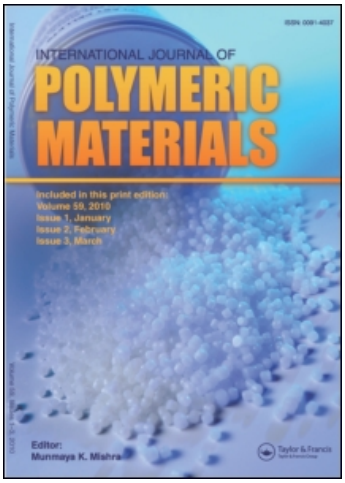

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Hanafi Ismail[a]; H. D. Rozman[a]
[a] School of Industrial Technology, Universiti Sains Malaysia, Minden, Penang, Malaysia

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Studies on the Tensile Properties of Rubberwood Fibre – Natural Rubber Composites

HANAFI ISMAIL* and H. D. ROZMAN

School of Industrial Technology, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia

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Natural rubber (NR) composites were prepared by incorporating rubberwood fibres at different loadings into the NR matrix in a mixing mill according to a base formulation. Tensile properties, swelling measurement and tensile fracture surfaces of gum and composites with 0, 10, 20, 30 and 50 phr of rubberwood fibres were studied. Incorporation of rubberwood fibres in the composites increases the tensile modulus but reduces the tensile strength and elongation at break. Scanning electron microscopy (SEM) studies and swelling measurement indicate that the increasing rubberwood loading has weakened the rubber–filler interactions.

Keywords: Rubberwood fibre; scanning electron microscopy natural rubber; tensile properties; swelling measurement

1. INTRODUCTION

With growing demand for light weight, high performance materials coupled with escalating costs of raw materials and energy, there has been of late a tremendous surge of interest in employing biofibres which are abundantly available and yet not completely, exploited for lack of adequate technology development [1]. Short fibres are known as reinforcing agents in polymers for more than three decades [2]. It has much advantages because of their renewable nature, low cost, easy availability and ease of chemical and mechanical modification [3].

*Corresponding author.

In our previous works [3, 4], we have reported the curing characteristics and mechanical properties of short oil palm fibre reinforced rubber composites. The modification of fibre surface and use of various bonding systems increased the mechanical properties of oil palm fibre reinforced rubber composites.

In the present study, a relatively new type of wood-based filler is investigated. Rubberwood fibre (RWF) is the by-product of rubberwood based industry and consists of about 76% of holocellulose and 26% of lignin [5]. The effect of filler loading on the tensile properties of rubberwood fibre filled natural rubber composites will be reported. Scanning electron microscopy (SEM) studies and swelling measurement are carried out to determine the failure behaviour of the composites.

2. EXPERIMENTAL

2.1. Materials

Natural rubber (SMR L) was obtained from Rubber Research Institute of Malaysia (RRIM). Rubberwood fibres were supplied by Pan Malaysian Wood Mill (M) Ltd., Penang. Other chemicals were supplied by Bayer (M) Ltd., Penang.

2.2. Processing

Formulations of the mixes are given in Table I. Rubberwood in fibrous form were ground into sizes of 180–270 μm and used in rubber compounding without further treatment. The mixing was carried out as per ASTM D 3182-80 on a two-roll laboratory size mixing mill (160 × 320 mm). Nip gap, mill roll speed ratio, time of mixing and the sequence of addition of the ingredients were kept the same for all the mixes. Optimum cure time, t_{90} was determined by a Monsanto Rheometer model MDR 2000. Vulcanization was carried out at 150°C on an electrically heated single daylight hydraulic press at 5.0 N/mm^2 pressure. The tensile properties were studied using on Instron Universal Tester (model 1114) according to ASTM D412 at 500 mm/min cross-head speed. All tests were conducted at room temperature (25°C).

TABLE I Composition of the mixes

	Mix. no.				
Ingredients	*A*	*B*	*C*	*D*	*E*
Natural rubber	100	100	100	100	100
Zinc Oxide	5	5	5	5	5
Stearic acid	2	2	2	2	2
CBS[1]	1	1	1	1	1
Sulphur	2.5	2.5	2.5	2.5	2.5
Flectol H[2]	1	1	1	1	1
Rubberwood fibre	0	10	20	30	50

Note: 1. N-cyclohexylbenthiazyl Sulphenamide (CBS) 2. Poly-1,2-dihydro-2,2,4-trimethylquinoline.

