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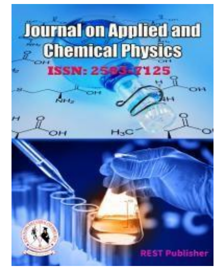

Investigation of Composite Materials for Significant Damping Response in Automotive Applications

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Abstract: *Through the examination of composite components, engineers and manufacturers can enhance their understanding of failure criteria, the initiation of initial failures, and the propagation of damage within laminates. This study delves into the evolution of impact-induced degradation and establishes upper limits on force or Hertz failure thresholds for three distinct composite categories. Impact investigations reveal that the strength of composite materials significantly increases under dynamic impact conditions compared to static ones, underscoring the material's sensitivity to loading rates. Composite materials play a crucial role in achieving effective ballistic protection for armor platforms, given the varying energy levels of the physical loads they must withstand based on their intended applications. Precise design and manufacturing are necessary to provide adequate protection against impacts of different energies: low-energy impacts from tools during maintenance and operations, intermediate-energy impacts from external elements striking the surface, and high-energy impacts from weapons. Fiber-reinforced composite materials find widespread use across the aviation, marine, and terrestrial industries due to their outstanding specific strength, weight reduction benefits, and ease of manufacturing. They are particularly crucial in aerospace and military applications. Polyester resins offer a cost-effective and easily moldable alternative to epoxy resins in many fiberglass applications. This study aims to explore the low-velocity impact characteristics of E-Glass composites, which are more readily available and cost-effective compared to other reinforced composites. The research focuses on evaluating the impact properties of these materials through testing three different samples.*

Keywords: *Composite Materials, Significant Damping, Automotive Applications, Investigation.*

1. INTRODUCTION

A composite material's response to low-velocity impacts can be represented through an energy profile, wherein the dissipated energy is plotted against the initial impact energy. This graphical representation elucidates the correlation between impact energy and dissipated energy, serving as a crucial tool for comprehending the low-velocity impact characteristics of composite materials. Industries prioritizing a superior strength-to-weight ratio increasingly rely on composite materials. The ability to identify and characterize common defects like delaminating or voids, both qualitatively and statistically, is gaining significance, particularly for well-engineered high-performance components. Defects possess the potential to significantly alter a material's structural integrity. Several studies and applications have showcased the effectiveness of thermograph in detecting flaws within composite materials, including those constructed from glass fiber reinforced polymer (GFRP) and carbon fiber reinforced plastic (CFRP). The utilization of thermal techniques has simplified the process of inspecting flaws in components bonded with adhesives. Understanding the properties, failure modes, and structures of composite materials is paramount. Furthermore, comprehensive analyses and further research into composite material failures are indispensable for examining airplane accidents. The insights gleaned from these evaluations can inform future studies on fracture analysis and failure mechanisms of composite materials, particularly concerning material analysis in aircraft accident investigations. Over the past few decades, the aerospace and aviation sectors have witnessed a notable rise in the adoption of composite materials and structures. While their popularity has surged in recent years, research exploring the potential applications of composite materials in aircraft construction dates back over eight decades.

As early as the 1940s, the aviation industry began exploring early technologies such as glass fiber reinforced composites and sandwich-type honeycomb constructions. Around two decades later, in the 1960s, another significant advancement emerged with the introduction of carbon fiber reinforced composites into the aviation sector

