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Dynamic Mechanical Analysis of Arenga Pinnata Fibre Reinforced Epoxy Composites: Effects of Fibre Aging

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Abstract. One of the major drawbacks for natural fibres reinforced in polymer composites deal with outside applications is the aging phenomena. This paper presents the effect of aging in Arenga Pinnata fibre reinforced epoxy composites. The samples composed of 30% long random fibre by weight were produced by using a hand lay-up process. The composites were than undergone accelerated aging process with aged conditions of 30 days, 67 days and 135 days respectively in according to ASTM F1980 prior series of Dynamic Mechanical Analysis (DMA) evaluation. Un-aged (0 day) specimens were used as a control environment. Contrary to popular believe, it is found that the aging conditions offer better dynamic mechanical properties, evidently from DMA result of Storage Modulus, Loss Modulus and Tan Delta.

1 Introduction

Sugar Palm or Arenga Pinnata can be found in South East Asia region. This fast growing plant is able to reach maturity within 10 years and it can reach up to 12 meters in high. The black fibre is extracted from its trunk, which is also known as ijuk in Malaysia. Resistance to sea water and high durability are one of the key features of the fibre. The fiber has multipurpose usage in traditional products such as ropes, mats, brushers and brooms for many decades [1].

Natural fibre reinforced in polymer composites is one of the new emerging materials that provide significant function nowadays. Many automobile makers have embraced these materials into automobile interior components such as dashboard, door panels and acoustic absorbing material. These materials offer cost saving features while remain sustainable for long term usage. More importantly, this material could offers acceptable mechanical strength relatively similar to man-made fibres [2, 3].

Currently, the applications of the natural fibre are still limited and usually practical to the non-aggressive load bearing due to many reasons. The natural fibres are less understood because of the plant itself, the complexity of cellulose form inside them [4]. As a product that originated from the nature, the fibre is subjected to decomposition arise from the exposure of sunlight, heat and oxygen over the time period. Arengga Pinnata fibre could suffers from aging element that inevitably could weaken its strength and durability. The study of aging conditions of Arenga Pinnata composite has been reported by Aidy Ali and co-worker [5]. Contrary to popular believe, the result showed that the aged fibres tend to have better tensile and flexural properties. While static mechanical was evaluated, its dynamic mechanical characteristic is still remained unknown and much of work is needed for scientist and researcher to understand this behaviour.

Dynamic mechanical analysis (DMA) is non destructive test (NDT) methods that usually perform on heterogeneous polymer systems under temperature dependent dynamic properties. The DMA helps researcher to insight interaction between polymer matrix and fibre reinforcement in the glass transition region by evaluating the intimation of the stiffness of the material, Storage Modulus. Tan Delta is a measurement of the damping of the material meanwhile Loss Modulus measures the energy dissipated as heat, representing the viscous portion

To the best author's knowledge, no study however are reported or presented in the literature on the effect of aging conditions of the Arenga Pinnata composites using DMA technique and therefore, it will be the main focus of the present investigation.

2 Methodology

2.1 Fibre preparation and accelerated aging process.

The Arenga Pinnata fibres were harvested directly from its own tree in Kampung Dioh, Kuala Pilah, Negeri

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Sembilan, Malaysia. The fibre where then treated with Natrium Hydroxide (NaOH) for improving the interfacial fibre-matrix properties prior the aging process.

2.2 Accelerated aging process

Accelerated aging can be defined as a testing that uses aggravated conditions of heat, oxygen, sunlight and so on to speed up the normal aging processes. Accelerated aging process was done by heating the specimen in the oven. Using the formula that referred from ASTM F1980 to obtain AATD (Accelerated Aging Time Duration) and DRTA (Desired Real Time Aging), the accelerated aging time for 30 days were 31 hour 49 minutes, for 67 days were 71 hour 3 minutes and for 135 days were equivalent with 143 hour 11 minutes

2.3 Composite fabrication

In the specimen fabrication phase, the Arenga Pinnata specimens were prepared by using hand lay-up technique. The Arenga Pinnata fibre, epoxy resin and hardener were weighted first in order to get the weight fraction and ratio between epoxy and the hardener were determined. The hand lay-up technique began when the Arenga Pinnata fibres were arranged and placed inside the mould. Next, the mixture of epoxy and hardener was poured slowly into the mould and the resin was spread evenly into the mould. The composite product was left around 5 minutes to allow the bubbles entrapped inside the matrix to float to the surface. After that, the mold was covered with A3-size transparent paper and close by using another steel plate. Finally, the composite was cured overnight by compressing the top steel plate with load so uniform thickness was maintained and air was prevented from entering the mold.

