Reliable Damping Measurements of Solid Beams with Special Focus on the Boundary Conditions and Non-Contact Test Set-Ups

Ferhat Kadioglu, Ahmet Reha Gunay

Abstract—Correct measurement of a structural damping value is an important issue for the reliable design of the components exposed to vibratory and noise conditions. As far as a vibrating beam technique is concerned, the specimens under the test somehow are interacted with measuring and exciting devices and also with boundary conditions of the test set-up. The aim of this study is to propose a vibrating beam method that offers a non-contact dynamic measurement of solid beam specimens. To evaluate possible effects of the clamped portion of the specimens with clamped-free ends on the dynamic values (damping and the elastic modulus), the same measuring devices were used, and the results were compared to those with the free-free ends. To get clear idea about the sensitivity of the boundary conditions to the damping values at low, medium and high levels, representative materials were subjected to the tests. The results show that the specimens with low damping values are especially sensitive to the boundary conditions and the most reliable structural damping values are obtained for the specimens with free-free ends. For the damping values at the low levels, a deviation of about 368% was obtained between the specimens with free-free and clamped-free ends, yet, for those having high inherent damping values, comparable results were obtained.

Keywords—Vibrating beam technique, dynamic values, damping, boundary conditions, non-contact measuring systems.

I. Introduction

AERIAL and ground vehicles are subjected to the vibratory conditions during their service life, resulting in fatigue, noise, comfort and health problems that are not desired by the designers. A remedy to overcome these problems is to use the components with high structural damping in these vehicles. There have been many efforts to increase the damping values in the structures. For example, Prabhakaran et al. [1] investigated sound absorption and vibration damping properties of flax fiber reinforced composites and compared with the glass fiber reinforced composites. The experimental results suggested that the flax fiber reinforced composites could be a viable candidate for applications which need good sound and vibration properties. Sargianis et al. [2] explored and characterized the sound and vibration damping properties of natural material-based sandwich composites. It was experimentally observed that utilizing a balsa wood core with a natural fiber-based face sheet had a 100% improvement in coincidence frequency, a metric of acoustic performance, and the combination of a natural fiber-based face sheet with a synthetic core exhibited a 233% increase over a fully synthetic sandwich composite. Jeyaraj et al. [3], [4] studied the vibration and acoustic response of a composite plate and visco-elastic sandwich plate in a thermal environment with inherent material damping. They reported that the inherent damping reduces resonant amplitudes of vibration and acoustic response. Arunkumar et al. [5] analyzed vibro-acoustic response of honeycomb core sandwich panel with composite laminate facings and found that the inherent damping associated with composite facing reduces the resonant amplitudes and increases the sound transmission loss significantly. Petrone et al. [6] calculated experimentally the radiated acoustic power from the aluminum foam sandwich panel. Petrone et al. [7] attained an improvement in damping value by filling the wool fiber in core, thereby achieved the better acoustic performance in eco-friendly honeycomb cores for sandwich panels. It has been shown that the inherent damping in materials has positive impacts on their fatigue life [8], [9].

From the efforts mentioned above, it is obvious that correct damping measurements of the structures are a vital issue for a reliable design. Therefore, when a sample of the relevant structures is subjected to the experimental tests, all precautions must be taken as the test set-up has important effects on the measured values. As far as a vibrating beam test is concerned, a specimen under the test is quite likely to be interacted with measuring and exciting devices, and also with end conditions that bear possibility of extraneous damping values. There have been many works in literature related to such experiments, but a specific emphasize made on the values of possible extraneous damping is rare. For example, Attard et al. [10] conducted a series of vibration tests to quantify the damping properties of composite beams, either as self-standing composite laminates or as retrofitting materials for structural substrates. The specimens were supported horizontally in a clamped-clamped end conditions, and a laser vibrometer was used to measure velocity-time histories of the test beams. Forced vibration tests were performed using an electromagnetic shaker. Banded white noise excitations with peak acceleration amplitudes of 0.3 g and 3 g were used to excite the beam specimens. Two accelerometers were mounted on the shaker base to ensure that the actual excitation signal complied with the desired input signal. Rafiee et al. [11] used a vibrating beam technique to measure the natural frequencies and damping factors of nanocomposite specimens in the form of cantilever beams. The

