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Effect Aging Treatment on Tensile Properties of Natural Fiber Reinforced Polyester Composites

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Abstract

The application of natural fiber reinforced composites has given a bright opportunity in replacing synthetic fiber in order to prevent global pollutions. But this application limited only for interior automotive parts and therefore, for these composites to be utilized as exterior application parts, weathering or aging treatments must be simulated on natural fiber composites to investigate this effect on mechanical properties. According to the present results, maximum load and maximum elongation were strongly affected by the aging treatment where higher aging temperature conducted produced lower tensile properties but no significant difference found for material stiffness.

Keywords: Natural fibers, tensile properties, aging treatment, fiber pull-out, fiber debonding.

1.0 Introduction

Applications of natural fiber in automotive industries are not new. Nowadays, natural fiber reinforced composites have been replaced glass fiber composite especially for non-load bearing application parts and interior parts such as center console, dash board, door trim panels and others. Figure 1 shows the examples of the utilization of natural fiber reinforced composites [1].

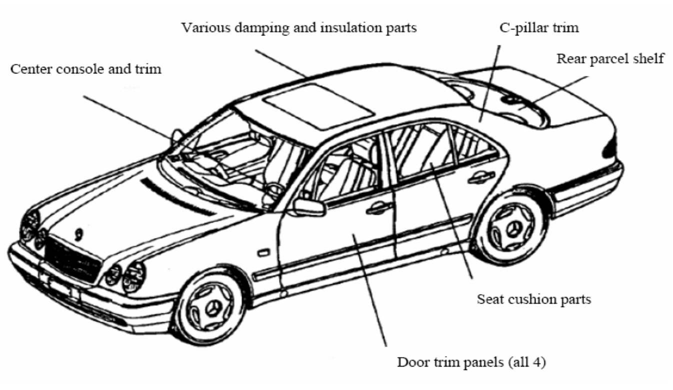

Figure 1 Natural fiber reinforced composite application in automotives [1].

Lack of literature discusses on the effect of retention of mechanical properties of natural fiber reinforced composites during long-term environmental exposure. These effects are crucial for them to be utilized in outdoor application parts or materials. Some studies on this effect on the mechanical properties have been reported [2 – 4]. For most natural fiber composites, interfacial bonding between two constitutive materials is the primary problem because of the

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presence of hydroxy and other polar groups which lead to composite degradations. According to [2], the tensile strength did not change significantly after aging for 3 months in water at temperature 25^0C, while a slight increase in tensile modulus is observed and they added a 2 – 19% reduction in tensile modulus is seen after 6 months. Increasing aging temperature to 75^0C, tensile strength slightly whereas moderate reduction in tensile modulus is observed. Natural or cellulosic fibers normally contained higher moisture weight percentages. Therefore, increasing aging temperature will dry the fiber and shrink itself and then producing dimensional instability of fiber and leave a space between the matrix/fiber interfaces. [2] reported that the bonding between the layers of the natural fiber were destroyed during the aging by the attacking water, leaving them detached from each others.

This present work reported the behavior of coir fiber reinforced polyester composite under tensile test when experienced aging treatment at different temperatures are studied. The results from this work will discuss by considering the effect of fiber loadings, aging durations and fracture surfaces.

2.0 Materials & Method

2.1 Sample fabrication and preparation

Coconut fibers were obtained from local factory in Batu Pahat, Johor in random orientation and different length ranged between 50 – 150mm. Purification processes were conducted to modify the fiber surfaces to enhance the quality of bonding with polymeric matrix. The fibers were soaked into 5% sodium solution for 24 hrs and rinsed with distilled water 3 times. The fibers were dried in furnace environment at 80^0C for 24 hrs in order to remove moisture content. Dried fibers were placed into rectangular steel mould 250x250x10mm with different fiber loadings: 5, 10, 15 and 20%. Polyester resins with ratio 1:4 with hardener were poured into mould and light compressive loading was applied to the composite, after 24 hrs of curing process, the composite was removed from the mould. This was to obtain optimum hardness and shrinkage. Aging treatment was carried out at different temperature 27, 50 and 80^0C and aging times were kept constant for 3 months. The aging process conducted in furnace environment.

2.2 Tensile and impact testing

Standard specimen followed from ASTM D638 was used to stress the specimen to final failure under tension at a constant cross-head speed 1.5mm/s using GOTECH tester. An extensometer was also attached to the gauge section to measure specimen elongations. Tensile properties were carried out from this test and there were three specimen tested for each specimen conditions.

