

Mechanical Properties of Rubber-Wood Fiber Filled PVC/ENR Blend.

Chantara Thevy Ratnam^{*1}, Radin Siti Fazlina² and Shuhaily Shamsuddin²

¹Radiation Processing Technology Division, MINT Tech-Park, Malaysian Nuclear Agency (Nuclear Malaysia),
Bangi, 43000 Kajang, Selangor Darul Ehsan.

²Department of Polymer Technology, Faculty of Applied Sciences, University Technology Mara,
40450 Shah Alam, Selangor Darul Ehsan.

ABSTRACT: The effect of rubber-wood fiber (RWF) on the mechanical properties of the 50/50 polyvinyl chloride/epoxidized natural rubber (PVC/ENR) blend was investigated over a range of fiber loadings (0 to 30%). The RWF filled PVC/ENR blend was prepared by using a Haake mixer at 150°C mixing temperature, 10 min. total mixing time and 50 rpm rotor speed. Changes in tensile strength (Ts), Young's modulus, modulus at 100% elongation (M100), elongation at break (Eb), flexural modulus, hardness and impact strength with the RWF loadings were investigated. The results revealed that the flexural modulus, Young's modulus and hardness increased with the RWF loading. However, the impact strength, Ts and Eb were found to decrease with the increase in RWF loading. The morphology of tensile fracture surfaces of the composites, examined by a scanning electron microscope provides evidence for the poor adhesion between the RWF and the blend matrix.

Keywords: PVC/ENR blend, rubber-wood fiber, properties, reinforcement

1.0 INTRODUCTION

Epoxidized natural rubber (ENR) forms miscible blends with polyvinyl chloride (PVC) [1,2] in which PVC is expected to impart high tensile strength and good chemical resistance whereas ENR acts as a permanent plasticizer to PVC, induces good tear strength and enhances resistance against hydrocarbon oils [1-3]. In view of modification of PVC/ENR blends, a number of reports indicated that the physical and mechanical properties of the blend could be enhanced by electron beam irradiation [4-6]. Subsequent studies by the similar group of authors have highlighted that such enhancement in blend properties attributed to the occurrence of irradiation-induced crosslinking [5,6].

Fiber reinforced polymers offer several advantages over other conventional materials when specific properties are compared. Many studies have described the use of natural fibre as filler/reinforcing agent in polymer matrices [7,8]. These fibers are relatively cheap and lightweight (lower density) compared to inorganic fillers. In addition, the biodegradable nature of the natural fibers offers a potential solution to the growing waste disposable problem. In previous studies, the effect of oil palm empty fruit bunch (OPEFB) fiber and poly (methyl acrylate), PMA grafted OPEFB on the mechanical, thermal and structural properties of PVC/ENR blends were investigated. The reports on the grafting of OPEFB fiber with methyl acrylate [9], radiation modification [10], and physical properties [11,12], of the PVC/ENR/OPEFB composites were published elsewhere. Raju *et al.* found [11], that the OPEFB fiber has the improved the mechanical properties of PVC/ENR blends. The grafting of OPEFB fiber with methyl acrylate, MA contributes to the improved interfacial wetting between OPEFB and PVC/ENR blend matrix [11]. The present work

Corresponding author : Chantara Thevy Ratnam, Email: Chantara@nuclearmalaysia.gov.my

attempts to enhance the PVC/ENR blend properties by using rubber-wood fiber (RWF) as filler. The main aim of this study is to gain some insight on the effect of RWF on the mechanical properties of PVC/ENR blends prior to surface modification of the RWF.

2.0 EXPERIMENTAL

2.1 Materials

Epoxidized natural rubber, grade "Epoxyrene 50" with 50 % epoxidation level was supplied by Guthrie Polymer Ltd. as a free sample; poly(vinyl chloride), PVC with a K-value of 66 (<Mn> of 66,000), grade "MH66, 6519" was purchased from Industrial Resin (M) Ltd. The PVC stabilizer used, tribasic lead sulfate (TS-100M) was purchased from Lonover Scientific Suppliers Ltd., London. The rubber-wood fibre (RWF) was obtained from Merbuk MDF Sdn. Bhd., Sg. Petani, Kedah, Malaysia. The RWF was ground to 250 μm by using a crusher machine.

2.2 Formulations

The RWF filled PVC/ENR blends were prepared by mixing 50 parts of PVC with 50 parts of ENR50. The recipes used to prepare the composites are given in Table 1.

