Mechanics of Advanced Composite Structures 12 (2025), Serial Number 24, 25 – 42

Mechanics of Advanced Composite Structures

Semnan University

Journal homepage: https://macs.semnan.ac.ir/

ISSN: 2423-7043

Review Article

Studies on Progress of Aluminum Based Composites for Automotive Applications and its Damping Characteristics – A Review

Karthikeyan Lakshmanan [a] *, Pitchipoo Pandian [b], Rajakarunakaran Sivaprakasam [a], Kathiravan Sundaram [a]

[a] *Department of Mechanical Engineering, Ramco Institute of Technology, Rajapalayam, 626117, India*

[b] *Department of Mechanical Engineering, PSR Engineering College, Sivakasi, 626140, India*

ARTICLE INFO

Article history:

Received: 2023-12-03
Revised: 2024-03-30
Accepted: 2024-05-21

Keywords:

Aluminum matrix composites;
Automotive;
Damping;
Scientometric mapping.

ABSTRACT

The automotive industries have been compelled to build lighter, more fuel-efficient vehicles because of rising fuel costs and environmental laws. When the overall vehicle weight is reduced by adopting lightweight metals like aluminum-based composites, the fuel consumption also gets reduced. Aluminum-based composites are broadly used in the automotive and air transport industry due to their remarkable mechanical and tribological characteristics. The importance of composites made of aluminum used in automobile applications, as well as their damping characteristics, are discussed in this article. Due to the need for mechanical stability and performance in engineering applications, vibrations are unacceptable. Damping capability refers to the ability of materials to manage mechanical vibrations at the time of cyclic stress. To reduce mechanical vibrations in today's environment, materials with superior mechanical and damping capabilities are needed. Composites are a better alternative because they have better mechanical properties and damping capacity. The literature delves into the different aspects that influence aluminum-based composites and the need for damping studies in automotive applications. Finally, the research progress of aluminum-based composites towards damping characteristics has been reported by the Scientometric approach using VOSviewer. The Scopus engine search found 1329 documents relevant to Damping & vibration studies. Subsequently, a statistical analysis was conducted exclusively for the 628 research documents spanning the years 2010 to 2022.

1. Introduction

The prospective replacements for traditional engineering materials, such as steel and cast iron for automotive applications are light alloys (Aluminum, Magnesium, and titanium alloys), HSS alloys, and composite and advanced materials represented in Figure 1 [1]. Many automotive parts, including the vehicle dashboard, bumper (front & rear), engine, body covering, wheel, suspension components, brake system, steering system, battery, seat assembly, and gearbox have been constructed using these lightweight materials. Generally, aluminum is extensively used in the automobile industry due to its great strength-to-weight ratio. The use of aluminum in automobile manufacture is a result of contemporary development trends; yet, producing lightweight

* **Corresponding author.**
E-mail address: karthikeyan.designresearch@gmail.com

Cite this article as:

Lakshmanan, K., Pandian, P., Sivaprakasam, R., and Sundaram, K., 2025. Studies on Progress of Aluminum Based Composites for Automotive Applications and its Damping Characteristics – A Review. *Mechanics of Advanced Composite Structures*, 12(1), pp. 25-42

https://doi.org/10.22075/MACS.2024.32547.1589

cars with new, inventive materials like aluminum has a long history.

Composites are made by combining two or more basic materials, giving them greater qualities than the original material. Low density, high strength, excellent stiffness-to-weight ratio, high-temperature performance, conductivity, corrosion resistance, hardness, and high damping capacity are all characteristics of the composite [2], [3]. Base metals including Ti, Mg, Cu, Ni, and Al are frequently employed in the development of Metal Matrix Composites (MMCs), but aluminum is the most widely used metal due to its inherent advantages like excellent strength-to-weight ratio, great thermal and electrical characteristics, and cost-effectiveness [4]. The focus of this review work is on metal matrix composites, primarily Aluminum Matrix Composites (AMCs). The nature of materials and their volume fraction can be changed to alter the properties of AMCs. The foremost benefits of AMCs compared to non-reinforced materials are improved strength and stiffness, weight reduction, controlled thermal expansion, improved abrasion and wear resistance, and finally enhanced damping abilities. AMCs have recently been used in high-tech structural and functional applications in the fields of aerospace, defense, automotive, and thermal applications areas. The key benefits of AMCs in the automotive industry include lower airborne emissions, lower fuel consumption, and noise reduction. The utilization of AMCs in the automotive industry will become necessary and desirable in the coming years as environmental rules become more rigorous and an emphasis on improved fuel economy is maintained [5].

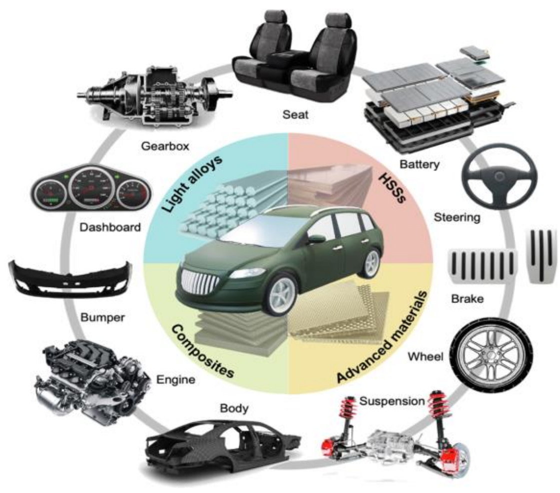

Fig. 1. Category of materials used in automotive applications [1]

An investigation was conducted into the various aluminum metal matrix composite gears that are commonly used in the power transmission systems of automobiles and other forms of machinery. AMCs were chosen because of their good mechanical qualities and lightweight, and they were employed to create lightweight car parts. The materials used in this study are Al 6061-T6, Al 6106-T6, Al 7075-T651, and Al 7050-T7451 [6]. Aluminum is one of the most popular used matrix materials in Metal Matrix Composites (MMC). In most cases, aluminum reinforced with Silicon Carbide (SiC), Alumina (Al_2O_3), Boron Carbide (B_4C), boron, and carbon can be considered. Stir casting, centrifugal casting, and Powder metallurgy are the most common methods for producing AMCs. An automotive connecting rod is made of aluminum oxide-reinforced metal, aircraft wing panels are made of aluminum reinforced with SiC whiskers, for missiles and helicopters, and graphite fibers in an aluminum matrix are utilized. The metal matrix-based composite material replaces most traditional auto parts such as the piston stem, brake drum, and connecting rods [7].

Aluminum, the automobile industry's most valuable asset, is widely employed in passenger cars and a variety of other commercial vehicles. Demand is increasing at a rate of 6-8 percent each year, and it is mostly employed in the manufacturing sector [8]. Ceramic particle-reinforced AMCs have a lot of potential in the automobile industry to replace heavyweight ferrous materials and improve vehicle efficiency and emissions control. In cars, composites can provide weight savings ranging from 15 to 40% [9]. Alumina (Al_2O_3), Silicon Carbide (SiC), Boron Carbide (B_4C), Titanium Carbide (TiC), Graphite (Gr), and carbon nanotubes are the most commonly employed reinforcements to improve the mechanical and tribological qualities of AMCs. High strength and stiffness, improved thermal properties, controlled thermal expansion coefficient, controlled heating of the material, better electrical conductivity, and increased abrasion resistance and wear are the advantages of composite materials with aluminum matrices over conventional aluminum alloys [10]–[17]. Alumina nanoparticles and natural fiber reinforced with epoxy resin enhanced the physical, thermal, and mechanical characteristics [18]. Ceramic and aluminum-reinforced hybrid composites resulted in significant improvement in tribological applications at elevated temperatures [19].

In this context, many researchers concluded that AMCs are attractive materials due to their effective functional properties such as high strength, wear resistance, and thermal characteristics for automotive applications. AMCs, on the other hand, consistently meet the current auto-market demand for lightweight requirements, durability, and high-rendering components. It is evident that only a few researchers attempted to study of dynamic behavior of AMCs. This review article aims to provide information to researchers regarding AMCs in automotive applications and their damping characteristics. The novelty of this review work lies in the fact that no such study has been reported for AMC damping characteristics and its current research progress. In addition to that, Scientometric mapping is also performed using VOSviewer software to provide extensive stances in research transition for interested researchers in this field.

This review paper comprises four sections. In the first section, a concise introduction of AMCs used in automobile sectors and current trends has been elaborated. The second section describes the fabrication techniques of AMCs, and the third section summarizes the importance of damping studies with prospectus reinforcements and the Scientometric mapping approach used to examine the field of damping studies in AMCs. Finally, the Summary and concluding remarks of the review have been presented.

2. AMCs in Automotive Applications

Aluminum was first extracted in 1888 as an element with attractive characteristics. The density of aluminum is 2.69 g/cm^3, which is almost 1/3rd of the density of conventional steel. As a result, it is feasible to create lighter, aluminum-based cars with better fuel efficiency, acceleration, braking, and handling and outstanding special behavior like high strength-to-weight ratio. On average, using aluminum instead of cast iron or traditional steel can result in a middle-size sedan vehicle emitting 18 tonnes fewer greenhouse gases over the course of its lifetime. Additionally, combining aluminum with other components (such as Cu, Mn, Si, Mg, and Zn) to create alloys may provide more exceptional qualities (such as increased strength compared to structural steel, improved corrosion resistance, and superior electrical and thermal conduction) [20]. The typical application of aluminum in automotive applications is shown in Figure (2).

AMCs have been widely used in the automotive industry because of their outstanding mechanical and tribological properties. Additional possibilities for increased demand for aluminum come from the electric vehicle revolution, which is entering the market sooner and faster than anyone might expect. In recent days, the electric vehicles market factors like reduced cost and drive range are more important factors to consumers than performance. In order to achieve a high operating range for a given battery size and weight, it is necessary to reduce the weight of the electric vehicle. In weight reduction, Aluminum is favored in this area as well for the manufacture of electric vehicles. According to the literature, adding homogeneous reinforcement elements has been proven to be effective in increasing the strength and hardness of these composites. It has been noted that the importance of using less-weight materials in the automotive sector for component and part production has recently been overstated. This is due to stringent emission regulations and demand by the customers for enhanced and comfortable automotive interiors with all electronic components and other accessories which imposes additional weight to the overall weight [21].

