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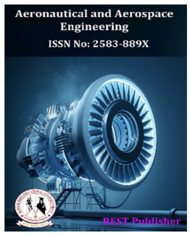

Investigation of Composite Materials for Significant Damping Response in Automotive Applications

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ABSTRACT

The study of composite materials offers engineers and manufacturers essential insights into understanding failure criteria, initial failure onset, and damage propagation within laminates. This research delves into examining the growth of impact-induced damage and identifying Hertz failure thresholds and maximum force limits across three distinct composite types. Through impact testing, it is observed that the strength of composite materials significantly rises under dynamic loading conditions compared to static loading scenarios, underscoring the material's sensitivity to strain rate.Composite materials play a crucial role in providing effective ballistic protection as part of armor solutions. These materials encounter impact loads of varying energy levels depending on their specific application. Ensuring adequate protection involves a meticulous design and manufacturing process capable of withstanding low-energy impacts, such as those from dropped tools during operational and maintenance tasks, intermediate-energy impacts caused by external materials striking the surface, and high-energy impacts from weapons.Fiber-reinforced composite materials find extensive utilization across aviation, marine, and land platforms, owing to their remarkable specific strength, weight reduction benefits, and manufacturing convenience. These materials hold pivotal roles in the aerospace and defense sectors as well. Polyester resins serve as a cost-effective and user-friendly alternative to epoxy resins in many fiberglass applications. This study focuses on exploring the low-velocity impact behavior of E-Glass composites, which are more economically viable and widely produced compared to armed composites. The research examines three distinct test samples to analyze the impact characteristics of these materials.

1. INTRODUCTION

A graphical representation of the dissipated energy against the initial impact energy enables the derivation of the energy profile of composite materials subjected to low-velocity impacts. This diagram serves as a valuable tool for comprehending the low-velocity impact behavior of composite materials by illustrating the correlation between dissipated energy and impact energy. Composite materials are increasingly employed in numerous applications demanding a high strength-to-weight ratio. Particularly for optimally designed high-performance components, the ability to detect and characterize typical defects like delaminating or voids, both qualitatively and quantitatively, is becoming increasingly crucial. The presence of defects can significantly alter the structural strength of materials. Numerous studies and applications have showcased the efficacy of thermograph in detecting defects within Carbon Fiber Reinforced Plastic (CFRP) and Glass Fiber Reinforced Polymer (GFRP) composite materials. Thermal techniques have proven valuable in examining defects in components bonded with adhesives. Understanding the nature of composite materials, their structures, and failure modes is essential.

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Moreover, comprehensive studies and further investigation into composite material failures play a crucial role in aircraft accident inquiries. The insights gleaned from such reviews can inform future developments related to composite material failure modes and fracture analysis, particularly regarding their relevance to material analysis during aircraft accident investigations .Over the past few decades, there has been a notable rise in the utilization of composite materials and structures within the aerospace and aviation sectors. Despite their recent prominence, research into potential applications of composite materials for aircraft construction dates back nearly 80 years. Early innovations such as sandwich-type honeycomb structures and glass fiber reinforced composites were introduced to the aviation community as far back as the 1940s. Carbon fiber reinforced composites, another significant development, entered the aviation field approximately 20 years later, in the 1960s.

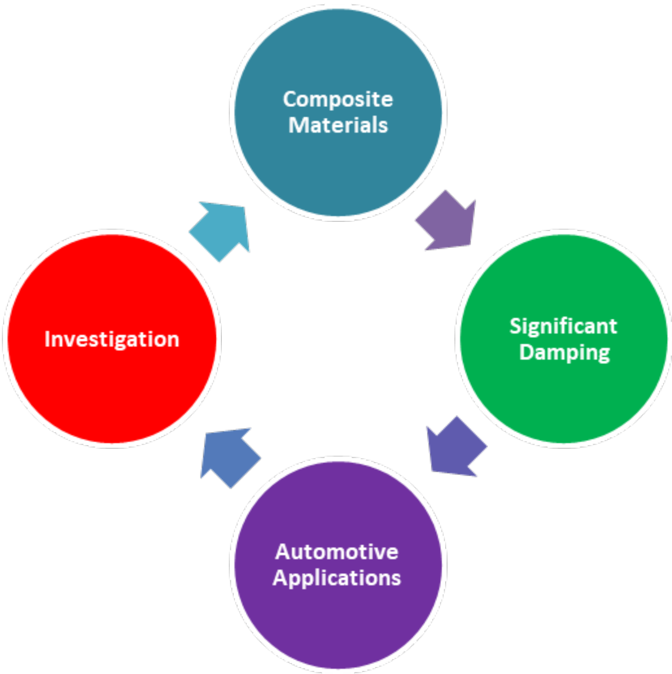

FIGURE 1. Investigation of Composite Materials

The mechanical properties of composite materials, particularly Young's modulus and Poisson's ratio, can be influenced by the inherent waviness of annotates embedded within polymers. To explore this phenomenon, researchers employ a three-dimensional finite element model. This model allows for the examination of how variations in volume fraction and waviness impact the mechanical characteristics of composites reinforced with waved carbon nanotubes.

