International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Damping Properties of Al Matrix Composites

L. Siva Sankara Reddy[1], P. Thimmaiah[2], K. Narasimhulu[3]

[1, 2]Department of Physics, Sri Krishnadevaraya University, Anantapur- 515003, A.P. India
[3]Department of Physics, SSA Government First Grade College (Autonomous), Ballari, Karnataka

Abstract

The ability of a material to absorb and release mechanical vibrations during cyclic loading is known as damping capacity. When it came to resonant loading and deformation, modern structural materials needed to have good mechanical and damping qualities. The suitable damping properties of metal alloys and metal matrix composites make them useful for marine, automotive, and aerospace structures. Lightweight materials can achieve both improved cargo capacity and lower fuel consumption. The development of lightweight composite materials with a high damping ability for the structural parts has greatly aided in meeting the aforementioned requirements. Pure metals and alloys have demonstrated superior mechanical capabilities, while having the least amount of dampening capacity. As a result, composites that have both good mechanical and damping qualities have been introduced. The damping characteristics of lightweight materials like aluminum and their equivalent composites have been determined in the literature that is now available. This review concludes and presents the damping characteristics of metals, alloys, and their composites.

Keywords: Aluminium, Composite, Microstructure, Damping Properties, Elastic Modulus

1. Introduction

Metal matrix composites (MMCs) have become a popular structural material because to their mechanical, thermal, and tribological qualities (Davis & Artz, 1995; Ibrahim et al., 1991; Miracle, 2005). They also have an effect on applications such as automotive, submersible vehicles, and aerospace structures (N. Gupta et al., 2012), which are subjected to temperature changes and dynamic loading conditions during the course of their service life. A strong incentive for customized MMCs is the substantial benefit of the pre-existing applications, which are primarily in heavy machinery, automotive, and aerospace constructions with high mechanical vibration and damping capabilities of material (Sastry et al., 2001; J. Zhang et al., 1993). Combining features like damping qualities and mechanical vibrations will aid in material selection and achieve a significant performance.

In order to meet the constantly evolving needs of the automotive, aerospace, and marine industries, material designers are very interested in lightweight composite materials with improved damping capabilities (Shunmugasamy et al., 2016). According to Kumar et al. (2017), a material's damping capacity is its capability to absorb and eliminate mechanical vibrations during periods of cyclic loading. This property is not necessary for engineering applications because it impacts structural stability and subsequently material efficiency. The damping capacity of various metals and alloys is generally lower, which limits their applications and performance in dynamic structures. The aforementioned findings all point to the enormous need for materials with great damping capacity because they were able to eliminating unwanted noise and vibration, enhancing vehicle and instrument stability.

Noise and vibration have become a significant and dangerous influence in the context of modernization and highly advanced technology, primarily in complicated mechanical engineering systems. (Yang and others, 2017). Additionally, the use of composites based on magnesium or aluminum as a dampening material effectively removed the vibrations and sound. Despite this discrepancy, the damping properties of magnesium or aluminum-based composites were significantly more prominent than those of dense materials when compared to viscoelastic polymers (M Gupta & Wong, 2015). In the recognized line, the traditional particle-reinforced metal matrix composites (MMCs) with high strength and stiffness were improved with improved damping qualities. Vibrations and sound have not been favorable when taking into account the sophisticated systems in mechanical engineering, and with the enormous advancements in science and technology, they have emerged as a major threat. This attracted a lot of attention to the dampening materials. Lightweight magnesium, aluminum, and their corresponding alloys have established themselves as reliable engineering materials due to their high specific stiffness, superior energy/sound absorption capabilities, and low density.

Numerous mechanisms, including microstructural defects, grain boundary damping, porosity, intrinsic particle damping capability, interface damping, thermo-elastic damping, and thermal mismatch between the particulate and the matrix, can be responsible for the overall damping enhancement of magnesium or aluminum alloys and their composites (Lu et al., 2009; Surappa, 2003). The current study's primary goal is to focus on lightweight structural metals like magnesium and aluminum. This suggests that the potential for further research has been established and that the composites with high damping characteristics were on the verge of being established.