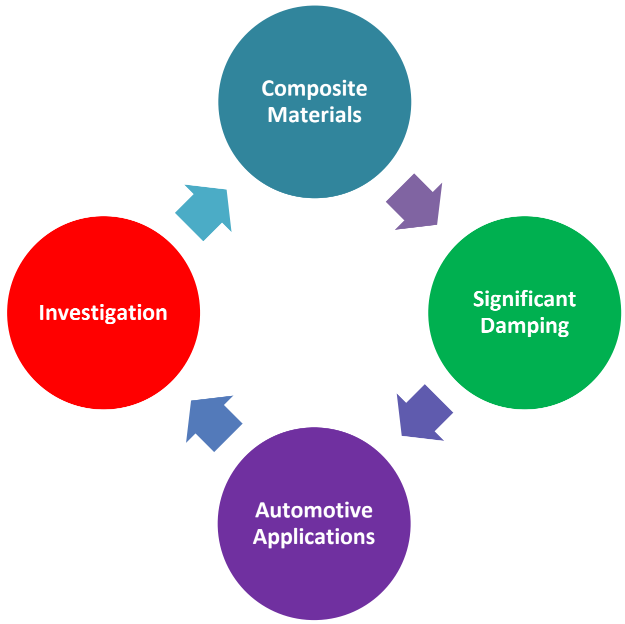

FIGURE 1. Investigation of Composite Materials

Fiber-reinforced composite materials are widely utilized in the aviation, marine, and terrestrial industries due to their remarkable specific strength, weight reduction benefits, and ease of manufacturing. They are particularly essential for military and aeronautical applications. Polyester resins often serve as a cost-effective and easily moldable alternative to epoxy resins in many fiberglass programs. This research aims to explore the low-velocity impact characteristics of E-Glass composite materials, which are more accessible and cost-effective compared to other reinforced composite materials. Three distinct samples have been evaluated as part of the research to assess the impact properties of these materials.

2. INVESTIGATION

This study introduces an approach to estimate composite loss factors at high frequencies associated with discrete bending and tensional vibration modes, with a focus on integrating experimental and computational modeling analyses. The utilization of numerical methods like finite element analysis may be required. Prior to constructing a computer model, comprehending the material parameters of a viscoelastic material, including mass density, Poisson's ratio, Young's modulus, and complex shear modulus, is crucial [1]. A comprehensive comprehension of elastomeric material properties and the techniques employed to characterize the behavior of elastomeric components is essential to attain the desired performance. This encompasses various isolator applications such as power train mounts, suspension control arm bushings, shock absorber bushings, exhaust hangers, flexible couplings, cradle mounts, body mounts, and vibration dampers, each with distinct design requirements and functional objectives. The objective of an isolation system is to minimize the force transmitted to the support below the excitation force acting on the mass. Enhancing vehicle performance and passenger comfort by leveraging composite materials to achieve substantial damping response in automotive applications is a multifaceted endeavor. The initial phase of this exploration involves a comprehensive analysis of existing research and literature to grasp the properties and potential applications of various composite materials [2]. Researchers have selected carbon fiber, fiberglass, and polymer matrix composites due to their promising damping capabilities. Subsequently, experimental techniques such as vibration testing and dynamic mechanical analysis are employed to quantify the damping capacity of these materials across different conditions. To enhance performance while maintaining structural integrity, adjustments in material composition, fiber orientation, and manufacturing processes are informed by computational modeling and simulation techniques, which also aid in predicting and optimizing damping behavior [3]. Comprehensive validation studies substantiate the improved performance of composite materials in real-world applications, paving the way for their integration into automotive components and systems. The overarching objective of this research is to elevate vehicle dynamics and mitigate noise, vibration, and harshness, thereby advancing the frontiers of automotive engineering and design.