2. INVESTIGATION

This article introduces a methodology that integrates experimental and computational modal analyses, focusing on assessing composite loss factors at higher frequencies associated with discrete bending and twisting vibration modes. Therefore numerical methods such as the finite element analysis may have to be adopted. The material properties of a viscose-elastic material such as mass density, Poisson's ratio, Young's modulus, and complex shear modulus G must be known before a computational model can be developed [1]. An understanding of elastomeric material properties and the methods used to characterize elastomeric component behavior is necessary to achieve desired performance. Typical design criteria and functional objectives for various isolator applications, including power train mounts, suspension control arm bushings, shock absorber bushings, exhaust hangers, flexible couplings, cradle mounts, body mounts and vibration dampers are also discussed. The goal of an isolation system is to reduce the magnitude of the force transmitted to the support to a level below that of the excitation force acting on the mass[. The investigation into composite materials for significant damping response in automotive applications is a multifaceted endeavor aimed at enhancing vehicle performance and passenger comfort. This investigative process begins with a comprehensive review of existing literature and research to understand the characteristics and potential applications of various composite materials [2]. Through meticulous material selection, researchers identify candidates with promising damping properties, including carbon fiber, fiberglass, and polymer matrix composites. Experimental testing, such as dynamic mechanical analysis and vibration testing, is then employed to quantify the damping capacity of these materials under different conditions. Computational modeling and simulation techniques further aid in predicting and optimizing damping behavior, guiding the modification of material composition, fiber orientation, and manufacturing processes to enhance performance while maintaining structural integrity[3]. Rigorous validation tests validate the effectiveness of the optimized composite materials under real-world conditions, paving the way for their integration into automotive components and systems. Ultimately, this investigation seeks to mitigate noise, vibration, and harshness while improving vehicle dynamics, thereby advancing the forefront of automotive engineering and design.

FIGURE 2. Investigation

The study examines the damping characteristics of hybrid flax/carbon fiber-reinforced composites. Various hybrid composites, combining carbon fiber and flax fiber with epoxy resin as the matrix, were fabricated using the vacuum-assisted resin infusion molding technique. Enhancing the damping properties of materials used in manufacturing automotive components offers a logical strategy for reducing engine noise and vibrations. Additionally, the susceptibility of modern electronic onboard equipment to factors like pyre shock and vibration stems from its increasingly compact size [4]. While existing variable damping solutions have addressed diverse damping requirements, they still exhibit several significant drawbacks. To surmount the limitations inherent in these variable damping solutions, a hybrid design approach is proposed. This hybrid design integrates a conventional hydraulic damper with a linear motor topology to create a novel hybrid variable damper system. A combination of electromagnetic and viscous damping mechanisms is integrated to tackle the limitations of current adaptive damping mechanisms. During the preliminary optimization process, the dimensions of the conductor tube were not treated as variable parameters; rather, they were manually chosen to ensure proper fitting inside the damper main body [5]. The study revealed that the magnetic flux densities inside the conductor steel reached the point of magnetic saturation. Understanding elastomeric material properties and employing appropriate methods to characterize elastomeric component behavior are imperative to achieve the desired performance levels. Subsequently, each composite material underwent testing for tensile properties employing a universal testing machine while a damping experiment was conducted using an impulse hammer and a Laser Doppler Micrometer[6]. The tensile investigation revealed that incorporating a flax layer into the external layers of carbon fiber laminate led to a reduction in Young's modulus by 28% for a single layer and 45% for two layers. As components decrease in size, their resonant frequencies increase, rendering them more vulnerable to failure induced by vehicular vibrations, shocks, and impact conditions Common failures in vehicles include the loosening of solder balls causing short circuits, cracking or breaking of crystal and ceramic elements, switch and relay chatter, and deformation of fragile structural components[7]. One approach to enhance vehicle damping properties is by utilizing hybrid fiber-reinforced composites, which include cellulose molecule chains. The mechanical stiffness and strength of these fibers are attributed to the cellulose microfibers and their arrangement. Flax fibers exhibit high strengths due to processing methods that prevent internal or surface flaws, which typically weaken glass fibers as vehicles age, their vibration and noise levels tend to escalate. Simultaneously, there has been a notable rise in consumer consciousness regarding the long-term health consequences of prolonged exposure to elevated noise and vibration levels. Active noise and vibration control systems, available commercially or documented in literature, primarily rely on adaptive signal processing and adaptive feed forward control theory [8]. These systems aim to generate a waveform that matches the magnitude but is out of phase with the original noise or vibration signal, thereby inducing destructive interference and effectively nullifying the impact of incoming excitation. For instance, consider an engine mount designed to restrict engine movement. Ideally, a very stiff mount is desired for this purpose. However, to mitigate the transmission of engine vibrations into the passenger compartment, a very soft engine mount is necessary. Passive noise and vibration treatments at low frequencies are physically unattainable [9]. Consequently, active control technologies have been explored for low-frequency noise and vibration control in automotive vehicles.

