NEW APPROACH OF DYNAMIC VIBRATION ABSORBER MADE FROM NATURAL FIBRES COMPOSITE

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ABSTRACT

With the current trend use of lighter structure and more power-intensive engines in automotive and aircraft manufacturing, vibrations are expected to increase due to its adverse effects on the vibratory behaviour. This could turn out to be a critical problem if the vibration not being controlled through a proper approach. Due to that reason, this paper aims to develop a small-scale and weightless vibration absorber made from natural fibres-based polymer epoxy composites. Two types of natural fibres were selected for reinforcement; sugarcane bagasse fibres and kenaf fibres at different fractions 5–20 wt%. In prior to vibration study, the tensile mechanical test was performed in order to determine the optimum fraction of the composites, as well as making comparisons of both composites reinforced by sugarcane bagasse fibres and kenaf fibres. It was found that the 20 wt% of sugarcane bagasse fibres composite achieves the highest Young's Modulus and tensile strength of 0.97 GPa and 21 MPa, respectively compared to epoxy reinforced kenaf fibres. Subsequently, the transmissibility test was carried out to determine the vibration absorption energy by using VCS software. Again, the result indicated that 20 wt% sugarcane bagasse/epoxy composite accomplishes the highest resonance frequencies at 22.9 Hz for 1 mm and 20.6 Hz for 1.5 mm. For the damping properties, it was found that sugarcane bagasse composites increase the damping ratio up to 8%. In the final stage of study, the small-scale vibration absorber was fabricated by using the optimum fraction of composite which determined from both previous testing. The vibration test was performed on a fixed-fixed ends beam and the results showed the resonance amplitude of the beam decreased significantly when it attached with vibration absorber. It concludes that adding more vibration absorbers attached on the beam produce better result in vibration reduction.

Keywords: sugarcane bagasse, kenaf, vibration absorber, mechanical properties, transmissibility.

INTRODUCTION

The rapid advancement of technology has changed the way the manufacturing industry operates, where more lighter structures are being utilized mainly in aircraft and automotive industries (Starke Jr. and Staley, 1996), (Goede *et al.* 2008). However, the trend towards lighter structure has potential to lead to structure being more susceptible to vibration. This could turn out to be a critical and growing problem in the society as it could affect more people in their daily life if vibration not being controlled through a proper approach.

Over the past 10 years, there are numerous research works concerning on excessive vibration of light structures and thin panel, which are commonly employed in automobiles and aircraft (Fuller *et al.* 1991), (Hu and Tsuiji, 1999), (Bich *et al.* 2013). Generally, the standard solutions to eliminate and minimize the vibration are by (i) redesign the system for instance increase the thickness of the panel and stiffening the structure, (ii) apply damping materials on vibrating structure to dampen the response and (ii) adding resonators such as vibration absorber to absorber vibration. Nevertheless, the first two methods are difficult to apply due to their design complexity, costly and ineffective at low frequency range (Zaman *et al.* 2013a), (Zaman *et al.* 2013b). On the other hand, the latter is more practicality, although they are concerned of adding extra weight to the host structure (Carneal *et al.* 2004), (Acar and Yilmaz, 2013).

Our previous works have shown that adding dynamic vibration absorber to the vibrating structure have been succeeded in minimizing the structure vibration (Zaman *et al.* 2014a), (Zaman *et al.* 2014b), (Zaman *et al.* 2014c). Unfortunately, these resonant devices usually made of heavy metal or steel may no longer be an attractive solution in the current trend particularly in aerospace and automobile. This definitely will not bring any advantage to both industries since the weight of a host system is vital to overall performance as it effects on the fuel efficiency of vehicle.

Due to that reason, an alternative material of using polymers as a vibration absorber is obliged for further investigation. In contrast to metal and ceramic, polymeric materials feature low manufacturing cost, offering high design flexibility and weight savings. Despite these advantages, the major downsides of polymers include low mechanical properties and thermal stability. In fact, its application as vibration control materials is still in nascent stage as most polymers have low stiffness and damping behaviour. These requests promote the development of polymer composites-a combination of two or more materials, which has the potential to provide value-added properties absent in polymer (Ma *et al.* 2014).