2.3 Fracture surface observations

Microscopy observation included the use of scanning electron microscope (SEM). All fracture surfaces of composites were studied using LEICA Stereoscan 420. Specimens were gold coated using coating machine Polaron CA508 in order to prevent electron discharge during observation process.

3.0 Results and Discussion

3.1 Tensile test results

In order to observe the tensile damage patterns, it is essential to obtain the stress-strain curves for all set of specimens. Figure 2 revealed these relationships. It can be seen that the virgin polyester was more brittle than reinforced polyester but stress-strain curve patterns were not dependent on fiber loadings. Generally, the stiffness of the reinforced composites decreased or they capable to elongate if compared with virgin polyester but when the composites were aged higher at 50 and 80^{0}C, virgin polyester elongated almost 14 times if compared with virgin polyester aged at 27^{0}C. As aging temperature increases, strain at failure of aged composite higher that aged material at ambient temperature and this mean that aged composite absorbed more tensile energy than aged material at lower temperature. Figure 3 summarized the tensile properties under different aging temperatures functioned to fiber loadings.

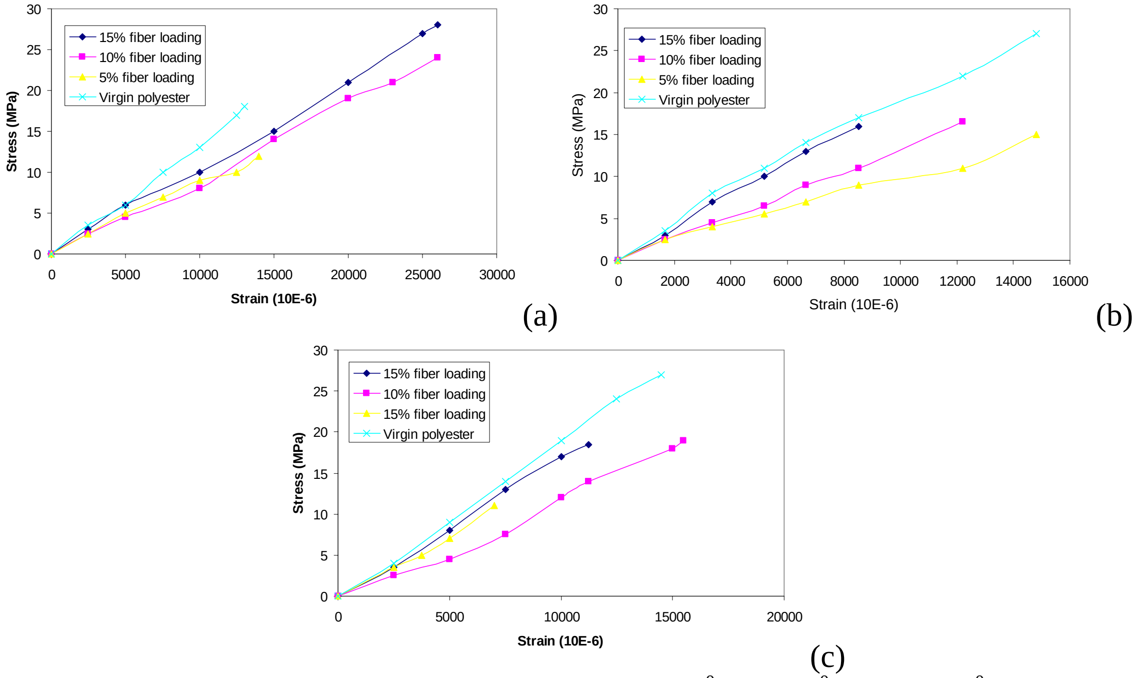

Figure 2 Stress-strain curves of aged composite at (a) 27^{0}C, (b) 50^{0}C and (c) 80^{0}C at different fiber loading and virgin polyester.

According to Figure 2a, 5% fiber loading composite aged at 80^{0}C sustained higher maximum load compared with virgin polyester and other composites. But, as fiber loadings increase, both maximum load and maximum elongation decreased gradually (Figure 2b). Higher aging temperature than 27^{0}C degraded the tensile properties and fiber loading increased also reduced the mechanical performance of composites. Composites reinforced with 10% and 15% fiber loadings showed the fluctuated values of maximum loads and elongations compared with 5% fiber loading composite increased both values as aging temperature increased. Higher aging temperature degraded and shrinkage the natural fibers and this will leave between the interface and creating higher localized stress concentrations. While, Figure 2c revealed the material stiffness and virgin polyester stiffer than fiber reinforced composite. As expected, fiber reinforcement in composites has reduced material stiffness and reinforced composites showed lower stiffness than virgin polyester.

