Effect of Vibration Control Mechanisms on the Vibrational Behavior of Al 6061/SiC Composite Beam

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Abstract. A machine in action in a plant mine or other mechanical system is a major source of vibrations that spread from foundation and across the surrounding area. There should be the least amount of vibrations possible. The vibrations must be isolated, absorbed, or dampened in order to do this. This study investigates how an oil damper and various types of vibration isolators affect vibration frequency of a stir cast composite beam made up of 90% Al6061 and 10% SiC to examine the influence of an oil damper well, as single and double absorbers on the vibration frequency of a stir cast composite beam. Investigating the frequencies on the Vibration Fundamental Trainer under fixed-hinged, hinged-hinged, and fixed-free boundary conditions. The experiments were carried out on the constructed composite beam. The results indicate that the absorbers vibration amplitudes decrease, along with the damper and isolators effects. Absorber and isolator frequencies observed were lower, than the frequency. Increased beam holes resulted in decreased stiffness and reduced frequencies. Compared to scenarios the frequencies were higher when the beam had fixed end conditions without holes. When compared to absorbers and isolators, oil dampers have more effectively decreased vibrations.

1 Introduction

Aluminum metal matrix composites can be tailored to be light-weight and with added useful characteristics including excellent heat conductivity, high specific strength, high hardness, and wear resistance. As a result, these materials are widely employed in the automotive, sporting goods, offshore, and marine industries, among other industries. Under the steady-state harmonic excitation, the dynamic system is allowed to vibrate at excitation frequency. Harmonic excitation can be achieved using methods, like the sine sweep technique and both constant and variable frequency approaches. When the excitation frequency matches the systems frequencies during resonance conditions it can lead to vibrations that pose risks of damage and the displacement of the system is maximum and hence the structural failure, i.e., bridges, buildings, or airplane wings, etc. Thus, the determination of frequencies plays a crucial role in the study of harmonics.
Ramachandran et al. [1] recently tested the vibration properties of Al6061 SiCD and Al6061 Al203 MM composites used in IC engine mountings. It was determined that both types of materials offer improved stiffness and damping characteristics when contrasted with steel. A similar kind of attempt has been made by Santhosh et al. [2] conducted research, on creating MM composites using al as material and incorporating SiC particles, for reinforcement while also examining the impact of varying amounts of SiC and fly ash in the process. The experimentation was conducted for the cantilever beam and postulated that the frequency of beam increased with increase in SiC incorporation. Taj et al. [3] tested the aluminum/ graphite metal matrix composite to investigate natural frequency analytically as well as experimentally. Allien et al. [4] examined the aluminum metal matrix sandwich composite's inherent frequency and damping ratio after silicon carbide particles were added. Magnetorheological fluid was used to create the core, and it was discovered that the composite containing MR fluid has remarkable vibration reduction capabilities. Additionally, they looked at the impact of MR fluid and the glass fiber reinforced polyester composite's ability to suppress vibration. [5]. Kelly et al. [6] have attempted to

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replace steel by providing fiber reinforcement in elastomeric material thereby improving the structural rigidity of elastomer. Karmakar et al. [7] studied how delamination and the order of stacking affect the characteristics of graphite reinforced epoxy material. The composite shell was pre-twisted to introduce the compressive stress. Shilpa et al [8] altered the B4C weight percentage during the stir casting process to create the Al2O24/B4C particle composite. They investigated how the wt.% of B4C affected the tensile behavior and came to the conclusion that the weight percentage of B4C tends to improve UTS and YS while decreasing the % of elongation. Abdi et al. [9] research delved into how the addition of 5% TiB2 impacts the strength and hardness of Al356 alloy at different temperatures. Sandeep et al. [10] experimented the influence of different wt% of SiC from 2%-9% in the range of 2% and 6% fly-ash which is reinforced with Aluminium 6061 on the tensile, hardness, impact strength. The mechanical characteristics of the Al6063/SiC composites were investigated by Meena et al. [11] by changing the SiC particle size and different weight percentages. The hardness, tensile strength as well as yield strength substantially enhanced with increase in size of the particle and weight % of SiC, however, impact strength, ductility decreased. Rana et al [12] researched the wear as well as the mechanical characteristics of Al7075/B4C.Roseline et al. [13] created the Al alloy MMC having a weight fraction percentage of fused zirconia alumina and carried out tests to look into the mechanical characteristics including hardness, impact strength, and tensile strength. The 90% Al and 10% zirconia by weight% composition was determined to have the best mechanical properties. The impact of using fly ash & zircon as reinforcement materials, in Al 7075 was studied by Jithin et al. [14]for mechanical properties - as wear rate, hardness and tensile . Jenixet al. [15] created a blend of Al6064 and Alumina (Al203) by incorporating zircon and then tested its characteristics. The results showed that 4wt%ZrSiO4+4wt% Al2O3 has given a higher value of the hardness and tensile strength. Girisha et al [16] examined the hardness as well as the wear properties fabricated nanocomposite made of-Al356.1/ZrO2 with different weight fractions of ZrO2 nanoparticles. They inferred that the increase in weight fraction of ZrO2 particles increases the wear properties. Baghchesara et al. [17] fabricated the composite with Zircon and TiB2 particles with size 1μ at temperature of 750C and investigated the mechanical properties.
Anil Kumar et al. [18] studied mechanical characteristics of the fabricated composite with Al6061/fly ash. Found that an increase in particulate size of fly ash lessens mechanical properties. Muruganandhan et al. [19] examined how incorporating fly ash into Al6061 enhances the properties showing that higher fly ash content leads to improved performance.Metal matrix composite was incorporated with particles viz., TiC [20], AlO [21], SiCa [22], Carbon nanotubes [23], Graphene [24], etc.
According to the literature reviewed above, the majority of studies have looked into the mechanical and tribological characteristics, while very few have looked into the frequencies on artificial specimens constructed from various reinforcement materials. Among all the materials listed above, silicon carbide particles stand out for their cheap and accessible availability together with their vibration-suppression capabilities. This research shows how the oscillation frequency and strength of a beam made of Al6061/SiCW is influenced by the presence of an oil damper and absorber along, with isolators and multiple perforations.

