DEVELOPMENT AND TESTING OF LOCALLY PRODUCED
NATURAL RUBBER (NR) AND PVC BLENDS

Dr. B. M. Mutagahywa
Faculty of Engineering
University of Dar es Salaam
P.O. Box 35131
Dar es Salaam. TANZANIA.

ABSTRACT

The mechanical properties of natural rubber - poly(vinyl chloride) blends have been studied. Tensile and tear strengths of the vulcanizates has been shown to increase with increasing proportions of PVC up to about 20 pphr. Abrasion loss and hardness decreases slightly with increasing concentration of PVC. Increased loading of carbon black lowers the tensile and tear strength while increasing the abrasion loss and hardness values. This may be explained by the fact that PVC exists as a discontinuous rigid phase in the polymer compound. At normal loading of black (37 pphr) PVC improves processability and acts in the same way as reinforcing particulate fillers in elastomers. Compression set has been shown to decrease with increased PVC for a normally loaded compound.

INTRODUCTION

Natural rubber belongs to a family of materials known as high polymers. A polymer is a very large molecule comprising hundreds or thousands of atoms, formed by successive linking of one or two, occasionally more, types of small molecules into chain or network structures. Rubbers are a sub-division of polymer materials class, having flexible molecular chains and the ability to deform elastically when cross linked. Polymer materials are of interest both to life sciences in the study of natural macro molecular substances such as proteins, nucleic acids and polysaccharide and to engineering in the synthesis and application of polymeric materials especially plastics, rubbers (elastomers), fibers, coatings and adhesives. Of the polymer materials in engineering use, the plastics (thermoplastics and thermoset) form the largest tonnage group. In fact thermoplastics comprise the four most important commodity materials in the world today - i.e. polyethylene, polypropylene, and poly (vinyl chloride) - together with a number of more specialized engineering polymers. The main advantage of polymer materials over other materials in engineering applications lies in the fact that polymers are easily processed in mass production, and also that polymer materials can easily be tailor made to suit specific applications.

The production of synthetic polymers, especially thermoplastics demands a high level of chemical technology and is confined largely to a small number of major companies mainly in the developed world. **Fig. 1** shows the structure of polymer materials industry. The polymers (with the exception of a few types produced by modification of vegetable substances such as cellulose and natural rubber) are produced from petroleum or natural gas raw materials.

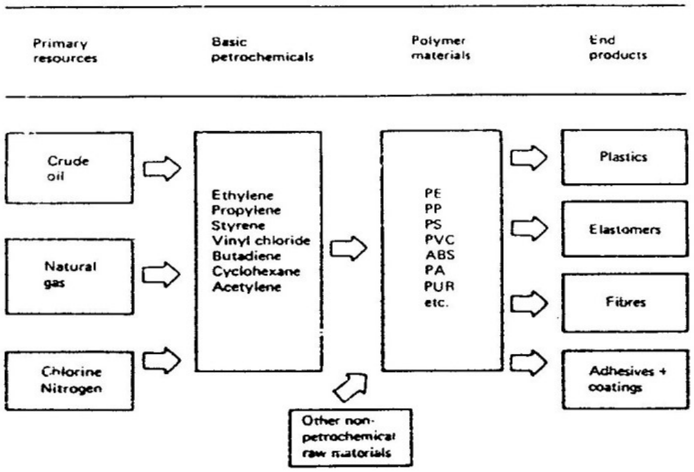


Fig.1 Production of polymer-based products from raw materials.

Polymer materials locally available in Third World countries are mainly natural polymers, with the exception of Saudi Arabia and Nigeria where a significant chemical industry for polymer production is emerging. In Tanzania two types of polymers of economic significance have been identified. One is natural rubber (NR) from Zanzibar farms owned by the Zanzibar governments and from General Tyre (East Africa) Ltd farms in Tanga Region. The second type of polymer material locally available in Tanzania is a thermosetting resin derived from the cashew nut shell liquid (CNSL).