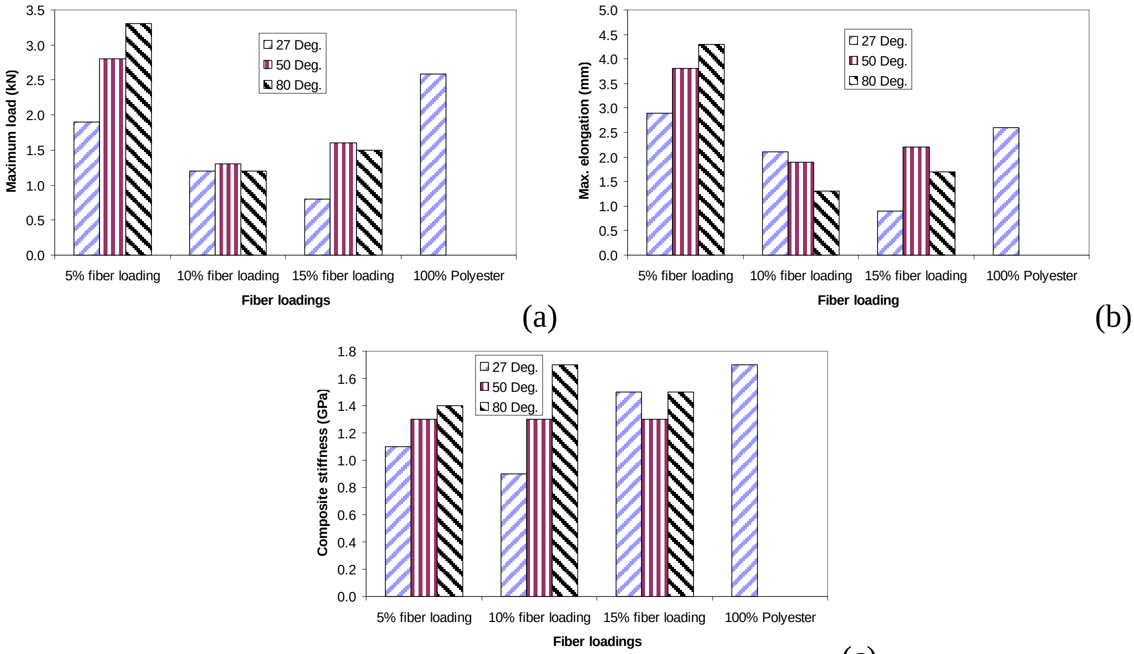

Figure 3 Tensile properties of natural fiber reinforced polyester composites, effect of (a) maximum load, (b) maximum elongation and (c) stiffness on fiber loadings.

From SEM studies, aging temperatures not play an important role in the level of degradation of natural fiber. At low aging temperature, fibers were well embedded in matrix and relatively, the push-out fibers were longer than composite heated with higher aging temperatures as shown in Figure 3 and 4. Composites aged with 27^0C, it can be seen that push-out holes were bottomless and as a result longer push-out fibers were observed. This will increase higher maximum sustained loads and higher maximum elongation as revealed in Figure 3a and 3b through fiber bridging that preventing the composites to break and therefore increasing the interfacial friction between matrix and fibers. As aging temperature increases, material stiffness increased but it was strongly dependent with fiber loading as shown in Figure 3c. This behavior can be correlated with fracture mechanisms as depicted in Figure 5. Shorter push-out fibers were observed and it can be seen that the fibers were well griped by the polyester matrix and at certain location, interfacial debonding observed especially at matrix/fiber interfaces. Fiber morphology not affected by the thermal treatment and the fiber still intact as Figure 4. Apparently, as suggested by most available data, temperature has no effect on altering the mechanisms of fracture mechanisms and crack growth [5].

