MECHANICAL BEHAVIOR of FIBERS REINFORCING in NATURAL RUBBER STR 5L

[*]SiriwanPANNARAY[1], *Benchawan BOONPAI[2], Kritsakorn THONGSIRI[2], Kittipat DAUNGSUWAN[2]and Patcharaporn PANDEE[3]*

[1]Department of Mechanical Engineering, King Mongkut's Institute of Technology Ladkrabang Prince of Chumphon Campus, Chumphon 86160, Thailand
[2]Department of Agricultural Engineering, King Mongkut's Institute of Technology Ladkrabang Prince of Chumphon Campus, Chumphon 86160, Thailand
[3]Department of Biotechnology, King Mongkut's Institute of Technology Ladkrabang Prince of Chumphon Campus, Chumphon 86160, Thailand
Corresponding author: Siriwan PANNARAY. E-mail: pang_som@hotmail.com

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ABSTRACT

The mechanical properties of Natural Rubber STR5L reinforced with chopped fibers were studied. Types of natural fibers (biofibers) were used palm oil fiber and coconut shell fiber and treated with 3%NaOH solution for improving skin fiber. In addition, adding E-glass to combine with natural fibers was investigated. In preparation, fibers were chopped to 5 (L_1) and 10 (L_2) mm. at fiber loading 5phr. The fibers and STR 5L were mixed using a mixer, and compounded using two-roll milling, then compressed to obtain the plates of thickness 2mm. The hardness of coconut shell fiber with addition of E-glass gave maximum hardness shore A of 66.1 ±0.16 in both lengths. The tensile strength of coconut shell fiber with non-adding E-glass at L_2 gave maximum strength at 14.7± 0.76 MPa when comparing with coconut shell fiber added with E-glass showed decreasing of strength at 2.1±0.1 MPa. Decreasing strength in case of adding E-glass resulted from longer fibers undergoing fibers entanglement and dispersion irregular fibers.

INTRODUCTION

In recent years, there is a growing trend to use biofibers as fillers and/or reinforcers in plastics composites. Their flexibility during processing, highly specific stiffness, and low cost make them attractive to manufacturers. This century has witnessed ever-increasing demands for the utilization of plastics as important raw materials, more than 80% of which are thermoplastics. Biofibers reinforced plastic composites are gaining more and more acceptance in structural applications [1-4].

Natural Rubber (NR) was the first commercially viable elastomer ever rapidly developed and is still the only non-synthetic rubber in worldwide use. Natural rubber currently to derive an ideal combination of properties. Waraporn [14] reported grade of natural rubber in Thailand such as Ribbed Smoked Sheet (RSS), STR 5L, STR 5, STR 10, STR 20, STR XL, STR 5CV, STR 10CV, STR 20CV and have well mechanical, good toughness, high elastic and high abrasion resistance.
Natural Rubber increasingly used for various applications such as aerospace, marine, automotive, infrastructure, military, leisure boats, aircraft industry and sports equipment [13].

Many researchers have studied the effect of different fibers in natural and synthetic rubbers [5-7]. A detailed investigation on the characterization and properties of natural fiber was done such as sisal fiber, bamboo, silk, jute and pineapple. Natural fibers consist of three types: seed hair, bast fibers, and leaf fibers, depending upon the source. Some examples are cotton (seed hairs), ramie, jute, and a flax (bast fibers), and sisal and abaca (leaf fibers). Of these fibers, jute, ramie, flax, and sisal are the most commonly used fibers for polymer composites. Natural fibers have advantages over synthetic fibers because of their renewable nature, low cost, easy availability, biodegradability, and ease of chemical modification. The main disadvantages that are usually encountered when natural fibers are used as reinforcement are that the combination of a hydrophilic fiber into a hydrophobic polymer leads to a heterogeneous system. Several studies have shown that natural fibers composite combined good mechanical properties with low specific mass, to offer an alternative material to glass fiber –reinforced composites [8].

Consequently, rubber toughening is often used to overcome the brittleness of glassy polymers such as polystyrene (PS). Polystyrene has been toughened by blending with rubbers such as styrene–butadiene (SBR), natural rubber (NR), polybutadiene(BR), ethylene–propylene–diene terpolymer (EPDM) and nitrile rubber (NBR).