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Throughout the years, the interests in using natural fibres as reinforcement for polymeric composites are increasing due to their unique properties such as renewability, low density, high specific strength, non-abrasively, combustibility, non-toxicity, low cost and biodegradability (Cao *et al.* 2006). In addition to that, such fibres have high specific properties such as stiffness, impact resistance, flexibility and modulus. Other properties include less skin and respiratory irritation, vibration damping, excellent sonic insulation properties and enhanced energy recovery (Nishino *et al.* 2003), (Zaman *et al.* 2009), (Zaman *et al.* 2012). Natural fibres may play an important role in developing biodegradable composites to resolve the current ecological and environmental problems. There are various type of fibres today, and the variety continues to increase. Some examples in use include ramie, hemp, kenaf, jute sisal, banana and sugarcane. Despite these advantages, dispersions of natural fibres in the polymeric composites are still a critical issue that most researcher trying to solve since it is the most important aspects in determining the structure and properties of composites (Puglia *et al.* 2008), (Gu, 2009).

In this study, the polymer epoxy composites reinforced by natural fibres are exploited as an alternative design material for vibration absorber. Two natural fibers were selected in this study which are sugarcane bagasse fiber (SBF) and kenaf fiber (KF). Although research works on these natural fibres have been extensively investigated as sound absorption material (Nishino *et al.* 2003), (De Rosa *et al.* 2009), there is less to consider its application as design material for vibration absorber. In-depth investigation is carried out to determine the mechanical properties, transmissibility and damping properties of epoxy/natural fibers composites, and its performance to attenuate vibration of structure. It is expected that this research will provide a guideline of utilizing natural fiber polymer composites featured by high performance, cost-effectiveness and weight savings as better alternative material for vibration control.

METHODOLOGY

Preparation of Natural Fibres

In order to improve the adhesion between the matrix and fiber, the preparation of treated fibers was continued by immersing fibers with sodium hydroxide solution using ratio 5:95 of NaOH:water for 24 hours as shown in Figure-1. Then, fibers were washed with distilled water until any alkalinity reaction was detected. After that, the fiber was dried at 80°C for 12 hour in oven as shown in Figure-2. This alkali treatment removed natural and artificial impurities which improves the fibers and matrix adhesion (Gu, 2009). This treatment also destroy the hydrogen bonding in cellulose hydroxyl groups of fibers, thereby making it more reactive to the functional group of coupling agent which produces stronger bonds to matrix (Zaman *et al.* 2014).

Figure-1. Fibers immersed with sodium hydroxide.

Figure-2. Fibers dried in oven.

Preparation of Composites

After the treated dried fibers were prepared, the fibers are crushed by using granulator machine to get small sizes of random fibers. Then, the fibers were sifted using a sieve equipment size of 3.15. The fibers and epoxy were mixed together and stirred manually to disperse the fibers in the matrix. This was followed by pouring the mixture into the moulds which prepared for tensile test, transmissibility and vibration tests (as shown in Figures-3a and 3b). The cast of each composite was left to solidify in the oven for 6-12 hours before it removed from the mold.

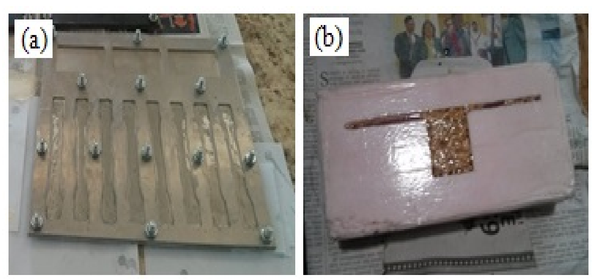

Figure-3. a) Aluminium and b) silicone rubber moulds

Transmissibility Test

Transmissibility test was carried out at various base excitation levels that is (i) 1 mm and (ii) 1.5 mm in the frequency range of 18-30 Hz successively. There were two blocks with weight of 483 g were loaded to the moveable top plate and locked on the sliding top plate. Figure-4 below shows the transmissibility test machine used in this study.

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Vibration Absorber Test

The vibration testing experiment was conducted to obtain the frequency and amplitude of vibration by using DEWE Soft 6.5.3 and the sensor connected to the beam structure. In this study, a motor shaker was used as a vibrating load to the beam structure and the motor speed was controlled using controller unit. The experimental procedure was operated in three conditions; (i) the vibration analysis without vibration absorber attachment, (ii) vibration analysis with single absorber attachment and lastly (iii) with the multiple vibration absorber attachment as shown in Figure-5. The vibration absorber was attached on the beam structure at points which vibrations are found maximum.