FIGURE 5. Investigation

The research investigates the damping characteristics of composites reinforced with a hybrid combination of flax and carbon fiber. Using the vacuum-assisted resin infusion molding method, various hybrid composites are produced by integrating flax and carbon fiber with epoxy resin serving as the matrix. Enhancing the dampening properties of materials used in vehicle components makes sense for reducing engine noise and vibrations. Additionally, as current electronic onboard equipment becomes smaller, it becomes more susceptible to factors such as vibration and pyre shock [4]. While existing variable damping methods effectively fulfill various damping requirements, they exhibit notable limitations. To overcome these constraints associated with variable damping systems, a proposed solution involves a hybrid design strategy. This innovative approach combines a linear motor architecture with a conventional hydraulic damper, resulting in a new hybrid variable damper system. To address the shortcomings of current adaptive damping methods, a blend of electromagnetic and viscous damping mechanisms is integrated During the initial optimization phase, parameters that are not adjustable, such as the diameter of the conductor pipe inside the damper main body, are manually selected to ensure proper fit[5]. Following the analysis, the magnetic flux density of the conductor steel reached saturation, indicating that desired performance levels were achieved. To attain the desired performance, appropriate techniques are used to describe the behavior of elastomeric components and their material properties. This necessitates a comprehensive understanding of elastomeric material behavior. To assess the tensile properties of each composite material, a universal testing machine was utilized in conjunction with a laser Doppler micrometer and an impulse hammer to conduct experiments simultaneously [6]. According to the findings from the tensile analysis of carbon fiber laminate, the addition of a linen layer to the outer layers resulted in a decrease of 28% per layer and 45% for two layers in the material's Young's modulus. Consequently, the reduced component sizes and increased vibration frequencies have made the material more susceptible to vibrations, impacts, and failures caused by the motion of vehicles. Common car malfunctions include solder balls becoming detached and causing short circuits, breakage or cracking of ceramic and crystal components, switch and relay chatter, and deformation of delicate structural components [7]. Utilizing hybrid fiber-reinforced composites, which incorporate chains of cellulose molecules, presents a method to enhance vehicle damping properties. The arrangement of cellulose microfibers contributes to the mechanical stiffness and strength of these fibers. Flax fibers, processed without internal or surface faults that degrade glass fibers over time as cars age and vibration and noise levels increase, are particularly robust. Simultaneously, there is a noticeable rise in consumer awareness regarding the lasting health effects of prolonged exposure to high noise and vibration levels. Active noise and vibration control systems, commercially available or documented in literature, rely on adaptive signal processing and adaptive feed forward control theory as their cornerstones [8]. Active control systems harness incoming stimuli to leverage destructive interference, effectively eliminating undesired resonances or noise signals by aligning waveforms in phase with their original signals. For instance, a machine mount designed to regulate machine movement prioritizes a rigid configuration for improved stability in such scenarios In the passenger compartment, the transmission of engine vibrations necessitates a more compliant engine mount to minimize their impact. Passive noise and vibration treatments frequently fall short, particularly at low frequencies. Therefore, there is a growing interest in exploring active control technologies to effectively manage vibration and noise in vehicles, especially at lower frequencies [9]. There is a growing interest in control solutions, particularly driven by the availability of Low-Cost Digital Signal Processors and advancements in Adaptive Control Theory, as well as NVH (Noise, Vibration, and Harshness) design and analytical tools. Recent developments, particularly in the automotive industry, focus on active solutions to tackle frequency challenges in vibration-acoustic systems, making them economically viable. Specific criteria are employed to design the optimal equivalent linear damping coefficient, ensuring high damping rates even under low damping conditions [10].Achieving high damping ratios for high-frequency excitations while maintaining low damping for low-frequency excitations is a crucial consideration. Similarly, defining the nonlinear damping force necessary to enhance suspension ride performance is established using a single-degree-of-freedom vehicle model. It is evident that maintaining nearly constant damping rates with a linear damper is insufficient to meet these damping requirements. While offering adjustable damping characteristics through active and semi-active suspension systems may be beneficial, concerns regarding cost, complexity, and reliability remain significant [11]. This practical example illustrates the effectiveness of the proposed method in estimating the equivalent linear damping coefficient or damping ratio of the system. The energy balance method was utilized to determine the equivalent linear damping coefficient for any nonlinear damper whose damping force is contingent on relative displacement and velocity. Employing a position-velocity dependent damper across the entire excitation frequency spectrum can enhance ride dynamics performance further. The proposed approach was employed to analyze an experimental scenario involving varied damping forces provided for compression and regeneration, applying the damping force in a conditional functional form [12]. Energy transfer induces changes in vibration patterns, influenced by the positioning of piezoelectric ceramics within the structure and their respective piezoelectric constants. Enhanced energy transfer is typically achieved with higher piezoelectric constants. Power shunts are strategically designed to enhance power dissipation, utilizing passive or active mechanisms, both in linear or non-linear manners, resulting in a diverse array of network configurations The selection of the optimal network depends on several factors including desired performance, the availability of energy sources, and the vibration characteristics of the mechanical structure in response to various types of excitation. Additionally, the representation of the contact area utilizes a layer with distributed stiffness and damping properties. These layers maintain contact with the surface and provide two translations in both in-plane and out-of-plane directions as degrees of freedom [13]. The braking disc annulus is modeled according to Kirchhoff's plate theory, treating it as a disk. Modified measurements are conducted on the brake test loop with the brakes engaged. The frequency bandwidth of the damping effect is determined experimentally through a specific procedure. Even after the initial loud noise subsides, ambient noise, which can reach levels up to 75 dB, continues to actuate the brake disc. The sound produced by the electric motor is particularly significant in this context. Furthermore, a novel method called SSTI (Spectral Subtraction with Discrete Integration) is introduced to evaluate the effectiveness of the techniques. These assessments suggest that the performance is approximately 25% better than LR (linear regression) networks [14]. This study examines two technological applications, focusing on a bladed disc model and the integration of screeching disc brakes. Practical implementations involving piezo ceramics and electrical shunting are explored in both scenarios. Measurements are conducted to validate the simulation results, particularly concerning the use of shunted piezo ceramics to mitigate brake noise. This addresses dynamically generated vibrations that can lead to unpleasant sound emissions or component fatigue cracking. Current trends emphasize the enhancement of vehicle performance and the reduction of vibration issues. The automotive engine-transmission system undergoes continuous dynamic loads, akin to a cantilever beam structure. The study investigates a vibration reduction method derived from basic aluminum cantilever beams [15]. In this study, two technical applications, namely the bladed disc model and screeching disc brakes, are explored. Practical implementations involving piezo ceramics and the integration of electrical shunting are investigated for both scenarios. Simulation results are validated through measurements, particularly focusing on the attenuation of brake noise using shunted piezo ceramics The study focuses on addressing unpleasant sound emissions and dynamically developed vibrations that can lead to component fatigue cracking by effectively eliminating vibrations. Current trends emphasize the reduction of vibration issues to enhance vehicle performance. The automotive engine-transmission system experiences continuous dynamic loads similar to those experienced by a cantilever beam structure. The study investigates a vibration reduction method derived from basic aluminum cantilever beams to mitigate structural vibrations [16]. The hysteresis loop's enclosed area per unit volume of material represents the dissipated mechanical energy or work done by the damping force. The expected vibration response, including acoustic radiation, is calculated using Classical Laminate Plate Theory (CLPT), which is defined by theoretical assumptions Furthermore, the critical buckling temperature and vibration responses are determined using elemental methods. Additionally, the acoustic radiation properties are evaluated using both Finite Element Method (FEM) and Boundary Element Method (BEM) techniques, with integration defined to characterize sound radiation properties [17]. Aerodynamic heating causes thermal strains in structures, resulting in curvature and changes that lead to instability. The heat-induced stress alters the stiffness of the structure, thereby affecting its dynamic properties. A uniform temperature distribution on the plate's surface is believed to result in thermal overload. Consequently, this thermal load increases membrane forces, which in turn affect the lateral deflections of the plate.