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clamped-free beam was excited by a vibration shaker at the clamped end, and the response of the beam was tracked by means of accelerometers and the computed frequency response functions (FRFs) gave information about the natural frequencies of the composite beams. To study the vibration behavior of the composite and sandwich beams, free vibration tests were carried out by Monti et al. [12]. The beams were tested in a clamped-free configuration and excited by an impact hammer close to the clamped end. The displacement of the free end was measured by a laser vibrometer. The experiment set-up created by Sargianis and Suhr [13] involved a beam with clamped–clamped end conditions. An electrodynamic shaker with an impedance head attached to it to measure the input force was excited with a random noise signal ranging from 20 to 4000 Hz. A micro-accelerometer with a mass of 0.6 g was used to measure the FRF at the equidistant points along the beams. In another work [14], an experimental set-up included an excitation force applied centrally on the plate via an electromagnetic shaker attached to the plate using glue, and an accelerometer was glued to the surface of the plate to record the response. Arunkumar et al. [15] used an electrodynamic shaker to vibrate a honeycomb structure fixed at the bottom in the center by a clamping system, and an accelerometer was mounted on the honeycomb structure to get the response. In another work, beam specimens from the carbon fiber reinforced polymer (CFRP) laminates and nanocomposite plates were tested in both the free vibration and forced vibration. In the free vibration test, the specimens with clamped-free end conditions were used, while the free end was deflected to a desired displacement before release. The resulting vibration response was continuously monitored using the accelerometer attached to the tip of the specimen, which was stored in a digital storage cathode ray oscilloscope [16]. A modal analysis was carried out using experimental test set incorporating the specimens with clamped-free ends. The specimens were vibrated by giving the excitation using an impact hammer, and the response was obtained using an accelerometer [17]. A dynamic mechanical analysis was performed on composite specimens to provide a clamp-free measurement using a non-resonant damping experiment. Also, vibration beam measurements were conducted to allow measurement of resonant damping at very large amplitudes, identify many modes of vibration and the study of a broad frequency range. The test was performed on the clamped-free beams with a pre-defined deflection and the response was obtained with a laser displacement sensor. Accelerometers were mounted to the free edge and to the shaker for controlling purposes [18]. For another test, a strain gauge was glued on the specimen vibrated with a shaker and connected with the data acquisition system to receive data [19].

More references can be given [20]-[25] for similar experiments but one common conclusion coming out is clear; all the instruments attached to the specimens are likely to affect the dynamic values. Namely, any exciting and/or measuring device such as accelerometers, shakers and strain gauges attached to the specimens under the vibration test is believed to contribute to the measured damping values. Similar situations would be the case for the specimens with fixed (clamped) ends. Despite this fact, any study on the specimens with non-contact measuring device, and also with free-free ends is quite limited.

The aim of this study is to propose an experimental set-up to be able to measure reliable damping values of specimens subjected to a vibrating beam technique. For this purpose, first, the specimens with free-free ends were vibrated using non-contact measuring and exciting test devices to make sure the specimens were isolated as much as possible. Then, with the same experimental devices, the same specimens were tested using clamped-free end conditions to evaluate any potential extraneous damping value in the clamped part. The specimens were classified into three different categories to see the impact of the extraneous values on the structural damping of the specimens: Category1- those with low structural damping values, category2- those with medium values, and category3- those with high values. The analytical formulations as well as solutions relevant to the boundary conditions have also been presented to calculate the dynamic values (damping and flexural modulus) of the specimens used.

II. Experimental Works

A. Materials and Specimens Used

To be able to see sensitivity of the specimen's damping value to the boundary conditions and the two test techniques, the specimens were classified into three different categories which can be seen in Fig. 1; category1- the Specific Damping Capacity (SDC) values up to 2%, called the specimens with low damping, category2- the SDC values between 2% and 5.5%, called those with medium damping, and category3- the SDC values above 5.5%, called those with high damping. It is important to note that the set-up with free-free boundary conditions was considered for this classification as this set-up was found more reliable compared to that with clamped-free boundary conditions, especially the case for measuring the specimens with low damping values. For this purpose, the specimens were manufactured from three different materials, a 2024-T3 aluminum alloy, a glass fiber-reinforced polymer matrix composite, and a carbon fiber-reinforced epoxy matrix composite. For the specimens with low damping category, the 2024-T3 aluminum alloy (Al), the glass fiber-reinforced prepregs with longitudinal (0°) directions (designated as GFL specimens), and the woven carbon fiber-reinforced prepregs with longitudinal directions (designated as CFL specimens) were selected. While for those with medium damping category, the glass fiber-reinforced prepregs with ± 10° (GF10), ± 20° (GF20, and ± 35 (GF35), for those with high damping category the glass fiber-reinforced prepregs with ± 45° (GF45), ± 80° (GF80), and the woven carbon fiber-reinforced prepregs with ± 45° (CF45) were selected. For the glass fiber-reinforced specimens, the composite plates with 10 layers, Hexply 913/33%/UD280, produced by Hexcel, were cured according to the manufacturer's data sheet, 130 °C for 120 minutes under a pressure of 5 bars, and machined to required dimensions of beams. For the carbon fiber-reinforced specimens, the beams manufactured from a prepreg of woven carbon fiber-reinforced epoxy matrix composite, Hexply 8552S/A280-5H, produced by

Hexcel, were cured at 120 °C for 120 minutes, after an initial heating-up procedure of 80 °C for 90 minutes under a pressure of 5 bars.