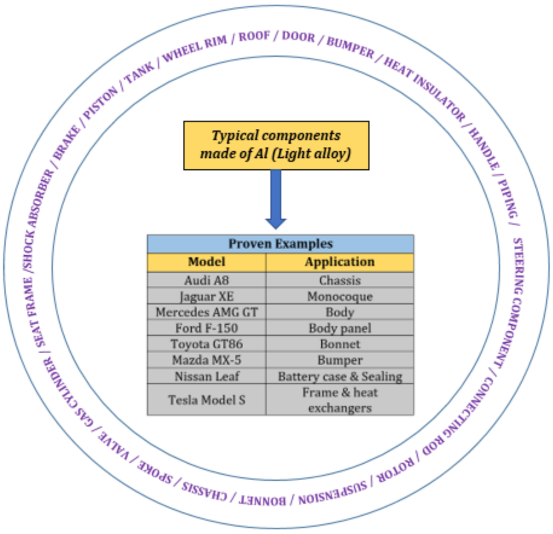

Fig. 2. Summary of aluminum-based material used in automobiles[1]

The advancements in composite materials based on aluminum composites are connected to the concept of using high-performance reinforcements to enhance the performance of existing materials. Physical and mechanical characteristics of composites which comprise mechanical strength, stiffness, weight, fatigue life, corrosion, and wear are greatly improved [22]. In the automotive industry, ferrous materials can be replaced with ceramics particle-reinforced aluminum matrix composites for achieving lighter vehicles, improving effectiveness, and maintaining recent emission norms. Utilizing lightweight composite materials can reduce a vehicle's overall weight by 15% to 40% [23].

The following are some of the important automobile components that have been successfully made using AMCs:

Pistons and cylinder liners: According to reports, the University of Wisconsin-Milwaukee (UWM) produced aluminum alloy pistons and cylinder liners with scattered graphite particles for solid lubrication [24]. The graphite-containing aluminum has a lower friction coefficient, and wear rate and does not seize when lubricated at the boundary. The results of testing aluminum/graphite pistons and liners in gas and diesel engines, as well as race vehicles, revealed lower friction coefficients and wear rates. Al-graphite composites friction coefficient was measured and found to be as low as 0.2 [25]. This makes it a good choice for cylinder liners in lightweight aluminum engine blocks because it allows engines to reach operating temperatures faster while also delivering superior wear resistance, lower cold-start emissions, and decreased weight [26].

Connecting rod: For parts that require improved strength at high-temperature applications such as Connecting rods, cast aluminum matrix Nano composites are superior compared to Steel, forged aluminum, and Titanium parts while reducing the reciprocating mass. Brakes: Automobile brakes (Disc type) and brake calipers usually made of cast-iron is an area where weight can be considerably reduced. Silicon carbide aluminum brake discs have been adopted by a number of renowned car manufacturers [26]. Light duty parts: The components aren't exposed to overloading as A/C pump brackets, chain covers, alternator housing, transmission housing, valve cover, and intake manifold could be replaced with composites made of aluminum and fly ash to improve the performance and conserve energy [27]. Suspension systems: Most automobile manufacturers consume aluminum and light steels for suspension system components to reduce the unsprung weight for better comfort which leads to improved vehicle dynamics. The control arm made of SiC-reinforced aluminum composites enhances existing aluminum alloy design by improving the strength using less material [28].

AMCs exhibit superior functionality with weight saving to replace the traditional materials in automotive applications. The current research is focused on improving the dynamic capabilities, energy absorption, recycling methods, and manufacturing feasibility with low cost towards the progression of zero-emission vehicles.

3. Current Scenario

The current generation of automotive innovation is coupled with a requirement for weight-reduction materials along with favorable mechanical and tribological properties able to satisfy all criteria. Utilizing aluminum and aluminum-based composite materials leads to elite automobiles with improved security, productivity, and environmental perspectives. An extension in motor lifespan should be achievable due to the use of aluminum in the automotive industry. Utilizing aluminum composites rather than steel reduces the mass of the automobile (5 to 7%). On the contrary, a rise in fuel prices on the global market has led to an increase in the use of aluminum and its composites rather than steel. Figure (3) shows a few proven applications of AMCs in the automobile-based sector and manufacturer details.

Aluminum-based composites have the possibility of being used in the manufacturing of tribo-mechanical components, Al-SiCp composite is used to make cam, poppet valve guides, and valve seat inserts [30]. Figure (4) depicts the various components of automotive fabricated by AMCs or Aluminum composites. Overall, this chapter concludes that AMCs have a great perspective to contribute to the automobile sector demanding lightweight, improved strength, and wear resistance.

On the other hand, the biggest barrier to aluminum recycling today is the scarcity of scrap metal at reasonable prices. In view of the reuse and recycling concept in the aerospace and automotive industry, aluminum with Sic and spent catalyst were prepared to fabricate a novel composite. The spent catalyst is extracted from oil refineries. The study revealed that there is a significant improvement in mechanical properties when compared to pure aluminum [31].

However, given the significant rise in aluminum use over the past several decades, it is anticipated that the amount of post-consumer scrap will increase going forward. Researchers created a dynamic model of material movement to assess the aluminum cycle on a worldwide vehicle scale in order to determine whether these actions increase the retrieval of aluminum scrapings for automobiles.

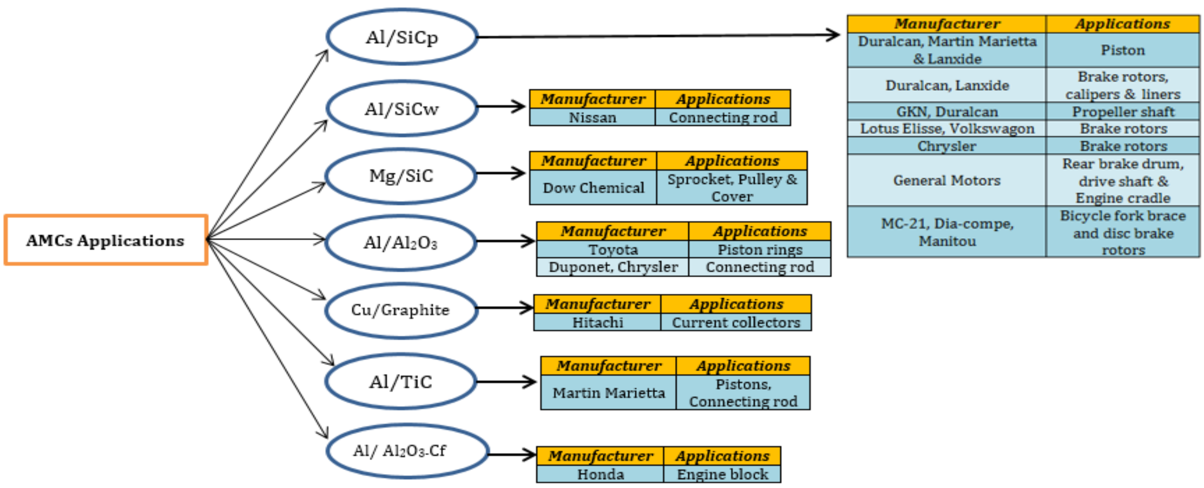

Fig. 3. Few proven applications of AMCs [29]

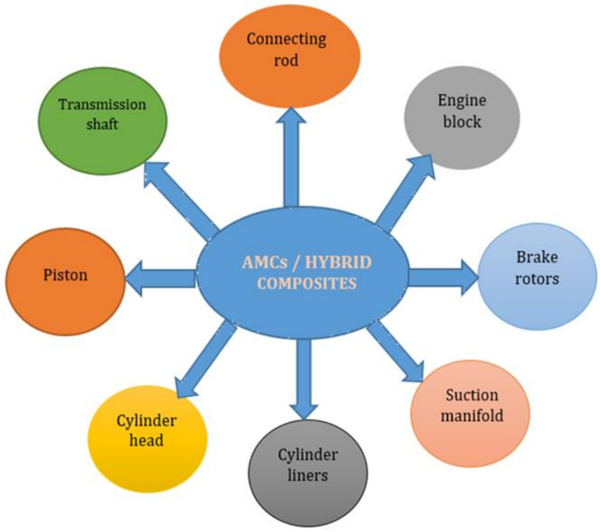

Fig. 4. Automobile parts developed from AMCs / hybrid composites

The system is composed of three distinct processes: manufacture, use, and end-life management for passenger cars. Then, based on a theoretical stock dynamics model, a demand-driven model was created to assess both inflows and outflows in the processes. A number of policy solutions were suggested to prevent the scarp surplus and in turn less environmental harm, in accordance with the assessment of the possibility, timing, and magnitude of the scrap surplus [32]. Summarized in Figure (5). Overall, the automotive sector is gradually adopting the AMCs as a strategy to achieve weight reduction, enhance performance, and comply with evolving regulatory requirements. Several research efforts are expected to achieve in improving dynamic characteristics and affordability for extensive adoption in future vehicles.

4. AMCs Manufacturing Techniques

The two most common processing techniques used to create these composites are liquid and solid-state processing. The choice of a specific manufacturing technique depends on various factors like matrix type, reinforcement material (Particle composition, size, and distribution), Mechanical, chemical and thermal properties of the matrix and prospectus reinforcement materials [33]. Figure (6) illustrates the different manufacturing techniques of composites / hybrid composites. The liquid state process comprises processes like stir casting, Squeeze casting or pressure casting, gas pressure infiltration, injection methods, and vortex casting. A solid-state process includes powder metallurgy, diffusion bonding, and vapor deposition.

Stir casting is often regarded as a promising production technology due to its inexpensive cost, minimal reinforcing damage, and the fact that stir-cast components are not limited in size or shape. It also has advantages such as ease of use, versatility, and suitability for large-scale production. Stir casting is the best practical choice for the fabrication of particulate-based composites using liquid-state processing techniques since it is simple and commercially available [34]. Using the stir casting technique, a novel Al6061-SiC-hexagonal boron Nitride (hBN) self-lubricated composite was developed, with an average stirring speed of 400–500 rpm. The microstructural study indicates that the manufactured composites had good reinforcement dispersibility in the matrix material [35].