From a control standpoint, it's evident that feed forward control offers the capability to address a wide range of disturbance signals, from pure tones to fully random excitation. Recent advancements in NVH design and analysis tools, along with the development of low-cost digital signal processors and adaptive control theory, have rendered active vibro acoustic systems a practical and economically feasible solution for addressing low-frequency issues in automotive vehicles[10] Specific criteria have been established to design the desired form of equivalent linear damping coefficient, which offers a high damping ratio for low-frequency excitations and a small damping ratio for high-frequency excitations. Correspondingly, the nonlinear damping force necessary to enhance suspension ride performance using a 1-degree-of-freedom quarter car model is also defined. Clearly, achieving such damping characteristics is not feasible through a linear damper where the damping ratio remains nearly constant. Although using active and semi-active suspension systems could be beneficial to providing variable damping properties, there are serious concerns regarding their cost, complexity, and reliability [11]. It is also evident from this practical example that estimating the equivalent linear damping coefficient/damping ratio of the system by using the proposed method makes it possible to do the frequency analysis of any nonlinear damper. The equivalent linear damping coefficient of any nonlinear damper whose damping force is a function of relative displacement and velocity was derived using the energy balance method. The ride dynamics performance could be improved even further by using a position-velocity dependent damper over the entire range of the excitation frequencies. The proposed method was also applied for analysis of an experimental case in which the damping force in a conditional function form provides different damping force in rebound and compression [12]. The transferred energy depends on the piezoelectric constants as well as the vibration mode and the location of the piezo ceramics within the structure. While higher piezoelectric constants generally increase the amount of transferred energy, the design of the electrical shunt aims to maximize the energy dissipation. Different networks have been developed, which can be classified into the categories passive, active, linear or non-linear. The best choice of network depends on the performance target, the availability of electrical power supply and the vibration behavior and excitation type of the mechanical structure. . However, the contact area is represented as a layer with distributed stiffness and damping properties. Both pads have two translational degrees of freedom (out-of plane and in-plane direction) and stay in contact with the brake disc. The coefficient of friction m between disc and pads is assumed to be constant [13]. The brake disc is described as an annular disc according to the Kirchhoff plate theory. Measurements are conducted at the brake test rig with the modified brake. The following procedure is used to experimentally determine the frequency bandwidth of the damping effect. . The remaining sound without the squealing is environmental noise, which has been measured as high as 75 dB, and is dominated by the sound of the electric motor that drives the brake disc. Additionally, a novel approach for determining the performance of SSDI-techniques is presented. Based on these calculations, the performance is about 25% higher than for the LR-networks [14]. A squealing disc brake and a bladed disc model are studied as technical applications. For both cases practical realizations for the integration of piezo ceramics and electrical shunting are presented. Measurements are conducted which validate the simulation results. In particular, it is possible to suppress the brake squealing by shunted piezo ceramics. This leads to dynamically induced vibrations which can end in fatigue cracking of components and/or undesirable acoustic emissions. With recent trends in optimizing/ minimizing mass of vehicles, vibration problems are becoming an even more pronounced problem. In this research, a way has been investigated to reduce structural vibrations for a simple aluminum cantilever beam object, which is deduced from a cantilever beam of an automotive engine-transmission system. Dynamic structures subjected to periodic loads compose a very important part of industrial machineries. One of the major problems in these machineries is the fatigue and the cracks initiated by the fatigue [15]. The effect of this will be seen in the form of reduction in the maximum displacement of the beam when they will be vibrating at their Eigen frequencies. In, it is given that dynamic properties of a mechanical structure are theoretically characterized by its Eigen frequencies and their corresponding Eigen modes. The friction acting between the contact surfaces will take away some energy from the system which will lead to the decrement of total mechanical energy of the vibrating beam. In the case of oscillatory forcing functions, the stress (or the internal forces) is found to lead the strain (or the deformation). Thus a hysteresis loop is formed and completed during each cycle [16].The area inside the hysteresis loop represents the mechanical energy dissipated, or the work done by the damping force, in a unit volume of the material. The vibration response predicted is then used to compute the sound radiation. The critical buckling temperature and vibration response are obtained using the finite element method based on the Classical Laminate Plate Theory (CLPT) while sound radiation characteristics are obtained using a coupled FEM/BEM technique [17]. Thermal stresses due to aerodynamic heating may induce buckling and dynamic instability in structures. The pre-stress effect due to thermal load will affect the dynamic behavior of the structure due to the change in the stiffness of the structure. The thermal load is assumed to be created in the plate due to a uniform temperature distribution across the surface of the plate. The thermal load applied on the structure will induce membrane forces, which in turn influence the lateral deflections associated with the plate.