2. Processing Routes for Metal Matrix Composites

Metal matrix composites (MMCs) have many advantages as compared to monolithic metals as discussed above so their applications are increasing day by day in various fields.

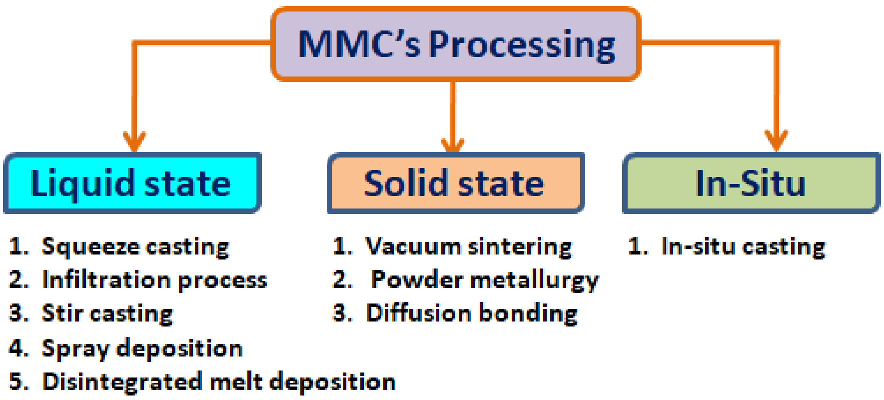

Figure 1. Various categories of processing of metal matrix composites.

In order to optimize the microstructure and damping properties of metal matrix composites, a variety of processing methods have been developed by industry and researchers over the last two decades. Generally, MMC fabrication can be classified into three categories: (1) Liquid-State processing, (2) Solid-State processing, and (3) In-Situ processing. Figure 1 shows the various categories of processing of metal matrix composites.

3. Damping Characteristics of Al-based MMCs

In general, the damping capacity possessed by Al was comparatively low. Through the thermal mismatch strain induction, the matrix microstructure including reinforcement and dislocation in the matrix were attained by MMC fabrication techniques.

Penchal et al. (Matli et al., 2020) used a microwave to study the microstructural and damping response of Al-NiTi nanocomposites with the help of two-directional quick sintering and hot extrusion in succession. This technique requires the Al matrix and amorphous Ni50Ti50 reinforcement (0.5%, 1%, and 1.5 Vp.%) materials. The prepared powders were ball milled for 120 minutes at 200 rpm to create a composite powder. Blended powders were compacted at 97 bar (50 tons) of compaction pressure. A 40mm and 35mm diameter cylindrical billet is obtained. The compacted billets were sintered using a hybrid microwave setup at 550oC. The sintered billet was hot extruded at 350 degrees Celsius to create an extruded rod with an 8 mm diameter. the sintered billet was hot extruded at 350^{o}C at an extrusion ratio of 20.25:1.

The damping properties were measured using the resonant frequency damping analyzer (RFDA). The vibration damping properties of pure Al and Al-NiTi nanocomposites are shown in Table 1. It was discovered that the damping capacity (Q-1) and the damping loss rate (L) of the pure Al were greatly increased by the addition of NiTi nanoparticles larger than or equal to one volume percent. The study found that the Al-1.5 NiTi nanocomposite had optimal damping capacity and damping loss rate of around 6.15 and 17.15X10-4, respectively. The damping capacity and damping loss rate of the nanocomposite sample were increased by approximately 15.4% and 16.2%, respectively, in comparison to pure Al.

Penchal Reddy et al. (Penchal Reddy et al., 2018) studied the Al/BN nanocomposites can be developed by two-directional microwave assisted rapid sintering. The processing details were similar to earlier studies in Penchal et al. (Matli et al., 2020).