Figure-4. Vibration transmissibility test machine.

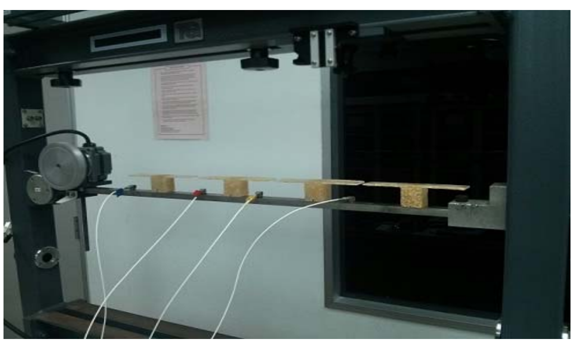

Figure-5. Vibration absorbers attached on the fixed-fixed ends beam.

RESULTS AND DISCUSSION

Mechanical Properties of Composites

Generally, it can be derived that the values of Young's Modulus of natural fiber reinforced composites increased with increasing fiber content up to optimum value before declining (Ku *et al.* 2011). However for tensile strength, it will be different since the strength of composite depending on the polymeric matrix. In this study, both of epoxy composites reinforced by sugarcane bagasse fiber (SBF) and kenaf fiber (KF) were found that the tensile strength drops dramatically compared to neat epoxy by 50% to 80% as shown in Figure-6. The drop in tensile strength is caused by: (i) the brittle properties of epoxy matrix is hardly improved of tensile strength by natural fibers, and (ii) the incompatibility between matrix and fibers (Ma *et al.* 2013). Due to this incompatibility, effective load will not take place and causes to failure quickly.

The selections of the optimum value for reinforcement of fiber for the following process are based on the high Young modulus and tensile strength. From the findings, the 20 wt% epoxy/SBF composite is selected based on the highest Young's modulus value compared to KF composite as indicated in Figure-7. On top of that, the 20 wt% epoxy/SBF composite also has the highest tensile strength compare to epoxy/KF composite. This finding was found similar to the previous finding by Tewari *et al.* (2011). According to Tewari *et al.* with the increased fiber content, the strength, modulus and work of fracture increase and the best combination was found with 20 wt% of sugarcane bagasse fiber. Based on this result, 20 wt% SBF composite is selected for subsequent analyses test.

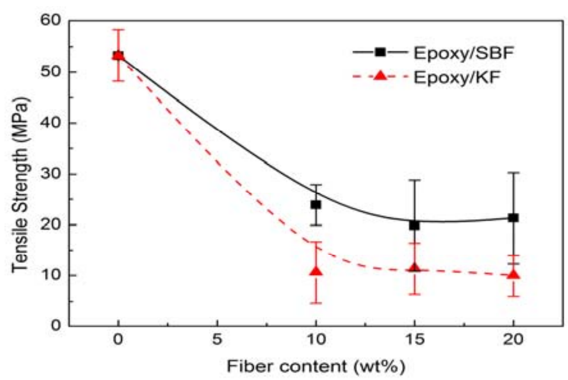

Figure-6. Tensile strength of epoxy/SBF and epoxy/KF composites

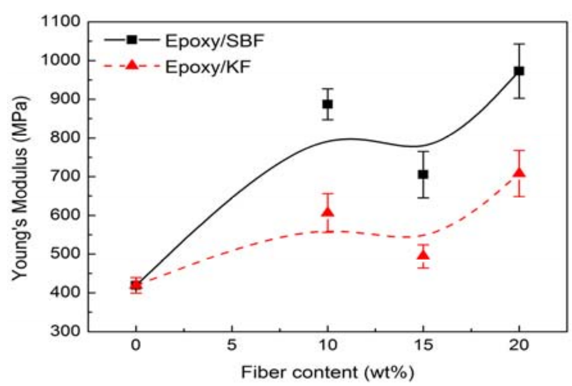

Figure-7. Young's modulus of epoxy/SBF and epoxy/KF composites.