Table 1: Recipes used to prepare RWF filled PVC/ENR blends*

	1	2	3	4	5
ENR	50	50	50	50	50
PVC	50	50	50	50	50
TBLS	4	4	4	4	4
RWF	0	5	10	20	30

* parts per hundreds of total polymer (php)

2.3 Sample preparations

PVC and the stabilizer were premixed at room temperature in a tabletop high-speed mixer at 1200 rpm for 10 min. Melt blending was carried out at 150°C and 50 rpm rotor speed in a Haake mixer having a mixing cam attachment. The blending was done as follows:

When the desired temperature was reached, ENR was charged into the mixing chamber and mixed for 1 min. The PVC compound was then added, and the PVC/ENR compound was allowed to melt in the mixer for 4 min. before RWF is charged. The mixing was continued for another 5 min.

2.4 Molding

The blends obtained from the Haake mixer were then compression molded into sheets of 1, 3 and 6 mm thickness under a pressure of 14.7 MPa at 160 °C for 3 min. The sheets were immediately cooled between two plates of a cold press at 25 °C. Test pieces were cut from these sheets in accordance with standard procedures stated in the proceeding sections.

2.5 Measurement of tensile properties

The tensile strength (Ts), elongation at break (Eb), Modulus at 100% elongation (M100) and Young's modulus were measured with a Instron Universal Testing Machine (Model 4301) using a crosshead speed of 50 mm/min in accordance to BS6746. Altogether, eight samples were used for the tensile test and an average of six results was taken as the resultant value.

2.6 Hardness

The Shore A hardness test was carried out according to ASTM D2240-89 using the Zwick 7206 Hardness Tester. Disc shaped specimen with 6 mm thickness were used. The measured value of hardness was taken after 15 seconds of contact in Shore A indenter obtained at three different points distributed over the test piece. Three test pieces were used and their average value was determined.

2.7 Flexural modulus

The flexural modulus was determined using an Instron Model 4301 machine in accordance with ASTM D 790-97 standard. Five rectangular bar shaped specimens are tested for each composition with a thickness of 3 mm and their average values were calculated.

2.8 Impact strength

The Izod impact test was performed using a 4 joule hammer on notched samples by a Universal Digital Pendulum Model CEAST machine in accordance to ASTM D 256-97. A total of seven samples were used for the tensile test and an average of five results was taken as the resultant value.

2.9 Scanning Electron Microscopy (SEM)

SEM studies were performed on selected tensile fractured samples (50/50 PVC/ENR blend at 0, 5 and 30 phr RWF loadings). The tensile fractured surfaces were sputter coated with gold and examined using a Philip 515 Scanning Electron Microscope.

3.0 RESULTS AND DISCUSSION

3.1 Tensile properties

Incorporation of filler to a polymer matrix may increase or decrease the Ts of the resulting composites. Fiber type fillers normally result in improved Ts, as the fibers are able to support the stresses transferred from the polymer. Figure 1 shows the effect of RWF loading on the Ts of 50/50 PVC/ENR blend. Ts found show a slight increase (5.1%) with the addition of 5 phr RWF. However a further increase in RWF loading reduces the Ts of the blend. As the filler loading is increased, eventually a level is reached whereby the filler particles or aggregates are no longer as equally separated or wetted by the polymer matrix. The poor wetting of the fiber by the PVC/ENR blends will lead to poor interfacial adhesion between the fiber and polymer matrix resulting in weak interfacial regions. Thus, the reduction in strength may be due to agglomeration of the filler particles to form a domain that acts like a foreign body as well as weak interfacial region. Similar trend of Ts was observed by Ismail *et al.* [12] in their work on white rice husk ash filled natural rubber compounds.

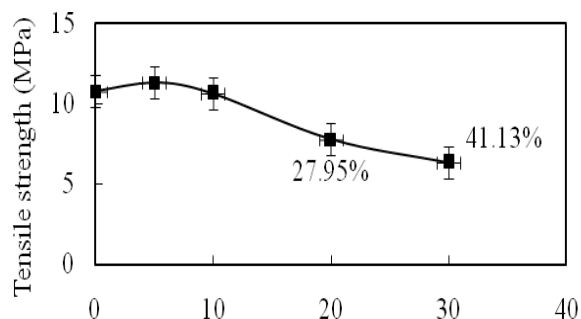


Figure 1: Effect of RWF loading on the tensile strength of 50/50 PVC/ENR blend (the data labels indicate the % decrease in Ts)