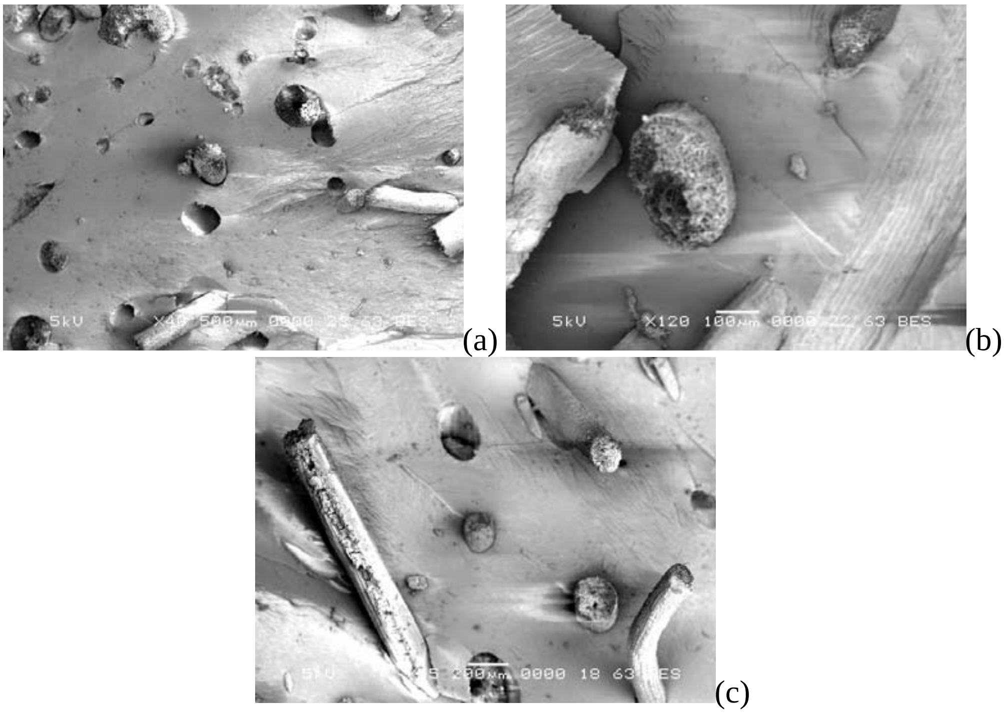

Figure 4 Fracture mechanisms of fiber reinforced composites contained (a) 5%, (b) 10% and (c) 15% fiber loadings aged with 27^0C.

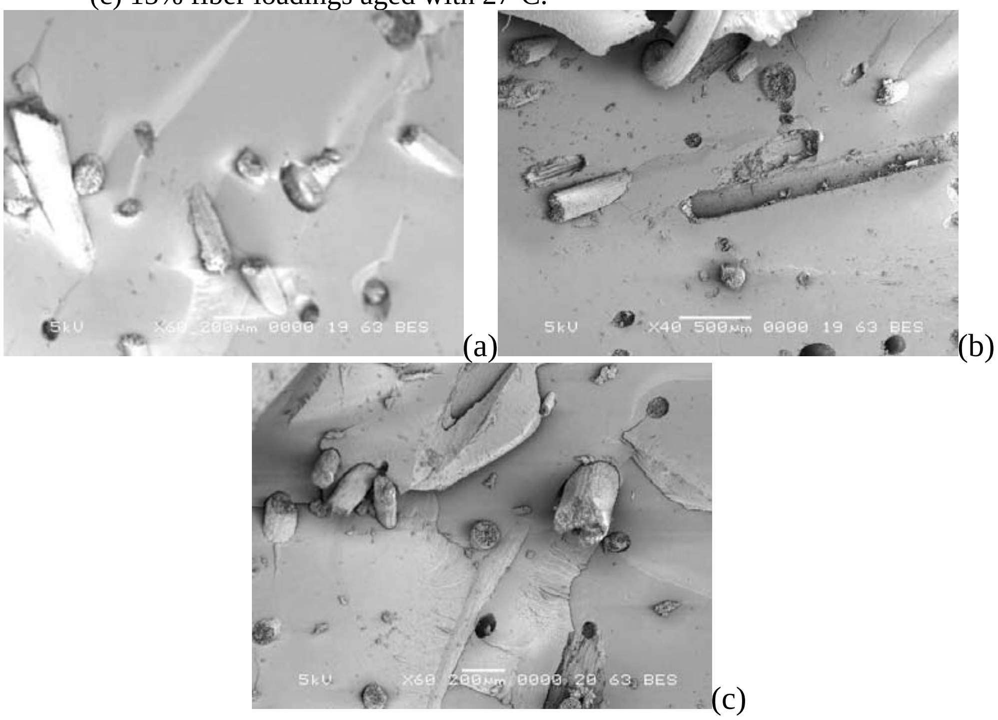

Figure 5 Fracture mechanisms of fiber reinforced composites contained (a) 5%, (b) 10% and (c) 15% fiber loadings aged with 50^0C.

4.0 Conclusion

Strong evidence had been observed that aging treatment had played an important role in determining the tensile and impact strengths of coconut coir reinforced polyester composites.

a) Maximum load and maximum elongation decreased as aging temperatures increased and but at the same time material stiffness increased this is due to fiber/matrix experienced interfacial debonding.
b) Higher aging temperatures accelerated shrinkage process that produced a gap at interface between fiber and matrix therefore reducing load-bearing capability of composites.
c) Long-term high temperature conducted on natural fiber composite degraded material integrity through fiber dimensional instability.

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