EFFECT OF DIFFERENT LAYUP SEQUENCES ON VIBRATION RESPONSE OF KENAF CORE REINFORCED COMPOSITE FOAM

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ABSTRACT

Recently, the use of natural resources tends to replace the use of synthetic resources in the composite field. The natural resource has comparable mechanical properties compared to the synthetic resource. An experimental investigation was conducted to investigate the effect of different layup sequences of different mesh sizes of kenaf core (KC) reinforced composite foam. Composite foam was manufactured using a simple process of mixing and cold pressing to ensure the equivalent thickness of the composite foam formed. A total of 27 layup sequences with two types of resin used were soft epoxy (SE) and polyurethane (PU). 3.0 mm, 20 mesh and 30 mesh of KC size were used and the motor vibration test was used to evaluate the performance of the composite foam. Based on the results, it was found that most of the specimens of reinforced PU composites had better vibration energy absorption properties compared to the specimens of reinforced SE composites. The BAC layup sequence reinforced PU composite shows good agreement in vibration energy absorption properties, which improved 64.78 % compared to pure PU foam. It was also found that the 3.0 mm mesh size of the KC used showed better performance in the absorption of vibration energy.

KEYWORDS: KC, Mesh Size, Polyurethane, Soft Epoxy, Composite

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INTRODUCTION

In recent years, there has been an increasing interest in the use of natural fibre as reinforcement in the field of composite materials. Natural fibres can be categorized into three types according to their origin, i.e. animal fibre, plant fibre and mineral fibre [1]. There is a large volume of published studies describing the use of natural fibres in a variety of ways. According to the review presented by Pickering et al. [2], natural fibre composites have been used in many areas such as the aircraft and automotive industries, toys, funerals, marine railings, electronic equipment and sports equipment. Rohit and Dixit [3] also stated that natural fibre was also used in windows, furniture, automotive panels and gardening products due to its light weight, low price and low maintenance requirements.

In addition, there are abundant natural fibres that can be obtained from plants such as kenaf, sisal, cotton, hardwood, etc. However, the focus of this study will be on the kenaf plant. The Kenaf plant comes from the Hibiscus Cannabinus family [4]. In addition, kenaf is also a potential crop to replace tobacco in Malaysia due to the tropical climate in Malaysia that was suitable for kenaf cultivation, as indicated in the comprehensive review of Journey of Kenaf in Malaysia by Basri et al. [5]. Tezara et al. [6] have stated that the containment of cellulose and

hemicellulose in the kenaf plant will influence the mechanical properties of the material when it is reinforced in the composite material. Kenaf plants have an enormous potential to be used in engineering applications [7]. Akil et al. [8] mentioned that KC can be used as summer forage, animal bedding, and potting medium. In addition, Saad and Kamal [9] have stated that KC can also be used for the production of composite insulation, medium density particle boards, fire retardant particle boards, polymer composites, thermoacoustic applications and sound barrier due to its light and porosity properties. Porosity is very important as it determines the ability of the composite material to absorb energy as it refers to the amount of cell form in a material that can help to absorb energy. Radzi et al. [10] also proposed that the mesh core size used as a filler would influence the interfacial bonding of the composites due to the contact of its surface area with the matrix.

In addition, Arenas and Crocker [11] argued that porous material may be used to reduce noise and vibration produced by machinery, vibration isolation, barriers, sound absorbing materials, machine enclosures or cabin enclosures. They also stated that the porous characteristics of the materials have a high value of the sound absorption coefficient. This finding was consistent with the findings of past studies by Dhanapal and Kannan [12], which indicated that the most effective shock absorption materials are in footwear, polyurethane foam and elastomer. The proposed concentration of polyol and dissociate will influence foam density and cushioning, the more closed macro cellular structure will be achieved and the higher cushioning capacity will result. Berardi and Iannace [13] indicated that the material must have a high porosity as a characteristic for absorbing sound. They also describe that the closed pores in the material allow only minimal sound absorbency, while the open pores, which have a continuous channel to the surface of the material, have higher sound absorbency.