3. COMPOSITE MATERIALS

Various theoretical and experimental studies have been undertaken to anticipate the elastic behavior of carbon nanotubes (CNTs). Researchers have conducted experimental inquiries using diverse methodologies to scrutinize the mechanical characteristics of CNTs. Consequently, a wide spectrum of values for their mechanical properties has been reported by investigators. Composite materials, owing to their exceptional properties and adaptability, are transforming numerous industries, including automotive applications [18].Composite materials are formed by combining two or more different materials to produce a structure with enhanced performance attributes compared to its individual components. In the automotive sector, composites offer notable advantages, including a high strength-to-weight ratio, resistance to corrosion, and flexibility in design. Carbon fiber, fiberglass, and polymer matrix composites are prevalent in automotive applications, finding use in components like body panels, chassis structures, and interior trims. These materials facilitate weight reduction, thereby enhancing fuel efficiency and overall vehicle performance while also maintaining or even elevating safety standards. Moreover, composites empower designers to innovate with shapes and geometries, leading to vehicles that are both aerodynamic and visually striking [5].Advancements in composite manufacturing research and development offer promising prospects for the automotive industry [19]. These developments pave the way for the emergence of lighter, stronger, and more sustainable materials, heralding the advent of the next generation of vehicles. This trajectory towards efficiency, safety, and environmental consciousness underscores the transformative potential of composite materials in shaping the future of automotive engineering and design.

Composite materials find wide-ranging applications in various industries including aeronautics, sporting goods, domestic sectors, railways, energy fields, and automotive due to their lightweight and high aspect ratio. Components and parts fabricated from Glass Fiber Reinforced Polymers (GFRPs) necessitate specific machining processes such as milling, grinding, and drilling for fastening purposes. Among these operations, traditional drilling stands out as the most suitable and widely accepted method for creating holes in composite materials. The drilling process of composite materials has been investigated, revealing that delaminating increases on both sides of the holes with higher feed rates [20]. Hochberg and conducted a study on drilling-induced damage of composite materials, utilizing specialized drill bits. Their findings indicated that delaminating was minimized at lower thrust forces across all drill bits. In composite materials, assuming

FIGURE 3. Investigation of Composite Materials

Coulomb-type friction at the fiber-matrix interface and employing standard frictional coefficient values, it has been demonstrated that shrinkage-induced clamping pressure may significantly influence the frictional stresses observed on deboned fiber-matrix interfaces during pullout

4. SIGNIFICANT DAMPING

These principles apply broadly to brittle matrix composites and are particularly relevant to cement-based composite materials. Given the critical role of the fiber-matrix bond, numerous analytical models and experimental findings have been documented in the literature over the years. These efforts aim to quantify the bond strength between the fiber and matrix across various fiber-matrix systems the evolution of composite materials has been extraordinary, witnessing a rapid expansion in volume and diverse applications, continually penetrating new market sectors. The demand for these engineered materials spans from consumer goods to advanced niche applications, underscoring the substantial advancement of composite materials [21]. Particularly, composite materials have become increasingly prevalent in aircraft and automobile applications. The structural efficacy of composite structures relies heavily on their joints rather than their foundational structures. Mechanical joints, including bolts, pins, screws, and rivets, are pivotal components in industrial systems, preferred for assembling composite elements within primary structures [8].This article introduces a variable stiffness system aimed at achieving consistent damping performance in shock absorbers, necessitating adjustments in stiffness and damping properties. Automobiles are engineered to accommodate maximum mass by determining suspension parameters such as stiffness and damping coefficient. Past research has explored variable stiffness and damping to optimize vibration isolation performance. Liu et al. introduced the Voigt element, integrating a controlled damper with a constant spring. Fluid dampers offer a reliable and cost-effective solution for automobile suspensions, with their oil flow characteristics tunable to enhance vibration isolation performance across a broad spectrum [22]. The prototype under investigation aims to be integrated into a vehicle suspension system to achieve variable stiffness. However, besides energy storage, the disclosed system also serves for energy dissipation, acting as a damping mechanism. Properties such as Young's modulus, shear modulus, and damping coefficients are discussed, along with methods for estimating these properties for automotive applications. Characterizing foam damping materials within finite element structural models, represented as discrete springs and dashpots, offers an accurate and cost-effective approach to incorporate these features. Significant damping holds critical importance across various engineering applications, notably in automotive engineering, where it significantly enhances vehicle performance, safety, and comfort [23]. Damping refers to a material or system's ability to dissipate energy from mechanical vibrations, thereby reducing oscillations and minimizing the transmission of noise and vibration to surrounding components. In automotive systems, significant damping helps to mitigate road-induced vibrations, engine vibrations, and impacts from uneven surfaces, thereby improving ride quality and passenger comfort. Moreover, it contributes to vehicle stability, handling, and maneuverability by minimizing body roll and enhancing tire-to-road contact Furthermore, substantial damping assists in diminishing noise, vibration, and harshness (NVH) levels inside the cabin, thus fostering a quieter and more enjoyable driving environment for occupants. Through the utilization of advanced materials and damping technologies, automotive engineers can attain optimal damping characteristics, thereby striking a harmonious balance between performance, comfort, and efficiency in contemporary vehicles.