2. Experimental Details

The mixture specimen was created by the stir casting technique with Al6061 as the primary material and SiC serving as the reinforcement material. This process involved adding SiC to molten Al6061 and blending it thoroughly with a stirrer, for uniform mixing. The beam was a rectangular cross-section fabricated with 10wt.% of silicon carbide. The dimensions of the beams are as follows: length-730mm, width-40mm, and thickness-8mm. Many holes were drilled of size ϕ10mm along length of beam to assess the effect of the holes on vibration characteristics. To examine the effect of the passive isolator, damper, and absorber and the number of holes, The Al6061/SiC beam was subjected to fundamental vibration training experiments under boundary conditions such, as hinged-hinged and fixed-free configurations as well as fixed-hinged setups for testing purposes. Figure 1 shows specimen with, without holes depicted while Figure 2 shows the equipment used for experiments. Table 1 provides details regarding the specimen weight in grams and the quantity of holes, in it.

(a)

(b)

Fig. 1. Specimen details (a) Without holes, and (b) With holes

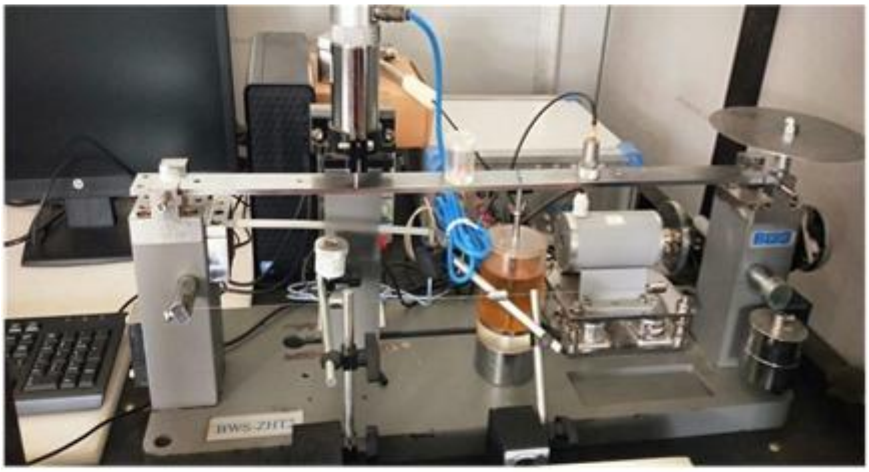


Fig. 2. Vibration fundamental trainer

Table 1. The weight of composite beam in grams

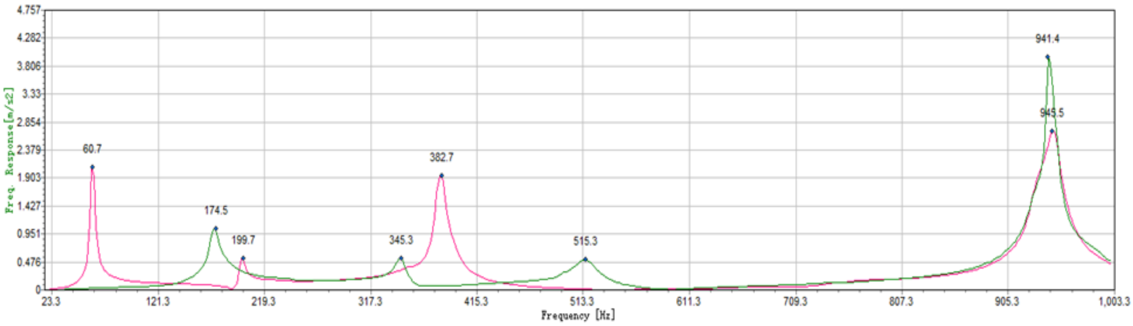
Number of holes	Weight in grams
Without any openings (holes)	640
With two openings (holes)	630
With four openings (holes)	620

3. Results and Discussion

Experiments were carried out using the AL6061/Si beam to study the response, to forced vibrations, in scenarios involving the oil damper and different types of absorbers and isolators which had an impact frequency changes as elaborated in the subsequent sections.

3.1. Effect of oil damper

Figs. 3-5 shows the frequency response plots represent the output to the input signal (Acceleration) vs frequency. The frequency response plots exhibit peak values that correspond to the distinct natural frequencies found in the beam under various boundary conditions. The pink curve is the frequency response of the beam without an oil damper and the green curve is the frequency response of the beam with an oil damper. From Figs. 3-5, it is observed that the first natural vibration frequency has been absorbed by the oil damper regardless of the limiting conditions and the number of holes. For both Hinged-hinged and Fixed-free boundary conditions, the natural vibration rose with an increase in the number of holes in the beam, while for Fixed-hinged boundary conditions, it dropped. The reduction in stiffness is the cause of this. Additionally, depending on the boundary conditions, the presence of perforations on the beam significantly affects the inherent vibration behavior of the beam.