Figures 2, 3 and 4 show the effect of RWF loading on the Eb, M100 and Young's modulus of the PVC/ENR blends, respectively. It can be seen that increase in modulus (Young's modulus and M100) and decreases in Eb occur with increasing RWF loading. This observation indicates that incorporation of RWF into the PVC/ENR blend matrix improves the stiffness of the PVC/ENR blends. This is a common observation with almost all filled polymer systems. Reduction in Eb is due to the decreased deformability of a rigid interphase between the fiber and the matrix material. However, the increase in M100 is less pronounced compared to the changes in Ts and Young's modulus with RWF loading. This trend of results indicate that the addition of RWF to PVC/ENR blends do not cause remarkable effect to the modulus at 100% elongation of the blends. Such observation could be attributed to the stress-strain behavior of the PVC/ENR blend that does not undergo stiffening effect at 100% elongation.

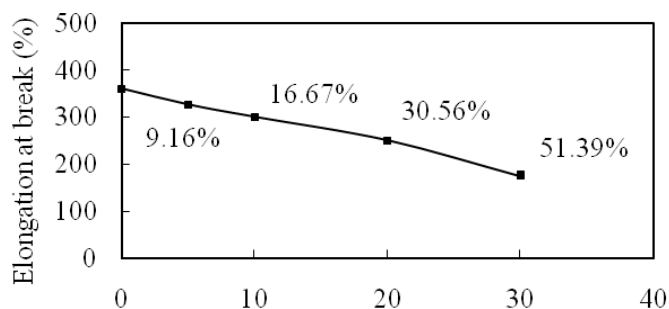


Figure 2: Effect of RWF loading on the elongation at break of 50/50 PVC/ENR blend (The data labels indicate the % decrease in Eb).

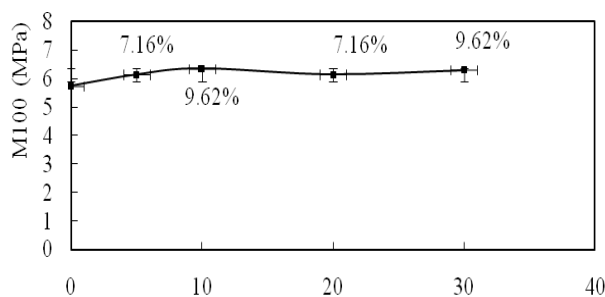


Figure 3: Effect of RWF loading on the M100 of 50/50 PVC/ENR blend (The data labels indicate the % increase in M100).

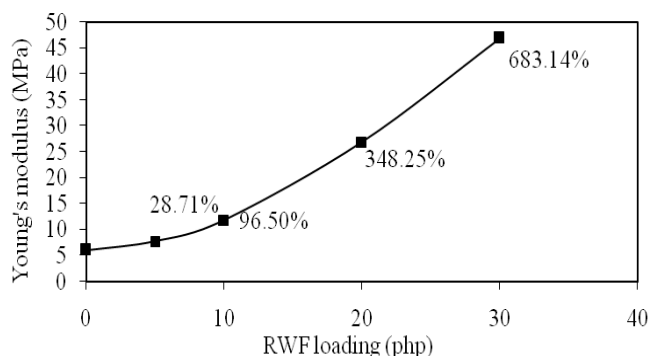


Figure 4: Effect of RWF loading on the Modulus Young of 50/50 PVC/ENR blend (The labels indicate the % increase in Young's Modulus)

Flexural Modulus

One of the primary intentions of filler incorporation into polymers is to increase the stiffness of the resultant material. Figure 5 depicts the flexural modulus of the RWF filled PVC/ENR blends. The flexural modulus found to increases steadily with increasing RWF content. This is a common phenomenon. Similar observation also reported by Zaini *et al.* [14] in their studies on polypropylene/oil palm wood flour composites.

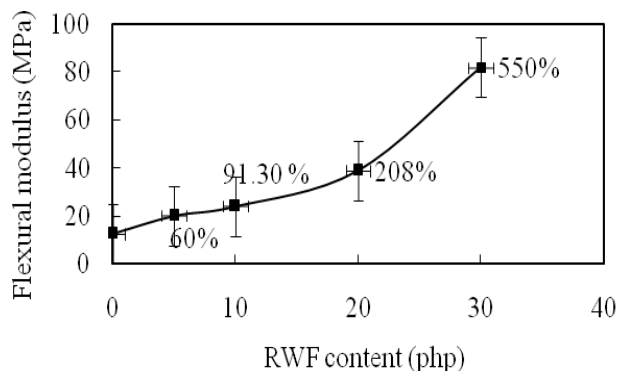


Figure 5: Effect of RWF loading on the flexural modulus 50/50 PVC/ENR blend (The labels indicate the % increase in flexural modulus).

