Empirical Estimation of modal Performance of Metallic laminates Supported by Composites

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Abstract

Most industries effort strive for gathering metallic with composite to produce designs which are safe and effective. This study examines the dynamic response of metal plates as well as the effects of composite reinforcement. Modal testing was conducted to ascertain impact on treating various sheets with various lay-ups composite. Structures' stiffness and damping qualities might alter because of this reinforcement. Fiber may manage such reinforced plates stiffness whilst damping features result from the matrixes viscoelastic nature. The specimens are put during vibration testing and experimentally derived modal factors. This study demonstrates how changing stiffness and damping features possibly be achieved by employing composite materials.

Keywords: industries**,** metal, composite materials, dynamic response**,** stiffness, damping features**.**

الملخص

تسعى معظم جهود الصناعات جاهدة لجمع المعدن مع المواد المركبة لإنتاج تصميمات آمنة وفعالة. تبحث هذه الدراسة في الاستجابة الديناميكية للألواح المعدنية بالإضافة إلى تأثيرات التقوية بالمواد المركبة. تم إجراء اختبار الاهتزاز للتأكد من تأثير التقوية بالمواد المركبة مختلفة الاتجاهات على الصفائح المعدنية. قد تتغير خصائص التخميد وصلابة الهياكل نتيجة لهذ التقوية. قد تتحكم الألياف في صلابة الصفائح المقواة في حين أن ميزات التخميد تنتج عن طبيعة لزوجة المادة اللاصقة. يتم وضع العينات في اختبار

الاهتزاز لأثبات عوامل الاهتزاز بالتجربة العملية. توضح هذه الدراسة تغيير الصلابة والتخميد باستخدام المواد المركبة.

الكلمات المفتاحية: الصناعات، المعادن، المواد المركبة، الاستجابة الديناميكية، الصلابة، ميزات التخميد.

1. Introduction

All dynamic action contains stiffness, mass and damping qualities is affected by the collection of different variables. Numerous investigations conducted to find damping qualities on layered plates due to the viscoelastic characteristics of the composites [1–5]. Laminate beams were analyzed in vibration tests, that showed the damping capability of composite beams has superior strength compared to metals [6-11]. There have been several research focus on characterizing symmetrically composite, analyze stiffness and damping, it is expected that the composite laminate and all of its components would respond linearly viscoelastically [12–18]. Elastic-viscoelastic matching concept is considered being appropriate as a result [19–21]. Many methods for passively governing vibration for metallic [8] including damped free layer [16], dampening in a confined layer, as well as many layers dampening [13,14,19,20-23]. Such methods primarily employ viscoelastic nature of layers to increase damping by dissipating strain energy [24] under dynamic loadings and vibrations. These methods have certain drawbacks too, including the fact that the weight penalty occurs without recovering stiffness. Composites with a polymer matrix can gain both rigidity and dampening characteristic. Research on hybrid layups using various asymmetric composites is even less thorough according to an analysis of earlier research efforts for stiffness and damping. Our goal is to describe both stiffness and damping processes in hybrid composites made of aluminum plates and polymer matrix composites in this work. To maximize the rigidity and damping of metallic panels this fabrication is advised. This work also looks at the reinforcements that lead to asymmetric lay-ups. Natural frequencies and modal damping will be determined by using methods of extracting modal parameters.