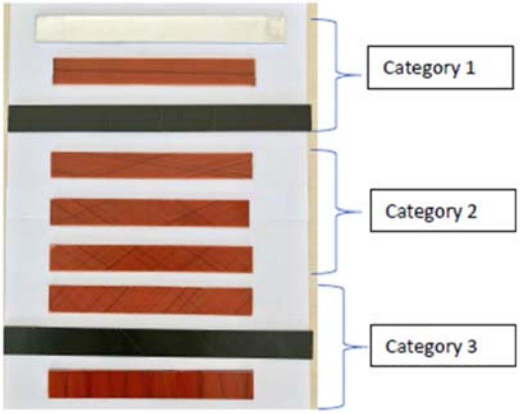

Fig. 1 A representative of specimens from each category used for the vibration tests

TABLE I
DETAILS OF THE SPECIMENS USED FOR THE DYNAMIC EXPERIMENTAL WORK.

Specimens	Width (mm)	Thickness (mm)	Length (mm)	Mass (g)	Density (kg/m^3)
Al	26.10	1.97	250.0	35.42	2755.50
CFL	25.37	2.31	301.0	27.22	1543.10
GFL	25.44	1.909	202.8	17.70	1797.46
GF10	24.98	1.873	200.4	16.68	1778.91
GF20	24.97	1.842	196.5	16.24	1796.58
GF35	24.89	1.853	200.1	16.52	1789.72
CF45	25.60	2.32	301.5	27.28	1523.45
GF45	25.64	1.937	200.5	17.62	1769.14
GF80	25.65	1.958	199.4	17.50	1747.68

The specimens were machined from the plates, and the details of the specimens for the vibration test are shown in Table I. All the tests were carried out under a controlled environment, at room temperature (23 ºC) and 50% relative humidity, to avoid environmental effects on the specimens, and four specimens of each type were tested to see if the results were repeatable.

B. Experimental Set-Up with Free-Free end Conditions

A detail about the two dimensional (2-D) vibrating beam test set-up with a configuration of free-free ends is shown in Fig. 2. It is seen from the test that an electromagnetic shaker connected to the power amplifier is used to produce sinusoidal motion. The response from the beam is detected via a laser doppler (laser head) placed above the specimen. The input and output signals together are connected to an oscilloscope to observe the resonant frequency at which all measurements are made. In vibrating the specimens, a non-contact mechanism was aimed, which has been detailed in the three-dimensional (3-D) drawing, Fig. 3. For this purpose, a thin plate with an area of 4.6 cm^2 was glued to the top of the shaker, and when it was vibrated, the plate was able to produce a sinusoidal induced air flow and so to vibrate the specimen. It is believed that a true damping measurement of a material could be achieved by such a mechanism since there is no direct a contact between the shaker and the specimen during the excitation or between the specimen and the laser head during response pick-up. In this way, it was possible to isolate the specimens from the measuring and exciting devices that were parts of experimental set-up. It is also important to note that the specimen under the test should be placed at the exact nodal positions that is crucial for the correct measurements, too. For the current study, all the measurements were made at the first (fundamental) natural frequency, so the first mode shape, and this case, the specimen beams with length l were placed on the ropes connected to the U-shaped mobile supports shown in Fig. 3. For the first mode, 0.224l of the beams were placed at the theoretical nodal positions, distances from the free ends.

C. The Experimental Set-Up with Clamped-Free End Conditions

The experimental set-up for the specimens with clamped-free boundary conditions is shown in Fig. 4.

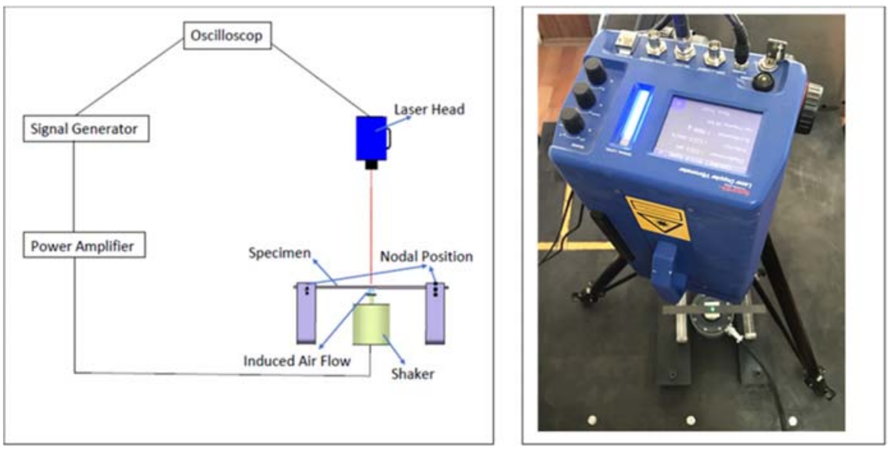

Fig. 2 A representative 2-D illustration of the vibrating beam test with free-free end conditions

