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The Influence of the Number and Position of the Carbon Fiber Lamina on the Natural Frequency and Damping Ratio of the Carbon-Glass Hybrid Composite

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Abstract. The purpose of this research is to examine the influence of the number and position of the carbon layer to the dynamic characteristic of carbon-glass fiber hybrid composite. The hybrid composite was consist of unsaturated polyester resin reinforced glass and carbon fiber with the volume fraction of 0.4 and made by hand lay-up method. The vibration test was conducted according to ASTM E756. The experiment variables studied were the number of carbon fiber layer (without carbon layer, 2 carbon layer, 4 carbon layer, and 6 carbon layer) and carbon layer position (layer 1 and 8, layer 2 and 7, layer 3 and 6, layer 4 and 5). The vibration data was acquired using Dynamic Signal Analyzer (DSA) system that consists of an accelerometer, an impact hammer, and a data acquisition. The result indicated that the number and position of carbon layer affected the natural frequency and the damping ratio of the carbon-glass fiber hybrid composite. The increase in the number of carbon layer would increase the natural frequency of the composite and decrease the damping ratio. Also, the position of carbon layer gave significant effect to the dynamic characteristic of the carbon-glass fiber hybrid composite. Position of the carbon layer at the outer layer of the hybrid composite would have the highest natural frequency and the smallest damping ratio.

INTRODUCTION

The composites material are widely use in the engineering applications. Several industries use them like automotive, aircraft, marine, household, etc. It is because of some advantages of the composites materials than other materials. The main advantages of the composites are a high strength-weight ratio, adaptability to different situations, and the relative ease combination with other materials to serve specific purposes and exhibit desirable properties. A composite is a structural material that consists of two or more constituents that are combined at the macroscopic level and are not soluble each other. One constituent is called reinforcing phase, and the other is the matrix. The reinforcing phase can be found in the form of fibers, particles, or fluke, while the matrix phase materials are generally continuous. Hybrid composites are a composite consisting of two constituents at the nanometer or molecular level. The purpose of the hybridization is to take benefits in cost and enhancement of mechanical properties. The combination of the two fibers is more profitable from an economic standpoint because it allows maintaining the balance between mechanical properties and economic value of composites. An example of a hybrid composite is glass - carbon fiber hybrid composite. This material has been the object of studies to obtain its mechanical and dynamic characteristics.

Some researchers about mechanical properties of the carbon-glass fiber hybrid composite are as follows: [1] studied the response of hybrid glass/carbon composite under compression. Using overall fiber volume of 30%, it was observed that the failure strength decreased as the hybrid ratio of glass fiber to carbon fiber increased, with minimum decrease coinciding with a ratio of 50% glass fiber and 50% carbon fiber. [2] and [3] found that tensile and compression strength of the hybrid carbon-glass composite are lower than non-hybrid composite, i.e. glass-epoxy composite or carbon epoxy composite. Also, they found that when the carbon fiber contains in the hybrid composite

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increased, the mechanical properties of the hybrid composite also increased. Beside affected by the fiber contains, the mechanical properties of the carbon-glass hybrid composite is also affected by the angle ply orientation of the fiber. [4] found that angle ply orientation of $0^o/90^o$ showed a significant increase in tensile properties of the hybrid composite in compare to angle ply orientation of $45^o/45^o$ and $30^o/60^o$.

Another important property of the composites for engineering applications is dynamic characteristics like their natural frequency and damping ratio. The studies of the dynamic characteristics of the carbon/glass fiber composite are not as many as the mechanical characteristics studies. Among them are as follow: [5] conducted an experimental approach to investigate the free vibration of woven fiberglass/epoxy composite plate in free-free boundary conditions. They found that increasing the number of the lamina and the aspect ratio of the width to height increased the natural frequency of the composite while increasing the orientation of the fiber decreased the natural frequency. [6] studied the vibration of the carbon-glass hybrid composite beam through modeling using ANSYS software. From his work, it was observed that increasing the number of carbon layer increases the natural frequency of the composite, and the natural frequency decrease when the carbon layer position changes from the surfaces towards mid-plane, also the orientation angle of the fiber give effect to the natural frequency of the composite. Also, [7] studied the effect of the layer number to the vibration of glass epoxy composite plate through ANSYS modeling. They found that increasing the number of the composite layers would increase the natural frequency of the composite. And the first three mode was same although the thickness was varied. [8] investigated the effect of the carbon addition in the glass epoxy composite to the damping characteristic of the hybrid polymer matrix composite. They found that glass fiber-epoxy matrix with 5% carbon particles had better damping properties which can be used for the structural application. [9] conducted vibration testing to study damping properties of the basalt epoxy composite laminates. Their testing referred to ASTM 756 standard. The damping ratios were determined using half-power bandwidth method. They found that the damping ratios and vibration characteristic of the basalt epoxy composite are strongly affected by fiber orientation of basalt/epoxy.

