Study of Vibration Absorbers Using Epoxy Reinforced Natural Fibers

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Abstract. It is well known fact that vibrations contribute to excessive wear, fatigue failure and other premature failure of machine components. Thus, various methods have been applied to control these vibrations. One of the commonly used is vibration absorber. The aim of this paper is to explore the potential of epoxy reinforced natural fibers as an alternative material for vibration absorber. Both mechanical properties and dynamic characteristic of the composites are investigated through tensile test and transmissibility test, respectively. Two types of natural fibers were selected for the study; coconut coir and pineapple leaf. The results show that the tensile modulus of composites increases with the increase of fiber content, although the strength was found decreases. This reduction indicates an ineffective stress transfer between the fiber and matrix. From the tensile test result, 20 vol% of pineapple leaf fiber was found to be the optimum fraction, in which afterward was employed for fabrication vibration absorber. Meanwhile, from the transmissibility test, it was noticed that when base excitation increases, the resonance peak and attenuation frequency were changed to the lower value. The fixed-fixed end beam with attached composite vibration absorbers showed that the resonance amplitude of the beam decreased significantly. More absorbers attached on the beam produce better result in attenuating the global structural vibration.

Introduction

Vibration can occur in a variety of mechanical and structural systems. If the system uncontrolled, catastrophe circumstance can happen because of vibration. For instance, vibration machine tool or machine tool chatter can lead to improper machine parts; large dynamic pressure developed during an earthquake or wind induced vibration can result in structural failure and other examples of failure include imbalanced helicopter blades due to high speed spinning.

There are various methods have been used to control the vibration. One of the commonly used is vibration neutralizer or vibration absorbers. Vibration absorbers are devices attached to the flexible structures in order to minimize the vibration amplitudes at a specified set of points [1,2]. The concept of vibration absorber is using a simple spring, mass and damping elements to suppress the vibration of host structure. However, the major drawback of vibration absorber is only adapted to one single excitation frequency and not capable to reduce the global structural vibration comprehensively. This is where multiple passive vibration absorbers are obliged in order to achieve this objective [3–5].

In this study, a new control strategy is developed by using a small scale and lightweight passive vibration absorbers made from polymer composites to reduce the vibration of a beam structure. It is expected that by using multiple vibration absorbers, the vibration of beam structure can be reduced extensively. Since natural fibers have many advantages such as nontoxic, environmental friendly, inexpensive and low operation and production cost, they will be used as an alternative filler of composite material for making the absorbers system. The use of natural fibers in the manufacture of a product can contribute to a greener planet because it is a renewable resource and environmentally friendly. The products are produced from natural fibers can be reproduced over and over again and does not pollute the environment or cause of greenhouse gases [6]. In this case, the pineapple leaf fiber and coconut coir fiber were infused into a polymer by taking an advantage of a high-damping performance, a high strength, high toughness and a good impact capability of natural fibers.

Literature Review

Polymer matrix composites. Polymeric matrix composites (PMCs) have been popularly used in infrastructure applications due to their many merits, including high strength to mass ratio, superior durability and easy in applications. One specific type of PMCs that has drawn significant attention is fiber reinforced polymers (FRP), which combine high strength and high modulus fibers with low modulus polymer matrices that serve as binding material to ensure an effective stress transfer between the fibers [7]. Unlike a ceramic matrix composite, the reinforcement in a PMC provides strength and stiffness that are lacking in the matrix.

Epoxy resins. Epoxy resins are considered as one of the most important classes of thermosetting polymers and widely used in various fields of coating, high performance, adhesives and other engineering application. In usual applications epoxy resin are rarely used without the incorporation of some other materials. Filling are both used to enhance their performance by providing additional mechanical properties or modifying the physical characteristics of the blends [7].

Pineapple leaf fiber. Pineapple is a plant that the fruit can be eaten. It is a tropical plant that believed to has originated from South America. Pineapple Leaf Fiber (PALF) is multi-cellular and lignocelluloses materials extracted from the leave of plant Ananas cosomus. PALF has a ribbon-like structure and is cemented together by lignin, pentosan-like materials, which contribute to the strength of the fiber. A study found that cells in this fiber have an average diameter of about 10µm and mean length of 4.5 mm with aspect ratio of 450. The thickness of cell wall (8.3µm) lies between sisal (12.8µm) and banana leaf fiber (1.2 µm).