2.3. Swelling Measurement

Cured test pieces of dimensions 30 × 5 × 2 mm were swollen in toluene until equilibrium swelling was achieved, which normally took 72 hrs at 25°C. In this study, Q (the weight of toluene uptake per gram of rubber hydrocarbon) was determined according to the expression derived by Park and Brown [6] as shown below

$$Q = \frac{\text{Swollen wt} - \text{De-swollen wt}}{\text{dry wt} \times (100/\text{formula wt})}$$

The rubber–filler interaction was calculated as suggested by Lorenz and Park [7].

$$\frac{Q_f}{Q_g} = ae^{-2} + b$$

The subscripts f and g refer to filled and gum vulcanizates respectively. Z is the ratio by weight of filler to rubber hydrocarbon in the vulcanizate, while a and b are constants.

2.4. Scanning Electron Microscopy (SEM)

SEM observations of tensile fractured surfaces were made using a scanning electron microscope model Leica Cambridge S-360. The fracture surfaces of the test samples were carefully cut out and then sputter-coated with gold within 24 h of testing.

3. RESULTS AND DISCUSSION

3.1. Tensile Properties

Stress–strain curves of the mixes $A-E$ are given in Figure 1. The deformation behaviour of the mixes can be seen from the stress–strain curves which exhibit the sigmoidal nonlinear characteristic of rubber like materials. The increasing loading of rubberwood fibre changed the deformation behaviour of the composites from elastic to brittle type deformation. Addition of fibres also increase the modulus of the composites. Figure 2 shows that the maximum torque increases with increasing filler loading. This is due to the presence of higher loading of filler which impart more restriction to deformation. Table II summarizes the tensile properties of the composites. It can be seen that the elongation at break decreases with increasing filler loading. With increment in rubberwood fibre loading, the stiffness and brittleness of the composites increase gradually with an associated decrease in the elongation at break. As discussed before, the tensile modulus

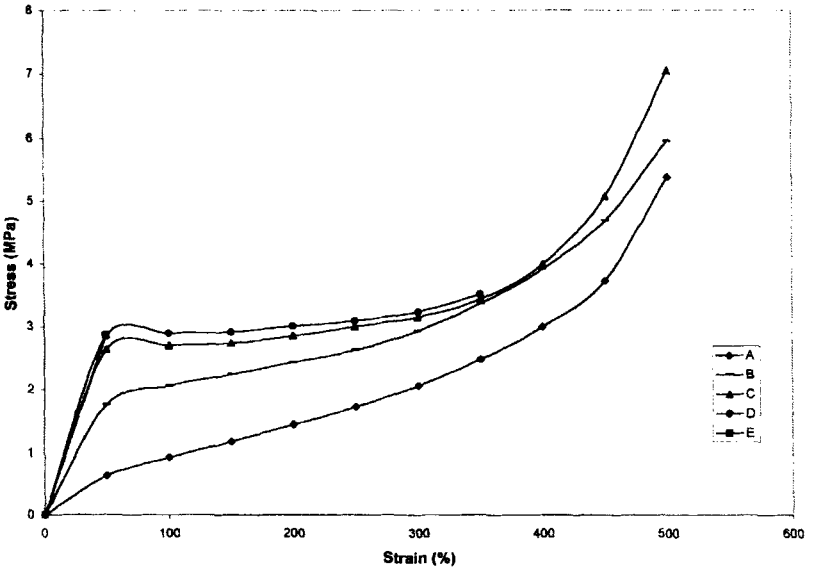


FIGURE 1 Stress–strain curves of the composites $A-E$.