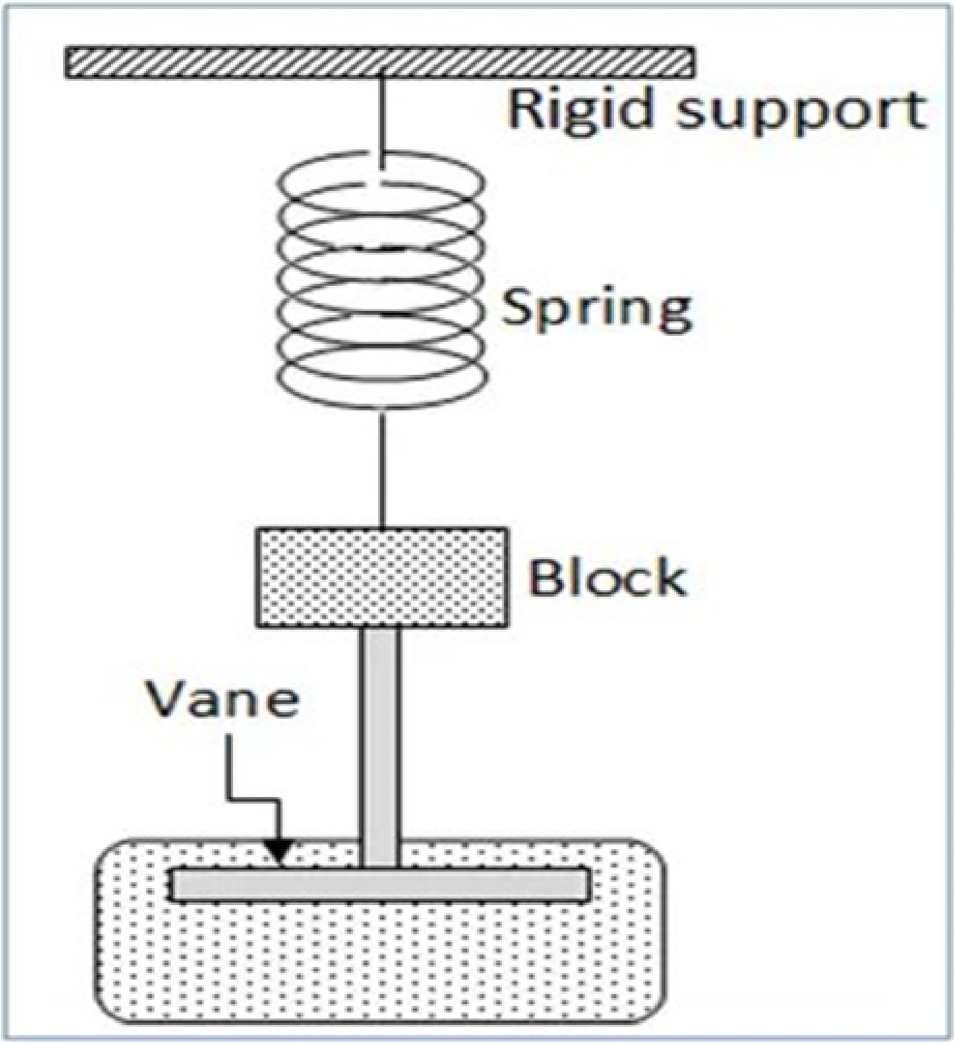

FIGURE 4. Damping

Damping materials serve to create a cushioning bond between metal components, typically linking the outer panel of automotive structures like the hood, roof, doors, or trunk lid to an inner reinforcement. These damping materials, often called anti-flutter buttons, commonly consist of epoxy or vinyl-based polymers infused with a chemical blowing agent that expands by around 150 percent when heated during the paint baking process. By employing these materials, the stiffness and damping attributes of the foam anti-flutter materials can be effectively incorporated. The most comprehensive approach to model the foam involves utilizing three perpendicular springs and a single dashpot in the direction perpendicular to the panel [24].This approach offers a precise and cost-effective means to integrate foam stiffness and damping effects into a finite element model. Sometimes, modifying the system's stiffness or mass can effectively alter resonance frequencies, reducing undesired vibrations, provided that the excitation frequencies remain unchanged. However, in most scenarios, vibrations must be either isolated or dissipated using isolators or damping materials. Semi-active methods leverage active control to enhance the damping properties of passive elements. Examples include electro-rheological (ER) and magneto-rheological (MR) fluids, as well as active constrained-layer damping (ACLD), wherein the conventional constraining layer is substituted with a smart material [13].Damping can be introduced to a system through the utilization of specialized viscoelastic materials in various manners. Damping involves extracting mechanical energy from a vibrating system, typically converting it into heat. Its function is to regulate the steady-state resonant response and diminish traveling waves within the structure. Material damping represents the inherent damping within the material, while system or structural damping encompasses damping at supports, boundaries, joints, interfaces, and other factors, in addition to material damping.

5. AUTOMOTIVE APPLICATIONS

Damping plays a crucial role in both the automotive and commercial airplane sectors. This paper aims to serve not only as an educational resource but also as a catalyst for exploring innovative applications across diverse industries. In the automotive realm, damping response is essential for managing and mitigating oscillations, vibrations, and impacts caused by road conditions, vehicle maneuvers, and external forces [25]. It profoundly impacts vehicle dynamics, affecting ride comfort, handling, stability, and overall safety. Below is a summary of the role of damping response in automotive contexts. Composite materials offer substantial transformative possibilities in numerous automotive applications due to their unique characteristics and adaptability. Composite materials find widespread use in automotive parts such as body panels, chassis structures, interior trims, and suspension systems. They enable weight reduction in body panels, leading to improved fuel efficiency and overall performance while maintaining safety standards. Chassis structures leverage composite materials for their excellent strength-to-weight ratio, enhancing structural integrity and crashworthiness while minimizing mass. Using composites for interior trims provides designers with expanded creative possibilities for aesthetics and customization, along with durability and resilience against wear and tear. Additionally, composite materials play a crucial role in suspension systems by dampening vibrations and reducing noise, ensuring a more comfortable ride for passengers. As automotive manufacturers pursue innovative solutions to meet changing demands for performance, efficiency, and sustainability, composite materials remain at the forefront, driving progress in automotive design, manufacturing, and overall performance.