Polymer matrix composites (PMCs) are composed of a variety of short or discontinuous fibers bound together by an organic polymer matrix. Bonding characteristic of cross-linking of the NR is typically performed by a vulcanization procedure; giving enhanced mechanical properties and increased durability, however, the vulcanization process also adds additional complexity [9].

It is of interest in the present study to determine the mechanical behavior of polymer matrix composites are composed of STR 5L matrix and fibers. The present work covers research on natural rubber composites containing short E-glass fibers as the addition reinforcement.

MATERIALS AND METHODS

Fiber Preparation

In Chumphon, Thailand, there are many agricultural residuals from industry. Palm oil fiber and coconut shell fiber using in this study was obtained. Palm oil fiber and coconut shell fiber was treated by soaking with 3%NaOH solution for 6 hours. Washing with distill water was done 4 times followed by drying in an air oven at 60°C for 6

hours. Then fiber, was chopped precisely to different lengths of 5 (L_1) and 10 (L_2) mm. Preparation of E- glass was only chopped to only length of 5 mm.

Composite Preparation

The composites were prepared by the combination of discontinuous fibers of different lengths of 5 (L_1) and 10 (L_2) mm at constant fiber loading of 5 phr [11] into STR 5L matrix as the formulation given in Table 1. STR 5L matrix were prepared to mastication by two-roll mixing mill, mixing with the compound and fibers. The samples were milled for a time sufficient to disperse the fibers into the matrix and to hold for 24 hours. The samples were vulcanized in Moving Die Rheometer (MDV) at 150 °C as per ASTM D1646-94 to their optimum cure time. Forming process used compression molding at compressed 1500 lbf/in^2 by Wabash machine.

Mechanical testing and characterization of the composites

The hardness was measured with a Shore A type durometer according to ASTM D 2240 and tensile strength following to ASTM D 412 as shown in Fig.1. Fracture strength was investigated to relate between mechanical properties to microstructure of composites. The fracture area were characterized by JSM-5800LV JEOL scanning electron microscopy (SEM).

Fig. 1 Tensile testing samples

Table 1 Mixes with Various Fiber Lengths

Ingredient[b]	Gum[a]	L_1	L_2
STR[c] 5L	100	100	100
Stearic acid	1	1	1
Zinc Oxide	5	5	5
MBTS[d]	0.5	0.5	0.5
TMTD[e]	1.5	1.5	1.5
Sulphur	5	5	5
E-glass	0	5	5
Fiber length (mm)	0	5	10

[a] Rubber non reinforcement
[b] Ingredient, part per hundred rubber (phr)
[c] STR, Standard Thai Rubber
[d] MBTS, benzothiazoledisulphide
[e] TMTD,tetramethylthiuram disulphide

RESULTS AND DISCUSSION

Cure characteristics

Table 2 shows the variation in the cure characteristics of composites with 5 (L_1) and 10 (L_2) mm at fiber loading 5 phr. The maximum torque is a measure of crosslink density in composites. Sequence of all of the mixes, the torque initially decreased, then increased, and lastly leveled off. Initially, torque was decreased to a minimum value due to the softening of the STR 5L matrix, whereas the increase in torque due to crosslinking of STR 5L matrix. Lastly, the leveled off indicated completion curing. Adding E-glass was occurred increasing torque value, scorch time and cure time comparing with non-adding. It was noticed to good forming. The torque values increased with increasing fiber length as noticed in L_2. Consideration of scorch time and cure time that noticed the initial viscosity time of STR 5L matrix. Mathew [10] reported that the torque reached a maximum at a fiber length of 10mm. It was increased due to the presence of longer fibers, which provided more than a restriction to deformation. For all composites, the torque value increases with an increase in filler loading. The increase in torque values with increasing filler content indicates that as more and more filler gets reinforced into the matrix, the mobility of macromolecular chains of natural rubber becomes reduced resulting in more rigid vulcanisates [12]. Corresponding by Stanier [9] reported vulcanization of natural rubber due to the cross-linked nature of the natural rubber prevented polymer chain movement, returns the platelets to their original orientation upon retraction of the load.