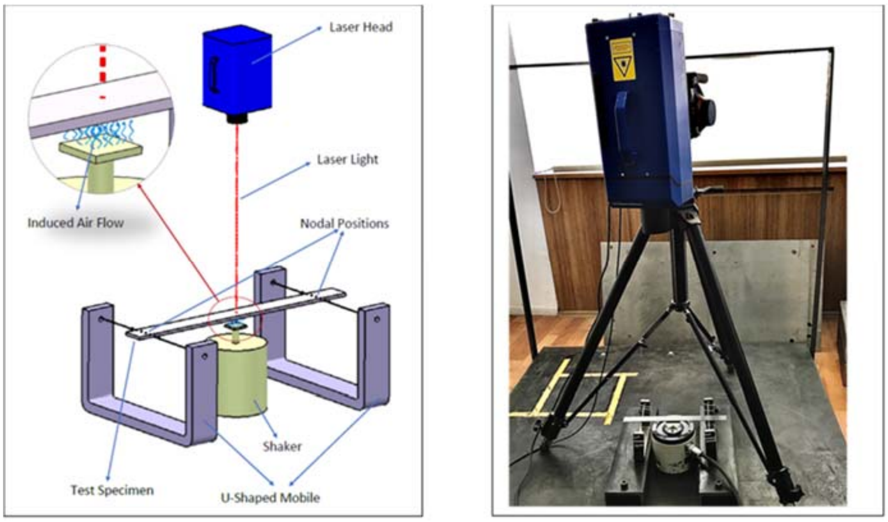

Fig. 3 A representative detailed 3-D illustration of the vibrating beam test with free-free end conditions

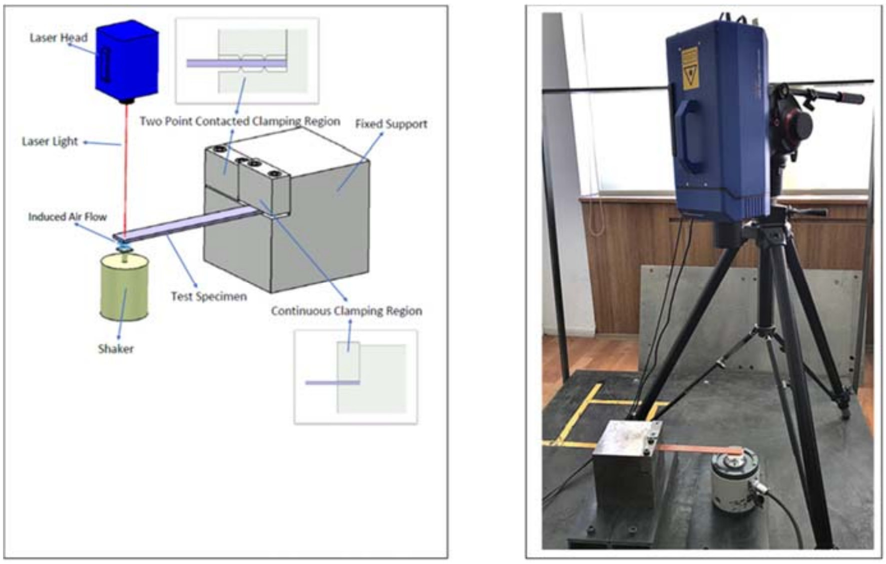

Fig. 4 A representative 3-D illustration of the vibrating beam test with clamped-free end conditions

The same measuring and exciting devices (with non-contact mechanisms) were used as for those with the free-free ends. The main reason to conduct this test is to be able to evaluate the potential extraneous damping value from the clamping part of the specimen. As indicated in Fig. 4, two different types of clamping region were prepared to get a better insight; 1- a 28 mm-continuous clamping region where there was a constant interaction of fixed support with the specimen's clamped part, and 2- a clamping region with two-contact points where there were two different points of interactions of the fixed support with the specimen's clamped part. It is important to note that the specimens subjected to the vibration tests were tightened firmly in the clamping region to avoid any undesired effects, and the fixed support from the mild steel had enough weight to provide a viable clamped condition.