Transmissibility Analysis

From the transmissibility test, the rigid systems installed with epoxy/SBF composite accomplished the highest resonance frequency. Figure-2 shows the transmissibility of epoxy/SBF composite when the displacement amplitude was excited at the base of system through shaker table. It can be observed that, the

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resonance frequencies for SBF composite are 22.9 Hz for 1 mm and 20.6 Hz for 1.5 mm. From the obtained result, it can be concluded that vibrations were absorbed by SBF/epoxy composite due to its damping effect. Though, it is known that the energy is dissipated due to frictional loss occurred in uniaxial motion of movable top plate (De Rosa *et al.* 2009).

From the previous research of Ab Latif and Mohd Rus (2013), the resonance frequencies result obtained in their study for high density biopolymer (HDB) foam are 21.4 Hz for 1 mm and 18.5 Hz for 1.5 mm. Thus from these results, it indicates that epoxy/SBF composite is better in terms of absorb the vibration compare to HDB foam.

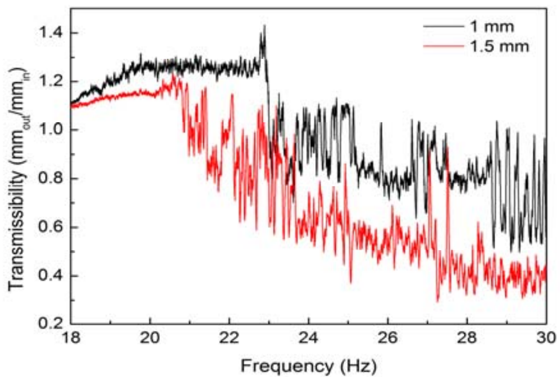

Figure-8. Displacement transmissibility of epoxy/SBF composite.

Damping Coefficient Analysis

Based on measurement data obtained from transmissibility test, the averaged damping ratio of SBF composite was calculated and expressed in Table-1. There were two factors influence that the damping effects generated in SBF composite which caused by; (i) frictional losses from bearings during vertical movement of top plate, and (ii) the SBF composite rigid inserted.

Based on the result obtained, epoxy/SBF composite produces high damping when the displacement increases. The damping ratios for displacement at 1 mm and 1.5 mm are 0.49 and 0.69, respectively. From the previous result of Ab Latif and Mohd Rus (2013) tabulated in Table-1, it shows that SBF/epoxy composites have a good vibration damping and increase the damping ratio up to 7.2% compared to high density biopolymer (HDB) foam except when the displacement base excitation at 1 mm.

Table-1. Damping ratio of SB rigid system.

Base excitation	Damping ratio in rigid system, ξ	
	1 mm	1.5 mm
Epoxy/SBF composite	0.49	0.69
HDB foam	0.56	0.64

Vibration Testing of Fixed-Fixed Ends Beam

The vibration absorber test was conducted to determine the performance of vibration made from material composite 20 wt% epoxy/SBF. In this study, the vibration absorber was attached to a fixed-fixed ends beam structure to reduce the vibration. The vibration load testing was running at 1200 rpm for around 20 seconds in the frequency range of 0 to 250 Hz. Later, the beam was attached with multiple absorbers in order to investigate the effectiveness of using multiple absorbers to absorb the vibration. Two points were selected for the measurement as these points indicate the maximum amplitude of vibration imposed on the fixed-fixed ends beam.

The response of fixed-fixed ends beam at point two with and without attached vibration absorber for point 2 was obtained as shown in Figure-9. Point two (center of the beam) is the most critical point which the vibration amplitude at this point is the maximum. The comparison of amplitude with and without attached absorber can be easily visualized from Figure-9. Tables-2 summarizes that by using four vibration absorbers attached on beam produce highest vibration attenuation compare to the others number of absorber at frequency modes 1, 3 and 4.

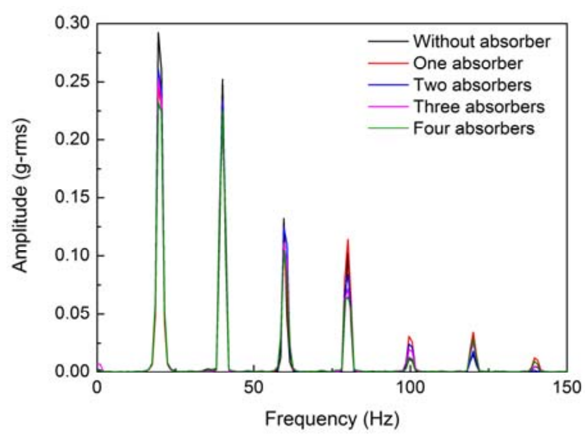

Figure-9. Frequency response function at point 2.