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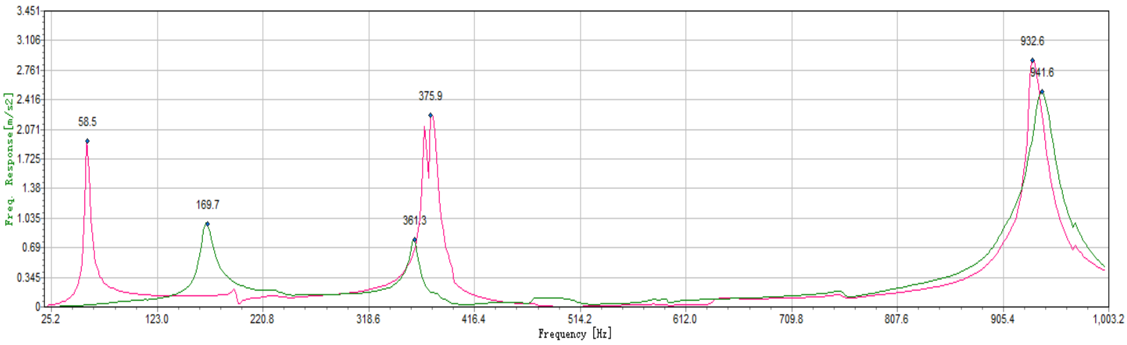

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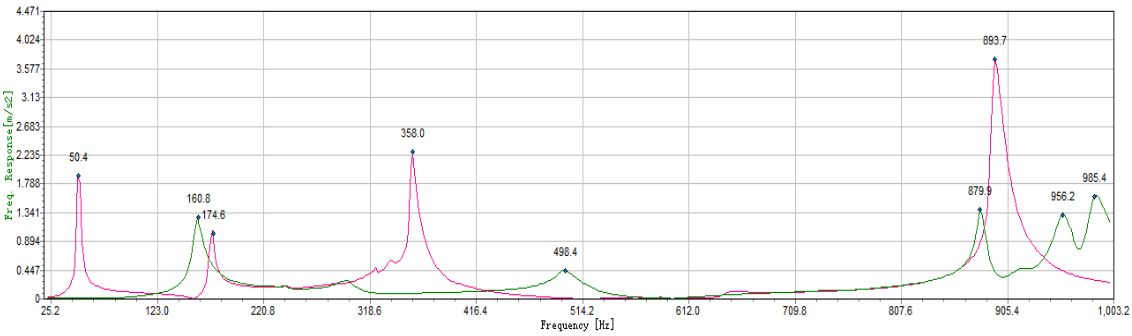

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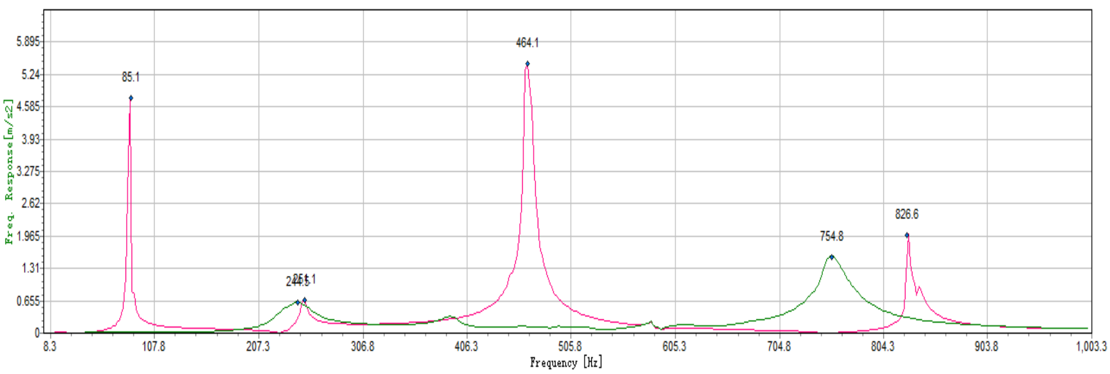
Fig. 3. Effect The impact of oil damper and hole count on hinged-hinged boundary conditions in the following scenarios: (a) without holes, (b) with two holes, and (c) with four holes



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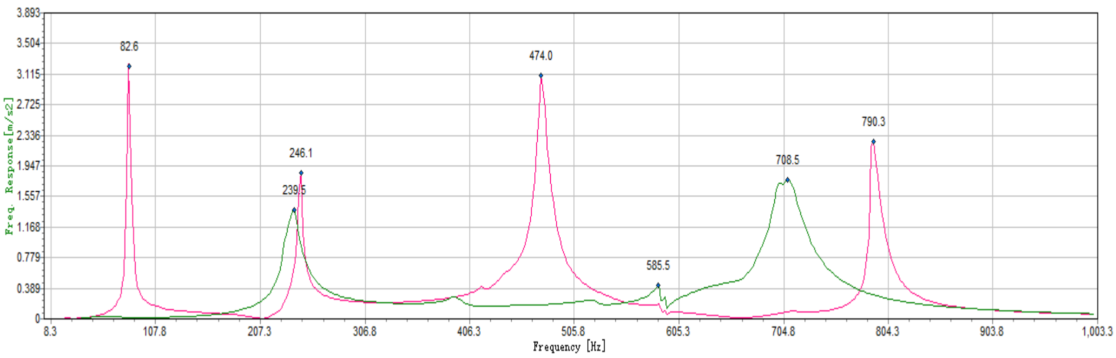