2. COMPOSITE MATERIALS

Extensive theoretical and experimental investigations have been conducted to explore the elastic properties of carbon nanotubes (CNTs) Researchers have employed various techniques in experimental inquiries to explore the mechanical properties of CNTs, yielding a diverse array of documented values for these properties. Composite materials, endowed with remarkable properties and adaptability, are revolutionizing numerous industries, including the automotive sector [18]. Within the automotive industry, composites present numerous advantages, including a high strength-to-weight ratio, resistance to corrosion, and flexibility in design. Automotive components such as body panels, chassis structures, and interior trims often utilize carbon fiber, fiberglass, and polymer matrix composites. These materials facilitate weight reduction, enhancing overall vehicle performance and fuel efficiency while maintaining or even improving safety standards. Moreover, the use of composites enables designers to explore new forms and geometries, resulting in vehicles that are both visually appealing and aerodynamic. Ongoing research and development advancements in composite manufacturing signal promising prospects for the automotive sector [19]. These advancements herald the advent of the next generation of automobiles, paving the way for the creation of stronger, lighter, and more environmentally friendly materials. The trajectory of automobile engineering and design towards efficiency, safety, and environmental consciousness underscores the revolutionary potential of composite materials.

FIGURE 2. Investigation of Composite Materials.

Composite materials, owing to their high aspect ratio and lightweight properties, are widely utilized across various industries, including automotive, energy, railways, sporting goods, and aviation. Components and parts made from glass fiber reinforced polymer (GFRP) necessitate specific machining methods such as drilling, grinding, and milling for fastening purposes. Among these processes, conventional drilling stands out as the most suitable and commonly employed technique for creating holes in composite materials. Research on the drilling process of composite materials has revealed that higher feed rates lead to increased delaminating on both sides of the holes [20]. Hochberg and his team utilized specialized drill bits to assess the damage caused by drilling in composite materials. Their research findings suggest that delimitation decreases at lower thrust forces across all drill bits. The study explores the effects of tensile loading on composites, particularly focusing on the frictional stresses observed at deformed fiber-matrix interfaces under compression-induced clamping pressure. The model employed in the study incorporates Coulomb-type friction at the fiber-matrix interface and relies on constant friction coefficient values to elucidate the phenomena.