2.4 DMTA test

The DMA properties were determined by using Perkin Elmer D8000 Analyzer. Samples in dimension of 10 mm in width, 3 mm of thickness and 30 mm in length was inserted into the machine cavity, employing a simple cantilevered mode for scanning. The heating process was maintained 2°C/min, starting from -10°C to -140°C across the band. The process was repeated 5 times for better results.

3 Results and discussion

3.1 Storage modulus

Fig. 1(a) shows the storage modulus (E') of as-produced Arenga Pinnata specimen, followed by 30 days, 67 days and 135 days of aging of Arenga Pinnata specimen along the temperature range between -10°C to 140°C. From the graph, there are several pattern can be seen, for example at -10°C, the storage modulus for all conditions are different. The storage modulus (E') for as-produced or 0 days condition of Arenga Pinnata specimen shows the lowest value when at -10°C compared with the aging specimen conditions of 30 days, 67 days and 135 days. There are also differences in values of storage modulus (E') between the aged specimens. As the aged conditions of specimen increased, the storage modulus (E') at temperature -10°C also follows the pattern.

Although there are increments in value of storage modulus (E'), the increment between 30 days of aging specimens and 67 days of aging specimens are relatively small as compared to 135 days. This may be due to the aging process for 30 days and 67 days are not affecting the specimens too much compared with the aging for 135 days. The small increment of storage modulus between 30 days and 67 days of aging compared with the as-produced specimen may be happened because the composition of fibre does not changed too drastically compared when the aged of the fibres was 135 days. According to Huda and co-worker [6] the increased in value of storage modulus (E') was due to the stiffness of the fibre increased. Therefore, based from the result shown in Fig. 1(a), as the aged of the specimen increased, the stiffness of the fibre also increased, hence increased the value of the storage modulus (E')

3.2 Loss modulus

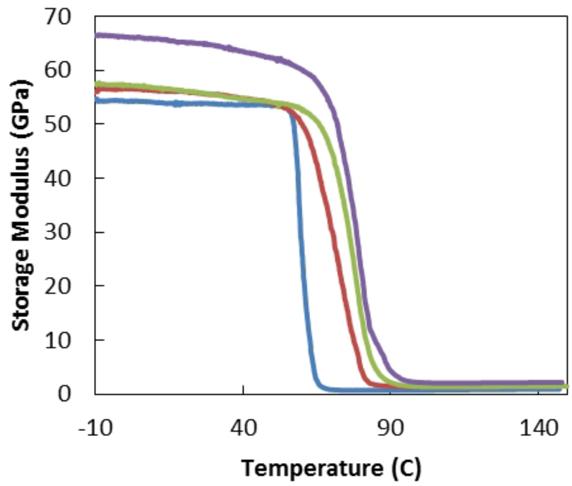
Fig. 1(b) shows the loss modulus (E") of Arenga Pinnata fibre composites for as-produced condition and the aging conditions for 30 days, 67 days and 135 days. First, as the aging of the composite fibre increases, the graph tend to shift to the right, indicates higher temperatures. This shows that the glass transition temperature (T_g) of the composite fibre increases when the age of the specimen increased. Glass transition temperature can be defined as a temperature range where thermosetting polymers change from hard glassy state to soft and rubbery state. As seen from the graph in Fig. 1(b), the value of glass transition temperature (T_g) for as-produced or 0 days specimen is 61.3°C, with the peak value of 8.9 GPa. Then, the glass transition temperature (T_g) of composite specimen for 30 days of aging is 76.7°C, with the peak value of 7.8 GPa. For 67 days, the glass transition temperature (T_g) is 78.3°C with the peak value of 7.5 GPa. Finally, for 135 days, the glass transition temperature (T_g) reaches 81.9°C with the peak value of 7.2 GPa.

From this parameter, it shows that the aging process cause the glass transition temperature to reach higher compared to the produced specimen. However, the value of the loss modulus (E") decreases as the aged of the Arenga Pinnata fibre composite specimens have been increased from 30 days to 135 days. This unique pattern could be possible due to the loss modulus (E") itself defined as proportional to the energy dissipated during one loading cycle such as energy lost as heat. In this case, since the aged Arenga Pinnata fibre composite specimens can stored more energy, the energy loss also decreases. Hence, for example, the as-produced specimen that has the lowest storage modulus (E') value exhibits the highest reading of loss modulus (E") value based from the Dynamic Mechanical Analysis (DMA) results. Same thing can also be said for the case of fibre composite specimen with aging process of 135 days. The value of its storage modulus (E') is the highest, but its loss modulus (E") is the lowest compared with other specimens. These suggest that the value of the loss modulus (E") is inversely proportional with the value of storage modulus (E').