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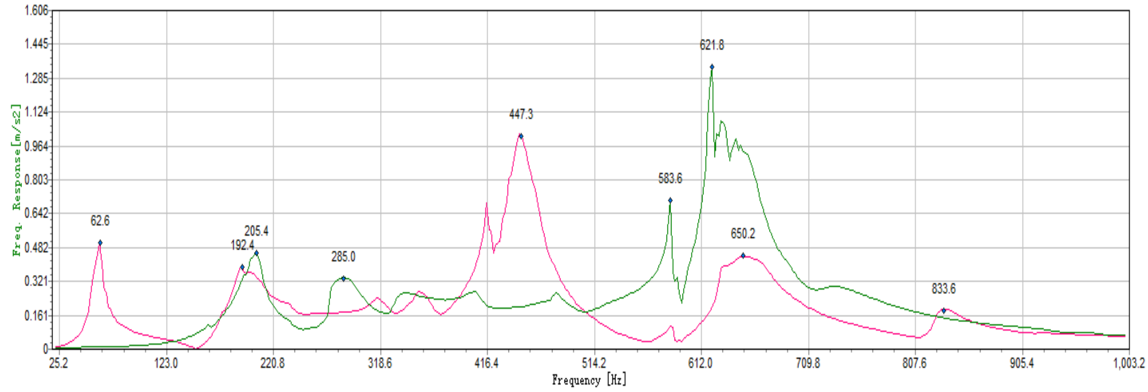

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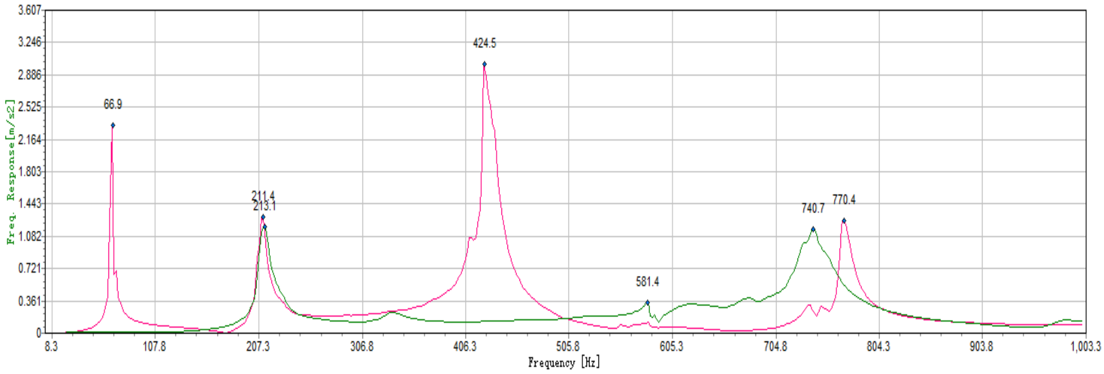
Fig. 4. The impact of oil damper along with the number of holes on Fixed-Free boundary conditions (a) without holes, (b) with two holes, and (c) with four holes.



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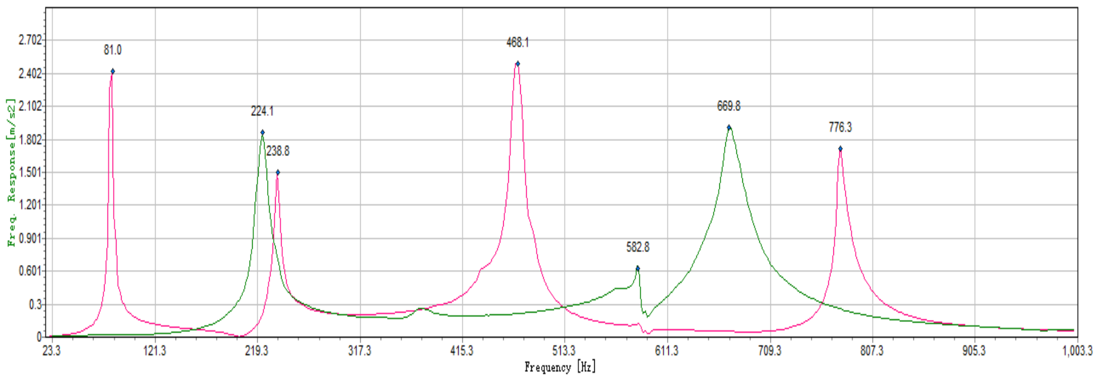