Coconut coir fiber. Coconut coir fiber (CCF), or simply named as "coir" is coarse and short fiber that extracted from the fibrous outer shell of coconut. It is generally measured up to 35cm in length with a diameter of 12-25 microns. There are two types of coir; brown coir and white coir. Brown coir is harvested from mature coconuts. It is thick, strong, and high abrasion resistance. By contrast, smooth and finer whiter coir is harvested from immature green coconuts after soaking up to 10 months. It was reported that white is generally weaker that brown coir [8].

Methodology and Characterizations

Natural fiber preparation. The natural fibers of CCF and PALF were done in two stages: (i) Alkali treatment, in which the fibers were treated with 5% of NaOH solution for 24 hours, followed by washing with distill water until NaOH residues were eliminated. Then the fibers were dried for 12 hrs at 80°C in an oven, and (ii) Fiber sizing, in which the fibers were crushed into short and finer fibers by using granulator machine. The average size of fibers size was ranged from 10-50 mm.

Composite preparation. The composites of epoxy/PALF and epoxy/CCF were prepared using 0–20 vol% of fibers. The fibers and epoxy were dry mixing using mechanical stirrer to disperse the fibers in the epoxy. Afterward, the epoxy composites were cured using hardener at ratio 2:1.

Tensile test. Tensile test is used to determine the mechanical behavior of materials under static, axial or stretch loading. In this study, there were 5 samples prepared for each fraction and the average values were obtained. The sample was tested according to ASTM D638 by using Universal Testing Machine (UTM) with strain speed of 2mm/min.

Transmissibility Test. The transmissibility test was measured by using UCON vt-9008 and a mass block system. The data obtained was transmissibility versus frequency generated by VSC software. It was produced at two base excitation levels that are 1mm and 1.5mm, and the frequency range between 18-25Hz and 18-30Hz, respectively.

Vibration test. The vibration test was carried out by attached the composite vibration absorber on the fixed-fixed end beam. The external force at 1300 rpm was produced by the electric motor shaker. There were one until four absorbers attachment were tested, in which later the amplitude displacement was plotted against frequency.

Result and Discussions

The results are divided into three major categories namely tensile test, transmissibility and vibration absorber test. Fig. 1a shows Young's modulus result of epoxy/PALF and epoxy/CCF composites. Obviously, the Young's modulus of epoxy/PALF composites increase with the increase of fiber fraction, although epoxy/CCF composites showed contrary, in which were found decrease with the increased fiber content. Based on the research by Bujang et al. [9,10], the reason of this drop is because of the increased fiber content lead to higher fiber to fiber contact which results to poor interface bonding between the fiber and the matrix.

On the other hand, the tensile strength was found drop for both epoxy/PALF and epoxy/CCF composites as displayed in Fig. 1b. This agrees with the previous conclusion [11-14], that the drop in tensile strength is due to the poor bonding at the interfacial region of the matrix and the reinforcement. From these results, it was concluded that 20 vol% epoxy/PALF composite was better than epoxy/CCF due to high stiffness and strength obtained, thus it was chosen for later analysis.

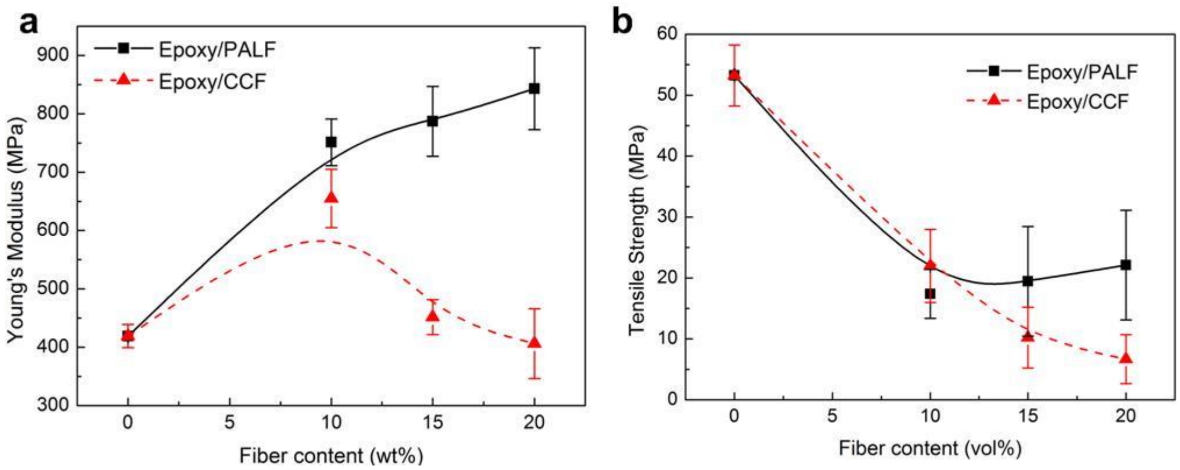

Fig. 1. Young's modulus and tensile strength of epoxy/PALF and epoxy/CCF composites