Preliminary studies on the potential of CNSL as a substitute of the more expensive synthetic polymers have been published [3]. CNSL is a blend of naturally occurring phenol based monomers extracted from the spongy, honeycomb structure of the cashew nut shell, from the cashew tree. **Table 1** gives the composition of natural and technical CNSL and **Fig. 2** shows the chemical structure of the constituents. During extraction processes involving heat, the anacardic acid is decarboxylated into cardanol and the latter becomes the major constituent in the technical CNSL.

TABLE 1: The composition of natural and technical CNCL [3]

Component	Natural CNSL (%)	Technical CNSL (%)	Molecular Weight
Cardanol	1.20	62.86	298
Cardol	11.31	11.52	314
2-Methly cardol	2.04	2.08	328
Anacardic Acid	64.93	<1.0	342
Monophenol	20.30	23.80	94

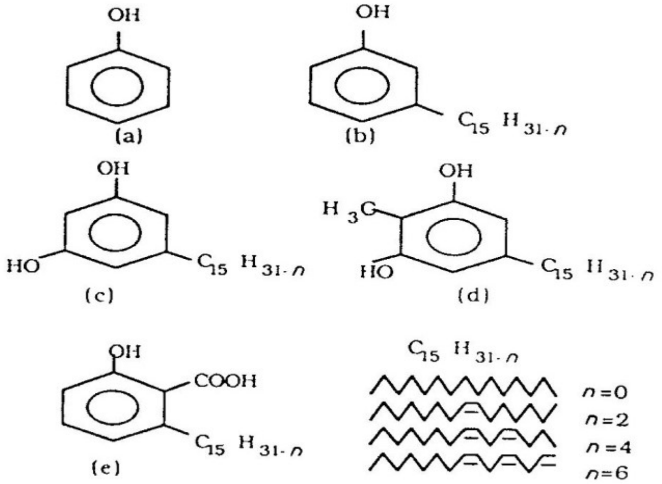


Fig.2 The chemical structures of constituents in natural CNCL (a) Monophenol (b) Cardanol (c)Cardol (d) 2-methyl cardol and (e) anacardic acid

Natural rubber is taped as a latex from a rubber tree originating from Brazil. The latex is a stereoregular hydrocarbon polymer produced by biosynthesis, using solar energy, carbon dioxide, water and the elaborate metabolic reactions of plant tissues. The chemical formula of natural rubber is $(c_5H_8)n$ where n is about 10,000 and C_5H_8 is the monomer isoprene. The configuration of each isoprene unit is in accordance with a definite and unique geometrical pattern (**Fig. 4.**) Any other arrangement would give a material of quite different properties. In natural rubber the arrangement is designated **cis,** hence the chemical name for natural rubber-cis-polyisoprene. A different geometrical arrangement of the isoprene unit is the **trans** configuration found in gutta percha (i.e. trans-poly isoprene).

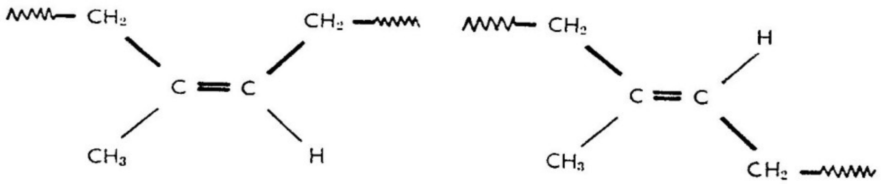
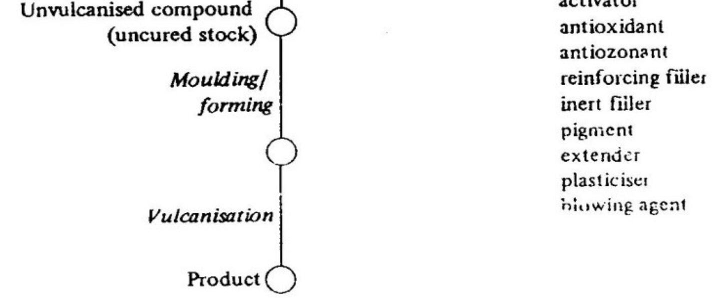


Fig.3 Alternative configuration of the isoprene monomer.