III. Theory

A. Measurement of Flexural Modulus

For every solid obeying Hook's Law, there is a specific natural frequency which is a function of its elastic modulus, geometry, density and the mode number. The natural frequency of a beam, f_n, is found as [26]:

$$f_n = \frac{1}{2\pi}\left(\frac{\lambda_n}{l}\right)^2\sqrt{\frac{EI}{\rho t b}} \quad (1)$$

where $\lambda_n = 1.875$ is the 1st eigenvalue for clamped-free end conditions, and 4.73 for the free-free boundary conditions, n is the mode number, E is the flexural modulus, I is the second moment of area, l is the length, ρ is the mass density, t is the thickness, and b is the width of the beam. The flexural modulus of the specimen was measured using (1), and only the first (fundamental) mode was taken into account for all the measurements.

B. Damping

For an elastic solid structure, damping is defined as the conversion of mechanical energy into thermal energy, and it is defined in a number of different, yet related ways [26]. In this study, the half-power bandwidth method was used for measuring the damping values, which is determined from the curve of velocity amplitude against frequency. The 'half-power bandwidth' is (f_2-f_1) where f_2, f_1 are the frequencies at which the amplitude falls to 1/√2 of its maximum value, reached at f_n, the resonant frequency (see Fig. 5). The loss factor, η is defined as,

$$\eta = \frac{f_2 - f_1}{f_n} \quad (2)$$

For convenience, damping is usually presented in SDC, ψ, which is defined as the ratio of the energy dissipated per cycle to the maximum elastic energy stored per cycle, per unit volume [27]. This ratio is usually expressed as a percentage.

For small damping, it is known that the relationship between the loss factor and SDC is as follows [26],

$$\psi = 2\pi\eta \; x \; 100 \quad (3)$$

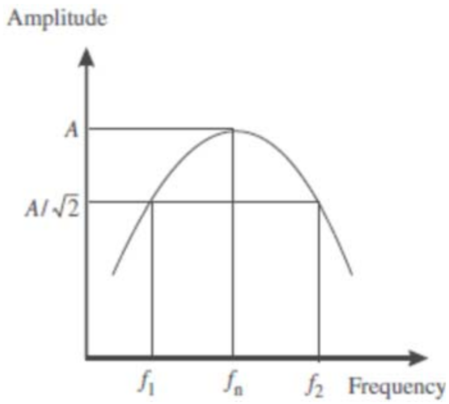

Fig. 5 Definition of damping for loss factor

IV. Results and Discussion

First, validation of the test was made with respect to the non-contact experimental set-up used in Figs. 3 and 4. For this purpose, the aluminum specimens considered to have well established data in the literature were subjected to the vibration tests, and their values presented through Figs. 6-8 are evaluated here to interpret the remaining results with confidence. The 2024-T3 aluminum alloy specimens were machined in the form of beams with dimensions of 250 mm length, 26.10 mm width and 1.97 mm thickness, and with a mass of 35.42 gr and a density of 2755.5 kg/m^3. The specimens with free-free ends and also with clamped-free ends were subjected to the vibration tests shown in Figs. 3 and 4, respectively. While the former gave a first natural frequency of about 164.30 Hz and a flexural modulus of about 70.86 GPa, the latter gave a value of about 30.20 Hz and 69.50 GPa. It was found that the elastic modulus (70.86 GPa and 69.50 GPa) obtained is consistent with the those obtained from the literature [28]. This gave a confidence about the values obtained from the non-contact experimental set-up explained above. On the other hand, the value of SDC was about 0.47% for the specimens with the free-free ends, and about 2.2% for those with the clamped-free ends. It was found that the latter gave more than 4.6 times greater values compared to the former. These results make the set-up with clamped-free boundary conditions questionable; that is especially true for the specimens with relatively low SDCs. These values were obtained from the continuous clamping region where there was a constant interaction of fixed support with the specimen's clamped part. For comparison reasons, the tests were also conducted using the clamping region with two-contact points where there were two different points of interactions of the fixed support with the specimen's clamped part (see Fig. 4). In this case, SDC was about 1.98% that was about 10% decrease in the value. However, it was found that the two-contact clamping region could cause some local failure in the specimens due to the concentrated contact loading, therefore, this type of clamping region was not used any more. Briefly, the remaining results to be discussed will be from the free-free boundary conditions and also from the continuous clamping region.