Moreover, Ashan et al. [14] studies on the preparation and characterization of natural fiber-filled asphalt based damping material. The sample was tested under a temperature range of 100°C to 50°C and a constant frequency of 1 Hz. They found that asphalt composite with 10 wt. % of kenaf fibre as reinforcement has the highest damping capability. The damping capability of the composite indicates the amount of damping peak amplitude that can be reduced. The higher the reduction of the damping peak amplitude, the more energy was dissipated during the damping mechanism. Shan et al. [15] used PU polymer composite reinforced coir fibres and recycled tires to enhance the damping and vibrational characteristics of the seat foam. They found that after the fillers were added, more vibration was dissipated by the foam composites developed. Composite foam was also found to provide better vibration damping at resonance compared to conventional seat cushions used in the Proton car. To the best knowledge of the author, many interesting results have been reported on the potential of natural plants in the use of vibration. However, most studies in open literature did not simultaneously examine the effect of different layup sequences of different mesh sizes of KC reinforced PU and SE composites. This was the motivation behind the current study.

MATERIALS AND METHODOLOGY

KC as a reinforcement was the raw materials used in this study. Three (3) KC types of 3.0 mm, 20 mesh and 40 mesh, as illustrated in Figure 1. Lembaga Kenaf & Tembakau Negara, Malaysia (LKTN) supplied the KC. The KC prices for 3.0 mm, 20 mesh and 40 mesh respectively were MYR850, MYR900 and MYR1100 per ton. The PU and SE have meanwhile been used as a matrix. Table 1 and Table 2 showed the properties of PU and SE. Ultimate Panel (M) Sdn. Bhd. provided the PU used in this research. The prices for PU and SE were MYR15.00 and MYR90.00 respectively per kilogram. The different mesh sizes of the KC used were dried in the oven at 115 °C for 6 hours before the manufacturing process. This process is

intended to remove the humidity content of the KC. The bonding between the KC and the matrix was also improved by this process. In addition, for all kinds of PU or SE reinforced composites the thickness of each composite sample was set to 10.00 mm. The composite reinforced PU and SE layup sequences were 27 types with different types of KC sizes as shown in Table 3. The example of layup sequences of different KC sizes is shown in Figure 2.

Figure 1: KC Mesh Sizes (A) 3.0 Mm; (B) 20 Mesh; (C) 40 Mesh

Table 2: Properties of SE

	Resin	Hardener
Appearance	Clear liquid	Clear liquid
Viscosity (CPS)	3,000 – 4,000 cps	180 – 220 cps
Mixing ratio	3 : 1	3 : 1
Pot life (25 °C)	30 minutes	30 minutes
Curing condition	12 hours with 25 °C Heating : 1 hour 15 minutes with 60 °C	
Shelf life	6 months	
Flash point	More than 300 °C	More than 150 °C

Figure 2: Example of Layup Sequences of Different Sizes of the KC

In addition, the engine vibration test was used to evaluate the energy absorption of KC composite foam. Samples were cut into 160 x 120 x 10 mm depending on the engine base size. The frequency of vibration of the engine was set to 100 kHz. The accelerometer was then placed on top of the engine. When the engine is on, the accelerometer starts detecting the vibration of the motor and all the results obtained have been graphically represented.

Table 3: Layup Sequences of Different Sizes of the KC

AAA	BAA	CAA
AAB	BAB	CAB
AAC	BAC	CAC
ABA	BBA	CBA
ABB	BBB	CBB
ABC	BBC	CBC
ACA	BCA	CCA
ACB	BCB	CCB
ACC	BCC	CCC

Note: A is 3.00 mm; B is 20 mesh; C is 40 mesh

RESULT AND DISCUSSIONS

Vibration Performance of KC Reinforced PU

From the data in Figure 3, the BAC layup sequence specimen had the lowest mean amplitude value of 0.230, which was 64.78 % lower than that of pure PU foam. The mean amplitude of the AAC layup sequence was 0.257, the second highest, followed by an ACA layup sequence specimen with 0.267. The mean amplitude value decreased by 60.64 % and 59.11 % compared to pure PU foam. In addition, the specimen with the ABB and AAB layup sequences had the same average amplitude value, which was 0.283, which also decreased 56.66 % compared to pure PU foam. However, the BCB layup sequence shows the highest mean amplitude value of 0.970, which was 32.68 % higher than pure PU foam. There were 0.733 and 0.650 of the mean amplitude values represented by the ACB and ABA layup sequence specimens. It represents 12.25 % higher and 0.46 % lower than the average amplitude of pure PU foam.

