of the tyre as effect of water on the tyre-road surface. The problem can be countered by patterning the tread.

1.2.5 TREAD PATTERN



*Figure - 04
Tyre tread pattern*

The tyre tread pattern is of great importance for the service life of the tyre, gripping power, noise level and driving comfort. The tread is often designed using a combination of transverse and longitudinal grooves in the tyre tread. The circumferential grooves are designed to channel water tangentially to the rear of the contact patch and the radial cuts to eject the water laterally. In the tread there is also a so called sipe in the ribs, in order to achieve flexibility in the tread against the roadway. Thus, tread sipes absorb water by capillary action at the contact patch and eject it by centrifugal action at the top of the tyre's cyclical motion. The tyre contact patch is thus maintained, and the high hysteresis tread ensures good road holding. The nature of the road surface is also critical, coarse textured surfaces tend to give better road holding than polished wet surfaces.

Trade Name	phr
SBR	100
Carbon black N339	80
ZnO	2.5
Stearine	1.0
Sulphur	2.0
Ageing inhibitors	1.0
HA-oil	35
Micro wax	1.0
Accelerators	1.8

*Table - 01
Typical TYRE TREAD Formula for car tyre*