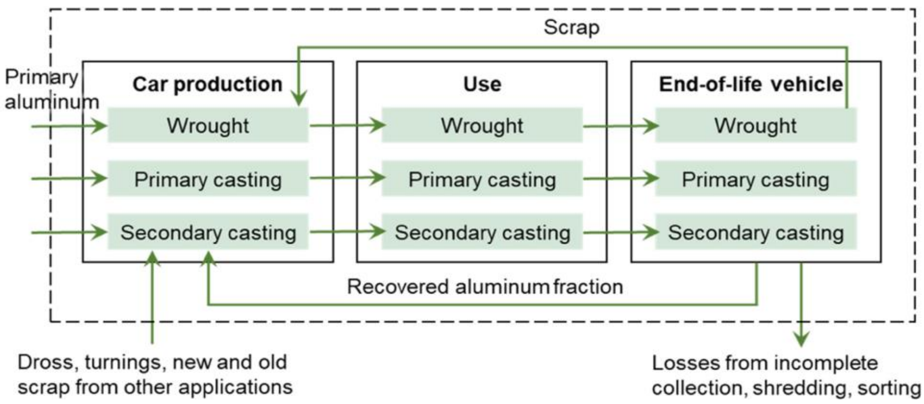

Fig. 5. Dynamic flow model of Aluminum life cycle [32]

The stir casting method was used to create an Al7075-Zinc alloy reinforced with zirconium diboride (ZrB_2) particles. Throughout the fabrication process, a stirring speed of 700 to 750 rpm is maintained. The fabricated composites show a significant uniform distribution of reinforcement particles and no voids were found in the sample prepared using a Scanning Electron microscope (SEM) [36]. The manufacturing techniques of aluminum-based composites were examined, with a focus on the stir-casting route. Reinforcement is added into a molten metal using this procedure, followed by a casting process [37]. To get the desired microstructural features of composites, several process factors such as stirring duration, speed, and feed rate can be governed [38]. An attempt is made to fabricate carbonized eggshell-reinforced aluminum-based composite using an electromagnetic stir casting process. Results indicate that under the ideal process conditions, hardness and tensile strength are greatly enhanced while maintaining toughness [39].

Increased stirring time and speed result in more evenly distributed reinforcing particles in the fabricated composites. The squeeze casting method is noted for its ability to generate structures that are almost net form and defect-free. Through a stir casting technique, SiC/Al7075 composite was effectively created and the mechanical characteristics were discussed [40]. The stir casting technique for aluminum metal matrix composites/Nanocomposites reinforced with SiC, TiO_2, Al_2O_3, B_4C, and TiC is influenced by factors such as weight, stirrer design, blade number, stirring speed, and melting temperature [41]. When a high content and equal distribution of reinforcement in the base matrix are sought, the gas pressure infiltration method is commonly used [42].

AMCs are developed using Al_2O_3/SiC Preform and the Gas Pressure infiltration technique. At three different pressures (1, 2, and 3 MPa) and temperatures (650°, 700°, and 750 °C), Al-matrix and preform were infiltrated. Archimedes' method was used to determine the porosity and density of the created AMCs. Pore size and porosity were reduced as SiC in the preform was increased. The highest bending strength of 558 MPa was attained at 800 °C and 3 MPa, respectively, for infiltration temperature and pressure [43]. The material is ground into fine powder form to attain the required form in the powder metallurgy process. The materials are then heated to a maximum temperature in a controlled atmosphere to fix them together [44]. Mixing, compaction, and extrusion are the three phases of successful powder metallurgy composite production [45]. The powder metallurgy method relies on consistent material mixing and sintering, as well as cold pressing and plastic working. In most cases, cold plastic work is carried out, with the green component being sintered initially [46]. The researchers used a PM method to make SiO_2/Al composites. To achieve homogeneous mixing, the powder mixture was pulverized for two hours under an argon atmosphere. The milled mixture was subsequently compressed using 200 MPa pressure in circular dies. The extrusion ratio for the sintered specimen was set to 8:1 [47].

Diffusion bonding with the foil-fiber technique was used to create Al 6061-boron fiber composites. However, Ti-based fiber-reinforced composites are more often produced using this method. The procedure is time-consuming and attains a high fiber volume fraction, Moreover, uniform fiber distribution is challenging. Complex forms and components cannot be manufactured using this method [5].

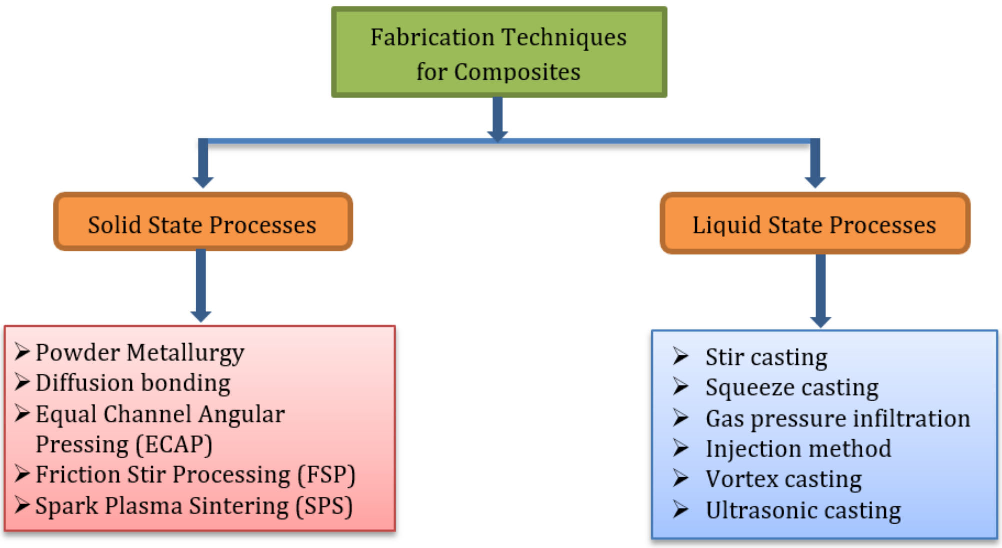

Fig. 6. Fabrication techniques for composites/hybrid composites [56], [57]

In recent days, some other techniques like Spark Plasma Sintering (SPS) solid-state fabrication process have been used for composite fabrication which involves direct current with lower voltage. High-density composites with exceptional grain growth can be obtained through this process also with excellent mechanical properties [48]. SPS is a costly procedure that is only used for simple symmetrical designs. Casting and powder metallurgy are used to make composites in the Hot Isostatic Pressing (HIP) process. The HIP process depends on the structure, density, and porosity of the materials. HIP is said to be a better method for improving mechanical qualities. Another approach for developing composites is Ultrasonic-Assisted Casting (UAC). UAC enables superior mechanical and property uniformity in generated composites, making it useful for composite bulk production and considered as little expensive. Friction-stir processing (FSP) is the technique of altering the characteristics of a material by applying intense and local plastic deformation. In this procedure, a non-consumable tool is introduced into the workpiece, permitting it to be stirred laterally. The use of FSP resulted in significant improvements in mechanical characteristics and fatigue life [49], [50].

The use of Spent Alumina Catalyst (SAC) in aluminum-based composite materials through the friction stir process (FSP) revealed a fair distribution of ingredients, increased tensile strength & hardness, significant effects on thermal expansion, and corrosion weight loss. [51]. FSP was used to produce an aluminum metal matrix composite with B_4C particles. The influence of process parameters such as tool rotational speed, tool tilt angle, and different pin profiles was explored by optimization and reported that increased rotational speed, reduced tilt angle, and square pin profile improved B_4C content dispersal and micro-hardness. The composite surfaces showed a 30% improvement compared to Al 6063 alloy [52].

Based on severe plastic deformation, ECAP is considered the most promising bulk material processing technology. [53]. The influences of ECAP on the microstructure and properties of aluminum wire were studied. The combined process resulted in wire with an ultrafine grain structure and greater mechanical properties. The 12-pass ECAP on stir-cast SiC/Al composites were studied and these fabricated AMCs resulted in reduced porosity, and improved tensile, compressive, and hardness with refined grains. [54], [55]. According to the findings of a market survey, pure aluminum, aluminum alloys, and aluminum matrix composites have a successful track record due to their beneficial properties, which include their high modulus of strength, fracture strength, compressive strength, and low thermal strength expansion coefficient.

Table 1. Comparison of fabrication method based on applications [56], [57], [58]

Fabrication technique	Cost of fabrication	Process parameters	Field of Applications	Limitations
Stir casting	Less expensive	Stirring speed and duration, Pouring velocity and temperature, Wetting agent, Preheat process of reinforcements	Suitable for the mass production of AMMCs and commercial products	Tearing happens at low speed
Squeeze casting	Moderate	Pressure level being used, temperature for preheating die, pouring temperature, Pressure duration	Various components of the automotive industries	Less cycle time, Tooling cost is high
Gas pressure infiltration	Moderate	Alloy composition, temperature, time	Rod, tube, and beam	Less production and High processing cost
In-situ (Reactive) processing	Low	Temperature, reaction time and mass fraction	Aerospace and automotive components	Choice of the dispersed phases are limited
Powder metallurgy	Medium	Powder compaction, sintering temperature, sintering duration, Reinforcement size	Tiny mechanical components such as bolts, valves, pistons, etc.,	High cost of tooling and basic materials
Diffusion bonding	Expensive	Temperature, bonding duration, and bearing pressure	The sheets have large areas, blades and turbine vanes, and other structural materials	High capital cost and time-consuming process

The output of Al-based composites is particularly high when compared to other metallic composites. The cost/performance ratio of aluminum products is the biggest worry among the aforementioned benefits.

Al-based composites will eventually see extremely big commercialization, which will happen soon [59]. The intensive comparison of various fabrication techniques based on the area of applications is tabulated in Table 1 In recent research, various fabrication methods to create aluminum metal matrix composites have been examined. Every fabrication technique has benefits and drawbacks. The choice of fabrication method depends on a number of variables, including manufacturing costs, the effectiveness of the process, the quality of the composites produced, etc. Finally, the technique of fabrication of composites plays a significant role in achieving the desired properties and quality [60].