Table 1 lists the damping characteristics of pure aluminum and its Al-BN (0.5, 1, and 1.5 vol.%) nanocomposites. Every specimen's vibration response in the free vibration mode is a function of both amplitude and time. The findings indicate that the amplitude and time required for vibration to stop the amplitude vary for each material. The use of nano-BN particles as reinforcement has improved the damping properties of the pure Al. The amplitude of Al-BN nanocomposites decreases abruptly, while the amplitude of pure Al decreases periodically. For the Al-1.5 vol% BN nanocomposite, vibrations are damped in less than ~0.27 seconds. The addition of nano-BN particles over time has produced a dominating

The greatest damping capacity of the Al-1.5 vol% BN nanocomposite was 0.000676, or 26.8 times that of pure Al. The resonance frequency for pure Al was then determined to be 8846 Hz, while the addition of nano-BN particles with different volume percentages, such as 0.5, 1.0, and 1.5 BN nanocomposite, caused the resonant frequency to slightly decrease, with values of 8573, 8528, and 8492 Hz, respectively. Benefits like lower vibration amplitude and resonance frequency as compared to pure Al have increased the nanocomposites' total dampening capacity.

Narasimalu et al. (Narasimalu & Gupta, 2006) examined the damping behavior of Al (AA1050) alloy-SiC composites using the disintegrated deposition method (DMD) approach. The findings showed that the presence of linked Fe wire and the addition of SiC (about 25 µm in size) to the matrix improved the Al matrix's overall damping capacity. When compared to SiC particles and Fe wire, the damping capacity of Al with 0.5 vol.% SiC and 2 vol.% interconnected Fe wire is 25% higher than that of pure Al. In contrast, interconnected Fe wire alone only provides 15% more than that of pure Al, and there was a 10% variation. So, the presence of both SiC particulates and Interconnected incorporates to attain the best damping capacity to the Al.

Table 1 Damping characteristics of Al based composites.

Composition	**Processing method**	**Damping capacity ($\times 10^{-4}$)**	**Damping loss rate**	**Elastic modulus (GPa)**
Pure Al	PM + MWS + HE (Matli et al., 2020)	5.33 ± 0.056	14.76 ± 0.09	71.65 ± 0.02
Al-0.5 vol % NiTi		4.17 ± 0.031 (↓21.7%)	11.65 ± 0.06 (↓21%)	75.99 ± 0.02 (↑6.05%)
Al-1.0 vol % NiTi		5.65 ± 0.029 (↑6%)	15.2 ± 0.06 (↑2.98%)	76.48 ± 0.01 (↑6.74%)
Al-1.5 vol % NiTi		6.15 ± 0.029 (↑15.4%)	17.15 ± 0.06 (↑16.19%)	75.93 ± 0.08 (↑5.97%)
Al-0.5 vol.% BN	PM + MWS + HE (Penchal Reddy et al., 2018)	5.88 ± 0.073 (↑10.3%)	15.78 ± 0.11 (↑6.91%)	71.88 ± 0 (↑0.32%)
Al-1.0 vol.% BN		6.18 ± 0.039 (↑15.9%)	16.48 ± 0.09 (↑11.65%)	72.2 ± 0.006 (↑0.76%)
Al-1.5 vol.% BN		6.76 ± 0.042 (↑26.8%)	18.3 ± 0.07 (↑24%)	73.08 ± 0.017 (↑2%)

Madeira et al. investigated Al composites enhanced with SiC particles (Madeira et al., 2016). The results show that while the particle size reduces the dynamic modulus, the frequency and particle size were directly proportional to the damping capacity.

Al 6061/SiC and 6061 Al/Gr composites were investigated by Zhang et al. (J. Zhang et al., 1994) and contrasted with those of Al alloy. In contrast to unreinforced alloys, this study found that reinforced composites improved damping capacity. While SiC is volume fraction independent, the graphite reinforcement's damping capacity depends on the volume percent.