Fig. 2 shows the transmissibility of epoxy/PALF when displacement amplitude (Fig. 2a) or acceleration amplitude (Fig. 2b) was excited at the base of system through shaker table. The transmissibility tests were generated at various base excitation levels that is (i) 1mm and 1.5mm, and (ii) in frequency range between 15-23Hz. It was observed that when the base excitation increase from 1mm to 1.5mm or 0.1g to 0.15g, the resonance and attenuation frequencies were shift to the lower values as well as resonance peak but sometime fluctuating data was found.

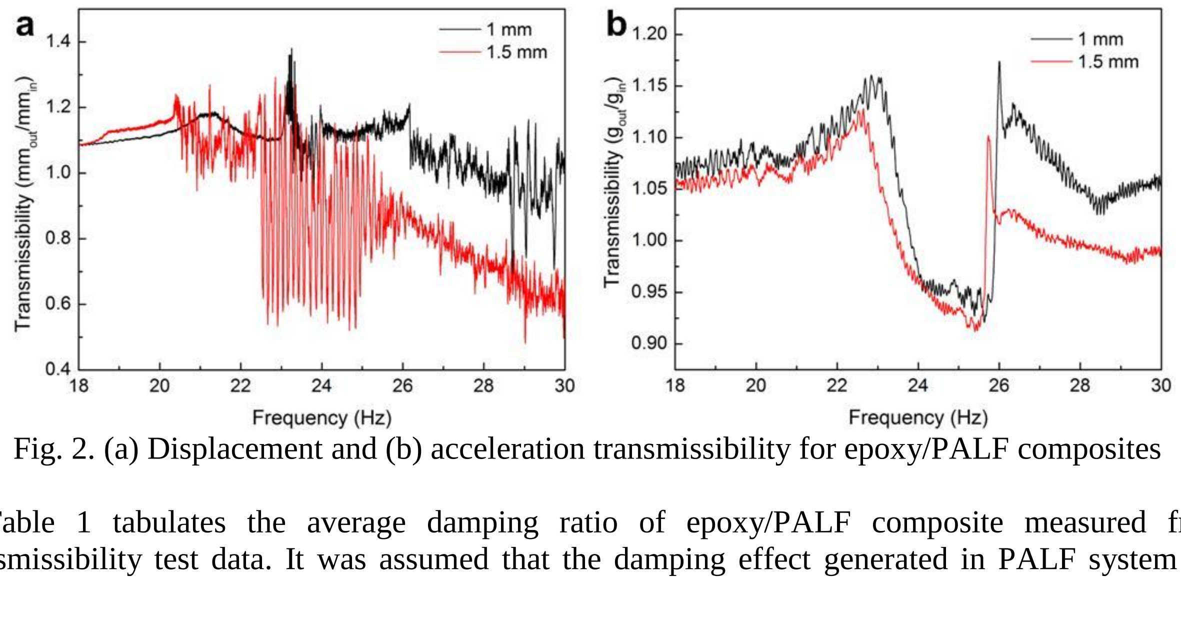

Fig. 2. (a) Displacement and (b) acceleration transmissibility for epoxy/PALF composites

Table 1 tabulates the average damping ratio of epoxy/PALF composite measured from transmissibility test data. It was assumed that the damping effect generated in PALF system are caused by (i) frictional losses from bearings during vertical movement of top plate, and (ii) the inserted PALF rigid system. The total damping ratio decreases when the thickness of PALF rigid increase.

Table 1. Damping of epoxy/PALF composites system

Index	Damping in PALF rigid system			
	Displacement		Acceleration	
Base excitation	1 mm	1.5 mm	0.1 g	0.15 g
PALF rigid	0.53	0.61	0.82	1.09

Figs. 3a–d display the vibration result of a fixed-fixed end beam attached with one, two, three and four vibration absorbers, respectively. There were four points on the beam structure that responses were measured. Apparently with adding vibration absorbers, the vibration amplitude of beam reduces significantly, although the result of without attached absorber was not shown in the manuscript. This is because it has been proved in our previous study [2-4], that the addition of absorber can minimize the vibration amplitude. From Figs. 3a–d, it was concluded that four absorbers attachment is more effective to reduce the vibration amplitude of a beam. This result thus corroborated well with our previous findings [3,4].