Among all available manufacturing techniques, stir casting is the simplest and most economical method for AMCs. Manufacturing defects and metallurgical imperfections increased with higher reinforcement weight fraction. From the literature, it is evident that the optimization of process parameters (Ref: Table 1) is crucial for obtaining desired properties and metallurgical perfection. Advanced techniques such as additive manufacturing, ultrasonic-assisted casting, in-situ processing, and FSP have shown superior properties compared to traditional methods.

5. AMCs Damping Characteristics

Structural damping is an important topic to investigate during the design of dynamic structures, and choosing the right structural material is a difficult issue for the designer. Mechanical vibrations are common problems that occur when machines are in operation. The vibration noise is transmitted to the structure elements, resulting in loose components, wear, and other problems. A vibration with a higher frequency or persistent low-frequency vibration might lead to machine failure. [61]. Most engineering structural components experience vibration issues that will become critical as the resonant frequency approaches. Damping is a significant characteristic for minimizing the effects of vibrations, but almost all structural materials possess low damping abilities. Damping is typically provided by external elements (viscous damping) and is referred to as active damping. The material itself can reduce the effect of vibrations in passive damping or structural damping [62]. Few investigations on damping qualities have been conducted, despite the promise of these Fe-based alloy/steel-reinforced AMCs for increased mechanical and structural performance. It is very common in most structural applications for materials to withstand different loads and vibrations, especially dynamic conditions. The material's capacity to absorb and disperse vibration energies will be critical to its proper function which is damping capacity [63]. Damping capacity is regarded as a crucial design factor, especially for structures used in the automotive and aerospace sectors.

Materials with a high damping capacity convert applied excitations to other types of energy, primarily heat energy. Superior composites with the right reinforcements offer superior mechanical and damping characteristics [64]. The damping property of the composites is improved by reinforcement with high distinctive damping or by revamping the matrix microstructure. AMC damping capacity is impacted by particle size, shape, and volume fraction. SiC, Graphite (Gr), Carbon Nano Tubes (CNT), and Rice husk ash (RHA) are all used as prospectus reinforcement to improve the damping ability of aluminum composites [65]. Iron-based ferromagnetic alloys (cast iron, steel, Fe-Ni-Mn, Fe-Al) While in damping alloys, the damping mechanism is attributed to the microstructure, which is considered as the damping metal used. The most widely used due to their low cost are aluminum alloys with (germanium, cobalt, zinc, copper, silicon or alloys 6061, 2017, 7022, and 6082), zinc alloys, lead alloys, tin alloys, titanium alloys, nickel superalloys, zirconium alloys, copper and magnesium alloys. In addition, metal-based composites can be considered as a kind of damping metal such as (Al/SiC, Al/graphite, Mg/carbon, and NiAl/AlN). Due to the interface between the reinforcement and matrix material, metal composites provide vibration damping, resulting in increased damping ability and stiffness, also responsible for vibration reduction [66]. In the study of 2024Al reinforced with CNTs fabricated by isostatic pressing followed by hot extrusion process. The results revealed, that CNTs react with Al developing Al_4C_3 phases when heated above 1,000°F. CNTs significantly improved the mechanical characteristics of nanocomposites, including tensile strength and Young's modulus, compared to unreinforced 2024 Al alloy and concluded that CNTs improve the damping abilities of composites at elevated temperatures without reducing their mechanical strength [67]. The composite density and hardness improved with CNT reinforcement quantity with pure aluminum [68]. Composites of Aluminum, Al7020 alloy, and Al-1wt% Nanocomposites made of Multi-Walled Carbon Nanotubes (MWCNTs) were developed and experimental work was completed for Transverse vibration, mechanical characteristics, and surface morphology. It was concluded that the main role of these variations is the dissimilar microstructure with different phases through the matrix base. The Al-based nanocomposite Al-MWCNTs indicated the lowest ultimate tensile strength, axial stiffness, and elongation, as well as the highest bending modulus and fracture toughness along with maximum deflection. Additionally, when the applied load and frequency were adjusted during the transverse vibration test, the dynamic response of samples varies [61].

Studies show that adding SiC or Al_2O_3 to AMCs resulted in significant improvements in the specific strength and stiffness, but no consistency was found in terms of damping capacity [69]. The inclusion of graphite increases the damping capacity of AMCs and is further improved by increasing the percentage of reinforcement; though, an equivalent reduction in storage modulus was observed with an increase in volume fraction [70]. Al alloy composites with graphite as reinforcement were studied within some range. However, the SiC-reinforced Al alloy composite, which showed no noticeable improvements in damping capability, did not follow the same trend. Independent studies have found that fly ash-reinforced AMCs significantly better in damping capacity compared to the monolithic Al alloy [71], [72]. The damping behavior of some AMCs reinforced with rice husk ash (RHA), fly ash, Fe powder, and SiC was investigated. RHA has the lowest damping capacity of all the reinforcing powders tested, and the damping properties of all powders are affected by the frequency and temperature of the test [73].

The damping capacity (tan delta) curves were plotted for three different composites Al-SiC particulate -13μm, 38.8μm, and 118μm (with three different particle sizes) measured at room temperature to 400°C, three different frequencies 1, 20, and 50 Hz and interpreted as shown in below figure (7) From the room temperature up to 100ºC approximately, a minor increase in damping capacity is evident, but the higher temperature rises yield more expressive gains. Furthermore, it was discovered that as frequency increases, the damping peak height decreases. The conclusion reached from Figure (7) was that SiC particles added to the AlSi matrix resulted in an improvement in damping capacity and that the damping capacity of the AlSi-SiCp composites was higher than the unreinforced AlSi (for the temperatures and frequencies as specified). Additionally, it was discovered that the damping capability increased as the size of the reinforcing SiC particles increased.

The result of SiC particle dimension on AlSi-SiCp composites damping ability and dynamic Young's modulus were investigated. Both the properties were improved by adding SiC particles to aluminum alloy in the meantime AlSi-SiCp composites exhibited improved damping capacity when increasing SiCp size and maximum modulus was found with minor SiC particles. Damping capacity improved with temperature rise, meanwhile, a modulus decrease was reported [74]. Table (2) highlights a few research studies in the field of material damping investigation.

With reference to the investigations, adding ceramic particles like Silicon Carbide (SiC) or Alumina (Al_2O_3) as reinforcements to aluminum can significantly improve the damping capacity. It improves with increasing ceramic reinforcement volume fraction. However, high-volume fractions resulted in reduced strength. Reinforcement size and shape also influence damping characteristics. The selection of reinforcement type, size, morphology, heat treatment, and processing steps in aluminum-based composites can significantly enhance their damping performance.

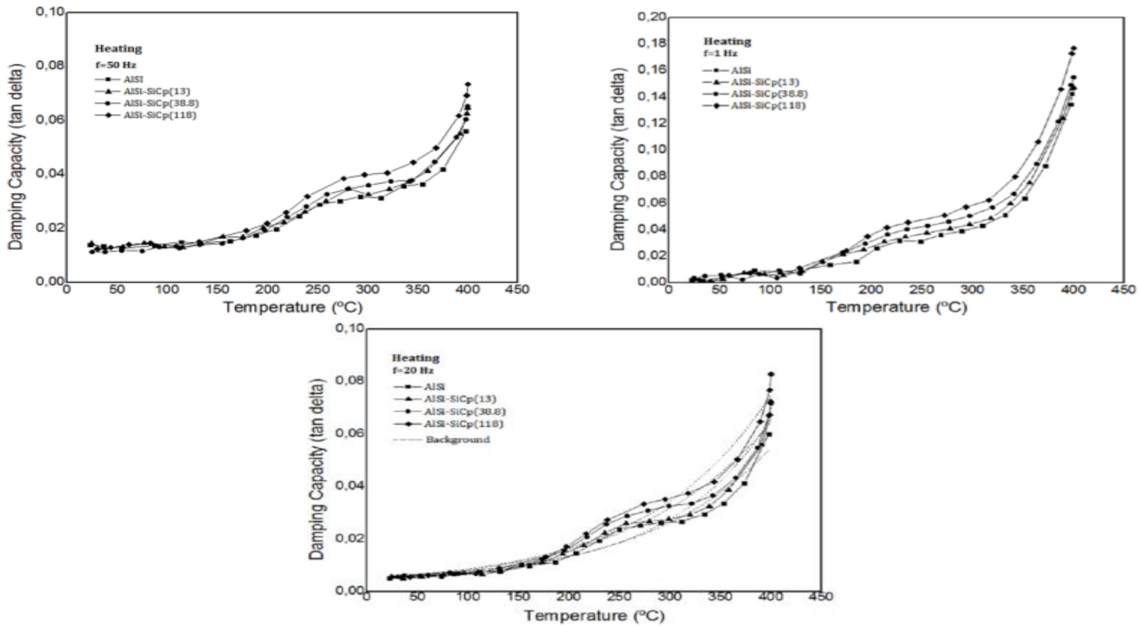

Fig. 7. Damping capacity Vs temperature for unreinforced AlSi and AlSi-SiCp composites at different frequencies [74]

6. Scientometric Mapping Approach

This approach is based on the 'mixed method systematic analysis' method, which combines quantitative and qualitative records to produce conclusions or interpretations for research themes. The search process in this review and the data collection are depicted in below figure (8) [75]–[77]

As illustrated in Figure (8), the preliminary search is data acquisition a mixed method systematic analysis of data possibly obtained from one database or a grouping of databases, such as PubMed, Web of Science, Google Scholar, and Scopus. Among all, the Scopus database was chosen for this study because it covers a wider range of topics, has a quicker indexing process, and comprises current publication records. The keywords "Aluminum and damping and Vibration" are used to extract the documents from the Scopus database. The initial search showed more than 1329 documents. The Scopus search algorithms give the connected synonyms and relevant words associated with the search keywords to offer a comprehensive record of results. Then, the keyword search was constrained to 'Aluminum and Vibration and Damping' in the span of 2010 - 2022 in order to concentrate on the latest research outcomes only. Excluded other language articles, review articles, book chapters, and conference proceedings. Finally, 351 journal articles available in the English language were taken for the Scientometric analysis. These publications were only used for Scientometric quantitative analysis to investigate the research trend, but other pertinent articles also were reviewed in the first three chapters.