3. SIGNIFICANT DAMPING

These principles have wide applicability across brittle matrix composites, with particular relevance to cement-based composite materials. Given the crucial significance of fiber-matrix bonding, numerous analytical models and experimental studies have been extensively documented in the literature over time. These endeavors span various fiber-matrix systems and aim to quantify the bond strength between the fiber and matrix. The evolution of composite materials has witnessed substantial advancements, leading to a diverse range of volumes and applications experiencing rapid expansion. This growth trajectory continues to extend into new market sectors. The demand for these engineered products varies from consumer goods to sophisticated niche applications, underscoring the remarkable progress achieved in composite materials [21]. In the realm of cement-based composite materials, these principles are applicable to brittle matrix composites overall. Numerous analytical models and empirical findings, focusing on the pivotal role of the fiber-matrix connection, have been documented in literature over time. These endeavors aim to assess the strength of the bond between fibers and matrices across different composite systems. Composite materials have undergone notable advancements, witnessing a rapid surge in production volume and diversification of applications, penetrating new markets previously unexplored. Both consumer products and specialized applications underscore the substantial progress of composite materials [22]. The goal of achieving variable stiffness is to integrate the prototype under investigation into a vehicle's suspension system. However, the revealed system not only serves as a means of energy storage but also functions as a damping mechanism for dissipating energy. Methods for estimating properties relevant to automotive applications, such as damping coefficients, Young's modulus, and shear modulus, are discussed. A cost-effective and accurate approach to incorporate these aspects involves characterizing foam damping materials as discrete springs and dashpots within finite element structural models. Significant damping plays a crucial role in various engineering applications, particularly in automotive engineering, where it substantially enhances vehicle comfort, safety, and performance. [23]. Damping refers to the capacity of a material or system to dissipate energy from mechanical vibrations, thereby diminishing oscillations and limiting the transmission of noise and vibration to adjacent components. In automotive systems, substantial damping serves to mitigate vibrations arising from road conditions, engine operation, and impacts on uneven surfaces, thereby enhancing ride quality and passenger comfort. Additionally, it optimizes tire-to-road contact and diminishes body roll to enhance vehicle stability, handling, and maneuverability. Moreover, effective damping aids in reducing noise, vibration, and harshness (NVH) levels within the cabin, fostering a tranquil and comfortable driving environment for occupants. Automotive engineers leverage advanced materials and damping technologies to attain optimal damping characteristics, enabling the creation of modern vehicles that strike a harmonious balance between efficiency, comfort, and performance.