4. Summary and Conclusions

In this review, I have briefly gone through most commonly used fabricating techniques to manufacture MMCs, in which DMD and PM were mostly employed. In the enrichment of damping properties, Secondary fabrication process such as extrusion was employed successfully. The damping properties of the matrix were influenced by the types of matrix, reinforcements, wettability, and reaction during the manufacturing process. Many investigations on magnesium and aluminum MMCs have been conducted over the last few decades in an effort to reach a conclusion and introduce them into increasingly advanced sectors. Much study has been conducted to fully understand the interaction of the processing route, microstructure, and damping qualities. Demand for MMC use has significantly increased in the automotive component, aerospace, electrical and electronic, and space technology sectors, among other product applications. Additionally, they stated that a unique study is necessary to see how MMCs are used in relation to cost and performance.

References

1. Davis, L. C., & Artz, B. E. (1995). Thermal conductivity of metal-matrix composites. *Journal of Applied Physics*, *77*(10), 4954–4960.
2. Gupta, M, & Wong, W. L. E. (2015). Magnesium-based nanocomposites: Lightweight materials of the future. *Materials Characterization*, *105*, 30–46.
3. Gupta, N., Luong, D. D., & Cho, K. (2012). Magnesium Matrix Composite Foams—Density, Mechanical Properties, and Applications. In *Metals* (Vol. 2, Issue 3).
4. Ibrahim, I. A., Mohamed, F. A., & Lavernia, E. J. (1991). Particulate reinforced metal matrix composites - a review. In *Journal of Materials Science*.
5. Kumar, A., Meenashisundaram, G. K., Manakari, V., Parande, G., & Gupta, M. (2017). Lanthanum effect on improving CTE, damping, hardness and tensile response of Mg-3Al alloy. *Journal of Alloys and Compounds*, *695*, 3612–3620.
6. Lu, H., Wang, X., Zhang, T., Cheng, Z., & Fang, Q. (2009). Design, Fabrication, and Properties of High Damping Metal Matrix Composites—A Review. In *Materials* (Vol. 2, Issue 3).
7. Madeira, S., Carvalho, O., Carneiro, V. H., Soares, D., Silva, F. S., & Miranda, G. (2016). Damping capacity and dynamic modulus of hot pressed AlSi composites reinforced with different SiC particle sized. *Composites Part B: Engineering*, *90*, 399–405.
8. Matli, P. R., Manakari, V., Parande, G., Mattli, M. R., Shakoor, R. A., & Gupta, M. (2020). Improving Mechanical, Thermal and Damping Properties of NiTi (Nitinol) Reinforced Aluminum Nanocomposites. *Journal of Composites Science*, *4*(1), 19.
9. Miracle, D. B. (2005). Metal matrix composites - From science to technological significance. *Composites Science and Technology*.
10. Narasimalu, S., & Gupta, M. (2006). Effect of the Presence of Continuous/ Discontinuous/ Hybrid Reinforcement on the Damping Characteristics of Pure Aluminium Matrix. *Solid State Phenomena*, *111*, 71–74.
11. Sastry, S., Krishna, M., & Uchil, J. (2001). A study on damping behaviour of aluminite particulate reinforced ZA-27 alloy metal matrix composites. *Journal of Alloys and Compounds*, *314*(1), 268–274.
12. Shunmugasamy, V. C., Mansoor, B., & Gupta, N. (2016). Cellular Magnesium Matrix Foam Composites for Mechanical Damping Applications. *Jom*, *68*(1), 279–287.
13. Surappa, M. K. (2003). Aluminium matrix composites: Challenges and opportunities. *Sadhana - Academy Proceedings in Engineering Sciences*.
14. Yang, K., Yang, X., He, C., Liu, E., Shi, C., Ma, L., Li, Q., Li, J., & Zhao, N. (2017). Damping characteristics of Al matrix composite foams reinforced by in-situ grown carbon nanotubes. *Materials Letters*, *209*, 68–70.