Table 2 Various Cure Characteristics

Mix Condition	[a]M_H	[b]M_L	[c]t_s	[d]t_{90}
L_1				
Palm oil fiber	66	1	0.8	1.8
Palm oil fiber add E-glass	72	2	1.3	2.3
Coconut shell fiber	67	1	0.8	1.9
Coconut shell fiber add E-glass	73	3	1.4	2.5
L_2				
Palm oil fiber	67	2	0.8	1.8
Palm oil fiber add E-glass	73	3	1.6	2.6
Coconut shell fiber	68	2	0.9	1.9
Coconut shell fiber add E-glass	78	3	1.4	2.6

[a]M_H, maximum torque (dN.m)
[b]M_L, minimum torque (dN.m)
[c]t_s, scorch time(min)
[d]t_{90}, cure time (min)

Mechanical properties

Effect of fiber length to hardness

The hardness value increased in longer fibers with the addition of E-glass as shown in Fig.2. Case of coconut shell fibers was obviously found increasing hardness. The hardness depends on the surface topology of the fibers because each fiber forms an individual interface with the matrix [13]. Increasing hardness of palm oil fibers and coconut shell fibers occurred in L_1 and L_2while coconut shell fiber has higher hardness values than palm oil fiber. Fiber length at L_2 of coconut shell fibers was highest due to occurring of better bonding and skinning character with the STR5L matrix. Noorunisa et.al [15] revealed treatments fiber have been proven effective in cleaning fiber's surface by removing impurities from fibers, decreasing moisture sorption, enabling mechanical bonding and thereby, improves matrix reinforcement interaction. The variance of various conditions indicated to differently significance. Because of differently hardness, value can be explained a case of surface morphology that

can be clearly indicated of treated fibers that reduced due to non-adding E-glass.

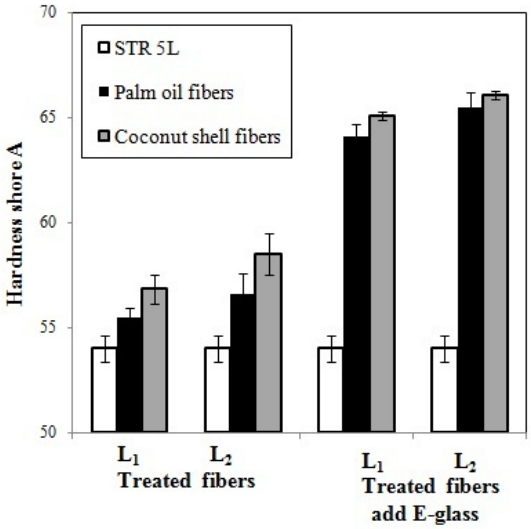

Fig. 2 Hardness of samples.

Effect of fiber length to strength

Decreasing of strength occurred when adding E-glass in both fiber lengths because E-glass has brittle fibers and high strength more than STR 5L matrix as shown in Fig.3. Treated of both fiber was above to 15 MPa that showed below STR 5L matrix owing to disarrangement the orientation of fiber. Fidelis et.al [11] revealed decrease in tensile strength is due to high fiber length leading to fiber agglomeration resulting in difficult stress transmission from matrix to fiber and disturbance of the continuity of the matrix phase. This result corresponded to add E-glass owing to different types of fiber. Effect of addition of E-glass resulted to lose strength. It rapidly separated and provided low cohesiveness during testing that significantly reduced the tensile properties of the composites.

Dispersion of fiber in STR 5L matrix was found randomly and caused a fracture to rapidly lose strength whereas, percentage elongation at break was observed to be decreasing similar to the strength as shown in Fig.4. The both of fiber length was obstructed during mixing and occurring disarrangement the orientation of fiber.