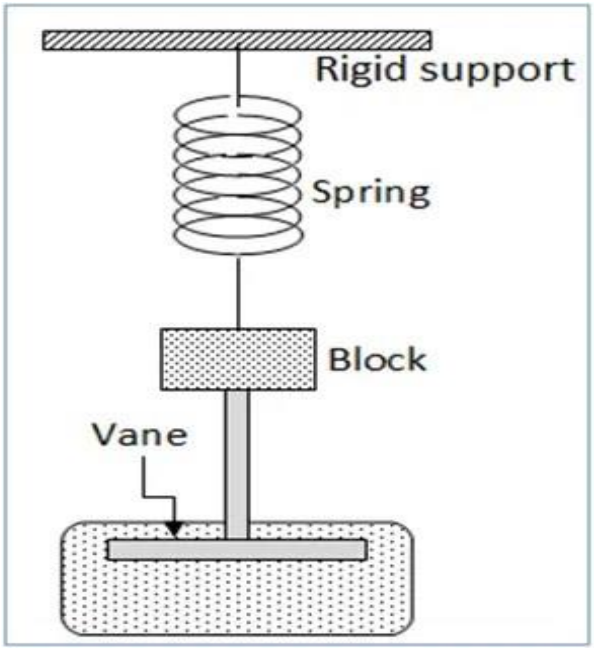

FIGURE 3. Damping

Damping materials are employed in automotive structures such as hoods, roofs, doors, or trunk lids to create a cushioning interface between metal components, typically connecting the outer panel with an inner reinforcement. These materials, often made of vinyl or epoxy-based polymers infused with a chemical blowing agent expand by approximately 150 percent when heated during the paint baking process, serving as damping materials or anti-flutter buttons in paint applications. The stiffness and damping characteristics of foam anti-flutter materials can be effectively integrated using these materials. The most comprehensive approach to modeling the foam involves employing three perpendicular springs and one dashpot in the direction perpendicular to the panel [24]. This approach offers a precise and cost-effective means to integrate damping effects and foam stiffness into a finite element model. In certain scenarios, altering the mass or stiffness of the system can effectively shift resonance frequencies and mitigate undesired vibrations, provided that excitation frequencies remain constant. However, in most cases, vibrations necessitate damping or isolation through damping materials or isolators. Semi-active techniques enhance the damping characteristics of passive elements by employing active control mechanisms. Examples include fluids with electro- and magneto-rheological properties, as well as active constrained-layer damping (ACLD), where a smart material replaces the conventional constraining layer. Incorporating special viscoelastic materials into different configurations enables damping to be integrated into a system. Damping assists in absorbing mechanical energy from a vibrating system, typically converting it into heat. Its primary aim is to regulate the steady-state vibration response and diminish traveling waves within the structure. Material damping pertains to the inherent damping properties of the material itself, while structural damping involves support from various elements such as boundaries, joints, interfaces, and other components to mitigate vibrations.

4. AUTOMOTIVE APPLICATIONS

Both the automotive and commercial airline sectors extensively depend on damping mechanisms. This research aims to serve as both an educational resource and a catalyst for exploring innovative applications across various industries. In the automotive industry, damping response is essential for controlling and mitigating oscillations, vibrations, and impacts arising from road conditions, vehicle maneuvers, and external forces [25]. Its influence extends to handling, stability, ride comfort, and the overall safety of the vehicle. The following provides a summary of the role of damping response in automotive contexts. Due to their unique characteristics and versatility, composite materials hold substantial transformative potential across various automotive applications. Components such as body panels, chassis structures, interior trims, and suspension systems commonly utilize composite materials. Composite materials enable the production of lighter body panels, enhancing overall performance and fuel efficiency while maintaining compliance with safety standards in the construction of chassis, composite materials with high strength-to-weight ratios are employed to enhance structural integrity and eligibility for durability, aiming to improve overall performance. Regarding interior trims, the utilization of composites provides designers with increased creative possibilities for aesthetics and customization, in addition to offering strength and resistance to degradation. Moreover, composite materials play a crucial role in suspension systems by reducing noise, vibrations, and enhancing ride comfort for passengers. As automakers strive to meet evolving demands for performance, efficiency, and sustainability, composite materials are at the forefront of automobile design, manufacturing, and overall performance.