2. Literature Survey

Damping in composite materials is presented [25], which includes a chronological review of test methods for damping estimation. New material configurations such as nano-composites, hybrid laminates, and sandwich materials are also discussed, and damping models specifically meant for non-homogeneous materials are addressed. The paper is concluded by summarizing the authors' ideas on needed steps to advance the state-of-the-art in each of the described topics. Various research methods and theory calculation models that are employed in engineering to study the static and dynamic vibration characteristics of viscoelastic damping material (VDM) formed structures is presented [26]. The review classifies traditional VDMs by their physical properties, application fields, and calculation methods. A thorough description and comparison between conventional and improved methods, and their applicability, and the advantages and disadvantages of each calculation theory in engineering structures that contain VDM are sequentially illustrated. VDM mathematical models in previous studies are then described and compared. Finally, the future development of VDM and its composites is discussed. A study on the vibration damping properties of composites made up of carbon fibers and a novel liquid Methylmethacrylate (MMA) thermoplastic resin is presented [27]. The damping performance of this composite system is compared with a traditional carbon fibers/epoxy resin composite system by the authors. The study includes dynamic mechanical analysis (DMA) tests and vibration tests to evaluate the damping capacity of the composites. The influence of the reactive liquid MMA resin and the thin plies in dampening the vibrations is also discussed by the authors. The design and experimental investigation of empty and foam-filled corrugated sandwich cylindrical panels (CSCPs) made of carbon fiber composite are discussed [28]. The aim is to improve the vibration damping behavior of these structures without adding too much weight. Finite element analysis (FEA) models are also used by the authors to study the effects of various design parameters on the modal properties of the CSCPs. Natural fiber-reinforced polyester hybrid composites are reviewed [29], with a focus on the vibration behavior of jute/roselle fiber-reinforced unsaturated polyester hybrid composites. The study involved the fabrication of 12 types of hybrid composites with different layering sizes and sequences, and the comparison of their natural frequencies and damping properties through experimental and numerical analyses. It was found that the natural frequency and damping ratio of the hybrid composites were significantly affected by the layering sizes and sequences. The natural frequencies of isotropic beams are mentioned, and an equation for calculating them is provided [30]. The use of rectangular cross sections in calculating natural frequencies is also discussed by the authors. The decay of displacement and velocity in a one-degree-of-freedom system with viscous damping is mentioned, and equations for describing this decay are provided. The effect of longitudinal ribbon reinforcement in conventional honeycomb structures on the dynamic characteristics of a hybrid composite sandwich plate is investigated [31]. Numerical and experimental methods are used to evaluate the stiffness, damping, and transverse vibration displacements of the ribbon reinforced hybrid composite sandwich plates. The governing differential equations of motion are derived using higher order shear deformation theory (HSDT) and solved numerically using a four-noded rectangular finite element. Experimental investigations are performed to evaluate the shear and loss moduli using the alternative dynamic approach. The efficacy of the developed finite element formulation is demonstrated by comparing the experimental and numerical results obtained in terms of natural frequencies and loss factors for the various prototypes of honeycomb composite sandwich plates. The vibration behavior of aluminum alloy 5083-reinforced nanoclay-montmorillonite nanocomposites is discussed [32]. The aim of the study is to improve the dynamic properties of the composite without affecting its mechanical properties. The composite samples were fabricated using the stir casting method with varying weight percentages of nanoclay. The results show that the natural frequencies of the composite increase with the addition of 2 wt% of nanoclay. It is concluded in the study that the addition of nanoclay can improve the vibration behavior of the composite without affecting its mechanical properties. The use of hybrid carbon fiber reinforced plastics-elastomer-metal laminates for damping vibrations in lightweight structures is discussed [33]. Modal analysis was conducted on various specimen geometries by the authors to investigate the influence of elastomer modulus and thickness, fiber orientation, and temperature on the damping behavior. An analytical model was used to predict the damping behavior, and the results were compared to the experimental data. The need for reducing the vibration response of composite laminates used in automotive and aerospace applications is discussed [34]. The paper aims to identify the damping properties of a commercial viscoelastic material that can be embedded and cured between the layers of composite laminates to reduce the severity of vibrations. The effects of the viscoelastic material on the modal parameters of carbon/epoxy thin panels are quantitatively assessed through experimental modal analysis. It is concluded that the investigated material is a promising solution for reducing the severity of vibrations in composite panels. It is concluded from all this that the previous researches were not experimental, and most of them were mathematical and simulated by different software, that is why we will conduct practical experiments during this study instead of theoretical studies.

3. Methodology

3.1 Impact on the Stiffness Property

Even though mass of laminates has a substantial position in layout, such work examines their stiffness and damping capabilities. As a result of natural frequency is a component of rigidity and mass properties, the stiffness possessions may be determined from the natural frequency [35], for example, given similar orientation, the material with lower natural frequency implies greater flexibility and a less stiffness. This study applies a glass/epoxy laminates to an aluminum 2024-T3 with dimension 150 mm X 150 mm. composites stiffness and damping may be altered by altering fiber volume percentage, fiber direction, layering order and fabrication method.