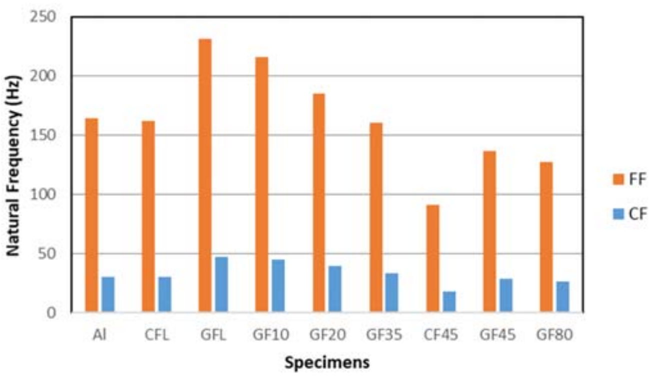

Fig. 6 The experimental first (fundamental) natural frequencies of the specimens with free-free (FF) and clamped-free (CF) boundary conditions

Fig. 6 represents the experimental first (fundamental) natural frequencies of the beams with free-free and clamped-free boundary conditions, respectively. As expected, fiber orientations and the dimensions of the specimens play important part on the values; while the higher values are from the specimens with low angles of the orientations (i.e. 0^0 and ± 10^0), the lower ones from those with the higher angles (i.e. ± 45^0 and 80^0). And also, the specimens with relatively short lengths give relatively higher natural frequency values, compared to those with relatively longer lengths. In general, the frequency values of the beams with free-free ends are higher than those with clamped-free ends, which is related to (1); while all the parameters affecting the natural frequency are the same, only the eigenvalue for the end conditions are different. While the values of the frequency for the specimens with free-free end are about 164 Hz, 162 Hz, 231 Hz, 216 Hz, 185 Hz, 61 Hz, 30

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Hz, 137 Hz and 127 Hz, those with clamped-free ends are about 30 Hz, 30 Hz, 48 Hz, 45 Hz, 39 Hz, 34 Hz, 96 Hz, 29 Hz and 26 Hz, respectively.

Through Figs. 7 (a)-(c), a comparison of the flexural modulus values from the beams with the two different end conditions, free-free and clamped-free, can be seen. Overall, the values of modulus are in agreement with respect to their angles of fiber orientations considering the composite specimens. The higher values are obtained from the specimens with the small angles (i.e. 0^0 and $\pm 10^0$), but the lower are from the higher angles (i.e. $\pm 4\ 5^0$ and 80^0), similar tendency to the results of the natural frequency. The modulus values are about 45 GPa, 39 GPa, 28 GPa, 22 GPa, 15 GPa and 14 GPa for the glass fiber-reinforced composite beams with 0^0, $\pm 10^0$, $\pm 20^0$, $\pm 35^0$, $\pm 45^0$ and 80^0 fiber orientations, respectively. The modulus values for the carbon fiber-reinforced CFL and CF45 specimens are about 59 GPa and 17 GPa, respectively. It is clear that the specimens with free-free and clamped-free ends give consistent results for all the categories (1, 2 and 3) described in Section II *A* and in Fig. 1, and the maximum deviation between the both end conditions (free-free and clamped-free) is about 2%, the case for the GF10 specimens. At least four specimens for each type were tested and a variation of less than 1% was obtained in the results that were repeatable fairly.

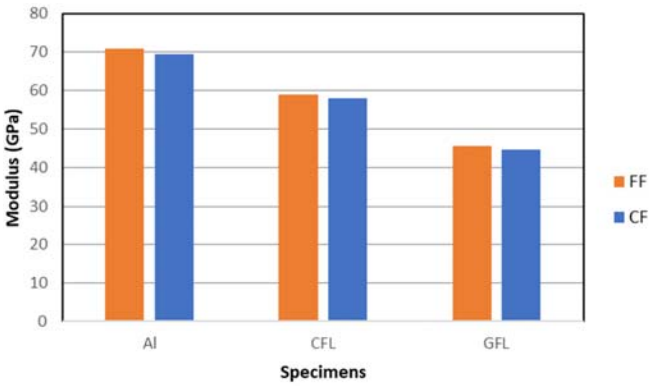

Fig. 7 (a) A comparison of flexural modulus results of category 1 specimens from the free-free (FF) and clamped-free (CF) ends boundary conditions

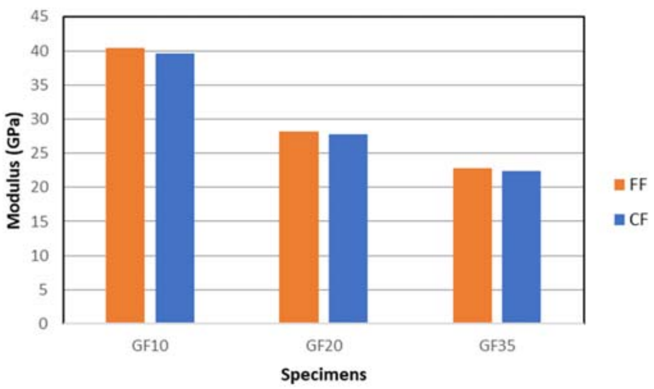

Fig. 7 (b) A comparison of flexural modulus results of category 2 specimens from the free-free (FF) and clamped-free (CF) ends boundary conditions