Table 2 outlines the techniques used to convert raw rubber latex to useful commercial rubbers. Very few applications of elastomers (rubbers) use the polymer in the unfilled state, as particulate fillers especially carbon black may increase the strength of vulcanized rubbers more than tenfold. [1,2,4]. The degree of reinforcement provided by a filler depends on a number of variables, the most important of which is the development of a large polymer filler interface. This can only be furnished by particles of colloidal dimensions.

TABLE 2: Compounding and processing operations in rubber technology.



Properties of natural rubber may be improved by using reinforcing fillers as mentioned above. Another method of significantly improving the properties of natural rubber is to blend it with synthetic rubbers or plastic materials. In this paper we report on the results of our investigations on the influence of blending locally produced natural rubber (NR) with Poly(vinyl Chloride) (PVC) plastics. These studies were prompted by frequent requests from our clients to develop material substitutes for imported specialized engineering plastics. Various methods are available for elastomer blending. These encompass latex blending, solution blending, combinations of these methods, conventional mechanical and mechanochemical mixing methods and powder mixing. Given the nature of materials available our investigations have been limited to conventional mechanical mixing only. It has been reported by Pazonyi et el [5] that, while two polymers may be mutually insoluble, blends may be produced which are macroscopically homogeneous and have useful properties, provided mechanical mixing is sufficiently intense and provided also that the viscosities after mixing are sufficiently high to prevent gross phase separation. Such blends are termed microterogeneous, and were first studied by Walters and Keyte [6] using phase contrast microscopy. Callan et el [7] has also shown, using electron microscopy, polymer blends to consist of discrete zones of the minor polymer dispersed in a continuous matrix of the major polymer, or the polymer of lowest viscosity. Properties of vulcanized filled elastomer blends are significantly affected by the dispersion (i.e. distribution and disaggregation) of the filler and also the distribution of soluble compounding ingredients in the polymer phases.

TABLE 3: Formulation of the mixes.

Ingredients	**Mix Number**					
	A	**B**	**C**	**A'**	**B'**	**C'**
Natural Rubber (NR)[a]	100	100	100	100	100	100
PVC	10	15	20	10	15	20
Carbon Black ISAF (N220)	37	**37**	**37**	**70**	**70**	**70**
Processing oil	5.3	5.3	5.3	5.3	5.3	5.3
Zinc Oxide	5.0	5.0	5.0	5.0	5.0	5.0
Stearic Acid	3.0	3.0	3.0	3.0	3.0	3.0
Antioxidant (IPPD)	2	2	2	2	2	2
Sulphur	2.7	2.7	2.7	2.7	2.7	2.7
MBT	1.5	1.5	1.5	1.5	1.5	1.5

a. Natural Rubber produced from Zanzibar Govern. farms, supplied by Bora Shoes Co. Ltd Dar es Salaam, Tanzania.

TABLE 4: Mixing times and sequences

Additive	Duration (min)
Rubber (NR)	4
Zinc Oxide	2
Black and Stearic Acid	3
PVC/CR	3
Antioxidant	2
Sulphur	3
Processing oil	2
MBT	3
Total	**22**

EXPERIMENTAL

Formulations of the mixes are shown in **Table 3.** Mixing was done on a laboratory two-roll open mill (150 mm x 330 mm, belonging to "Bora Shoes Company Ltd in Dar es Salaam) according to ASTM D3182-74 (part 37, 1980). The roll temperature was maintained at 70^0 C and speed of the rollers in the ratio 1:1.4, slow and faster roller respectively with 24 rpm for the slower roller. Sequence of addition of the ingredients and mixing times are shown in **Table 4.** Mixes were vulcanized at 150^0 C to their respective optimum cure times and one set of mixes was vulcanized at 170^0C. The compression molded samples were left at 20^0C for 24 hours for aging.

Tensile Tests

The dumb bell specimens (die C) with gauge length of 25 mm were punched out from the vulcanized sheets, and tested on the tensile tester machine. The rate of grip separation was 8.4 mm/s. The ambient room temperature was 20^0C. On the average a total of three specimen were tested for each sample, and the consistency in tensile strength values in each case were reproducible within to ± 6%.

Specific Gravity

This was measured by using specimens cut from vulcanized sheets. Hydrostatic methods were used.