The required Scientometric networks were mapped and presented using the VOSViewer for Scientometric mapping [78].

This analysis reveals insights into journal progress in damping studies, subject areas, leading countries, and collaborative networks. The important observations have been discussed in the subsequent contents.

6.1. Research Trend

Figure (9) indicates in what way the research interest in the area of aluminum/damping/ vibration has increased in the span of 2013-2021. In 2021 alone, 49 journal articles were published based on the keyword search, which exhibits a considerable rise of around 10 articles published from the previous year. Due to uncertain reasons, there is a decrease of roughly 13 journals in 2018 compared to the previous year. This statistic also demonstrates how interest in the area has increased since 2018. Apart from that year, the graph shows an upward trend until the year 2021. As of now, only 44 journals have been published as of now in 2022, but it is anticipated that this upward trend will continue.

6.2. Journal Subject Areas

Figure (10) shows the multidisciplinary and developing nature of this area of survey. Nearly 40% of the reviewed articles from the database were available in the core engineering journals. Consequently, the research on aluminum & damping doesn't focus only on the composite area and furthermore, this is not limited to the engineering discipline and materials. Instead, it represents a complete view of multiple perspectives or disciplines such as interdisciplinary, vibration and control, structural area, acoustics, and aeronautical subject areas. The multidisciplinary research approach has enabled a detailed survey of different and uncharted territories to address some practical application areas [77].

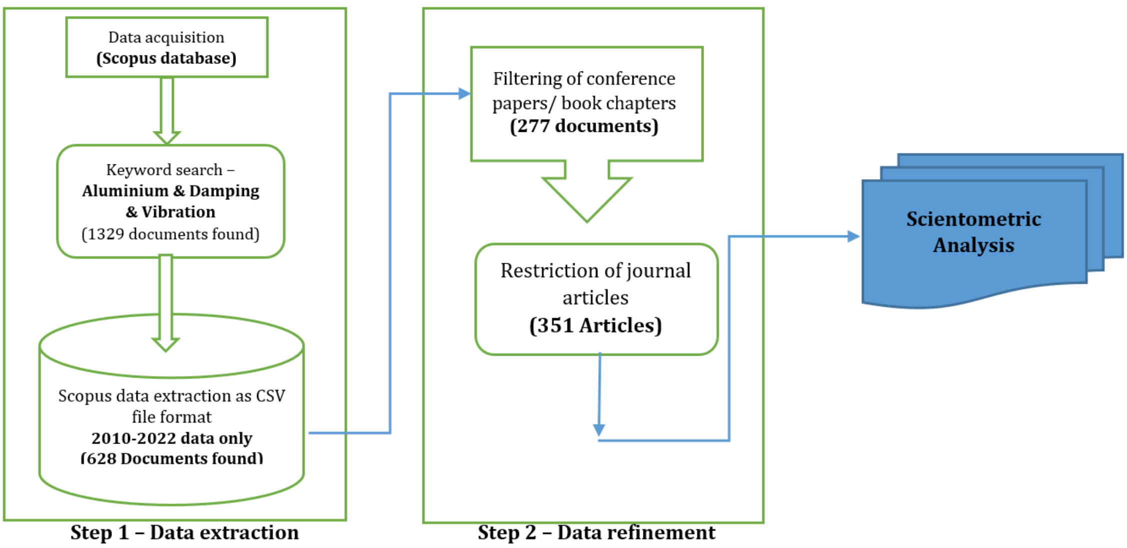

Fig. 8. Scientometric review approach

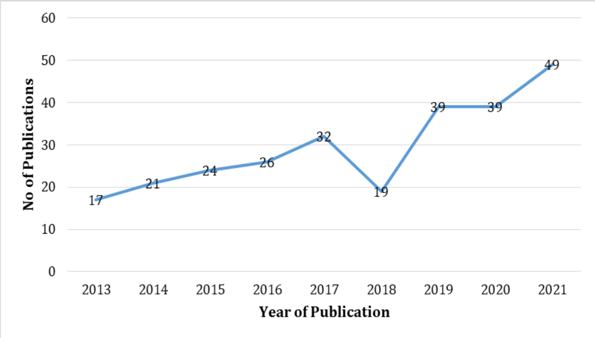

Fig. 9. Journal progress extracted from Scopus data [2013-2021]

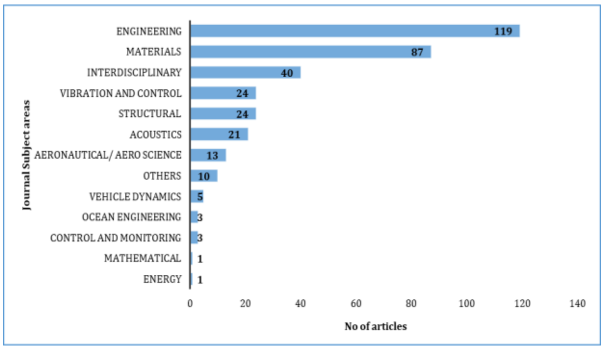

Fig. 10. Subject area of journal publications extracted from Scopus data [2010-2022]

6.3. Leading Countries and Institutes

The top publications for research on "Aluminum and damping" often reflect the best sources for experts as well as the best resources for beginner researchers to obtain or publish research on this area. Figure (11) depicts the top 10 countries that have leading publications in the research area.

For each of the 10 countries, the overall counts of the co-authorship associations with other countries were calculated. The countries with the highest link strength are chosen and shown. China is the leading country with its affiliated authorship with 87 journals in the span of (2010-2022). Next to China, Indian authors contributed to 53 journals in the same period. The US occupies the third position subsequently in terms of the number of journals.

6.4. Author Networks of Research on Interest Areas

Finding previous technical collaboration networks in several fields of study can make it easier to get funding, specialized knowledge, and experience. Furthermore, such comprehension might raise output and decrease the mindset to operate in isolation, which eventually promotes researcher communication and collaboration [95]. Figure (12) shows the researchers and collaboration work associated with the research area.

For visualizing this network system, the least number of journals for each author was fixed as two, which shows a linkage of 48 authors.

The journal authors were organized into 30 combined clusters. Cluster 10 led by Nanda B.K. and Singh B. shows the major interlinks between research collaboration work and the exchange of knowledge. Furthermore, more restricted joint networks, On the other hand, show a shortage of coordination among the authors in other clusters. In addition to that, the lighter yellow color represents the authors with current publications, whereas the purple color represents comparatively more experienced researchers in this area. The bottom scale from 2010 to 2020 represents the span of publication years.

The Scientometric approach is generally applied in many areas such as medical sciences, social sciences, manufacturing sciences, and construction management. This approach for researching "aluminum & Damping & Vibration" can aid the authors in better comprehension. This Scientometric analysis delivers a strong indication of the upward thrust in the field of Aluminum composites & damping characteristics. Despite this section's content, this approach has some limitations such as having data only limited to the Scopus database, conferences, book chapters, and review papers being excluded & addition and elimination conditions might produce somewhat different findings.

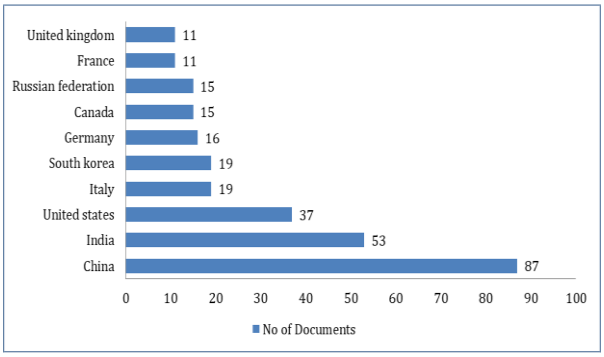

Fig. 11. Number of journal publications – Country-wise from Scopus data [2010-2022]

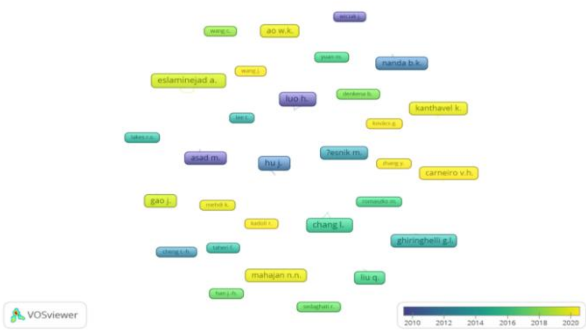

Fig. 12. Author networks of research on review field [2010-2020]

Table 2. A few previous research studies in the area of AMCs-based material damping

Material investigated	Manufacturing method	Inference	Ref. No
Al-Gr	Infiltration process under air pressure	An increase in graphite, particulate leads to a decrease in dynamic modulus, increases damping capacity	[79]
6061Al/SiC/Gr & 6013Al/SiC/Gr	Spray code position	The damping of 6061Al/SiC/Gr or 6013Al/SiC/Gr hybrid MMC outclasses that of 6061Al/SiC MMC up to 180^{0}C	[80]
2024Al with CNTs	Cold isostatic press and hot extrusion	To achieve high damping capacities at an elevated temperature, CNT is a promising reinforcement for metal matrix	[67]
Al/RHA	Vortex method	Heat-treated composites also have higher damping capacities than unheated composites	[81]
Al/Zn/Mg/Cu/Ni /Zr	powder metallurgy	The damping mechanisms are attributed to grain boundary and interface damping was high.	[82]
Ni / Al_2O_3 for Al-Si piston	Stirring and squeeze casting	Aluminum-piston alloy-based larger damping capacity	[83]
Al/ SnO_2 /Bi_2O_3	Squeeze casting	The damping capacity of the ABOw/SnBiO/Al composites is higher than that of the ABOw/Al	[84]
Aluminum foam	Sol-gel technology	Composite foam not only has a better mechanical strength but also a significantly increased damping capacity	[85]
AlSi/SiC	Hot pressing route	SiC particle size impacts dynamic Young's modulus and damping capacity	[86]
Al/SiC/RHA	Two-stage stir casting process.	A higher percentage of reinforcement is perceived to increase the damping capacity	[87]
AlSi-CNT-SiCp	Hot-pressing, in vacuum	Results indicated that hybrid composites have a higher damping capacity than single-reinforced composites	[88]
Al/SiC	Hot pressing technique	Damping capacity and Young's modulus appeared to be temperature-dependent. It was found that as the temperature rises, damping capacity increases	[89]
Al-Mg-Si alloy	Friction stir processing (FSP)	The process provides improved damping of commercial Al alloys without sacrificing their mechanical properties	[90]
Al-35Zn and Al-35Zn-0.5Sc alloys	Casting & Hot rolling	The damping capacity of the Al-35Zn alloy was improved by the Sc addition and hot-rolling	[91]
Al6061-SiC	Stir casting method	The Al6061-MMC mounts with 7.5% Sic exhibited a good damping ratio of 0.048551 and with least transmissibility ratio of 24.37	[92]
LM22/SiC/Fly ash	Casting & Heat treatment	In post-annealing damping ratio was lower than that of the base material, it was found that by increasing the reinforcing percentage, rise by 0.5%	[93]
Al-10 /Zn/SiC/Cu	Stir casting method	With all compositions showing an increase in damping capacity at test temperatures 100–200°C	[94]

7. Challenges and Opportunities

Aluminum composites have been proven as a prospective replacement for traditional materials in automotive, and aerospace applications. However, certain challenges exist in the development and research of aluminum-based composites subjected to high mechanical stress & temperature. The said challenges must be overcome to strengthen the usage of AMCs in engineering applications.