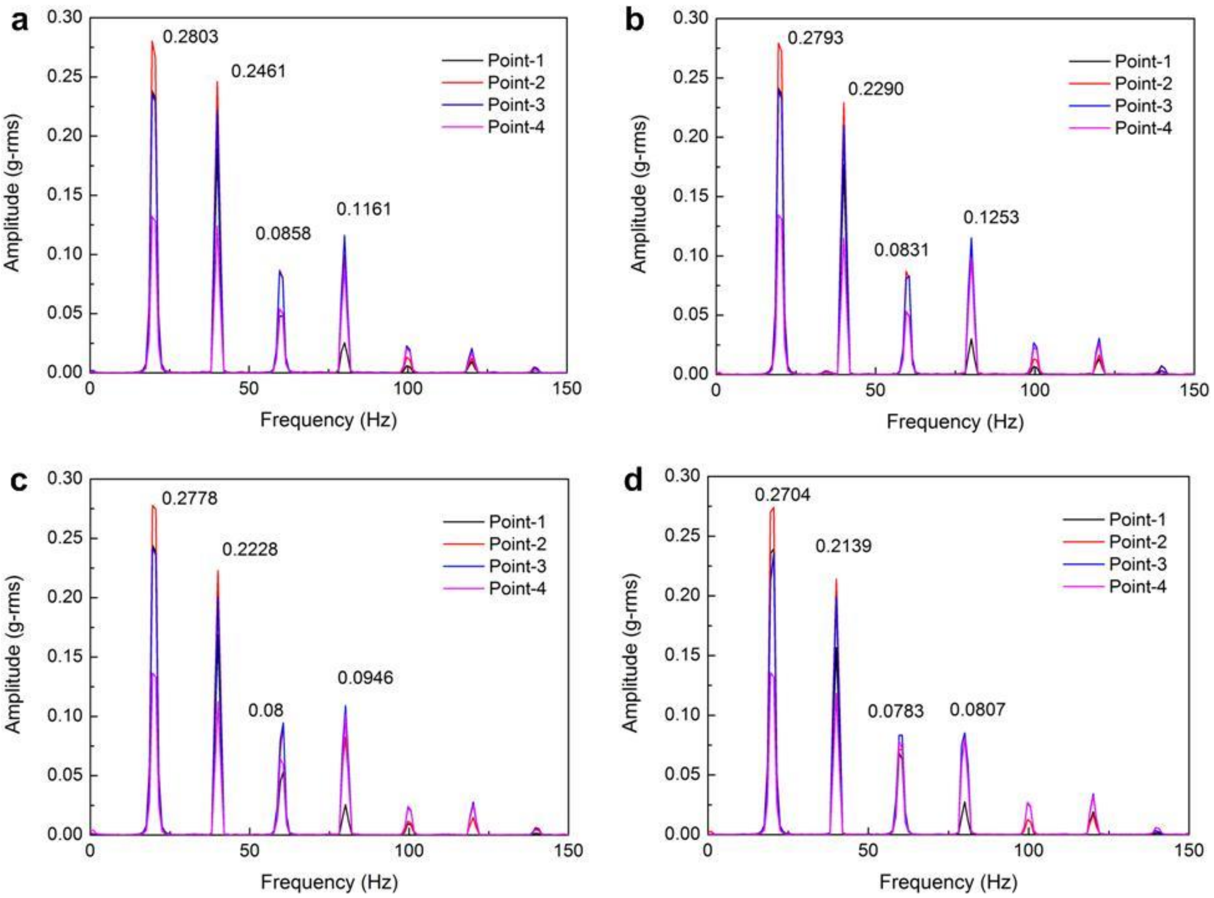

Fig. 3. Vibration response of fixed-fixed end beam with attached (a) one (b) two (c) three and (d) four vibration absorbers

Conclusion

The potential of epoxy reinforced natural fibers, such as in this case PALF and CCF as alternative materials for vibration absorber were studied. It is found that the Young's modulus and tensile strength were increased when the volume of fibers increased. Transmissibility test on the other hand declared that PALF composites have a good vibration damping behaviour by increasing the damping ratio up to 10%. As for vibration absorber test, the vibration amplitude was found reduce significantly as the number of attached vibration absorber increases.

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