Figure 3: The Average Amplitude of Pure PU and 27 Layup Sequence of KC Reinforced PU.

From the result obtained, the mean amplitude value of specimens with a double layer of 3.0 mm KC mesh reinforced PU was shown to be lower in their layup sequence. However, most of the sequencing specimens that used a double layer of 20 mesh sizes of KC reinforced PU have a higher average amplitude value. The lower mean amplitude value obtained by PU reinforced 3.0 mm mesh size KC was due to its content of more open pores due to the quantity of KC per cm^3 for the larger mesh size KC less than the smaller mesh size KC. In addition, the larger mesh size of the KC cannot mix well with the PU and cause the PU reinforced with the 3.0 mm mesh size of the KC formed by a higher number

of open pores compared to the 40 mesh size of the KC reinforced PU which is smaller enough to mix with the PU. The increase in the amount or size of the natural filler content used in PU composite foam causes a decrease in the average cell size of PU foam and leads to an increase in cell distribution in addition to the formation of more closed pores in PU composite foam [16-17].

Vibration Performance of KC Reinforced SE

Figure 4 shows that the result obtained from the CBA layup sequence specimen had the lowest mean amplitude value of 0.25, which was 61.54 % lower than the pure SE specimen. The mean amplitude for the BCC specimen was 0.28, which was the second lowest, followed by the BCB layup sequence specimen with 0.29. The mean amplitude value of the pure SE specimen was 56.92 % and 55.38 % lower. In addition, the sample layup sequence BBB and BBC has a mean amplitude value of 0.36 and 0.37. The difference in the mean amplitude value of these layup sequences to the pure SE specimen showed 44.62 % and 43.08 % declination. However, the CCA layup sequence was the highest in average amplitude between the different layup sequences, which was 4.43. It was 581.54 % higher than the pure SE specimen. The mean amplitude value of the specimen with the layup sequence CCC and BCA was 4.00 and 3.87. Compared to pure SE specimens, 515.38 % and 495.38 % have increased by an average amplitude value. For the CAC and CBB layup sequences, there was a total increase of 464.62 % and 458.62 % in the mean amplitude relative to the pure SE specimen. The mean amplitude value obtained by both of these layup sequences through the engine vibration test was 3.67 and 3.63, respectively.

Figure 4: The Average Amplitude of Pure SE and 27 Layup Sequence of KC Reinforced In SE.

In addition, from the five lowest and five highest average amplitude values obtained between the different layup sequences, the layup sequence specimen having 20 mesh sizes as the top layer has a lower average amplitude value. The reason for these layup sequence specimens has a lower mean amplitude value was because the KC size used to reinforce the SE was medium in size. The medium size KC was of an average size which could form more micro void when reinforced in SE compared to 3.0 mm and 40 mesh sizes of KC which were too large and too small to form enough micro void within the SE composite structure. This theory was supported by Hanan et al. [18] who argued that the uneven distribution of fibre caused the resin to consist of higher amounts of micro void and air bubbles. As a result, it can be shown that the layup sequence specimen with 20 mesh size KC as the top layer has better vibration absorption as the

average amplitude value of these specimens was lower than the other layup sequences. Moreover, the bonding structure of KC reinforced SE does not have a foamy texture and therefore only a minimum amount of micro void and air bubbles can be found. As a result, the SE specimens with 20 mesh KC as reinforcement on the top layer for the layup sequence were most effective for the energy dissipated during the engine vibration test.

Vibration Performance of KC Reinforced PU and SE

Figure 5 shows a comparison of the mean amplitude values of KC reinforced PU and SE composites. All specimens with KC reinforced PU had a lower mean amplitude value through the engine vibration test compared to the KC reinforced SE composite. The lower mean amplitude value for the specimens indicated that the lower vibration was detected during the engine vibration test. Therefore, from Figure 5, KC reinforced PU has better absorption of vibration energy compared to KC reinforced SE composite. The reason for this is the different bonding structure of the PU and SE. In the case of reinforced SE composite specimens, the crosslink density contained in the specimens was higher due to the higher number of epoxy groups present. The epoxy material has a high cross-linking density due to the bulk of the epoxy groups. Thus, epoxy has better mechanical properties [19], but the crosslink present in KC reinforced SE does not have a foamy structure that contains closed pores. As a result, the overall KC reinforced PU specimen showed a lower mean amplitude value, which meant better vibration energy absorption properties compared to the KC reinforced SE specimen.