Hardness

Hardness of the RWF filled PVC/ENR blends increases with increasing RWF loading as shown in Figure 6. It is apparent from Figure 6 that the addition of 5 to 30 php RWF to PVC/ENR blends results in enhancement in hardness of the blends from 8.7 to 17.4 %, respectively. This trend of results is expected because as more filler particles incorporated into the polymer matrix, the elasticity or flexibility of the polymer chain is reduced, resulting in more rigid blends. This observation is in perfect agreement with the results on Young's modulus and flexural modulus.

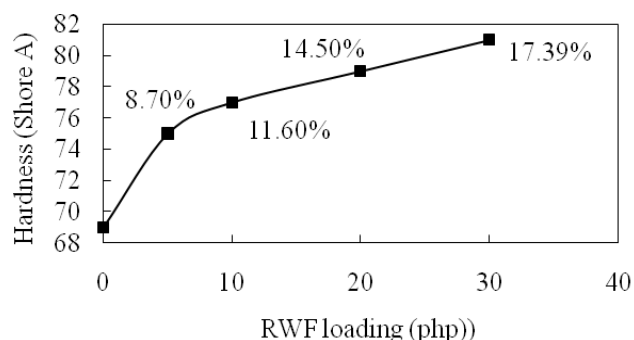


Figure 6: Effect of RWF loading on the hardness of 50/50 PVC/ENR blend (The labels indicate the % increase in hardness).

Impact strength

Figure 7 illustrates the changes in izod impact strength of the PVC/ENR blend with the increase RWF content. It is apparent from Figure 7 that the impact strength of the blend decreases as the RWF loading increases. Upon addition of 30 php RWF, the impact strength of the PVC/ENR blend found to drop to 37.48 J/m which is 40.69% reduction. This observation could be attributed to the poor wetting of the RWF filler by the PVC/ENR blends, which lead to poor interfacial adhesion between the fiber and polymer matrix resulting in weak interfacial regions. The poor interfacial adhesion is between hydrophobic matrix and hydrophilic nature filler usually results in decreased toughness as reported by Raju *et al.* [11] in their studies on PVC/ENR/OPEFB composites. Thus, the decline in impact strength with the RWF loading is attributed to the poor interfacial adhesion between the hydrophobic PVC/ENR blend matrix and hydrophilic RWF filler. During the impact test, cracks travel through the polymer as well as along the interfacial region. The latter cannot resist crack propagation as effectively as the polymer region, hence reducing the impact strength. Thus, increasing the RWF content merely increases the interfacial regions, which exaggerates the weakening of the resulting composites to crack propagation. In addition to this, incorporation of fillers would result in reduced polymer chain mobility, thereby lowering the ability of the system to absorb energy during fracture propagation.

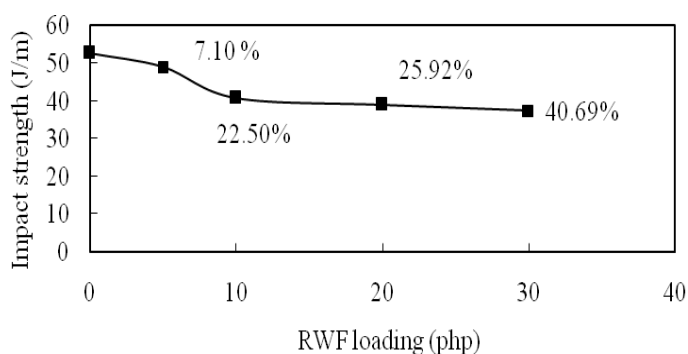


Figure 7: Effect of RWF loading on the impact strength of 50/50 PVC/ENR blend (The data labels indicate the % decrease in impact strength).