3.2 A Damping Property's Impact

In order to build structures for the automotive and aerospace industries, vibration damping has become a crucial necessity. When designing structures that are being vibrated close to resonance when being subjected to sudden stress, resonance amplitudes must be minimized in order to increase fatigue life. Particularly due to its lack of density & outstanding stiffness & damping properties, polymer composites have garnered attention on creation structural materials that have been dampened. Viscoelasticity is a property of all structural materials to some extent, and the degree of this behavior is frequently influenced by external factors like temperature [36]. For instance, viscoelastic effects manifest themselves at increased temperatures approaching half the melting point, even if architectural steel or aluminum could be basically elastic at ambient temperature. At ambient temperature, polymeric materials exhibit viscoelasticity which intensifies as temperature reached glass transition point. The damping characteristics under vibration are typically minimal in metallic constructions with poor viscoelastic capabilities, while polymer materials have opposite feature and composites have a significant quantity of this property.

4. Modal Analysis

Surface preparation is necessary before attaching polymer matrix composites to metallic panel. These preparations combine mechanical and chemical processes. Before to and next mechanical treatment these preparations are made by utilizing a solvent for the chemical preparation. Mechanical approach was done by introducing scrape and enhancing exterior quality by sandblasting technique to provide the best level of adhesion between metal and composite. These particular evaluations involve conducted with B&K vibration analysis apparatus shown in figure 1. Distributed spots designated adverse side of a laminate of every check are where the output or reply recording of such excitations is placed. The dynamic analyzer counted frequency response function. After acquiring frequency response function, it remains in computer furthermore converted to an ASCII format with real and imaginary data. The particular result filled out in MATLAB software (The modal parameters extraction technique, rational fraction polynomial, was used to approximate the frequency response function of a system using a polynomial function. The function was then expressed as a ratio of two polynomials, which could be used to extract the modal parameters of the system). Entire of aluminum 2024-T3 plates underwent treatment with glass-epoxy composites. The metallic components are 150 mm X 150 mm in size and have a 2.3 mm thickness. Four reinforced laminates are investigated, and a metallic plate lacking reinforcement is tested to assess effect of reinforcement. The free-free plate approach is the most often used external mounting technique. Two nylon threads hang the plate at its nodes as shown in figure 1. The accelerometer was used in the experiment, and it was positioned at the plate's corner, which is the anti-nodal position. Using a modally tuned hammer, the excitations were produced. The spectral function of an accelerometer used to stimulate external vibration modes was applied to specify natural frequency and damping parameter.

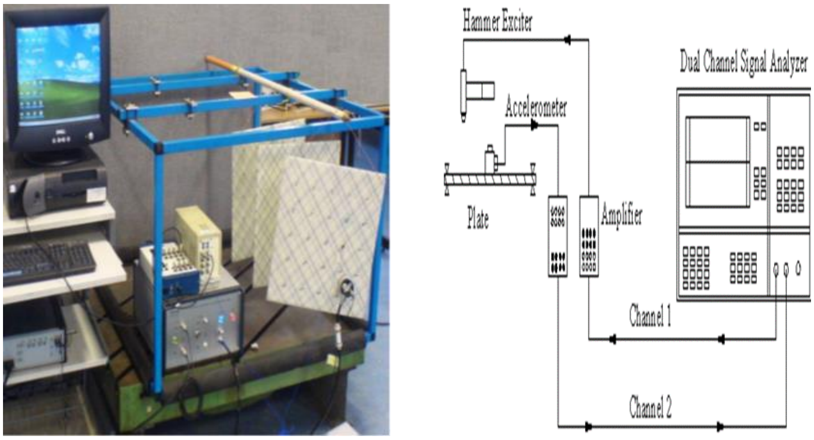


Figure 1. Setting up a modal test.

5. A Discussion of The Findings

In figures 2-6 the frequency response function produced from every check specimen is depicted, and the corresponding matching curve is displayed to demonstrate the precision of the contour shaping. Natural frequencies of all laminate in early four modes are shown in table 1. By adding layers, natural frequencies rise, and presence of extra layers result in higher natural frequencies. Natural frequencies of plates are more significantly impacted by a symmetry reinforcement (90/0/ 45/AL/45/0/90) than other layups in first and fourth modes. Natural frequencies of symmetric enhanced laminate design (AL / [±45/0/90] $_s$) at the second and third modes is higher than other layups.