1. The proper selection of reinforcement, composition, processing technique, and process parameters for obtaining better properties for high mechanical stress applications
2. Progressive additive manufacturing processes such as Laser bed fusion and Direct energy deposition can be used to manufacture Aluminum alloys with tailor-made reinforcement distribution and

microstructure for improving high temperature and strength potential.

3. A hybrid additive manufacturing process can be used to develop Aluminum alloys aiming for defects, high-strength alloys
4. Efforts should be made to develop AMCs with novel reinforcements for high-temperature applications.
5. Attempts should be taken to enhance the AMCs with constituents of industrial wastes to advance recycling technology.
6. Attempts should be taken on the temperature-dependent properties of aluminum alloys which is essential for selecting suitable alloys for the design of engineering components.

8. Summary and Concluding Remarks

The purpose of this review is to have a broader perspective of aluminum-based composites used in automotive applications, current trends, manufacturing techniques damping characteristics, and the parameters considered. Several research papers on the reinforcement of aluminum metal matrix composites have been discussed extensively.

The above review of the aluminum-based composite leads to the following conclusions:

1. This review evident the characteristics of aluminum-based composites for the development of auto components for automotive applications. To keep up with current market trends, it is evident that the majority of automotive manufacturers wish to change from traditional steel components to lightweight materials. Currently, the composite sector needs to showcase its strength along with dynamic behavior and aluminum is the most commonly used matrix material for manufacturing composites due to its properties and processability.
2. AMCs nowadays, find a wide range of industrial applications. The possibility of producing composites with exciting mechanical properties is revealed by several investigations, particularly mechanical, wear properties and damping properties achievable are remarkable
3. The percentage of reinforcement, type, size, multiple reinforcements, and types of aluminum matrix are critical parameters for improving mechanical and tribological properties. When compared to monolithic alloys, the tribological properties of aluminum composites are enhanced by reinforcing with various materials to some extent.
4. Different manufacturing techniques are well-studied and compared based on cost of fabrication, process parameters, field of applications, and limitations summarized in Table (3) According to the studies, it is very difficult to optimize the process parameters to produce the desired properties in AMCs.

   The stir casting technique is a simple and economical process, but issues such as porosity and wettability of reinforcement must be addressed. Along with material selection, proper fabrication technique selection is critical for the composite property.
5. Reinforcements such as SiC, Gr, CNT, RHA, and Sc are found effective in improving the damping characteristics of aluminum-based composites. Heat-treated composites and in-situ, reinforcement in composites are found to have improved damping ability than ex-situ reinforced composites and unprocessed materials. The effect of test frequencies and test temperature reported significant variation in damping. The study also reveals the possibility of improving stiffness and damping properties by selecting suitable sizes of reinforcement particles.
6. Based on the keywords aluminum/ damping/vibration, Scientometric analysis offers a more comprehensive view of the pertinent scientific activity. The quantitative values that were highlighted would recommend new research directions.

As indicated by the above review, AMCs provide several opportunities in the field of automotive applications and a better success profile in terms of strength and processing technique. Now, AMCs must be considered for dynamic behavior enhancements study and achieving good quality composites for automotive applications.

Acknowledgments

The authors gratefully acknowledge the support provided by the Ramco Institute of Technology, Rajapalayam, Tamilnadu, India.

Funding Statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

References

[1] Zhang, W., Xu, J., 2022. Advanced lightweight materials for Automobiles: A review. Mater. Des. 221, 110994. https://doi.org/10.1016/j.matdes.2022.110994

[2] Rao, S.S., 2003. Mechanical vibrations. Pearson Education India.

[3] Ronald F. Gibson., 2016. Principles of composite material mechanics. CRC press. https://doi.org/10.1201/b19626

[4] Madhukar, P., Selvaraj, N., Rao, C.S.P., 2016. Manufacturing of aluminum nano-hybrid composites: A state of review. IOP Conf. Ser.: Mater. Sci. Eng. 149, pp.1013-1024. https://doi.org/10.1088/1757899X/149/1/01211

[5] Surappa, M.K., 2003. Aluminum matrix composites: Challenges and opportunities. Sadhana - Acad. Proc. Eng. Sci. 28, pp.319-334. https://doi.org/10.1007/BF02717141

[6] Subramanian, C., Senthilvelan, S., 2010. Effect of reinforced fiber length on the joint performance of thermoplastic leaf spring. Mater. Des. 31, pp.3733-3741. https://doi.org/10.1016/j.matdes.2010.03.014

[7] Singh, H., Brar, G.S., Kumar, H., Aggarwal, V., 2020. A review on metal matrix composite for automobile applications. Mater. Today Proc. 43, pp.320-325. https://doi.org/10.1016/j.matpr.2020.11.670

[8] Sivanur, K., Umananda, K.V., Pai, D., 2021. Advanced materials used in automotive industry-a review. AIP Conf. Proc. 2317, 020032. https://doi.org/10.1063/5.0036149

[9] Ravishankar, B., Nayak, S.K., Kader, M.A., 2019. Hybrid composites for automotive applications – A review. J. Reinf. Plast. Compos. 38, pp.835-845. https://doi.org/10.1177/0731684419849708

[10] Prasad Reddy, A., Vamsi Krishna, P., Narasimha Rao, R., 2017. Al/SiC NP and Al/SiC NP /X nanocomposites fabrication and properties: A review. Proc. Inst. Mech. Eng. Part N J. Nanomater. Nanoeng. Nanosyst. 231, pp.155-172. https://doi.org/10.1177/2397791417744706

[11] Nair, S.V., Tien, J.K., Bates, R.C., 1985. SiC-reinforced aluminum metal matrix composites. Int. Met. Rev. 30, pp.275-290. https://doi.org/10.1179/imtr.1985.30.1.275

[12] Kerti, I., Toptan, F., 2008. Microstructural variations in cast B4C-reinforced aluminum matrix composites (AMCs). Mater. Lett. 62, pp.1215-1218. https://doi.org/10.1016/j.matlet.2007.08.015

[13] Albiter, A., Contreras, A., Salazar, M., Gonzalez-Rodriguez, J.G., 2006. Corrosion behaviour of aluminum metal matrix composites reinforced with TiC processed by pressureless melt infiltration. J. Appl. Electrochem. 36, pp.303-308. https://doi.org/10.1007/s10800-005-9073-z

[14] Mohapatra, J., Nayak, S., Mahapatra, M.M., 2020. Mechanical and tribology properties of Al-4.5%Cu-5%TiC metal matrix composites for light-weight structures. Int. J. Lightweight Mater. Manuf. 3,pp.120-126. https://doi.org/10.1016/j.ijlmm.2019.09.004

[15] Bradbury, C.R., Gomon, J.K., Kollo, L., Kwon, H., Leparoux, M., 2014. Hardness of multi wall carbon nanotubes reinforced aluminum matrix composites. J. Alloys Compd. 585, pp.362-367. https://doi.org/10.1016/j.jallcom.2013.09.142

[16] Chen, H., Pala, Z., Hussain, T., McCartney, D.G., 2019. Fabrication and microstrain evolution of al-tib2 composite coating by cold spray deposition. Proc. Inst. Mech. Eng. Part L J. Mater. Des. Appl. 233, pp.1044-1052. https://doi.org/10.1177/1464420717690559

[17] Shorowordi, K.M., Laoui, T., Haseeb, A.S.M.A., Celis, J.P., Froyen, L., 2003. Microstructure and interface characteristics of B4C, SiC and Al2O3 reinforced Al matrix composites: A comparative study. J. Mater. Process. Technol. 142, pp.738-743. https://doi.org/10.1016/S0924-0136(03)00815-X.

[18] Arpitha, G.R., Mohit, H., Madhu, P., Verma, A., 2023. Effect of sugarcane bagasse and alumina reinforcements on physical, mechanical, and thermal characteristics of epoxy composites using artificial neural networks and response surface methodology. Biomass Convers. Biorefinery. doi: 10.1007/s13399-023-03886-7

[19] Sharath, B.N., Madhu, P., Verma, A., 2023. Enhancing tribological performance: A review of ceramic reinforced aluminum hybrid composites for high-temperature engineering applications. Hybrid Adv. 4, 100094. doi: 10.1016/j.hybadv.2023.100094.

[20] Mallick, P.K., 2021. Materials, Design and Manufacturing for Lightweight Vehicles. Elsevier. https://doi.org/10.1016/C2018-0-04153-5

[21] Koli, D.K., Agnihotri, G., Purohit, R., 2015. Advanced Aluminum matrix composites: The critical need of automotive and aerospace engineering fields. Mater. Today Proc. 2, pp.3032-3041. https://doi.org/10.1016/j.matpr.2015.07.290

[22] Mavhungu, S. T., Akinlabi, E. T., Onitiri, M. A., Varachia, F. M., 2017. Aluminum matrix composites for industrial use: Advances and trends. Procedia Manuf., 7, pp. 178–182. https://doi.org/10.1016/j.promfg.2016.12.045

[23] Gupta, M. K., Srivastava, R. K., 2016. Mechanical Properties of Hybrid Fibers-Reinforced Polymer Composite: A Review. Polymer-Plastics Technology and Engineering, 55(6), pp. 626-642. https://doi.org/10.1080/03602559.2015.1098694

[24] Macke, A., Schultz, B. F., Rohatgi, P., 2012. Metal matrix composites offer the automotive industry an opportunity to reduce vehicle weight, improve performance. Adv. Mater. Process., 170, pp. 19–23.

