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Vibration characteristics investigation of sandwich composite materials of uni-directional and twill carbon fibers

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ABSTRACT

Vibration testing has carried out on the sandwich material composite specimen. This study aimed to determine the vibration characteristics of carbon-based sandwich composites. Sandwich composites were made by using the Vacuum assisted resin infusion method with two types of fiber directions, unidirectional and twill. The resin used for the sandwich composite was Vinyl Ester with Divinycell foam as the core. Each fiber direction was varied with 3 layers configurations, namely 2C2, 3C3 and 4C2. From the research results, it was found that the natural frequency in the twill fiber was smaller than the natural frequency in the unidirectional direction. The damping properties of both also indicate that the pattern of loss factor values in the UD fiber direction was more stable than the composite with the twill fiber direction. Research with the variations of fibers, resins, cores, and other components are needed to obtain a more complete dynamic characteristic database.

1. Introduction

Nowadays, the technology is growing fast and the needs for lightweight structural materials is also increasing. Lightweight material technology is essential in the aircraft industry. Structures on the aircraft are expected not only to be able to withstand the force in the form of general loads such as bending load and tensile load, but also expected to be more efficient with a lighter weight. The ability of the structure to withstand vibrations is also a critical matter that must be met. In an engineering system, a structure should stay stable and undamaged despite of the internal and external vibrations [1]. Sandwich composite material is one of the answers to this need. Sandwich composite material consists of two parts of the skin in the form of a laminate composite and a core between skins.

One of the aircraft structures that can utilize this material is the compartment of the float. This structure must have high strength and good damping properties. Carbon fiber was chosen because it has high mechanical strength. However, several studies have stated that carbon composites have lower damping properties than other types of composites [2,3]. This study aimed to determine the vibration characteristics in the form of damping properties from several variations of carbon composite specimens to obtain an effective carbon sandwich composite composition.

Many studies related to the dynamic characteristics of composites have been carried out. Several studies regarding glass/epoxy laminate composites also have conducted [4,5]. Other studies have shown that mixing brittle fibers with high-performance fibers, the hybrid Kevlar-S glass/Epoxy composites could provide a very effective damping capacity [6]. The experimental and numerical properties of vibration also have carried out on Abaca and Arenga Pinata fiber epoxy matrix composite beams [7].

There are three variables that can be chosen by a structural design engineer who is concerned with vibration absorption, namely the frequency ratio, the vibration absorber damping ratio and the mass absorbent [8]. Finding damping properties was one of the things done in this study.

There are several ways that can be used to determine damping properties which are grouped into two types of data, namely the time domain and frequency domain. At the frequency domain there are two methods, namely the half power bandwidth method and the magnification factor method. In the time domain, there are logarithmic decrement and hysteresis loop methods. In this study we used the frequency domain because it is considered to produce better results for unequal or combined materials [1,9]. Therefore, the half power bandwidth method were suitable for use in this study. The results of this study were damping properties in the form of loss factor and natural frequency of each sample variation. Data were collected in the frequency domain by searching for loss factors using the Half Power Bandwidth method. The test was carried out at room temperature.

2. Methodology

2.1. Composites material

All sandwich composite materials was prepared by Vacuum Asisted Resin Infusion (VARI) Method. VARI method is one of the methods used in the manufacture of composite materials on aircraft. VARI is a method used in the manufacture of composites that takes advantage of the difference in pressure from a vacuum pump. This method was chosen because the results are better than the Hand Lay-up method and cheaper in the process than the Prepreg (Pre-Impregnated) method. Therefore, the interest in using the VARI method for composite manufacture has been increased [10]. The materials used in this research were Carbon Unidirectional 12 K Tow and Carbon Twill 3 K Tow. Unidirectional

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Table 1
The Configuration of test samples.

Matrix	Number	Configuration	Mass (gr)	Thickness (mm)
Carbon UD 12K	1.a	2C2	40.62	8
	1.b	3C3	52.92	8.57
	1.c	4C2	52.62	8.86
Carbon Twill 3K	2.a	2C2	32.55	7.35
	2.b	3C3	37.18	7.75
	2.c	4C2	42.17	7.95

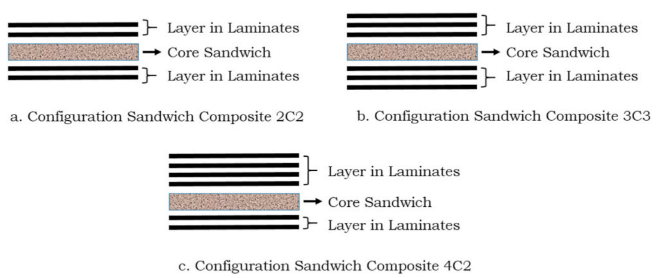


Fig. 1. Configuration of material test samples.