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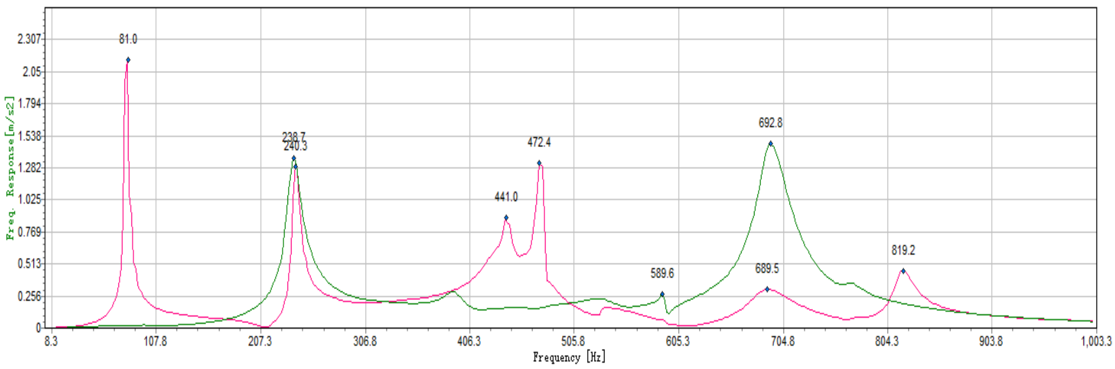

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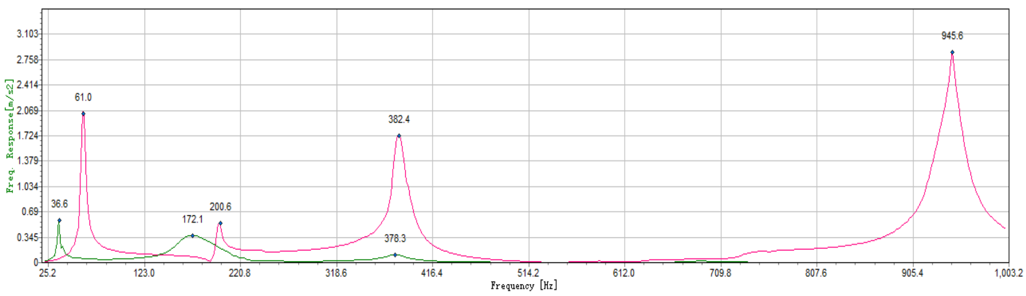
Fig. 5. The impact of oil damper along with the number of holes on Fixed-Hinged boundary conditions (a) without holes, (b) with two holes, and (c) with four holes.

3.2. Effect of passive isolator

The study report's results on the effects of isolators and the various boundary conditions on the natural frequency of the beams are covered in detail in Figures 6 and 7. The lower frequency vibration of the beam has been amplified. The vibration in the isolator is due to the rubber absorbers vibrating on their own accord. As for boundary conditions like hinged hinged and fixed ones along with free boundaries conditions the beams natural vibration increases as more holes are added but decreases in fixed hinged situations. This decrease is attributed to a reduction in stiffness. The hole's number in beam and type of conditions along with the isolator greatly affect the vibration, within the beam. When an isolator has four holes and a fixed-hinged boundary condition, its maximum and minimum percentage effects are 44.9% and 31.3%, respectively. In the absence of holes, the beam exhibits higher natural vibration frequencies due to its higher inherent stiffness.



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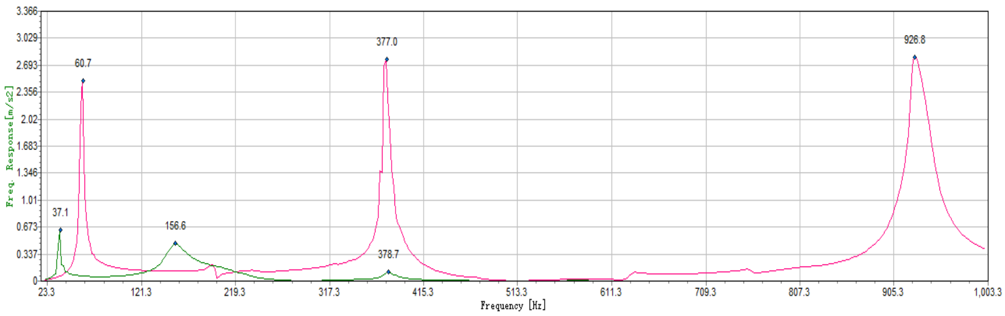

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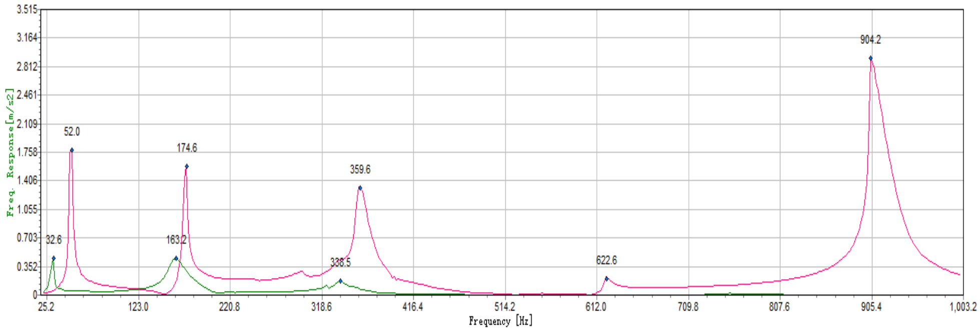

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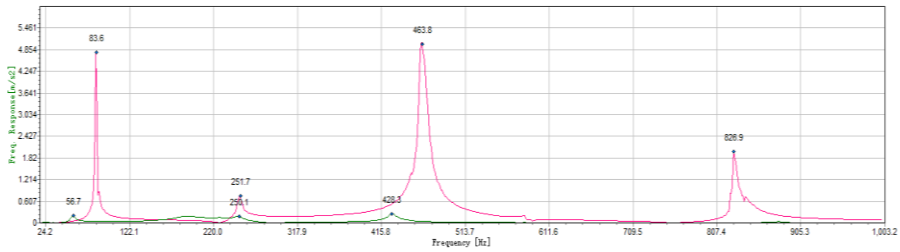
Fig. 6. Hinged-Hinged boundary conditions (a) without holes, (b) with two holes, and (c) with four holes: Effect of passive isolator and hole count.