Figure 5: Comparison of Average Amplitude for KC Reinforce PU and KC Reinforced SE.

Microstructure of Specimen Reinforced PU and SE Composites

Figure 6 shows the microstructure of all KC reinforced PU and SE composites. The microstructure of the pure PU specimen is shown in Figure 6(a). It has been shown that the pure PU specimen is made up of multiple pores linked together. Pores that are contained in PU foam can help in the transfer of energy when the energy is applied to it. The pure SE microstructure can be found in Figure 6 (b). The pure SE specimen has a flat surface and does not contain pore on the specimen. This is because the bonding structure present in SE is a cross-linked structure. The molecules in SE were packed tightly together. As a result, the pure SE specimen has lower vibration energy absorption under the engine vibration test. Figure 6(c) shows the 3.0 mm KC reinforced PU microstructure. Most PU reinforced 3.0 mm mesh size KC specimens at the top have higher vibration energy absorption because the larger size of the KC is too large and cannot be distributed evenly when the PU is reinforced and the larger size of the KC also causes the quantity of KC per cm^3 to be lower than the smaller KC. As a result, a higher number of open pores were formed in the specimen.

Figure 6. SEM Image Of (A) Pure PU; (B) Pure SE; (C) 3.0 Mm Size Of KC Reinforced PU; (D) 20 Mesh Size Of KC Reinforced PU; (E) 40 Mesh Size Of KC Reinforced PU; (F) 3.0 Mm Size Of KC Reinforced SE; (G) 20 Mesh Size Of KC Reinforced SE; (H) 40 Mesh Size Of KC Reinforced SE.

In addition, the lower amount of open pore was found in the 20 mesh size KC reinforced PU microstructure as shown in Figure 6 (d). This is because the smaller size of the KC was used as a reinforcement and most of the pores formed in the PU were enclosed by the KC. The vibration energy absorption properties of this specimen were therefore improved. Figure 6 (e) showed that all pores formed in PU were filled with KC and almost all of the pore structure was closed, which was less efficient in the absorption of vibration energy. Figure 6 (f) declared the structure of the specimen under the SEM observation, and the large void formed between the KC can be seen. However, due to the large size of the KC used and the stronger bonding structure formed between the KC and SE resin, this composite specimen could not absorb much vibration energy. Numerous smaller voids have been observed between the bonding of the KC structure as shown in Figure 6 (g). Without the foaming structure, the impact energy can only be absorbed and reduced during the energy transformation within the void area created between the KC bonding structures. Due to the smaller mesh size of the KC used as reinforcement, more micro void can be formed and contributes to the enhancement of vibration energy absorption properties. In addition, a sample of 40 mesh sizes of KC was shown in Figure 6 (h). When undergoing SEM observation, the SE specimen with 40 mesh size KC as reinforcement shows the least amount of void between the KC bonding structure. The underlying cause was the small size of the KC used as a SE reinforcement. As the KC size was small, it can therefore blend well with SE to form a compact and stronger bonding structure. This caused the vibration energy absorption properties of this specimen to be weakest compared to the two other specimens that reinforced the 3 mm

and 20 mesh sizes of KC.

CONCLUSIONS

The present study was designed to determine the effect of different layup sequences of different mesh sizes of KC reinforced composite foam. These studies have shown that the specimens that make up the PU have better vibration-energy absorption properties compared to the specimen made of KC reinforced SE composites. This was due to the more open pore content in the PU foam that makes the energy spread to the pore. 235.71 % of the vibration energy absorption capacity was increased when compared to the average vibration energy absorption of specimens made up of PU resin and SE resin. It was also shown that the best vibration absorbent composite foam was the BAC layup sequence specimen. This was because it can absorb the most amount of vibration energy compared to other sequencing specimens, even with different resins used. As a result, the BAC layup sequence specimen has an enormous potential to replace the current market motorcycle seat cushion due to its higher vibration energy absorption properties. In addition, enhanced KC in PU also bring environmental benefits such as reducing the amount of PU used in production, reducing the weight of the cushion and biodegradable reinforced KC.

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