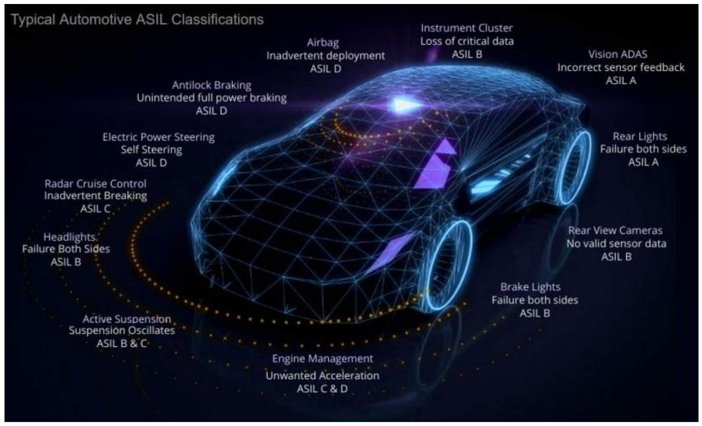

FIGURE 4. Automotive Applications

The suspension system of a vehicle comprises springs, dampers or shock absorbers, and various other components. Its primary roles include bearing the car's weight, mitigating shocks from the road, and absorbing vibrations. Dampening response is essential, and shock absorbers, commonly referred to as dampers, play a crucial role in this aspect. Hydraulic or pneumatic systems manage the movement of suspension springs. When the car encounters an uneven surface or a bump, the springs compress and release energy. Without dampers, the springs would continue oscillating, resulting in an uncomfortable and bouncy ride [26]. The damping ratio, which represents the proportion of damping in a system relative to its critical damping, is a critical parameter. Critical damping, the minimum amount of damping required to cease oscillation or bouncing, is the reference point. Damping ratios below 1 indicate under damping, potentially resulting in a bumpy ride but increased responsiveness. Conversely, damping ratios exceeding 1 signify over-damping, which may lead to a rougher ride but enhanced stability. Automotive dampers can utilize gas, hydraulic, or a combination of both damping methods. Hydraulic dampers utilize fluid displacement to absorb and release energy. Gas dampers incorporate gas chambers to provide additional resistance and damping force. Certain modern vehicles feature adjustable damping systems, allowing drivers to select different damping ratios based on driving conditions or personal preferences. By choosing between comfort, sport, or performance modes offered by these technologies, drivers can tailor the damping response of the vehicle to their liking. The damping response of a vehicle impacts various dynamics of the car significantly. Proper damping reduces rolling and pitching motions, enhances momentum, improves stability during braking and cornering, and aids in maintaining tire contact with the road surface. Ultimately, damping responsiveness in automotive applications is crucial for ensuring a smooth, stable, and comfortable ride by minimizing the vibrations and fluctuations transmitted from the road surface to the vehicle's structure this is achieved through careful design and calibration of suspension systems, along with selecting and fine-tuning absorbers to achieve the optimal balance of driving performance and comfort. Typically, damping peaks around the material's glass transition temperature or slightly above it. The polymeric structure can be altered by modifying the composition, and certain polymers contain multiple transition regions that can be intentionally designed to enhance peak damping capability within this spectrum. Both modulus and loss factor exhibit relatively low values, gradually transitioning through the glass and rubber stages with changes in temperature [27].

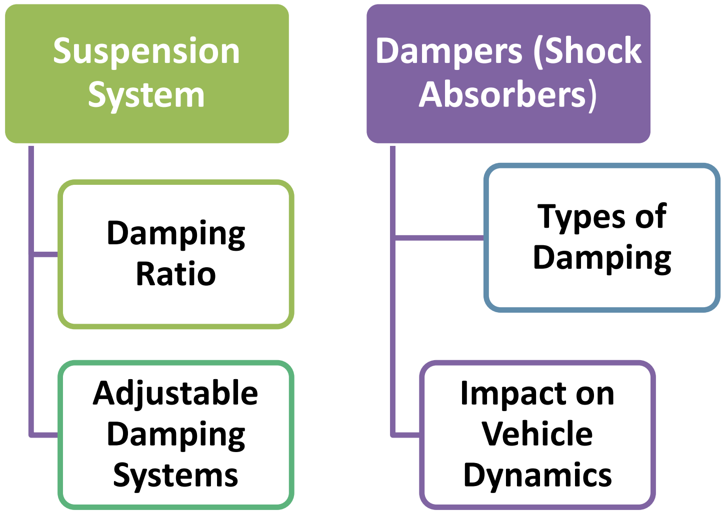

FIGURE 5. Damping Response in Automotive Applications

In technical contexts, the dynamic response of MR (magneto-rheological) dampers stands as a pivotal parameter. However, discrepancies in defining response time sometimes lead to measurement misunderstandings. Despite critical factors such as power consumption, maximum damping force, and dynamic range, the dynamic response remains paramount in assessing the viability of MR dampers for integration into mechanical vibration systems. Acquiring precise dynamic reaction times is crucial for optimizing MR damper performance. An MR (magneto-rheological) damper designed for vehicle suspension has been developed and manufactured with a maximum intended stimulation current of 3A or a stroke of ±50mm. However, due to volume adjustment issues, the damping force is not optimized [28]. The entire system is subjected to multiple cycles of excitation current until the dissipation power's recovery level relative to the initial state returns to its normal output level. The magneto-rheological (MR) effect signifies a substantial change in yield, which can be continuously adjusted by varying the intensity of the applied electromagnetic fields. Calibration methods encompass six primary categories: pulse encoding, time-of-flight, inductive, magnetic, capacitive, and resistive. Formal Kalman observers are frequently employed to estimate the elliptic velocity and damping force for a single semi-active shock absorption element, with the aim of enhancing noise cancellation and/or developing a virtual sensing mechanism [29]. A soft sensor enables real-time prediction of system variables, particularly useful when hardware devices cause unwanted actuation delays. It serves as a reliable benchmark for evaluating defect detection techniques, particularly focusing on sensor validation of rear suspension stroke. This involves establishing fault detection thresholds while considering factors like accurate problem identification and false alarms. Current literature presents two distinct approaches to spectral analysis. The first method involves discrete mode or narrow-band measurements, particularly in low- or mid-frequency ranges, utilizing methodologies like the ASTM approach. Practical challenges associated with noise and vibration management in vehicle environments often possess unique characteristics that make standard techniques unsuitable.