Tear Strength

Unnotched 90^0 angled tear test specimens (die C) were punched out from the vulcanized sheets and tested on a tensile tester machine. The rate of grip separation was 8.4 mm/s. The ambient room temperature was 20^0C. Shapes of the test specimens with the directions of the applied force and fracture propagation are shown in **Fig. 4**. Three specimen were tested for each sample and the consistency in tear strength values in each case were reproducible within to ±5.5%.

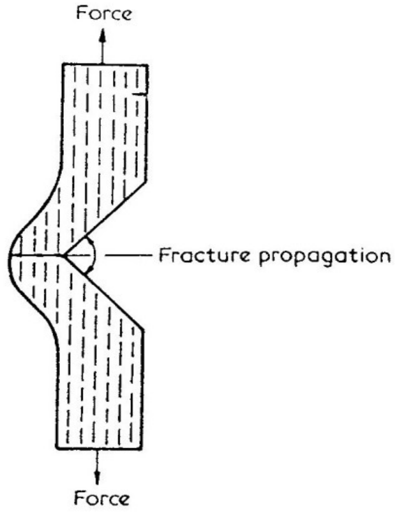


Fig.4 Shape of the tear test specimens and the direction of applied force and fracture propagation.

Abrasion Loss

The test specimen were compression molded cylindrical discs of dimensions 63.5 mm outer diameter; 12.7 mm inner diameter and 12.7 mm thickness. The tests were carried out on an abradic Akron machine (ASTM D-1630-61). Specification for the grinding stone were 150mm outer diameter, 25.4 mm inner diameter and 38 mm thickness with N40 grain size.

Hardness Test

Test specimen were compression molded cylindrical discs of diameter 30 mm and thickness 10 mm. The test was done on a dead load testing machine, "Wallace Hardness Tester, with 540 grams dead load, and an indentor ball of 2.5 mm diameter.

Compression Set

The tests were done according to ASTM D 395, method B. Cylindrical discs of 29.5 mm were compressed using spacer bars and placed into an oven at 70^0C for 22 hours. For each sample three specimen were tested, and 30 minutes, recovery time was allowed before taking final readings.

RESULTS AND DISCUSSIONS

Measured values of various properties investigated are given in Table 5. Figure 5 shows the trend of investigated properties for the two categories of NR blends. The first category indicates the influence of increasing PVC concentration on properties for a normally loaded (37 pphr of carbon black) NR compound. The second category does the same for a highly loaded (70 pphr carbon black) NR compound.

TABLE 5: Compound Properties

	Mix	A	B	C	A'	B'	C'
Tensile strength N/mm^2		132	148	153	80	85	100
Elongation at break, %		600	700	700	565	612.5	625
Specific gravity		1.016	1.0	0.986	1.03	1.04	1.07
Tear Strength KN/m		43.64	45.71	48.68	26.34	27.91	34.34
Abrasion Loss %		2.37	2.20	2.81	6.46	4.47	4.65
Hardness, IRHD		51.25	49.25	44.25	65.25	63.00	57.00
Compression Set, %		56.99	67.72	60.85	50.63	42.71	30.81

Tensile strength increased with increasing PVC concentration **(fig 5a)** and also improvement in tear strength **(fig. 5b)** has been noted. At the investigated concentrations, PVC exists as a discontinuous phase and as such supplementing the influence of reinforcing filler. NR is a strain crystallizing elastomer and this accounts for improved tensile and tear strengths as well.

Fig. 5(c) shows that the increase in PVC concentrations worsens the abrasion characteristics of the compound. Poor processability, probably due to reduced effective processing oil concentration, accounts for higher abrasion losses in the heavily black loaded compounds. As expected increased loading of carbon black improves hardness values **(Fig. 5d)**. On the other hand increased concentrations of PVC lowers the hardness values slightly.

A compression set is lower for a higher loading of carbon black (70 pphr) as compared to the normal loading of (37 pphr). For either loading, the effect of increased concentrations of PVC is to lower the compression set. As PVC is increased the rigidity of the compound increases accordingly.