[25] Rohatgi, K., Ray, S., Liu, Y., 1992. Tribological properties of metal matrix-graphite particle composites. Int. Mater. Rev., 37, pp. 129–152. https://doi.org/10.1179/imr.1992.37.1.129

[26] Warren, H., Hunt, D. B., Miracle., 2001. Automotive applications of metal matrix composites. In ASM Handbook: Composites. ASM International,Ohio. https://doi.org/10.31399/asm.hb.v21.a0003484

[27] Gumus, M., 2009. Reducing cold-start emission from internal combustion engines by means of thermal energy storage system. Appl. Therm. Eng., 29, pp. 652–660. https://doi.org/10.1016/j.applthermaleng.2008.03.044

[28] Withers, G., De Waas Tilakaratna., 2005. Performance evaluation of ULTALITE® Low cost Aluminum Metal Matrix Composite based brake drums. SAE 2005 Trans. J. Mater. Manuf., 114, pp. 902–907. https://doi.org/10.4271/2005-01-3936

[29] Srivyas, P. D., Charoo, M. S., 2019. Application of hybrid aluminum matrix composite in automotive industry. Mater. Today Proc., 18, pp. 3189–3200. https://doi.org/10.1016/j.matpr.2019.07.195

[30] Vencl, A., Rac, A., Bobić, I., 2004. Tribological behaviour of Al-based MMCs and their application in automotive industry. Tribol. Ind., 26(3–4), pp. 31–38.

[31] Pragathi, P., Elansezhian, R., 2022. Studies on microstructural and mechanical properties of (Nano SiC + Waste Spent catalyst) reinforced aluminum matrix composites. Mater. Today Commun., 30, pp. 103204. https://doi.org/10.1016/j.mtcomm.2022.103204

[32] Modaresi, R., Müller, D. B., 2012. The role of automobiles for the future of aluminum recycling. Environ. Sci. Technol., 46, pp. 8587–8594. https://doi.org/10.1021/es300648w

[33] Kumar, S., Singh, R., Hashmi, M. S. J., 2020. Metal matrix composite: a methodological review. Adv. Mater. Process. Technol., 6, pp. 13–24. https://doi.org/10.1080/2374068X.2019.1682296.

[34] Adeolu A., Adediran, Abayomi A., Akinwande, Oluwatosin A., Balogun, Bayode J. Olorunfemi., Saravana Kumar, M., 2021. Optimization studies of stir casting parameters and mechanical properties of TiO_2 reinforced Al 7075 composite using response surface methodology, Sci. Rep. 11, 19860, https://doi.org/10.1038/s41598-021-99168-1

[35] Sahoo, S., Samal, S., Bhoi, B., 2020. Fabrication and characterization of novel Al-SiC-hBN self-lubricating hybrid composites, Mater. Today Commun. 25, 101402, https://doi.org/10.1016/j.mtcomm.2020.101402

[36] Durga Vithal, N., Bala Krishna, B., Gopi Krishna, M., 2020. Microstructure, mechanical properties and fracture mechanisms of ZrB2 ceramic reinforced A7075 composites fabricated by stir casting, Mater. Today Commun. 25, 101289, https://doi.org/10.1016/j.mtcomm.2020.101289

[37] Sharma, A. K., Bhandari, R., Aherwar, A., Pinca-Bretotean, C., 2020. A study of fabrication methods of aluminum based composites focused on stir casting process, Mater. Today Proc. 27, pp. 1608–1612. https://doi.org/10.1016/j.matpr.2020.03.316

[38] Rohit Sharma., Saurabh Jha., Khushboo Kakkar., Kushal Kamboj., Pardeep Sharma., 2017. A review of the aluminum metal matrix composite and its properties, Int. Res. J. Eng. Technol. 4, pp. 832 – 842.

[39] Dwivedi, S. P., Maurya, N. K., Maurya, M., Saxena, A., and Srivastava, A.K., 2021. Optimization of casting parameters for improved mechanical properties of eggshell reinforced composites, *Mater. Test.*, vol. 63, no. 11, pp. 1041–1051. doi: 10.1515/mt-2021-0044.

[40] Bhushan, R. K., 2021. Effect of SiC particle size and weight % on mechanical properties of AA7075 SiC composite, Adv. Compos. Hybrid Mater. 4, pp. 74–85, https://doi.org/10.1007/s42114-020-00175-z

[41] Maurya, M., Kumar, S., Bajpai, V., Kumar Maurya, N., 2020. Process parameters, development and applications of stir cast composite: A review, *Mater. Test.*, vol. 62, no. 2, pp. 196–208, doi: 10.3139/120.111472

[42] Etemadi, R., Wang, B., Pillai, K.M., Niroumand, B., Omrani, E., Rohatgi, P., 2018. Pressure

infiltration processes to synthesize metal matrix composites – A review of metal matrix composites, the technology and process simulation, Mater. Manuf. Process, 33, pp. 1261–1290, https://doi.org/10.1080/10426914.2017.1328122

[43] Demir, A., Altinkok, N., 2004. Effect of gas pressure infiltration on microstructure and bending strength of porous Al_2O_3/SiC-reinforced aluminum matrix composites, Compos. Sci. Technol. 64, pp. 2067–2074, https://doi.org/10.1016/j.compscitech.2004.02.015

[44] Sharma, P., Khanduja, D., Sharma, S., 2014. Tribological and mechanical behavior of particulate aluminum matrix composites, J. Reinf. Plast. Compos. 33, pp. 2192–2202, https://doi.org/10.1177/0731684414556012

[45] Idris, J., Kabir, M. A., 2001. Powder metallurgy development for the production of metal matrix composite, In: K. A. Khor, M. Wang, W. Zhou (Eds.) Processing and Fabrication of Advanced Materials VIII, Singapore, pp. 921–931. https://doi.org/10.1142/9789812811431_0108

[46] Kaczmar, J. W., Pietrzak, K., Włosiński, W., 2000. The production and application of metal matrix composite materials, J. Mater. Process. Technol. 106, pp. 58–67. https://doi.org/10.1016/S0924-0136(00)00639-7

[47] Issa, H. K., Taherizadeh, A., Maleki, A., Ghaei, A., 2017. Development of an Aluminum/amorphous nano-SiO_2 composite using powder metallurgy and hot extrusion processes, Ceram. Int. 43, pp. 14582-14592. https://doi.org/10.1016/j.ceramint.2017.06.057

[48] Singh, L., Singh, B., Saxena, K.K., 2020. Manufacturing techniques for metal matrix composites (MMC): An overview, Adv. Mater. Process. Technol. 6, pp. 441–457. https://doi.org/10.1080/2374068X.2020.1729603

[49] Sharma, A., Sharma, V. M., Mewar, S., Pal, S. K., Paul, J., 2018. Friction stir processing of Al6061- SiC -graphite hybrid surface composites, Mater. Manuf. Process. 33, pp. 795–804. https://doi.org/10.1080/10426914.2017.1401726

[50] Yang, M., Xu, C., Wu, C., Lin, K., Chao, Y. J., An, L., 2010. Fabrication of AA6061/Al_2O_3 nano ceramic particle reinforced composite coating by using friction stir processing. J. Mater. Sci., 45, pp. 4431–4438. https://doi.org/10.1007/s10853-010-4525-1

[51] Dwivedi, S.P., et al., 2022. Alumina catalyst waste utilization for aluminum-based composites using the friction stir process, *Mater. Test.*, vol. 64, no. 4, pp. 533–540. doi: 10.1515/mt-2021-2074.

[52] Kumar, S., Kumar, K., Maurya, M., Vishal, 2021. Parametric optimization of friction stir processing on micro-hardness of Al/B4C composite, *Int. J. Mater. Res.*, vol. 112, no. 11, pp. 898–909. doi: 10.1515/ijmr-2020-8027

[53] Segal, V. M., 1995. Materials processing by simple shear, Mater. Sci. Eng. A. 197, pp. 157–164. https://doi.org/10.1016/0921-5093(95)09705-8

[54] Andrey Volokitin., Abdrakhman Naizabekov., Alexandr Bogatov., Ivan Leshchev., Vladimir Kozlov., 2017. Development and research of combined process of 'equal channel angular pressing - drawing, J. Chem. Technol. Metall. 52, pp.172–179.

[55] Arab, M. S., El Mahallawy, N., Shehata, F., Agwa, M.A., 2014. Refining SiCp in reinforced Al–SiC composites using equal-channel angular pressing, Mater. Des. 64, pp. 280–286 https://doi.org/10.1016/j.matdes.2014.07.045

[56] Garg, P., Jamwal, A., Kumar, D., Sadasivuni, K. K., Hussain, C. M., Gupta, P., 2019. Advance research progresses in aluminum matrix composites: manufacturing & applications. *J. Mater. Res. Technol.*, vol. 8, no. 5, pp. 4924–4939. doi: 10.1016/j.jmrt.2019.06.028

[57] Chandel, R., Sharma, N., Bansal, S.A., 2021. A review on recent developments of aluminum-based hybrid composites for automotive applications, *Emergent Mater.*, vol. 4, no. 5, pp. 1243–1257, doi: 10.1007/s42247-021-00186-6

[58] Maurya, M., Kumar, S., Bajpai, V., 2019. Assessment of the mechanical properties of aluminum metal matrix composite: A review, *J. Reinf. Plast. Compos.*, vol. 38, no. 6, pp. 267–298. doi: 10.1177/0731684418816379

[59] Pallav Gupta., Devendra Kumar., Quraishi, M. A., Om Parkash., 2016. Influence of processing parameters on corrosion behavior of metal matrix nanocomposites. J. Mater. Environ. Sci. 7, pp.3930-3937.