By examining the changes in stiffness and damping properties, it is possible to understand how a passive isolator and the number of holes affect the vibrational behavior of an Al6061/SiC composite beam under Fixed-Free boundary conditions. When there are no holes, the continuous structure of the beam produces more stiffness, which raises natural frequencies. However, adding two or four holes weakens the beam's stiffness and jeopardizes its structural integrity. This reduction in stiffness leads to smoother vibration and lower natural frequencies, according to the laws of vibration mechanics.



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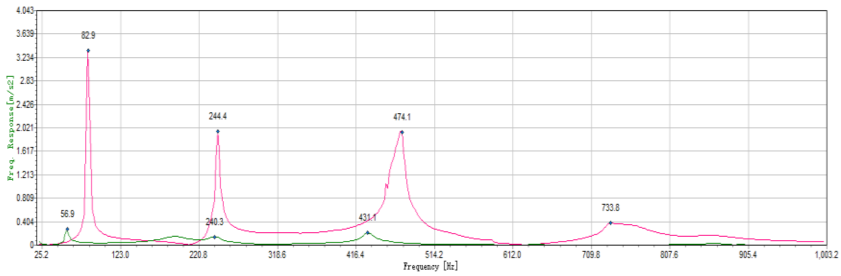

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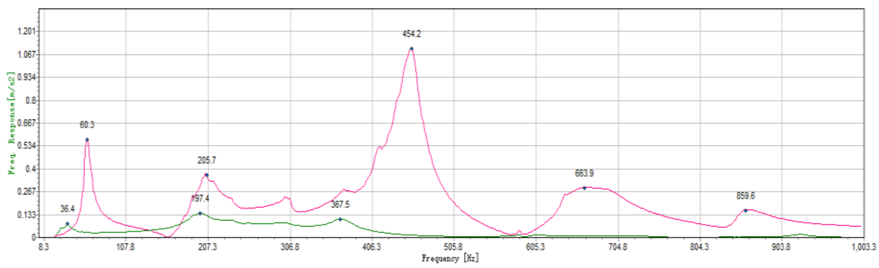

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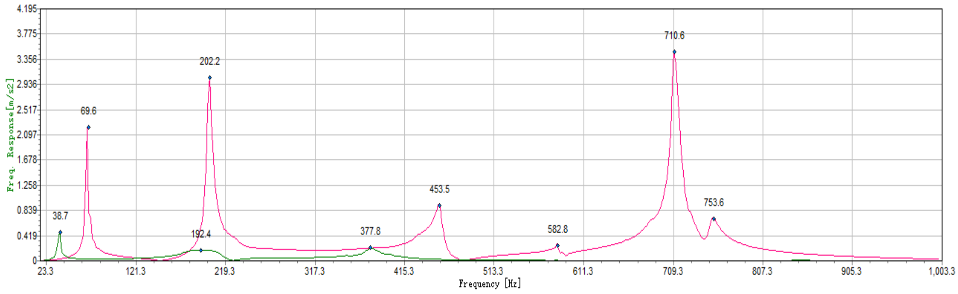
Fig. 7. The impact of passive isolator as well as the count of holes on Fixed-Free boundary conditions (a) without holes, (b) with two holes, and (c) with four holes.



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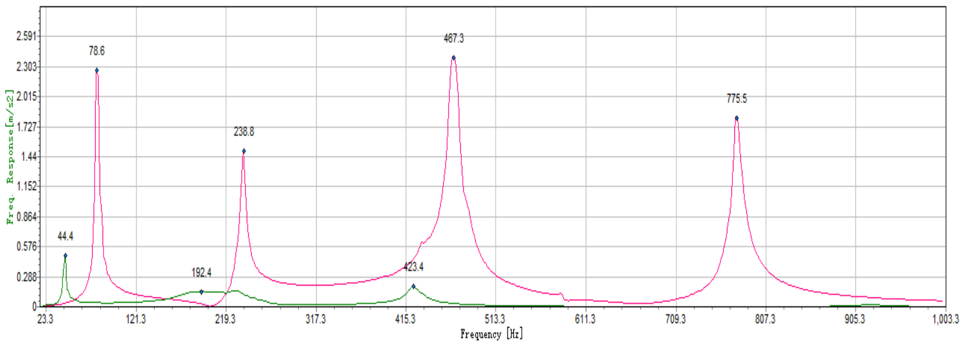

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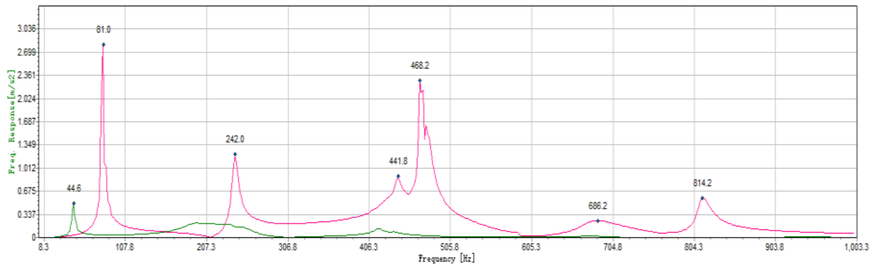

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Fig. 8. The impact of passive isolator and number of holes on Hinged-Hinged boundary conditions(a) without holes, (b) with two holes, and (c) with four holes.