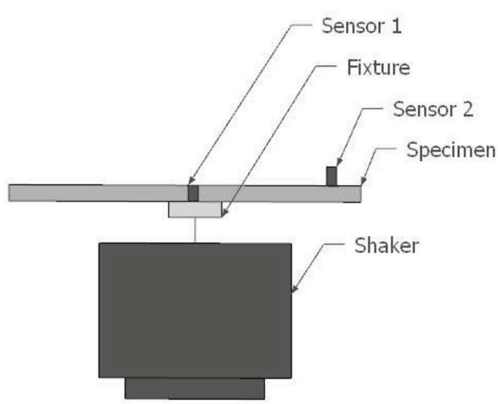


Fig. 2. The position of sensors and specimen on the shaker.

fabrics (UD) are fabrics in which most of the fibers travel in one direction only and we used 0° fibers direction in this research, while the twill carbon fiber is a fiber that is woven with 0°/90° direction. The core material used in the sandwich composite was Divinycell Foam and the matrix was Vinyl Ester Resin.

As seen in Table 1, there are 6 specimens with two types of fiber configuration. Each fiber configuration has three variations in the number of fiber layers. The letter *C* in the configuration refers to the *Core*, and the number in the configuration refers to the number of layers of upper and lower position at cores as in Fig. 1. Each specimen was made with the same size, which is 230 mm long and 50 mm wide while the total thickness varied according to the number of layers and fiber configuration as seen in Table 1.

2.2. *Experimental set-up*

Vibration testing on composite specimens was carried out using the Oberst method. Based on this method, the composite specimen that is vibrated in the middle has the same dynamic properties as the dynamic properties of the half cantilever beam [11–13]. The composite specimens were placed in a fixture and glued using Cyanoacrylate Ethyl. The Aluminum fixture was used as a link between the composite specimen and the modal shaker. In this test, 2 accelerometer sensors were used as the sensor. The first sensor was used as a feedback control for the shaker controller and was placed in the fixture. The second sensor was used as a vibration response signal reader that was placed on the composite specimen. There were two position variations in response to vibration signals. Position 1 was located at 5.5 cm from the center and position 2 was 9 cm from the center of the specimen (see Fig. 2).

The vibration profile used for testing was a type of sine swept. The value of the sweep rate used was 0.5 octave/minute with an excitation level of 1g. The sample was given a vibration in the form of a sine sweep ranging from 10 Hz to 2000 Hz and measured at each predetermined point variation.

The modal shaker that was used in this research was Bruel Kjaer type 4809 with frequency range from 10 Hz to 20 KHz bare table. This shaker has a maximum displacement of 8 mm and a maximum velocity of 1.65 m/s. The power amplifier that was used was Bruel Kjaer type 2706. Two accelerometer sensors used in this work are of the IEPE type. The sensor was made by SENZ with the type 3055B2. The sensitivity of the accelerometer sensor was 100 mV/g and the maximum value of acceleration that can be measured was 20 g. The two accelerometers were connected to a data acquisition module which was also used as vibration control. The data acquisition and vibration control module used was the software Medallion produced by Vibration Research. The module has 4 channels for reading the accelerometer. The experimental set-up that has been done can be seen in Fig. 3.

The accelerometer attached to the composite specimen provides the acceleration response value. At certain times, the response acceleration will be high. When the acceleration response has a value above 2 times of its initial value, the corresponding frequency can be called the natural frequency.