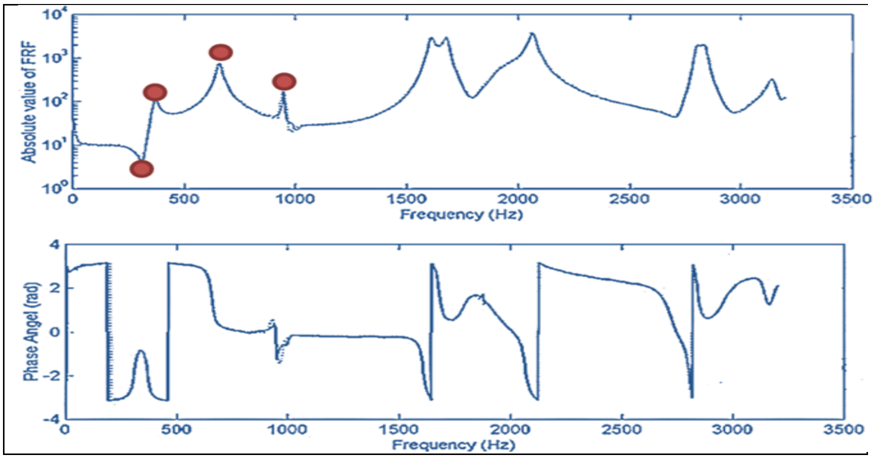


Figure 2. For the aluminum plate's phase angle and frequency response function

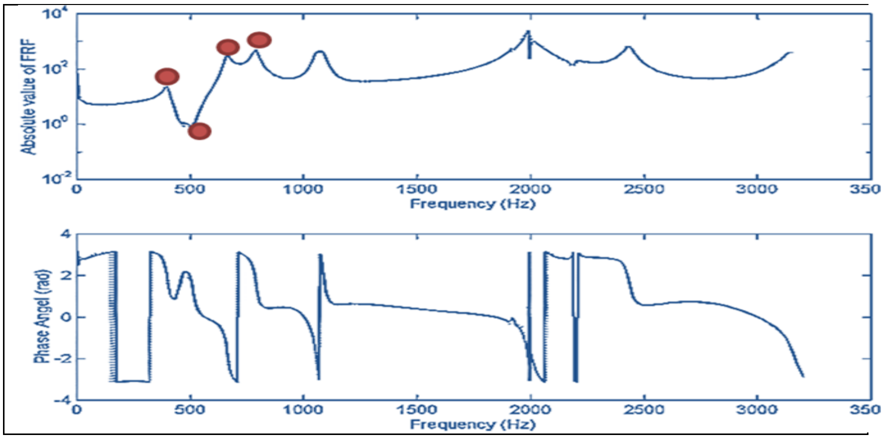


Figure 3. Phase angle and frequency response function for the strengthened plate with (AL/45/90/0) lay-up.

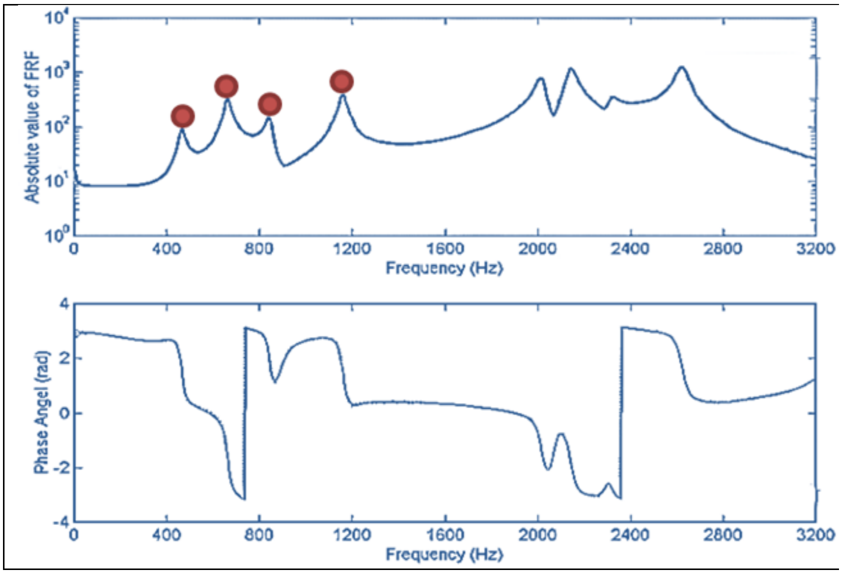


Figure 4. Strengthened laminate (90/0/45/AL/45/0/90) layering's phase angle and frequency response function.