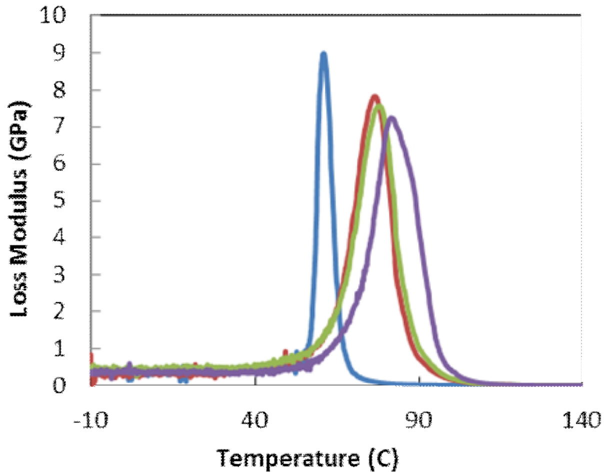
3.3 Tan delta

Fig. 1(c) shows the tan delta of Arenga Pinnata fibre composites for as-produced condition and the aging conditions for 30 days, 67 days and 135 days. First, the graphs tend to shift to the right following to the aging conditions of the composite fibre specimen. As the aging conditions become greater, the graph also exhibit some decrement in terms of the tan delta (δ) value. For example, the value of tan delta (δ) for Arenga Pinnata composite fibre at 135 days has the lowest value compare with the as-produced Arenga Pinnata composite fibre.

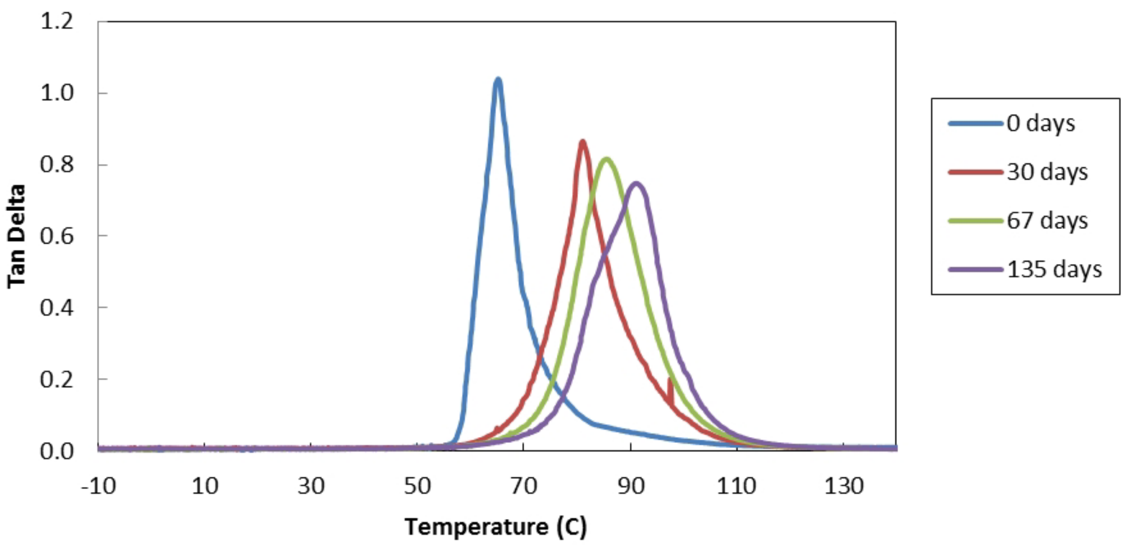
The pattern obtained from the graph in Fig. 1(c) may be due to the fact that tan delta (δ) is defined as the ratio between the loss modulus (E") and storage modulus (E'). Take the peak of the graph for 135 days of aged specimens, for example, the value of loss modulus (E") when at 89.7°C is 3.1 GPa while at the same reference temperature, which is 89.7°C, the value of the storage modulus (E') is 4.4 GPa. Hence, when the value of the loss modulus (E") is divided with storage modulus (E'), the results obtained for tan delta (δ) is 0.7. This proves that the tan delta (δ) is the ratio of loss modulus (E") and storage modulus (E'). According to ASTM D4065 [7], a high tan delta (δ) value means that the material has a high non-elastic strain component, while a low value of tan delta (δ) indicates that the material is more elastic. This suggest that as the Arenga Pinnata fibre composite undergone aging process, the higher the aging of the fibre, the more the elasticity of the fibre.



(a)



(b)



(c)

Figure 1. DMTA Results of (a) Storage Modulus, (b) Loss Modulus and (C) Tan Delta

4 Summary

In this study, effects of aging fibres of Arenga Pinnata reinforced epoxy composites are successfully investigated using DMA technique. The DMA result indicates that the aging fibres tend to have better stiffness, good interaction between fibre and matrix adhesion are achieved compared to the un-aged specimens, which is surprising for a natural fibre. The elasticity of Arenga Pinnata fibre on the other hand is improved when it undergone aging process.

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