The study of the dynamic properties of the glass-carbon fiber hybrid composite structure is still rarely conducted by researchers. Several types of the carbon-glass fiber hybrid composite can be constructed for a specific application. So, this paper discusses the influence of some carbon lamina and their position to the dynamic characteristics of the glass-carbon hybrid composite. The dynamic parameters studied were natural frequency and damping ratio.

EXPERIMENTAL METHOD

The composite specimens were made from glass and carbon fiber in the form of a bidirectional woven mat. The matrix used was unsaturated polyester resins Yucalac BQTN 157 - FR , and catalyst of MEKPO (methyl ethyl ketone peroxide). The composition ratio between carbon fiber and glass fiber was 50 % : 50 %. The total volume fraction of fibers was 40 % of the total volume of the composite. The fabrication of the glass – carbon hybrid composite used hand lay-up technique. The mold which dimension of 310 x 310 x 3 mm was used for fabrication. After applying this method, these composites were pressed for 24 hours at room temperature. Then, the composites were cut into a size of 250 x 10 x 3 mm according to ASTM E756. The pictures of the test specimens are presented in Fig. 1 below.

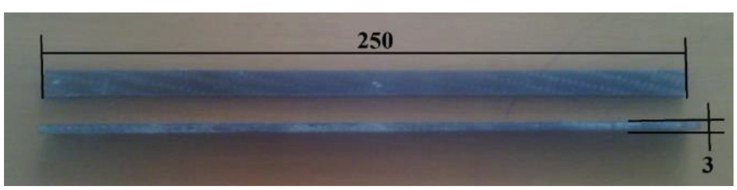

FIGURE 1. Test specimen for vibration test.

This research investigated the effect of the number of carbon laminates and its position. So its configurations were arranged in the configuration as shown in the Fig. 2 below.

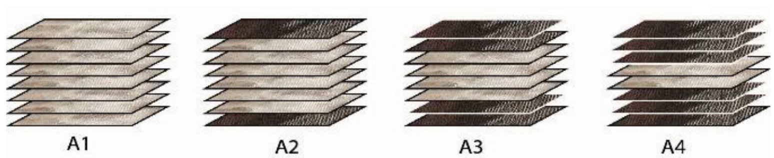

FIGURE 2. Layer configuration, A1. no carbon layer, A2. Two carbon layers, A3. Four carbon layers, A4. Six carbon layers.

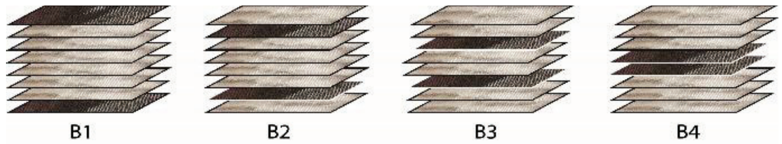

FIGURE 3. Layer position, B1. carbon at the surface, B2. carbon at the second layer, B3. carbon at third layer, B4. carbon at mid-plane.

The vibration testing was conducted using an impact hammer to excite the specimens. Impact hammer used was PCB Piezotronics 086C04 models. The vibration response was measured using accelerometer PCB Piezotronics 352C33 models attached to the composite sample, and acquisition data used 4 channels DEWESOFT 7 – DSA. The vibration test set up is shown in Fig. 4 below:

FIGURE 4. Vibration test set-up.

RESULTS AND DISCUSSION

To investigate the effects of the number of carbon layers and their position on the dynamic characteristics of glass-carbon hybrid composite, modal analysis technique was used in the experiment. The frequency response function was obtained from the signal spectrum from the accelerometer and impact hammer through fast Fourier transform analyzer. The natural frequencies and damping ratio of the specimens were found from the FRF graphics.

The relation of the number of the carbon layers and the natural frequency is represented in Fig. 5.