Table-2. Comparison response amplitude at point 2.

No. of vibration absorber	Vibration response at different frequency modes			
	1st	2nd	3rd	4th
Without	0.2922	0.2522	0.1421	0.1026
1	0.2778	0.2417	0.1334	0.1140
2	0.2607	0.2339	0.1245	0.0840
3	0.2524	**0.2412**	0.1111	0.0716
4	**0.2322**	0.2249	**0.1046**	**0.0649**

Figure-10 shows the frequency response function of fixed-fixed ends beam measured at point three (the second highest vibration amplitude) with and without attached vibration absorber. The excitation signal is measured in the frequency range of 0-150 Hz. From

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Table-3, the lowest amplitude observed at first frequency mode was using three absorbers. On the other hand, two attached absorbers gives the lowest amplitude at second and forth modes which are 0.1848 g and 0.0667 g, respectively, while the lowest amplitude observed at third mode is with the single absorber attached. From this result, it seems that different location of measurement produces different outcome on the effectiveness of multiple vibration absorber.

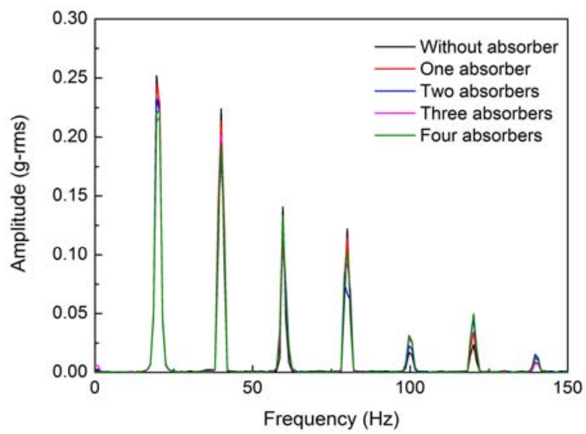

Figure-10. Frequency response function at point 3.

Table-3. Comparison response amplitude at point 3.

No. of vibration absorber	Vibration response at different frequency modes			
	1st	2nd	3rd	4th
Without	0.2518	0.2240	0.1405	0.1221
1	0.2447	0.2133	**0.1334**	0.0945
2	0.2329	**0.1848**	0.1235	**0.0667**
3	**0.2134**	0.2025	0.1278	0.0925
4	0.2201	0.1944	0.1331	0.1027

CONCLUSIONS

The objective of this study is to investigate the effectiveness of vibration absorber made from polymer reinforced natural fibers has been successfully achieved. Initial study focuses on investigating the mechanical properties of epoxy reinforced natural fibers, the absorbed energy, and later the vibration absorber at fixed-fixed end beam. The result of mechanical properties found that the 20 wt% epoxy reinforced sugarcane bagasse fibers (SBF) has been selected as the optimum weight fraction among the tested composites. The 20 wt% epoxy/SBF composite produces the highest young modulus and tensile strength compare to epoxy reinforced kenaf fibers which is 0.97 GPa and 21.3 MPa.

As a result for transmissibility, the result has been compare to the previous study. The system installed with 20 wt% epoxy/SBF composite accomplish the highest resonance frequency during the transmissibility test. For the damping analysis, it declared that 20 wt% epoxy/SBF composite increases the damping ratio up to 7.2% compared to high density biopolymer foam except at the displacement of 1 mm. Thus from the result, it show that epoxy/SBF composite is very good in terms of absorbing the vibration compare to high density foam.

As a result for vibration absorber analysis, the vibration was found reduce significantly for every attachment of vibration absorber. It can be proved by FRF obtained from vibration analysis without absorber, one absorber, two absorbers, three absorbers, and four absorbers attached. All the graph had similar characteristic which is the resonance occurred at the same frequency. The critical point has been occurred at point two which is the vibration at this point is maximum. The maximum resonance occurred at first mode. It may cause by frequency of speed during motor exciter actuate is approach to frequency of the beam at that point.

In general, this study is achieved its target which is to reduce vibration of the beam by using polymer reinforced natural fibers. It also can be disclosed that more vibration absorber attached on beam it give effectiveness of vibration reduction.

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