[60] Olszówka-Myalska, A., Szala, J., Cwajna, J., 2001. Characterization of reinforcement distribution in Al/(Al_2O_3)p composites obtained from composite powder, Mater. Charact. 46, pp.189–195. https://doi.org/10.1016/S1044-5803(01)00123-1

[61] Abed, M. S., Nayeeif, A. A., Ali, H. A. K., Jabbar, M. M., 2020. Comparative study of transverse vibration and mechanical properties of aluminum, al 7020 alloy, and MWCNTS

reinforced aluminum nanocomposites, Int. J. Nanoelectron. Mater. 13, pp.509–522.

[62] Mehmet Colakoglu., 2004. Factors Effecting Internal Damping In Aluminum, J. Theor. Appl. Mech. 42, pp.95–105.

[63] Treviso, A., Van Genechten, B., Mundo, D., Tournour, M., 2015. Damping in composite materials: Properties and models, Compos. Part B Eng. 78, pp.144–152. https://doi.org/10.1016/j.compositesb.2015.03.081

[64] Kenneth Kanayo Alaneme., Adetomilola Victoria Fajemisin., 2018. Evaluation of the damping behaviour of Al-Mg-Si alloy based composites reinforced with steel, steel and graphite, and silicon carbide particulates, Engineering Science and Technology, an International Journal, Volume 21, Issue 4, pp.798-805. https://doi.org/10.1016/j.jestch.2018.05.007

[65] Rahiman, A. H. S., Smart, D. S. R., 2019. Damping characteristics of aluminum matrix composites - A review, Mater. Today Proc. 11, pp.1139–1143. https://doi.org/10.1016/j.matpr.2018.12.048

[66] Chung, D. D. L., 2001. Review: Materials for vibration damping, J. Mater. Sci. 36, pp.5733–5737. https://doi.org/10.1023/A:1012999616049

[67] Deng, C. F., Wang, D. Z., Zhang, X. X., Ma, Y. X., 2007. Damping characteristics of carbon nanotube reinforced aluminum composite, Mater. Lett. 61, 14–15, pp.3229–3231. https://doi.org/10.1016/j.matlet.2006.11.073

[68] Hussain, M. Z., Khan, U., Chanda, A. K., Jangid, R., 2017. Fabrication and hardness analysis of F-MWCNTs reinforced aluminum nanocomposite, Procedia Eng. 173, 1611–1618. https://doi.org/10.1016/j.proeng.2016.12.262

[69] Lavernia, E. J., Perez, R. J., Zhang, J., 1995. Damping behavior of discontinuously reinforced ai alloy metal-matrix composites, Metall. Mater. Trans. A. 26, pp.2803–2818. https://doi.org/10.1007/BF02669639

[70] Wei, J. N., Wang, D. Y., Xie, W. J., Luo, J. L., Han, F.S., 2007. Effects of macroscopic graphite particulates on the damping behavior of Zn–Al eutectoid alloy, Phys. Lett. A. 366, pp.134–136. https://doi.org/10.1016/j.physleta.2007.01.061

[71] Sudarshan, Surappa, M. K., 2008. Synthesis of fly ash particle reinforced A356 Al composites and their characterization, Mater. Sci. Eng. A. 480, pp.117–124, https://doi.org/10.1016/j.msea.2007.06.068

[72] Wu, G. H., Dou, Z. Y., Jiang, L. T., Cao, J. H., 2006. Damping properties of aluminum matrix–fly ash composites, Mater. Lett. 60, pp.2945–2948. https://doi.org/10.1016/j.matlet.2006.02.018

[73] Prasad, D. S., Shoba, C., Varma, K. R., 2015. Damping behavior of commonly used reinforcement powders – An experimental approach, Eng. Sci. Technol. Int. J. 18, pp.674–679. https://doi.org/10.1016/j.jestch.2015.05.001

[74] Madeira, S., Miranda, G., Carneiro, V. H., Soares, D., Silva, F. S., Carvalho, O., 2016. The effect of SiCp size on high temperature damping capacity and dynamic Young's modulus of hot-pressed AlSi-SiCp MMCs, Mater. Des. 93, pp.409–417. https://doi.org/10.1016/j.matdes.2015.12.147

[75] Ghosh, A., Hasan, A., 2020. Recent patterns and trends in sustainable concrete research in India: A five-year Scientometric review, Mater. Today Proc. 32, pp.910–916. https://doi.org/10.1016/j.matpr.2020.04.744

[76] Guetterman, T. C., Babchuk, W. A., Howell Smith, M. C., Stevens, J., 2019. Contemporary approaches to mixed methods–grounded theory research: A field-based analysis, J. Mix. Methods Res. 13, pp.179–195. https://doi.org/10.1177/1558689817710877

[77] Burke Johnson., Robert Gray., 2010. A history of philosophical and theoretical issues for mixed methods research, In: A. Tashakkori, C. Teddlie, (Eds.), SAGE handbook of mixed methods in social & Behavioral research, SAGE Publications, Inc., USA. https://dx.doi.org/10.4135/9781506335193

[78] VOSViewer (2023) Visualizing Scientific Landscapes. https://www.vosviewer.com. (accessed 10 January 2023). https://doi.org/10.1016/j.compositesb.2016.01.008.

[79] Wei, J. N., Cheng, H. F., Zhang, Y. F., Han, F. S., Zhou, Z. C., Shui, J. P., 2002. Effects of macroscopic graphite particulates on the damping behavior of commercially pure aluminum, Mater. Sci. Eng. A. 325, pp.444–453. https://doi.org/10.1016/S0921-5093(01)01535-0

[80] Gu, J. H. Zhang, X. N., Gu, M. Y., Gu, M., Wang, X. K., 2004. Damping behaviour of aluminum matrix composites, Mater. Sci. Technol. 20,pp.1211–1214. https://doi.org/10.1179/026708304225022098.

[81] Prasad, D. S., Krishna, A. R., 2012. Effect of T6 heat treatment on damping characteristics of Al/RHA composites, Bull. Mater. Sci. 35, pp.989–995. https://doi.org/10.1007/s12034-012-0382-7

[82] Li, Y. G. C., Ma, Y., He, X. L., Li, W., Li, P. Y., 2012. Damping capacity of high strength-damping aluminum alloys prepared by rapid solidification and powder metallurgy process, Trans. Nonferrous Met. Soc. China, 22, pp.1112–1117. https://doi.org/10.1016/S1003-6326(11)61291-0

[83] El-Labban, H. F., Abdelaziz, M., Yakout, M., Elkhatib, A., 2013. Prediction of mechanical properties of nano-composites using vibration modal analysis: Application to aluminum piston alloys, Mater. Perform. Charact. 2, pp.454–467. https://doi.org/10.1520/MPC20130006

[84] Liu, G., Tang, S., Ren, W., Hu, J., Li, D., 2013. Damping peak and damping mechanism in Al18B4O33w/Al composite containing Sn and Bi interfacial phases at room temperature, Mater. Des. 46,pp.916–921. https://doi.org/10.1016/j.matdes.2012.11.045

[85] Hao, G. L., Han, F. S., Li, W. D., 2008. Novel technology for improving damping capacity of aluminum foam by interface layer, Mater. Sci. Technol. 24, pp.822–826. https://doi.org/10.1179/174328408X278501

[86] 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, Compos. Part B. Eng. 90, pp.399–405.

[87] Siva Prasad, D., Shoba, C., 2016. Experimental evaluation onto the damping behavior of Al/SiC/RHA hybrid composites, J. Mater. Res. Technol. 5, pp.123–130. https://doi.org/10.1016/j.jmrt.2015.08.001

[88] Carvalho, O., Miranda, G., Buciumeanu, M., Gasik, M., Silva, F.S., Madeira, S., 2016. High temperature damping behavior and dynamic Young's modulus of AlSi-CNT-SiCp hybrid composite, Compos. Struct. 141, pp.155–162. https://doi.org/10.1016/j.compstruct.2016.01.046

[89] Madeira, S., Miranda, G., Soares, D., Silva, F. S., Carvalho, O., 2017. Study on damping capacity and dynamic Young's modulus of aluminum matrix composite reinforced with SiC particles, Cienc. e Tecnol. dos Mater. 29, pp.e92–e96. https://doi.org/10.1016/j.ctmat.2016.08.003

[90] Jiang, H.J., Liu, C.Y., Zhang, B., Xue, P., Ma, Z.Y., Luo, K., Ma, M.Z., Liu, R.P., 2017. Simultaneously improving mechanical properties and damping capacity of Al-Mg-Si alloy through friction stir processing, Mater. Charact. 131, pp. 425–430. https://doi.org/10.1016/j.matchar.2017.07.037

[91] Jiang, H.J., Liu, C.Y., Chen, Y., Yang, Z.X., Huang, H.F., Wei, L.L., Li, Y.B., Qi, H.Q., 2018. Evaluation of microstructure, damping capacity and mechanical properties of Al-35Zn and Al-35Zn-0.5Sc alloys, J. Alloys Compd. 739, pp.114–121. https://doi.org/10.1016/j.jallcom.2017.12.234

[92] Ramachandran, T., Murugapoopathi, S., Dharmalingam, R., Surendarnath, S., 2022. Studies on engine vibration isolation behaviours of Al6061-SiC metal matrix engine mounts for diesel engines, Mater. Today Proc. 66, pp.1485–1491. https://doi.org/10.1016/j.matpr.2022.06.282

[93] Ashok, T. M., Maharudresh, A. C., Srinivas Reddy, M., Chidhananda, R. S., 2022. Study on the vibration and density properties of hybrid MMC with reinforcement of SiC and flyash, Mater. Today Proc. 54, pp.303–306. https://doi.org/10.1016/j.matpr.2021.09.173

[94] Alaneme, K. K., Ojomo, A. M., Bodunrin, M. O., 2022. Structural analysis, mechanical and damping behaviour of Al-Zn based composites reinforced with Cu and SiC particles, Manuf. Rev. 9, 5, https://doi.org/10.1051/mfreview/2022005

[95] Ding, Y., 2011. Scientific collaboration and endorsement: Network analysis of coauthorship and citation networks, J. Informetr., 5, pp.187–203. https://doi.org/10.1016/j.joi.2010.10.008