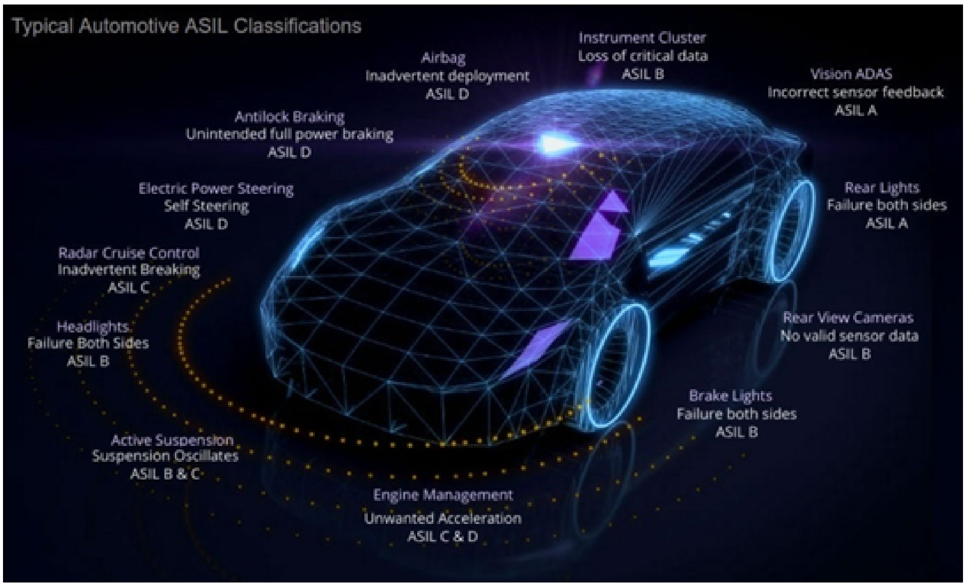

FIGURE 5. Automotive Applications

The suspension system of a vehicle consists of springs, dampers (shock absorbers), and other components. The primary function of the suspension is to support the vehicle's weight and to absorb shocks and vibrations from the road surface. Dampers, or shock absorbers, play a crucial role in damping response. They are hydraulic or pneumatic devices designed to control the movement of the suspension springs. When the vehicle encounters a bump or a disturbance in the road, the springs compress and release energy. Without dampers, the springs would continue to oscillate, leading to a bouncy and uncomfortable ride [26]. Damping ratio is a measure of the level of damping in a system relative to its critical damping. Critical damping is the minimum amount of damping required to prevent oscillation or bouncing. A damping ratio less than 1 indicates under damping, which may result in a bouncy ride but improved responsiveness. A damping ratio greater than 1 indicates over damping, which can lead to a harsher ride but better stability. Automotive dampers utilize various damping mechanisms, including hydraulic, gas, or a combination of both. Hydraulic dampers use fluid displacement to absorb and dissipate energy. Gas dampers incorporate gas chambers to provide additional damping force and resistance. Some modern vehicles come equipped with adjustable damping systems that allow drivers to select different damping settings based on driving conditions or preferences. These systems may offer settings for comfort, sport, or performance driving modes, enabling drivers to tailor the vehicle's damping response to their preferences. The damping response significantly influences various aspects of vehicle dynamics. Optimal dampings helps maintain tire contact with the road surface, improves traction, enhances stability during cornering and braking, and minimizes body roll and pitch motions. In summary, damping response in automotive applications is essential for ensuring a comfortable, stable, and safe ride by controlling the oscillations and vibrations transmitted to the vehicle's chassis from the road surface. It is achieved through the proper design and calibration of suspension systems, including the selection and tuning of dampers to provide the desired balance between ride comforts and handling performance. . The damping usually peaks at or around the glass transition temperature of the material. Some polymers can be made to have more than one transition region by changing the polymeric structure and composition to take advantage of the peak damping capacity in this region. In the rubbery state both modulus and loss factor take somewhat low values and vary very slowly with temperature [27].