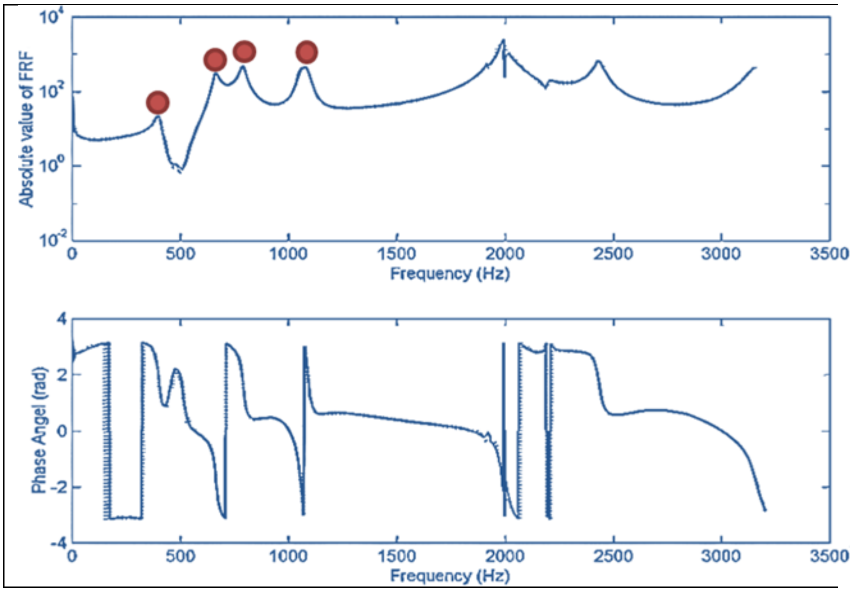


Figure 5. Reinforced plate of (AL/90_2/0_2/45_2) lay-up, the frequency response function and phase angle.

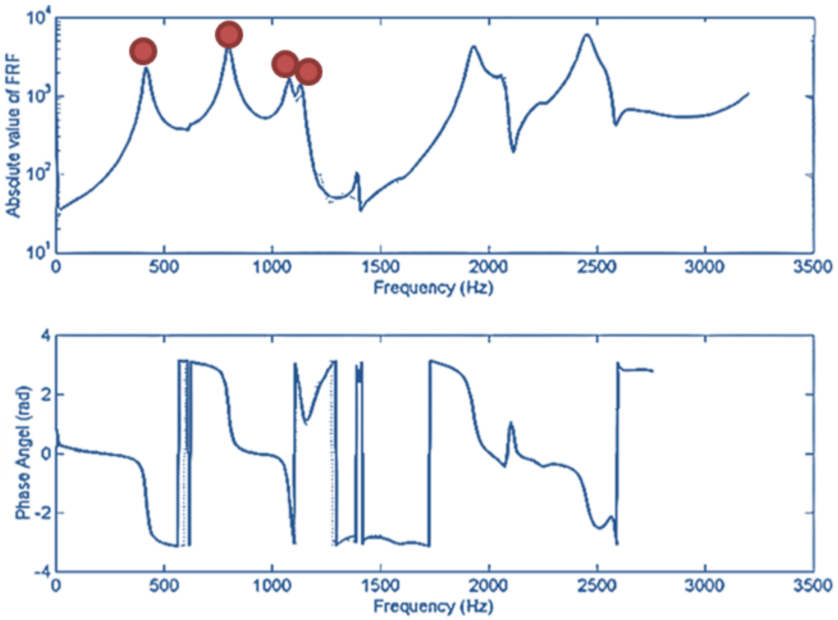


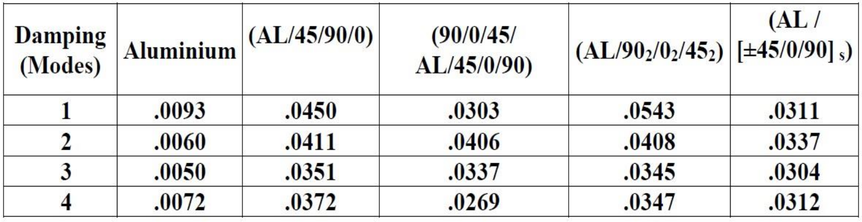
Figure 6. For the reinforced plate with an (AL / [±45/0/90]$_s$)lay-up, the frequency response function and phase angle.