6. CONCLUSION

Composite materials enable engineers and manufacturers to gain deeper insights into damage propagation within laminates, the onset of early failure, and failure criteria. This study investigates impact damage growth and establishes Hertz and failure thresholds, along with maximum force limitations for three distinct composite variants. Additionally, composite materials play a vital role in the aerospace and defense sectors. Polyester resins are commonly employed in fiberglass applications as a cost-effective alternative to epoxy resins. In this research, we analyze the low-velocity impact properties of E-Glass composites, which are more readily accessible and less costly compared to Agamid composites. To comprehend their behavior, we analyze three distinct test samples. Plotting dissipated energy against original impact energy allows us to obtain the energy profile of composite materials during low-velocity impact events. This graphical representation serves as a valuable tool for understanding the low-velocity impact properties of composite materials, illustrating the relationship between impact energy and dissipated energy. Defects hold the potential to significantly alter the structural strength. Numerous research endeavors and practical implementations have focused on glass fiber reinforced polymer (GFRP) and carbon fiber reinforced plastic (CFRP). The diagnostic thermograph method has exhibited proficiency in identifying defects within composite materials. Various approaches, including thermal analysis, have been employed to scrutinize defects in adhesively bonded components. Analyzing the damping properties of composite materials is crucial, especially for automotive applications, to mitigate noise and vibration in vehicles. Typically, the investigation begins with an extensive review of prior research and literature on composite materials and damping behavior. Scholars assess multiple composite materials to determine their suitability for automotive engineering applications. Considering the specific damping requirements of automotive applications, they identify potential materials such as metal matrix composites, carbon fiber composites, fiberglass composites, and polymer matrix composites, among others after the selection process, assessments are carried out to evaluate the damping properties of chosen composite materials through a series of rigorous testing procedures conducted on a daily basis. Researchers employ various testing methods, including vibration testing, modal analysis, dynamic mechanical analysis (DMA), and other relevant techniques, to measure the damping properties of materials under different conditions. Additionally, they develop computer simulations and algorithms to forecast the effectiveness of composite materials in damping automobile structures Researchers utilized Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) models to investigate vibrations and the intricate interplay of material compositions, delving into the complexities of their relationship, as well as the dissipation of energy in automotive components. Scientists explore various techniques to enhance the damping characteristics of composite materials. This involves improving damping properties while preserving other essential mechanical attributes such as stiffness and strength. Modifications to material composition, fiber orientation, layer stacking order, and manufacturing processes are considered in this endeavor Composite materials undergo thorough real-world testing to meticulously evaluate their damping characteristics and overall performance. Prototypes and parts utilizing the optimal composite materials undergo durability assessments and simulated driving scenarios to ensure reliability and effectiveness in automotive applications. Following validation, composite materials with notable damping response are integrated into diverse automotive systems and components, including suspension systems, body panels, chassis, and interior components. This integration aims to mitigate noise, vibration, and harshness (NVH) while enhancing the overall comfort and performance of the vehicle. In essence, exploring composite materials for significant damping response in automotive contexts necessitates a multidisciplinary approach that merges mechanical engineering, materials science, and experimental testing. Such an approach fosters innovative solutions for enhancing vehicle dynamics and passenger comfort. The Asymptotic Numerical Method (ANM) is applied to resolve the ensuing non-linear problem. Studies indicate that modal damping experiences an increase when flax fibers are aligned at a 90° angle. Upon comparing numerical outcomes with experimental data, the suggested finite element modeling exhibits a high level of precision in determining damped Eigen frequencies. Nonetheless, the anticipated modal loss factors surpass the experimental values, suggesting an overestimation in the predictions.

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