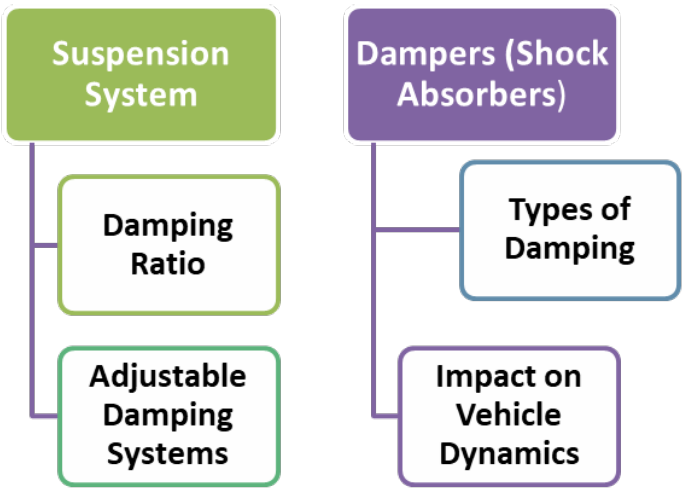

FIGURE 6. Damping Response in Automotive Applications

The dynamic response of MR dampers stands as a pivotal parameter in engineering applications. Nonetheless, the varying definitions of response time often result in measurement confusion. Despite essential traits such as dynamic range, maximum damping force, and power consumption, the dynamic response remains the paramount parameter for assessing MR damper viability in mechanical vibration systems. Acquiring precise dynamic response time is crucial for optimizing the performance of MR dampers; An MR damper intended for automotive suspension has been developed and produced with a stroke of ±50mm, and a maximum designed excitation current of 3A. However, the damping force is not optimal due to volume compensation [28]. To restore it, the system undergoes multiple cycles with excitation current until normal feedback is achieved, irrespective of the degree of damping force recovery compared to the initial state. Following prolonged periods of inactivity, the response time of the MR damper significantly increases due to sedimentation and other factors. The Magneto-rheological (MR) effect is observed as a substantial alteration in yielding shear, which is continuously regulated by the magnitude of applied magnetic fields. These technologies can be categorized into six primary types: resistive, capacitive, inductive, magnetic, time-of-flight, and pulse encoding. To enhance noise filtering and/or implement a virtual sensor, suitable Kaman observers have frequently been employed to estimate the elongation velocity and damping force of a single semi-active shock absorber [29]. A soft sensor can be adjusted to predict the system variable in real-time, especially when an undesired actuation delay is caused by corresponding hardware devices In conclusion, has been developed and can serve as a reliable benchmark for the evaluation of fault detection strategies, specifically focusing on sensor validation of rear suspension stroke. This involves identifying thresholds for fault detection, considering parameters such as false alarms and accurately detected faults. In terms of spectral analysis, existing literature presents two distinct measurement strategies [30]. The first approach involves discrete mode or narrow-band measurements, particularly in low or mid-frequency ranges. Instances encompass methodologies like the ASTM approach. Practical issues concerning noise and vibration control in automotive settings frequently display unique characteristics that cannot be adequately tackled by relying solely on a single vibration mode or a broad asymptotic technique. Indeed, numerous noise and vibration patterns in machinery manifest multiple pure tones, modulation, beating phenomena, or quasi-periodic responses.