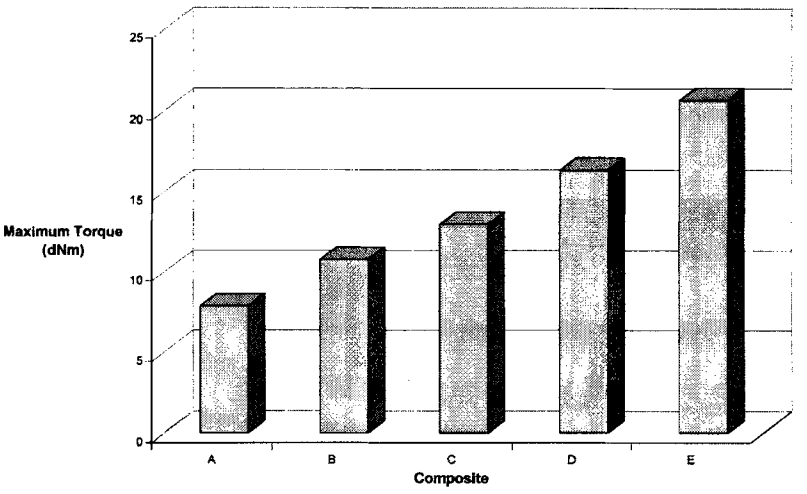


FIGURE 2 The effect of the filler loading on the maximum torque of the composites.

(modulus at 100% and 300% elongation) also increase with increasing filler loading. The incorporation of rubberwood fibre reduces the elasticity of the rubber chain, resulting in more rigid composites. Similar observations were also reported by other researchers [8–11] using different types of fibres and rubbers. Table II also shows that the tensile strength of the composites decreases with increasing fibre loading. The reinforcing effect brought about is insufficient to compensate for the dilution effect of the filler in the rubber matrix and hence the decrease in tensile strength.

TABLE II Tensile properties of the rubberwood fibre–natural rubber composites

Ingredients	*A*	*B*	*C*	*D*	*E*
Modulus at 100% elongation, M100 (MPa)	0.931	2.062	2.705	2.899	–
Modulus at 300% elongation, M300 (MPa)	2.064	2.931	3.154	3.241	–
Tensile strength (MPa)	22.7	12.0	6.4	3.6	2.9
Elongation at break (%)	676	578	515	359	44

*Sample break before 100% elongation.

3.2. Swelling Measurement

Figure 3 shows the effect of rubberwood fibre loading on the Q_f/Q_g of the composites. The Q_f/Q_g increases with increasing filler loading. It is clear that the increasing rubberwood loading has weakened the rubber–rubberwood fibre interactions since the higher the Q_f/Q_g values, the lower will be the extent of interaction between filler and rubber matrix.

3.3. Scanning Electron Microscopy Studies

SEM is an important tool for observing the surface morphology of fibres, the cause of crack initiation and the failure process in composite materials [12]. Figure 4a shows that the fracture surface of the composite *A* (without rubberwood fibre) exhibits the brittle fracture. However Figures 4b, c and d reveal that rubberwood fibre-filled composites exhibit a marked change in fracture surfaces. The presence of fibres in the composites change the failure modes. It can be seen in Figures 4b, c and d that the failure of the composites occurred due to

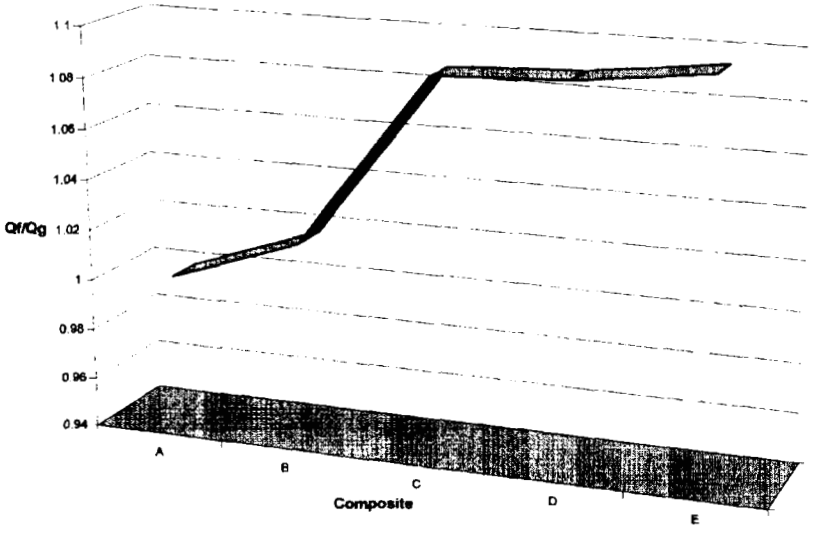


FIGURE 3 Relationship between filler loading and Q_f/Q_g of rubberwood fibre filled natural rubber composites.