3.2 Surface Morphology

Figure 8 displays SEM micrographs of the tensile fracture surface of 50/50 PVC/ENR blend at 0, 5 and 30 php RWF loadings. It is apparent from Figure 8 that the fractured surface of the RWF filled blend appear rougher and more brittle compared with the unfilled blend. Figure 8 also indicates that the composite did not fail by transverse fracture of matrix plane. This is evident from the presence of the holes that indicate occurrence of fiber pull out with less fiber breakage. Khalid *et al.* [15] in their studies on “Comparative study of polypropylene composites reinforced with oil palm empty fruit bunch fiber and oil palm derived cellulose” had attributed the occurrence of fiber breakage rather than pull out to the good interfacial strength between fiber and the matrix polymer. The holes reflex that the RWF could not provide an efficient stress transfer from the matrix. This observation suggests poor adhesion and dispersion between fiber and matrix. The fracture surface of blend in the presence of 30 php RWF shows more RWF pull out with less matrix tearing compared with the blend added with 5 php RWF. The holes also look smooth showing a complete separation of the fibers and the polymer matrix indicating the failure occurred at the weak fiber/matrix interface. It is observed that the fibers oriented in random arrangements. Besides that Figure 8 provides further evidence for the presence of more irregular shaped RWF fillers in the blend filled with 30 php RWF as compared to that of 5 php blends, which also lead to poor strength properties of the composites as observed in previous sections. Presence of larger holes in 30 php RWF composite is a clear indication of pull out of agglomerated RWF. Therefore, the morphological studies support the results on the tensile and impact properties of the composites.

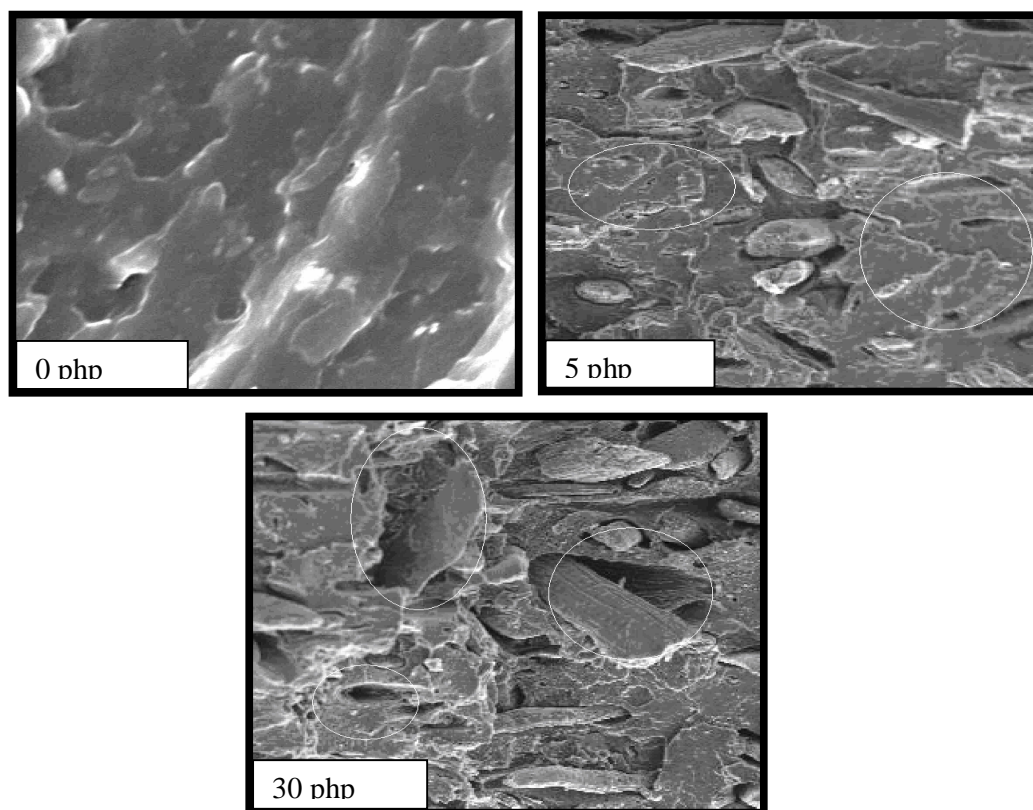


Figure 8: SEM micrographs of the tensile fracture surface of 50/50 PVC/ENR blend at 0, 5 and 30 php RWF loading (magnification x100).

4.0 CONCLUSION

A preliminary investigation was carried out to study the mechanical properties of RWF filled PVC/ENR composites. The upward trend exhibited in Ts with the addition of 5 php RWF coupled with the enhancement in Young's modulus, hardness and flexural modulus with the increase in RWF loading indicates the RWF has the potential to improve the mechanical properties of PVC/ENR blends. However a reduction in Ts at above 5 php RWF and the gradual drop in impact strength with RWF loading are also observed. It was evident from morphological studies that poor interfacial bonding, irregular shaped RWF fillers and agglomeration of RWF are the main factors responsible for the drop in tensile in impact strengths upon RWF loading. Therefore further studies will be made in order to improve the fiber dispersion and the quality of interfacial bonding between the RWF and PVC/ENR blend matrix.

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