6. CONCLUSION

Composite materials offer essential insights for engineers and manufacturers to grasp failure criteria, the onset of initial failure, and damage propagation within laminates. This research delves into analyzing the expansion of impact damage and identifying Hertz and failure thresholds, along with maximum force limits, across three distinct composite variants. Moreover, composite materials play pivotal roles in aerospace and defense sectors. In many fiberglass applications, polyester resins serve as a cost-effective and convenient substitute for epoxy resins In this study, we investigate the low-velocity impact properties of E-Glass composites, which are more affordable and commonly produced compared to Aramid composites. We analyze three distinct test samples to understand their behavior. By plotting the dissipated energy against the initial impact energy, we can obtain the energy profile of composite materials during low-velocity impact events.This graphical representation serves as a valuable tool for comprehending the low-velocity impact characteristics of composite materials, as it illustrates the correlation between dissipated energy and impact energy. The existence of defects can significantly alter the structural strength. Various studies and applications have showcased the capability of thermograph to identify defects in Carbon Fiber Reinforced Plastic (CFRP) and Glass Fiber Reinforced Polymer (GFRP) composite materials. Thermal techniques, in particular, have been employed to examine defects in adhesively bonded components. Exploring composite materials and their structural dynamics, particularly in the context of automotive applications, entails an examination of their damping characteristics to mitigate vibrations and diminish noise within vehicles. The investigative process typically begins with a comprehensive review of literature and prior studies concerning composite materials and their damping behavior.Researchers investigate various composite materials and assess their suitability for automotive engineering applications. They identify candidate materials such as carbon fiber composites, fiberglass composites, polymer matrix composites, and metal matrix composites, among others, based on the specific needs of automotive applications, particularly their damping properties. Subsequently, experimental tests are conducted to analyze and validate the damping characteristics of the chosen composite materials.Researchers employ various testing methodologies such as dynamic mechanical analysis (DMA), vibration testing, modal analysis, and other pertinent techniques to quantify the damping capabilities of materials across diverse conditions. Additionally, they create computational models and simulations to anticipate the damping performance of composite materials within automotive structures. By utilizing finite element analysis (FEA) and computational fluid dynamics (CFD) simulations, researchers gain insights into the interaction between composite materials and vibrations, as well as the dissipation of energy within vehicle components.Researchers investigate multiple strategies to enhance the damping capabilities of composite materials. This includes adjusting the material composition, fiber orientation, layer stacking sequence, and refining manufacturing processes to improve damping properties while preserving other essential mechanical attributes like stiffness and strength. Subsequently, the damping performance of composite materials undergoes thorough validation through extensive testing under real-world conditions. Prototypes and components featuring the optimized composite materials are exposed to simulated driving scenarios and durability assessments to guarantee reliability and effectiveness in automotive applications. Following validation, composite materials displaying substantial damping response are integrated into diverse automotive components and systems, including chassis, body panels, suspension systems, and interior components, to alleviate noise, vibration, and harshness (NVH) and amplify overall vehicle comfort and performance. In essence, exploring composite materials for noteworthy damping response in automotive contexts necessitates a multidisciplinary approach that intertwines materials science, mechanical engineering, and experimental testing to foster innovative solutions for enhancing vehicle dynamics and passenger comfort.The resolution of the ensuing non-linear problem is executed utilizing the Asymptotic Numerical Method (ANM). Empirical findings indicate that modal damping is heightened when flax fibers are oriented at 90○. Upon comparing numerical and experimental outcomes, the suggested finite element modeling proves adept at estimating damped Eigenfrequencies with notable precision. Nonetheless, the anticipated modal loss factors surpass experimental values, suggesting an overestimation in the predictions.

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