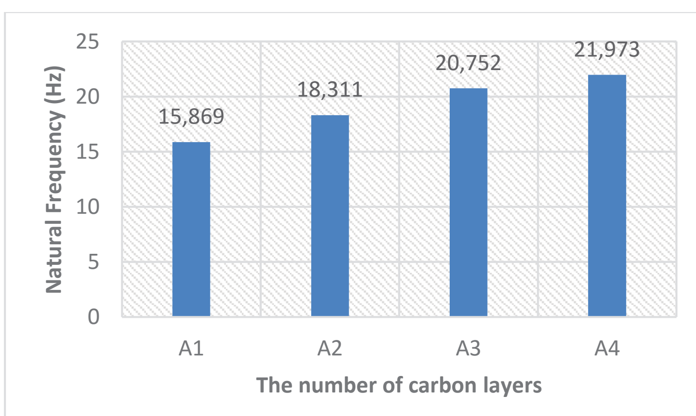

FIGURE 5. Effect the number of carbon layers to the natural frequencies of the glass-carbon hybrid composite.

From the figure above, it can be seen that increasing the number of layers is followed by increasing the natural frequency of the composite. This phenomenon is happened due to the stiffness factors. The adding of the carbon layers will make the carbon-glass hybrid composite more strength and rigid. The rigid structure of a beam will have higher stiffness value. Higher stiffness value consequently will have a higher natural frequency. This phenomenon is proven by bending test of the carbon-glass hybrid composite that can be seen in Fig. 6.

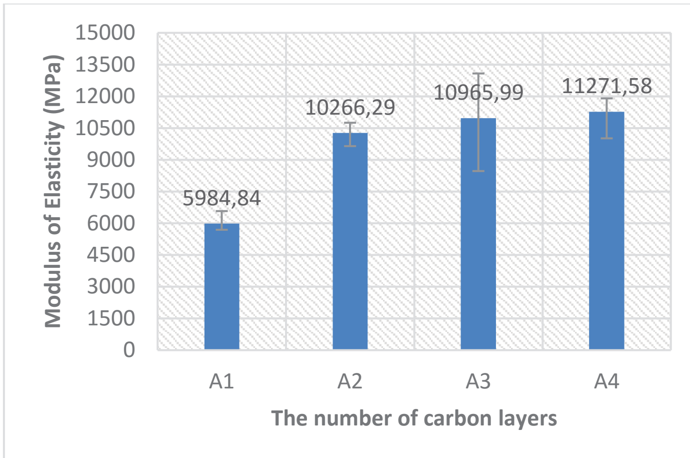

FIGURE 6. Elastic Modulus of glass-carbon hybrid composite at various number of carbon layers.

The bending test showed that the bending modulus of elasticity of composite hybrid with the number of carbon layer at most (variable A4) has the highest value, so the value of its natural frequency is the highest. While hybrid composite with the number of carbon layer at least (variable A1) has the lowest value, so that it has the smallest value of natural frequency.

The result of natural frequency and damping ratio showed in the opposite sense, where the value of highest natural frequency will have the lowest value of the damping ratio. This is shown in Fig. 7 below.

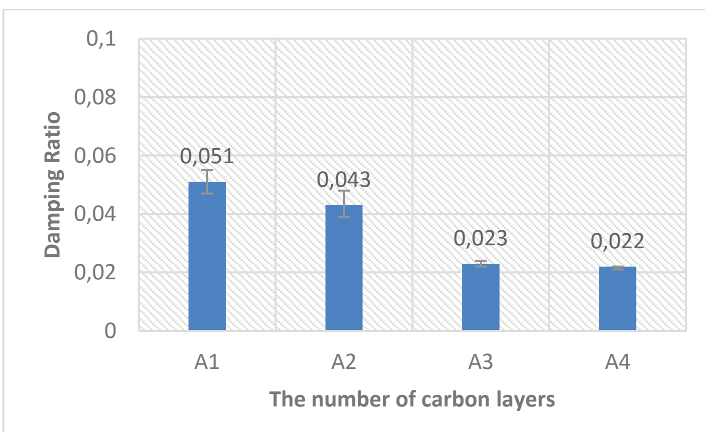

FIGURE 7. Effect the number of carbon layers to the damping ratio of the glass-carbon hybrid composite.

Figure 7 above shows the relationship of the number of carbon layers to the value of the damping ratio of composite hybrid. Damping ratio value influenced by the stiffness of composite, the higher of value the composite stiffness of damping ratio values would be lower, and so is the opposite.

The effect of carbon layers position to the dynamic characteristics of the carbon-glass hybrid composite can be seen in Figure 8 for the natural frequency and Fig. 9 for the damping ratio.