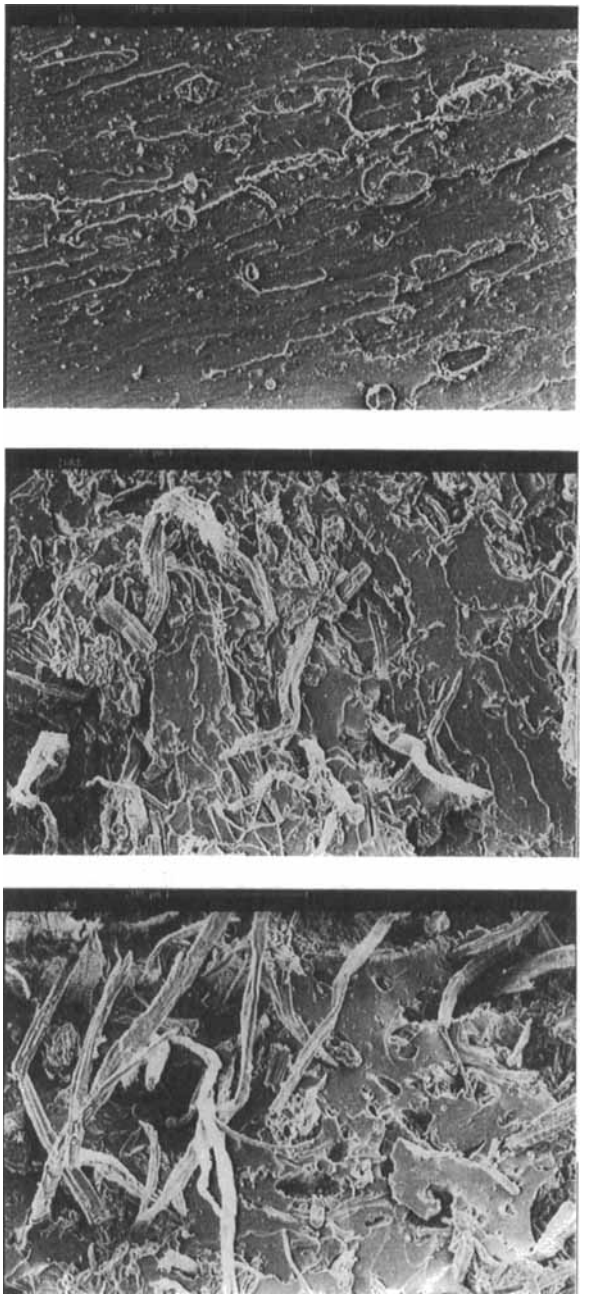
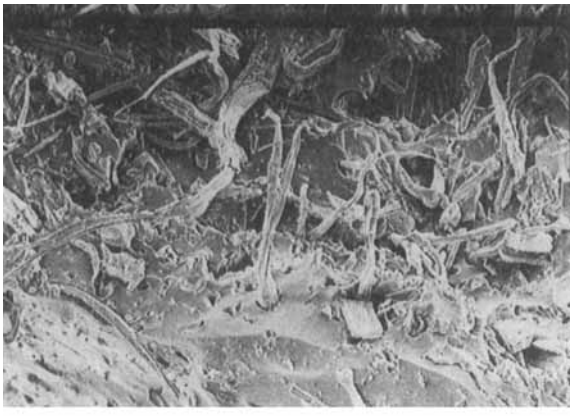


FIGURE 4 SEM micrograph of the rubberwood fibre filled natural rubber composites after tensile fracture at various filler loadings (a) 0 phr (control composite) (b) 10 phr (c) 20 phr (d) 30 phr (e) 50 phr at magnification X 150.



d

e

FIGURE 4 (Continued).

the breakage of fibres and the pull-out of several fibres from the rubber matrix. The decreased wettability and a large number of holes as a result of the pull-out of fibres contribute to the reduction of tensile strength and elongation at break as the filler loading in the composites increases.

4. CONCLUSION

The tensile properties of rubberwood fibre – natural rubber composites have been studied as a function of filler loading. Tensile modulus of

the composites increases with the filler loading. The incorporation of filler reduces the elasticity of the rubber chain, resulting in more rigid composites. However tensile strength and elongation at break show opposite trend. This is due to the poorer rubber–filler interactions as a result of increasing filler loading.

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