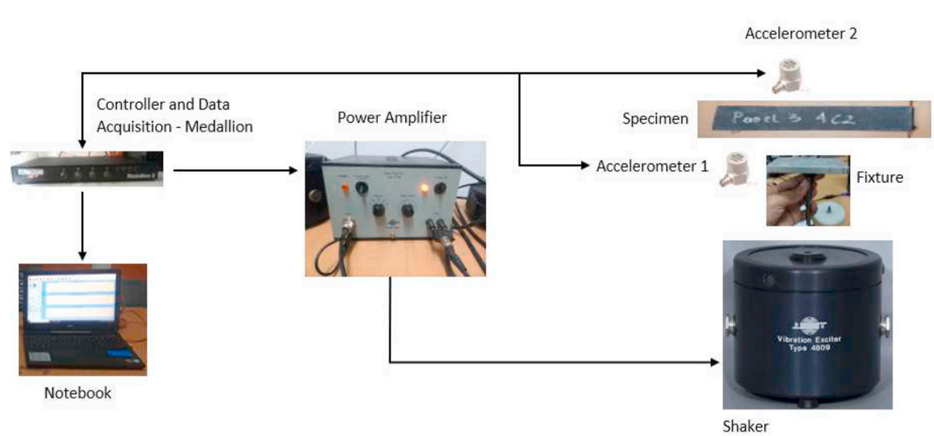
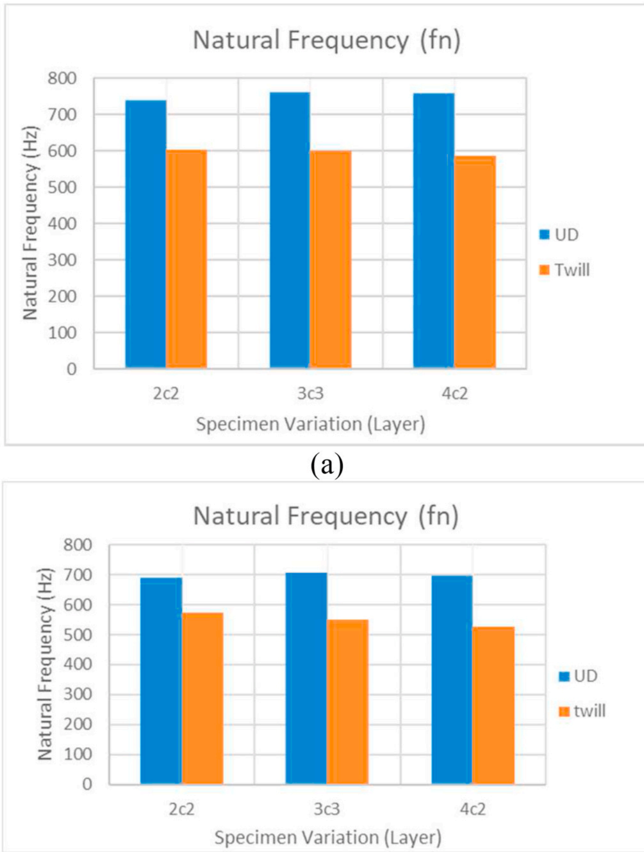


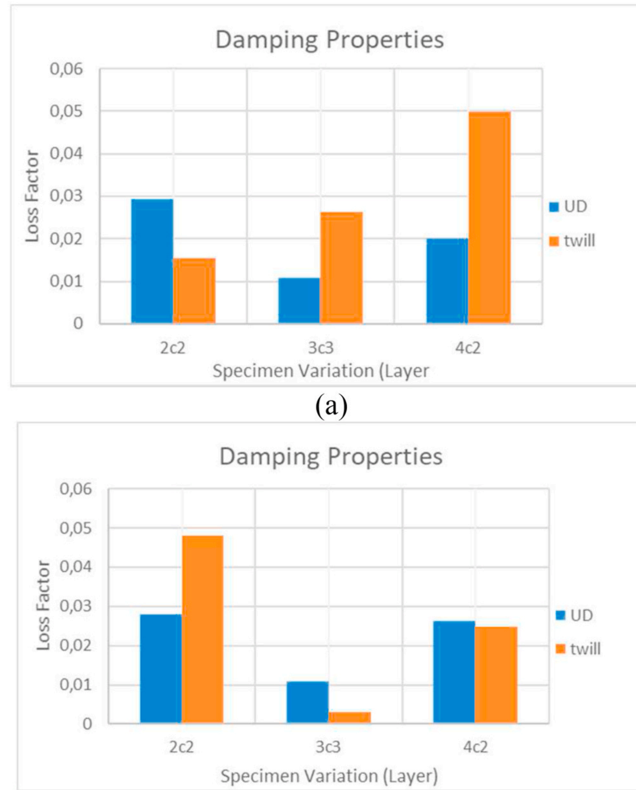
Fig. 3. The experimental set-up of vibration testing of sandwich composites carbon materials.