3.3 Effect of Absorber

The effect of the absorbers, the count of holes, and boundary conditions on frequency of the beam is presented in Figs. 9-10. From Figs. 9-10, it is seen that the frequency of the beam increase with a number of holes for fixed-hinged boundary conditions, the decrease occurs for hinged hinged & fixed free conditions. The absorber has the effect of lowering vibration amplitudes. The frequencies achieved with the absorber are lower than the primary frequency. Additionally, with fixed-hinged border conditions with 2 holes, the frequency has decreased by 8.9 %. Vibration amplitudes are successfully reduced by the absorber, producing frequencies that are lower than the primary frequency. This decrease is confirmed by the combined effect of the absorber's capacity to absorb energy and the perforations' decreased stiffness. The results demonstrate that the absorber, the number of holes, and the final conditions have a substantial impact on the beam's vibration frequency. These results show how important it is to consider these aspects when assessing and managing composite beam vibration behavior.

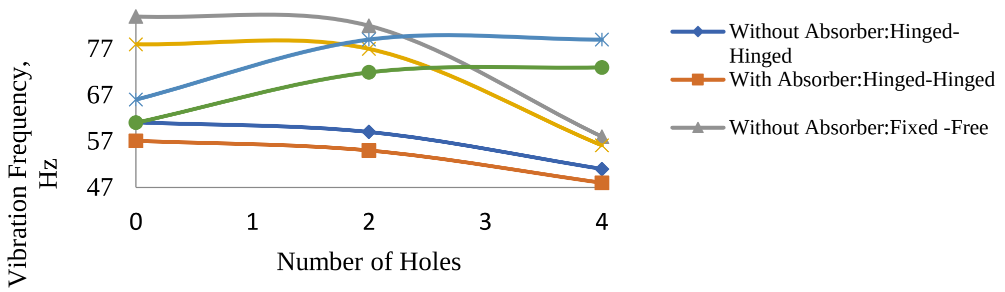

Fig. 9. The impact of single absorber, count of holes, and end conditions on the frequency.

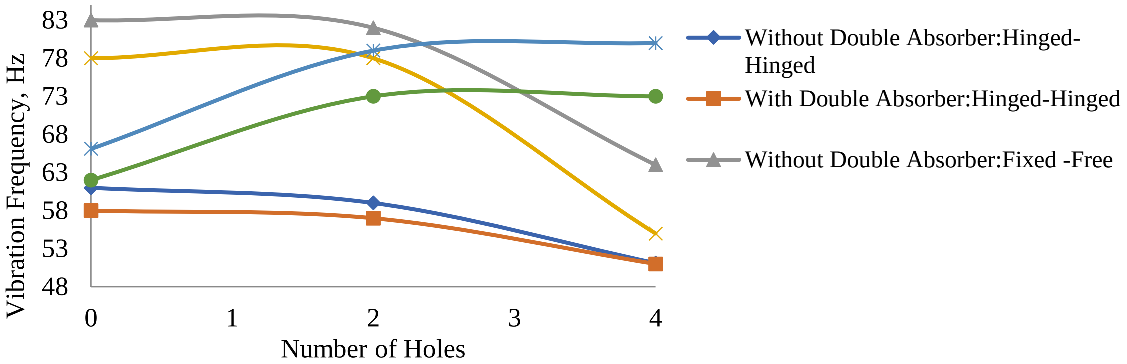

Fig. 10. The impact of double absorber, count of holes, and end conditions on the frequency.

4. Conclusions

Research on the effects of oil dampers and absorbers on the frequency of the aluminum (Al6061) and silicon carbide (SiC) composite beam has revealed that:

- Oil dampers perform better than absorbers and isolators in terms of vibration reduction;
- The effect of absorber, damper, and isolator is to reduce the amplitudes of vibration frequency.
- The frequencies produced by the absorber, damper, and isolator are lower than the primary frequency.
- Several holes have the effect of reducing both the frequency and the amplitude.

The cantilever beam with four holes showed the greatest decrease.
The oil damper, absorber as well as the isolator have a positive effect on reducing the amplitude, out of all these, the damper provided the highest reduction in amplitude of vibration. This composite beam could be an alternative to steel.