TABLE 1. Several Panels' Natural Frequencies Were Calculated by Vibration Measurement.

Natural frequency in Hertz	**Aluminium**	**(AL/45/90/0)**	**(90/0/45/AL/45/0/90)**	**(AL/90$_2$/0$_2$/45$_2$)**	**(AL / [±45/0/90]$_s$)**
First mode	**337**	**356**	**467**	**393**	**415**
Second mode	**483**	**526**	**658**	**662**	**894**
Third mode	**659**	**675**	**840**	**785**	**1078**
Fourth mode	**952**	**958**	**1158**	**1068**	**1127**

Lists in table 2 all modal proportions of damping of various plates. When relative to strengthened plates, aluminum plates modal damping is quite small. Possibly noticed that the single-sided reinforcement (AL/90$_2$/0$_2$/45$_2$) exhibits notably more damping than the symmetrical (90/0/45/AL/45/0/90) or double-sided (AL/$[\pm45/0/90]_s$) treatment, because damping of laminate relies on energy dispersion, since energy dispersion determines a damping of laminate, shear features in-plane and transverse directions dissipate more energy. Owing to shear features are able to dissipate energy in both the in-plane and transverse directions, they are particularly effective at improving the damping of a laminate material. This is because the energy dispersion is not limited to just one direction, but can occur in multiple directions, leading to higher overall damping. As a result, mode shapes that had a greater impact on both in-plane shear and transverse orientation expressed higher levels of damping. Assumably the manufacturing of the samples as well as the test conditions including the suspensions form outdoor area and calculation locations get a significant effect on damping features which specified from experiment.

TABLE 2. Different Panels' Damping Ratios Based on Modal Testing



Damping (Modes)	Aluminium	(AL/45/90/0)	(90/0/45/ AL/45/0/90)	$(AL/90_2/0_2/45_2)$	(AL / $[\pm45/0/90]_s$)
1	.0093	.0450	.0303	.0543	.0311
2	.0060	.0411	.0406	.0408	.0337
3	.0050	.0351	.0337	.0345	.0304
4	.0072	.0372	.0269	.0347	.0312

6. Conclusions

Under this work, the impact of employing polymeric matrix laminates to add strengthening to metal panels was investigated. The modal test was used to assess the effectiveness of the treatments on a number of panels with various lay-ups. Modal proofs may be used to deduce two fundamental characteristics consisting of natural frequencies, and damping proportions. This study takes into account a first four modes of natural frequencies with damping ratios. The cost-effective approach for increasing damping and stiffness involves panel reinforcing that is worth highlighting, design must strike a balance between stiffness and damping qualities, since damping and stiffness might alter negatively as a result of various lamination arrangements.

Following observations may be drawn from this work which focused on employing polymer matrix composites to strengthen aluminium plate:

- With extra layers there can be more natural frequencies and damping ratios. Alteration panel stiffness and mass qualities is what affects natural frequency.
- Single-sided treatments result in higher damping ratios than double-sided or symmetrical treatments, whereas symmetrical laminates have higher stiffness qualities than single-sided laminates.
- Damping ratios may change based on how fibers are oriented in the treated layers. The findings indicate that applying an angled layer at plates and damping layers contact improves damping qualities.
- Damping ratios seem to be extremely susceptible to production and testing circumstances because of various sources of energy dissipation. A higher damping ratio indicates that the material or structure can dissipate more energy during a vibration cycle, which means that it can absorb more shock and reduce the amplitude of vibrations.

7. Recommendations

1**.** It is recommended that the study be expanded to include more materials and configurations. While the effects of composite reinforcement on metal plates are focused on in this study, it is suggested that the effects of different types of composites, as well as different reinforcement configurations (e.g. sandwich structures), be examined in future research.

2. It is recommended that the effects of different loading conditions be studied. While the dynamic response of metal plates with composite reinforcement under vibration testing is examined in this study, it is suggested that the effects of different loading conditions (e.g. impact, bending, torsion) on the behavior of composite-metal structures be investigated in future research.

3. It is recommended that new composite-metal hybrid designs be developed. While the potential benefits of combining composite materials with metals are demonstrated by the results of this study,

it is suggested that new hybrid designs that can further improve the performance and efficiency of structures in various industries be developed in the future.

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