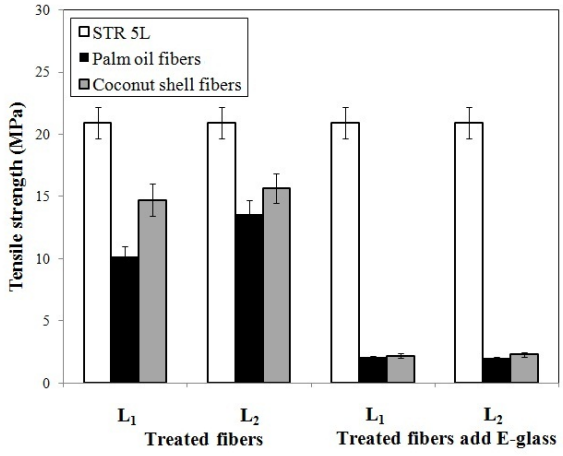

Fig.3 Tensile strength of samples.

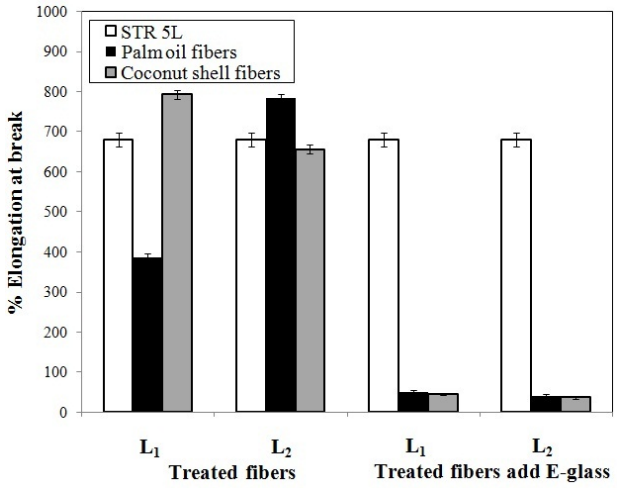

Fig.4 % Elongation at break of samples.

Effect of fiber length on microstructure

Fig.5 (a) shows the tensile fracture surface of palm oil fiber at L_1. It was observed to a rough surface as showed in position A that the palm oil fiber was inserted into STR 5L matrix. Position B appeared large area and rough surface. Palm oil fiber was obviously separated from STR 5L matrix as can be indicated voids. The cause of voids would reduce the toughness and elongation as can be showed by arrow. Characterization of coconut shell fiber at L_1 was dispersed in Fig.5 (b). It was noticed to a rough skin fiber as showed in position C. It caused of elongation value would result from higher than palm oil fiber.

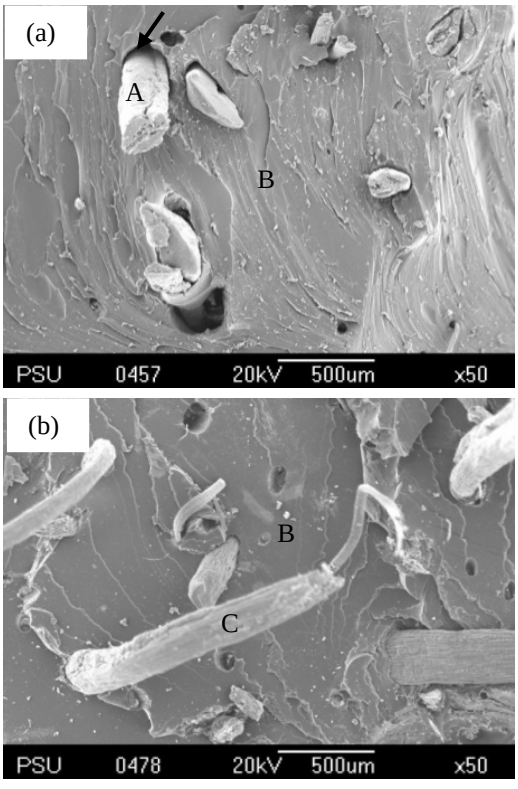

Fig.5 (a) SEM micrographs of tensile fracture surface of palm oil fiber (b) SEM micrographs of tensile fracture surface of coconut shell fiber.

CONCLUSIONS

It can be concluded from the present study that:

- Fiber length at L_2 was given higher hardness than L_1 in the both fiber.
- Adding E-glass was found to result in increasing hardness value, whereas decreasing strength.
- Percentage elongation at break was rapidly decreased when adding E-glass due to low adhesion and dispersion in STR 5L matrix.

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