References

1. T. Ramachandran, S. Surendarnath and R. Dharmalingam, Structural and suitability analysis of aluminium metal matrix composites for IC engine mountings. Materials Today: Proceedings. **37**, 1524-1528, (2021). https://doi.org/10.1016/j.matpr.2020.07.145
2. N. Santhosh, U.N. Kempaiah and S. Venkateswaran, Vibration Mechanics of Hybrid Al 5083/SiCp/Fly Ash Composite Plates for its Use in Dynamic Structures. J. Exp. Appl. Mech. **8**, 11-18, (2017).
3. A. Taj, S. Doddamani and T.N. Vijaykumar, Vibrational Analysis of Aluminium Graphite Metal Matrix Composite. International Journal of Engineering Research & Technology (IJERT). **6(**4), 1072-1078, (2017). https://doi.org/10.17577/ijertv6is040720
4. J. V. Allien, H. Kumar and V. Desai, Semi-active vibration control of SiC-reinforced Al6082 metal matrix composite sandwich beam with magneto rheological fluid core. Proc. Inst. Mech. Eng. Pt. L J. Mater. Des. Appl. 234(3), 408-424, (2020). https://doi.org/10.1177/1464420719890374
5. J. V. Allien, H. Kumar and V. Desai, Semi-active vibration control of MRF core PMC cantilever sandwich beams: Experimental study. Proceedings of the Institution of Mechanical Engineers, Proc. Inst. Mech. Eng. Pt. L J. Mater. Des. Appl. 234(4), 574-585, (2020).

https://doi.org/10.1177/146442072090307

6. J.M. Kelly and N.C. Van Engelen, Fiber-reinforced elastomeric bearings for vibration isolation. J. Vib. Acoust. 138(1), 011-015, (2016)
https://doi.org/10.1115/1.4031755
7. A. Karmakar, H. Roy and K. Kishimoto, Free vibration analysis of delaminated composite pretwisted shells. Aircraft Engineering and Aerospace Technology, 77(6), 486-490, (2005). https://doi.org/10.1108/00022660510628480
8. NagaralMadeva, R. Pavan, P.S. Shilpa, and V. Auradi, Tensile behaviour of Al2024 composites with B4C-reinforced alloy matrix. FME Trans., 45(1), 93-96, (2017).
9. F. Abidi, L.P. Borregoa, J.D. Costaa, J.A.M. Ferreiraa, Crack growth behavior of AA6082 and AA6061 aluminum composites. Procedia Eng. 74, 175– 178, (2014).
10. S. Sandeep Kumar, P. Chainarong, P. Muangjunburee, S. Suthummanon, Friction Stir Processing of SSM356 Aluminium Composite. Procedia Eng. 97, 732 – 740, (2014). https://doi.org/10.1016/j.proeng.2014.12.303
11. K.L. Meena, B. Baudouy and A. Four, Low temperature thermal conductivity of aluminum composite. Cryogenics. 60, 1–4, (2014). https://doi.org/10.1016/j.cryogenics.2013.12.008
12. Jian, Liang, Sun Jianhua, Li Xinmiao, Zhang Yongqin, and Peng Li., Development and Application of Aluminum Composite Drill Rod in Geologic Drilling. Procedia Eng. 73, 84 – 90, (2014). https://doi.org/10.1016/j.proeng.2014.06.174
13. Ren, Yongsheng, Wenhui Ma, Kuixian Wei, Wenzhou Yu, Yongnian Dai, and Kazuki Morita. Degassing of aluminum alloys via the electromagnetic directional solidification. Vacuum. 109, 82 – 85, (2014). https://doi.org/10.1016/j.vacuum.2014.06.026
14. Liu, Wen-hui, Zhen-tao He, Yu-qiang Chen, and Si-wen Tang. Dynamic mechanical properties and constitutive equations of 2519A aluminum composite. Trans. Nonferrous Met. Soc. China, 24, 2179–2186, (2014). https://doi.org/10.1016/S1003-6326(14)63330-6
15. J.JenixRino, The mechanical properties of Aluminium 6063 alloy composite enhance strengthened by addition of zircon. Materials Science. **102**, 256-212, (2014).
16. K.B. Girisha, The effect of various weight fraction of zirconium oxide reinforced with Al3561 metal. Vaccum. **109**, 2179-098, (2012).
17. M.A.Baghchesara, Mechanical properties of developed composite specimen using stir casting method. Materials Science. **200**, 234-97, (2012).
18. H.C. Anil Kumar, Mechanical Properties of Al 6061 reinforced with fly-ash. Walled Structures, **120**, 400-380, (2012).
19. P. Muruganandhan, The effect of flyash reinforced with Al6061 by stir casting method. Materials Science. **102**, 330-430, (2012).
20. W. Bae, S. Kim, Y. Kim, S.K. Lee, Suppression of machine tool spindle vibration using TiC-SKH51 metal-matrix composite. J. Mech. Sci. Technol. **35(8)**, 3619-3625, (2021).
21. N. Balaji, S. Balasubramani and V. Pandiaraj, Fabrication and Analysis of Al6061/Al2O3/TiC Hybrid Metal Matrix Composite. Paideuma Journal of Research **14(3)**, 24-35, (2021).
22. Baburaja, Kammuluri, K. Venkata Subbaiah, M. P. Arunkumar, Vinod S. Bhagat, and R. Kiran Kumar Reddy, Vibration and acoustic characteristics of aluminium silicon carbide metal matrix composite under uniform and non-uniform thermal environment. Silicon **13**, 4715-4736 (2021).
23. X. Miao, C. Li and Y. Jiang, Free vibration analysis of metal-ceramic matrix composite laminated cylindrical shell reinforced by CNTs. Compos. Struct. **260**, 113262, (2021). https://doi.org/10.1016/j.compstruct.2020.113262
24. J. Yang, D. Chen and S. Kitipornchai, Buckling and free vibration analyses of functionally graded graphene reinforced porous nanocomposite plates based on Chebyshev-Ritz method. Compos. Struct. **193**, 281-294, (2018). https://doi.org/10.1016/j.compstruct.2018.03.090.