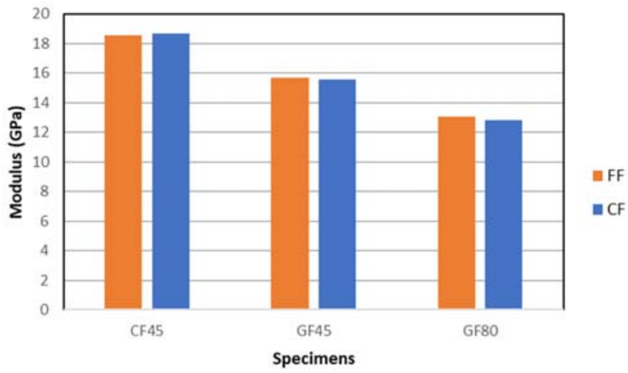

Fig. 7 (c) A comparison of flexural modulus results of category 3 specimens from the free-free (FF) and clamped-free (CF) ends boundary conditions

Figs. 8 (a)-(c) show a comparison of the SDC values of the specimens with free-free and clamped-free ends. The values of the specimens with the free-free ends in category1 that is Al, CFL and GFL are about 0.47%, 1.17% and 1.25%, respectively. On the other hand, the values from the same specimens with clamped-free ends are about 2.2%, 2.12% and 1.98%, respectively (see Fig. 8 (a)). The difference in the values of the specimens in category1 is quite large, and the latter end conditions give quite high values of SDC. The increases in the damping values are about 368%, 81% and 58% in comparison with the former end conditions for the Al, CFL and GFL specimens, respectively.

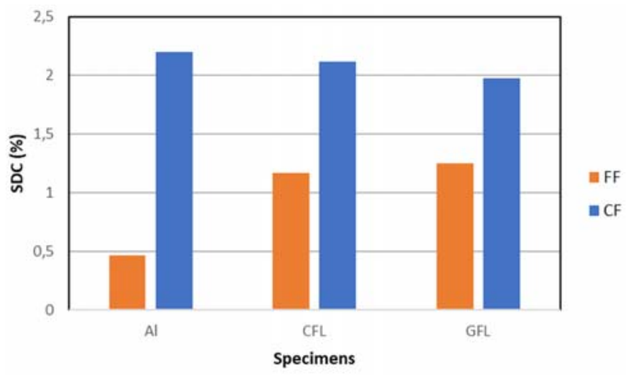

Fig. 8 (a) A comparison of SDC results of category 1 specimens from the free-free (FF) and clamped-free (CF) ends boundary conditions

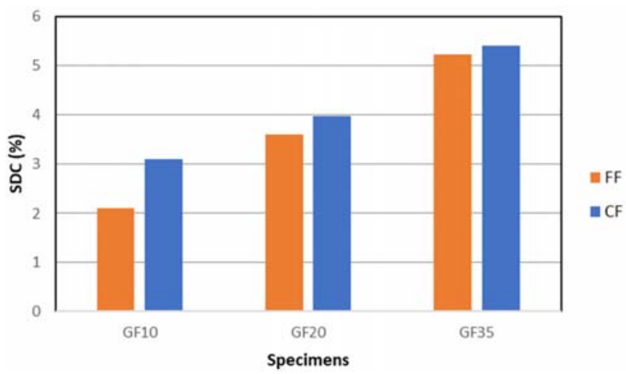

Fig. 8 (b) A comparison of SDC results of category 2 specimens from the free-free (FF) and clamped-free (CF) ends boundary conditions

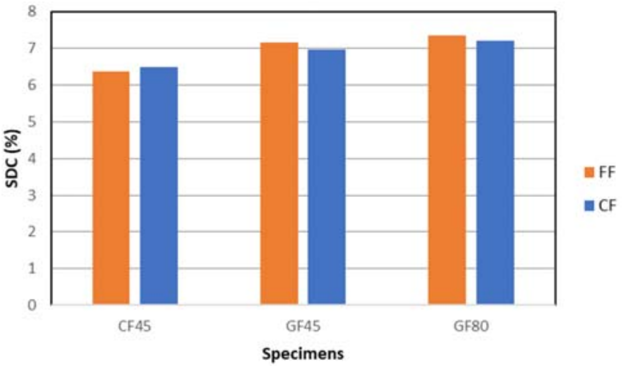

Fig. 8 (c) A comparison of SDC results of category 3 specimens from the free-free (FF) and clamped-free (CF) ends boundary conditions