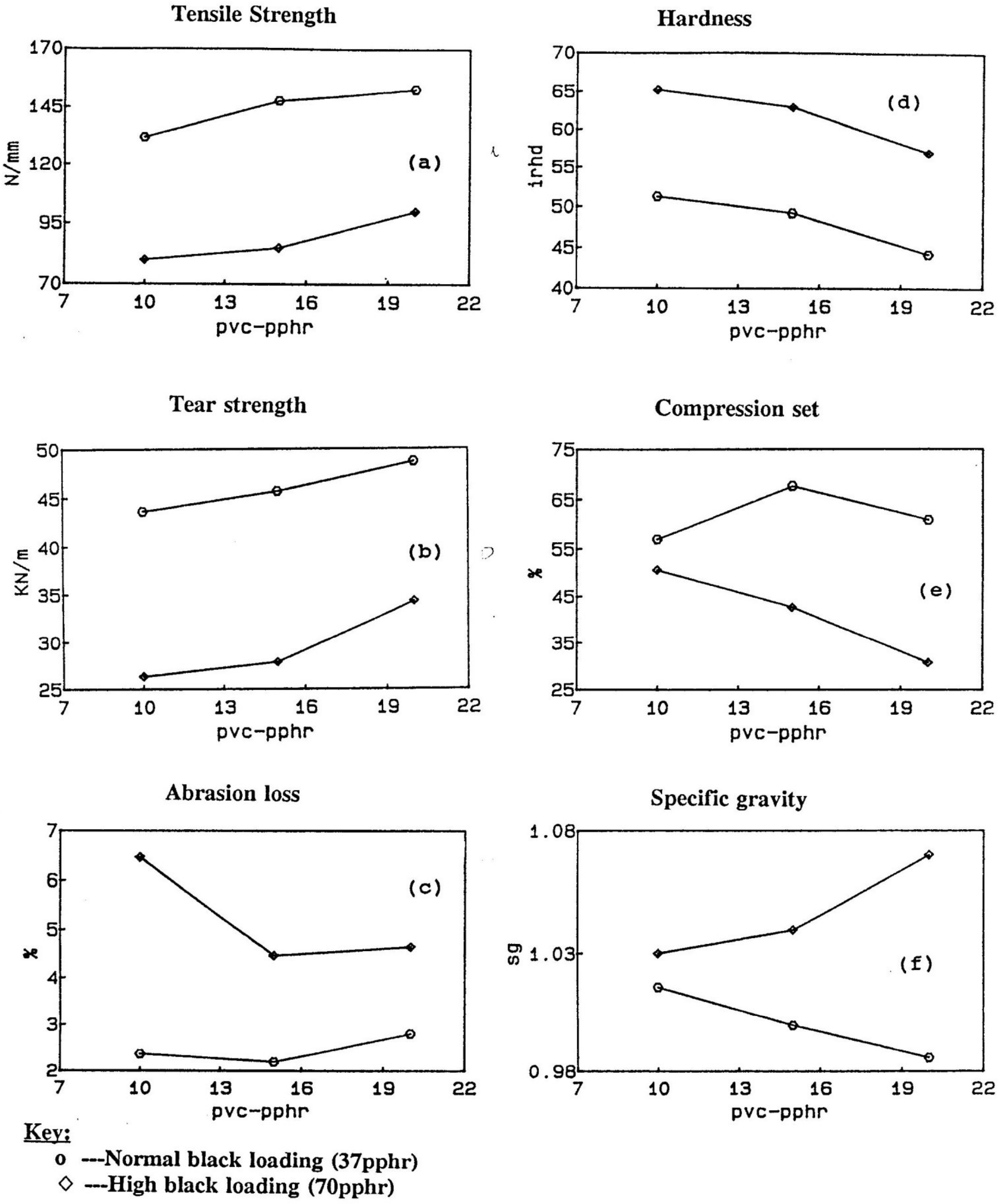


Fig.5 Plots of investigated blend properties.

CONCLUSION

Locally produced Natural rubber (NR) blended with PVC in small concentrations (10, 15, 20 pphr) shows improved tensile and tear strength. Abrasion and hardness properties for the compounds get worse with increased PVC concentrations. As NR production in the country is picking up, blending it with small proportions of plastics shows to be a viable alternative to imported engineering plastics especially in applications where wear characteristics are not critical.

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