(a)

(b)

Fig. 4. Natural frequency (Hz) of the 6 specimens (a) at position 5.5 cm (b) at position 9 cm.



(a)

(b)

Fig. 5. Damping properties of the 6 specimens (a) at position 5.5 cm (b) at position 9 cm.

2.3. Data analysis method

The dynamic characteristics that were the objectives of this study are the natural frequencies and the damping properties of the samples. Damping is a form of energy dissipation in a system in vibration. The amount of damping value can be presented with various parameters. Loss factor is a parameter that can be used to represent the amount of damping capacity per radian [1]:

$$\eta = \frac{D}{2\pi} = \frac{\Delta U}{2\pi U_{max}} \tag{1}$$

Where D is Damping capacity, ΔU is the energy loss per cycle and U_{max} is the total restored reversible energy in the system.

3. Result and discussion

From the test results of the two position variations, it was found that the twill carbon fiber has a lower natural frequency value than the unidirectional carbon fiber. This result was in accordance with the research conducted by Xiao Yuan Pei et al. which stated that with the increment of fiber-orientation differences, the natural frequency of the fiber composite will be smaller [14]. Natural frequency of unidirectional fiber did not have a large difference for each layer variation. In the UD carbon, the smallest natural frequency was found in the composite with a 2C2 layer configuration. Whereas for carbon twill, the smallest frequency was found in the composite with a 4C2 layer configuration.

The loss factor value on unidirectional carbon has almost the same pattern in both sensor positions. The lowest loss factor was produced by carbon composites with a 3C3 layer configuration. In the twill carbon composites, configuration 2C2 has different results at both sensor positions. This can be caused by many things, one of which is an error in the placement of the sensor or uneven composition of the material. The loss factor value on unidirectional carbon has the same pattern at both sensor positions. The lowest loss factor was produced by carbon composites with a 3C3 layer configuration. While in the carbon twill composite cases, carbon composite with a 2C2 layer configuration has different results at the two sensor positions.

As can be seen in Fig. 4 and Fig. 5, it was found that the sandwich composite with the unidirectional configuration aligned in the same orientation and the 2C2 layer configuration has a good value between the frequency and the loss factor value. The unidirectional 2C2 carbon sandwich composite has high natural frequency values and good damping properties compared to the other two-layer configurations and is more stable at two sensor positions compared to twill carbon fiber composites. Later on, the characteristic of sandwich composite is divided by mechanical properties such as compressive strength, three-point bending test, and impact test. Sandwich structures are light materials that have performances in stiffness and high strength-to-weight ratio. The most noticeable theory of sandwich structure is the surfaces or laminates will act as the components that transfer loads caused by flexural load and compression, while the core will transfer load caused by shearing [15]. Further testing is needed with a higher data retrieval resolution. In further research, a smaller sweep rate is needed so that the resulting data has a better resolution. Further research on the other variations such as fiber type, fiber orientation, resin type and also core type are needed to complete the dynamic characteristic data of sandwich composites. The more data obtained for both dynamic data and mechanical data from the sandwich composite, the easier it is to design the structure. The data properties of many variations will help to determine the correct composition of the composite to create a more effective design. In addition, the use of an accelerometer sensor with a considerable mass will likely affect the natural frequency measurement and the damping value of the composite specimen. The comparison of the test results using a non-contact sensor is considered as the next step of this research. The development of test designs using non-contact sensors needs to be implemented immediately.

4. Conclusions

Vibration measurements are widely used to evaluate the dynamic properties of materials including composite samples. From the test results of the six variations of the specimen, it was found that the specimens with unidirectional carbon fiber have a higher natural frequency compared to composites made from carbon fiber with twill fiber direction. The damping properties value of the unidirectional carbon composite was also more stable at the two sensor positions with the best damping value on specimens with a 2C2 layer configuration. These results place the 2C2 carbon sandwich composite material sample as the best combined results for the two characteristics that have been mentioned. However, research with other variations and smaller sweep rates is still needed, as well as the use of non-contact sensors in testing needs to be done in future studies.

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