From Fig. 8 (b), it is seen that the difference in the damping values of the specimens in category2 (GF10, GF20 and GF35) is not much, although the those with clamped-free ends are relatively higher, too. While the values of those with free-free ends are about 2.11%, 3.60% and 5.23%, those with clamped-free ends have about 3.1%, 3.98% and 5.4%. The difference in the SDC is about 47%, 11% and 3%, respectively. It is important note that as inherent damping values are getting increase, the difference between the both end conditions (free-free and clamped-free) decreases. This can be seen clearly in Fig. 8 (c) that is for the specimens in category3 (CF45, GF45 and GF80). The values of the SDC are about 6.4% and 7% and 7.3%, respectively. The maximum difference between the values from the both boundary conditions is only about 2% that is GF45 specimen. It is clear that all the results in category3 are comparable, and that the difference can be ignored.

The results have been obtained through the experimental set-ups shown in Figs. 3 and 4 that are able to vibrate the specimens via an induced air flow, a non-contact exciting mechanism. The measuring instrument selected to pick up the response from the vibrating beam has also a non-contact feature, a laser head. It is believed that a correct (reliable) damping measurement of structures is possible to obtain in this way because such a set-up is able to isolate the specimen under the test from its surrounding as much as possible.

It is seen from Fig. 8 (a) that the damping values are sensitive to the end conditions if the inherent value of a structure is low. For instance, the SDC values of the specimens in category1 deviate nearly 368%, 81% and 58% for Al, CFL and GFL, respectively, if the free-free ends are compared with clamped-free ends. Here, the fixed (clamped) part of the specimen creates some extraneous damping values that make the specimens with the low damping values questionable if the clamped ends are to be used. Although not as much as the specimens in category1, the deviation is still the case for the composite beams in category2, $\pm 10^0$ (GF10), $\pm 20^0$ (GF20) and $\pm 35^0$ (GF35), whose basic properties are controlled mainly by the glass fibers. It is well known that the specimens controlled by the mechanical properties of the fiber constituents have relatively high strength but low damping values, which is opposite to those controlled by the matrix constituent that presents high damping but low strength values. In line with this context, the experimental set-up with the free-free end conditions is able to provide reliable values for the specimens with 0^0, $\pm 10^0$, $\pm 20^0$ and $\pm 35^0$ fiber orientations compared to those with the $\pm 45^0$ and 80^0 orientations that are controlled by the properties of the matrix. This is also true for the CFL and CF45 specimens; while the former is controlled by the fibers, the latter is by the matrix. It is also believed that the experimental set-up with clamped-free end conditions is not able to produce reliable damping data especially for the high strength metals, too, as the current work has proven the deviation between the two end conditions (free-free and clamped-free) is too large that is 368% for the aluminum (Al) specimens. On the other hand, it is clear that there is no superiority of the free-free ends over the clamped-free ends as they both give consistent results for the specimens with high damping. In overall, it is fair to claim that the specimens with high inherent damping values, say more than 6% SDC, can be subjected to the vibrating beam technique with either free-free or clamped-free end conditions as they both produce comparable and reliable damping data. However, as the inherent damping values of structures are getting lower, the sensitivity of these values to the boundary conditions are getting large, especially the case for the specimens in category1 (low damping).

In spite of the effects of the boundary conditions on the damping values of the specimen beams, the results of flexural modulus presented in Figs. 7 (a)-(c) do not seem to be affected by the boundary conditions, considerably. The maximum difference between the two test set-ups is about 2% for the different categories of the specimens. For example, the value of the modulus for the aluminum specimens is about 70 GPa for the both end conditions, in spite of a large difference in the damping values.

It is important to note that any exciting and/or response measuring devices such as accelerometers, strain gauges etc. attached to the specimens under the vibration test are likely to affect their dynamic (damping and elastic modulus) results leading to much more complex calculations as existence of the each attached device introduces an extraneous mass on the specimens. Contrary to this, the experimental set-ups presented in Figs. 3 and 4 allow a straightforward calculation of the dynamic values of each specimen under the test.

V. Conclusions

The current study shows that the specimens with low damping up to 2% SDC should be subjected to a vibrating beam technique with free-free end conditions because the test with clamped-free ends is not able to provide correct/reliable data. This is especially true for the fiber-reinforced polymer composites mainly controlled by their fiber constituent; having high stiffness but low damping values. This is also the case for high strength metals. On the other hand, for the specimens with over 5.5% SDC, the tests with the free-free and also with the clamped-free ends conditions can be used as they both are able to produce reliable data. The correct damping values are mainly based on the exciting and picking up measuring devices, and also on the boundary conditions, as the case for the current study.

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