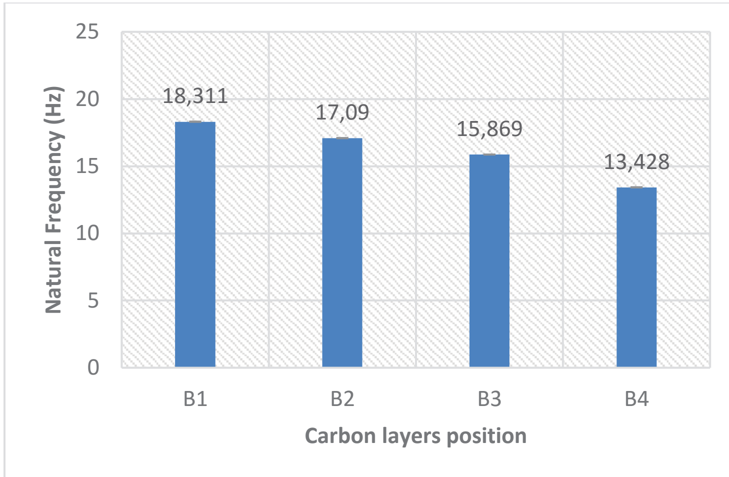

FIGURE 8. Effect of carbon layers position to the natural frequencies of the glass-carbon hybrid composite.

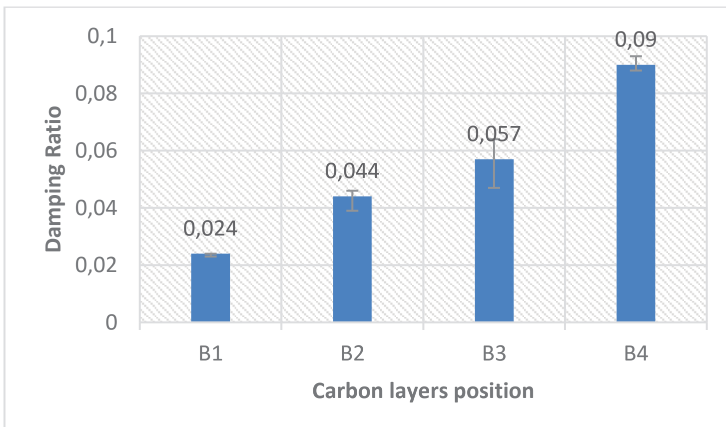

FIGURE 9. Effect of carbon layers position to the damping ratio of the glass-carbon hybrid composite.

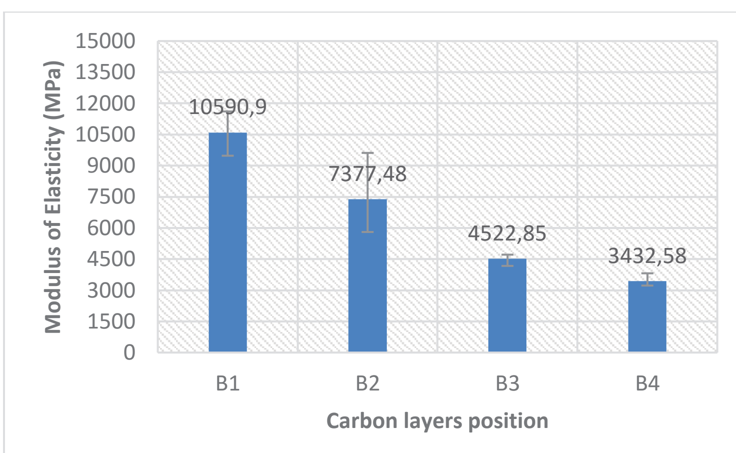

FIGURE 10. Elastic Modulus of glass-carbon hybrid composite at various carbon layers position.

The Figure 8 shows that carbon layers position in the outer layer or in the surface of the composite (B1 configuration) have the highest natural frequency value. While the lowest is the carbon layers position in the mid-plane (B4 configuration). In the other side, the B1 configuration has the lowest damping ratio value, and the B4 configuration has the highest damping ratio value. The position of the carbon laminate in the surface of the composite causes the ability of the structure to retain bending load better so that the composite stiffness will be higher. When the position of the carbon layers change toward the mid-plane, the bending load will be retained by glass layers that its bending strength is lower than the carbon layers [2] so the composite stiffness reduce. The rigidity of the composite also can be obtained from the bending test. The result of the bending test has an agreement with this work. It can be seen in Fig. 10.

CONCLUSIONS

This experimental work has been devoted to investigated the dynamic characteristics of the glass carbon hybrid composite. The resulting conclusions are as follows:

1. Increasing carbon layers in the carbon-glass hybrid composite will increase the natural frequency of the hybrid composite and decrease its damping ratio.
2. Changing the position of the carbon layer from the surface of the carbon-glass hybrid composite will decrease the natural frequency of the hybrid composite and increasing its damping ratio.

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