

# LOW VELOCITY IMPACT STRENGTH OF CARBON/GLASS REINFORCED EPOXY HYBRID NANOCOMPOSITES

## Abstract

The chapter reviews the low velocity impact strength of carbon/glass reinforced epoxy hybrid nanocomposites. The main objective of the paper is to critically analyse the research studies conducted in this field and to identify the key factors that affect the impact strength of these composites. The paper starts with an introduction to the concept of hybrid nanocomposites and their applications. Then, it discusses the various processing techniques used to fabricate carbon/glass reinforced epoxy hybrid nanocomposites. The paper also provides a detailed analysis of the effect of different types of nanoparticles on the impact strength of these composites. Finally, the paper summarizes the findings of the reviewed studies and highlights the future research directions in this field. The review concludes that carbon/glass reinforced epoxy hybrid nanocomposites have shown promising low velocity impact strength, and further research is needed to optimize the processing parameters and enhance their impact resistance properties.

**Keywords:** Low velocity impact strength, carbon fiber, glass fiber, epoxy, hybrid nanocomposites, processing techniques, nanoparticles, impact resistance, optimization.

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## I. INTRODUCTION

Composite materials have gained popularity in engineering due to their advanced mechanical properties compared to conventional materials. Composites are materials that are made by combining two or more different materials, each with their own distinct properties, to create a material with improved overall properties. They have become increasingly popular in various industries due to their unique properties, such as high strength, low weight, and corrosion resistance[1]. One of the main advantages of composites is their high strength-to-weight ratio. This means that they can be strong and durable, yet still lightweight, making them ideal for use in applications where weight is a critical factor, such as aerospace, automotive, and sports equipment. Additionally, composites can be engineered to have specific properties, such as stiffness, toughness, and thermal conductivity, which makes them highly versatile and adaptable for a wide range of applications[2]. Another advantage of composites is their low cost. While the initial cost of producing composite materials can be higher than traditional materials, their durability and resistance to wear and tear means that they often have a longer lifespan, which can lead to significant cost savings over time. Additionally, the manufacturing process for composites is often more efficient than that for traditional materials, which can also help to lower costs[3]. Due to these benefits, the use of composites has been increasing in various industries around the world. For example, the aerospace industry has been using composites for decades, with composites now being used in up to 50% of an aircraft's structure by weight. The automotive industry is also increasingly turning to composites, with the use of composite materials in cars expected to double by 2025. In addition, the use of composites is becoming more common in the construction industry, with composite materials being used to reinforce concrete structures, such as bridges and buildings[4][5].

Overall, composites offer a wide range of benefits that make them an attractive option for various industries. As technology continues to improve, it is likely that we will see even more applications for composite materials in the future.

## II. SCOPE FOR HYBRID COMPOSITES

The use of hybrid composites, which combine different types of fibers and matrices, has the potential to significantly improve the mechanical properties of composite materials, making them more durable and resilient[6]. Hybrid composites offer a unique combination of properties, such as high strength, stiffness, and impact resistance, which make them attractive for use in a wide range of applications, from aerospace and automotive to construction and marine engineering. Recent research has focused on developing new hybrid composites using advanced manufacturing techniques, such as additive manufacturing and nanotechnology, to further enhance their performance. However, there is still significant scope for further research in this area to optimize the properties of hybrid composites for specific applications[7].

In addition to improving the mechanical properties of composite materials, the use of hybrid composites can also provide economic benefits. By combining different materials, it may be possible to reduce the overall cost of the composite without sacrificing performance. For example, using natural fibers in combination with synthetic fibers can result in a composite that is both cost-effective and environmentally friendly. Furthermore, the use of

hybrid composites can enable the development of new, innovative products with improved performance characteristics[4]. As such, the scope for hybrid composites is broad, and continued research in this area can lead to the development of new, high-performance materials for a wide range of applications.

### **III. SCOPE FOR HYBRID NANO-COMPOSITES**

Hybrid nano-composites are a promising class of materials that combine the properties of nanoparticles and polymers to create materials with enhanced mechanical, thermal, and electrical properties. These materials have the potential to revolutionize a range of industries, including aerospace, automotive, and electronics. The scope for hybrid nano-composites is vast, as their properties can be tailored to suit specific applications. For example, the incorporation of nanoparticles into polymers can improve their mechanical strength, while the addition of conductive nanoparticles can enhance their electrical conductivity. Moreover, hybrid nano-composites can be designed to exhibit multifunctional properties, such as self-healing or self-cleaning, which can further expand their potential applications[8].

Nanocomposites have been extensively studied in recent years for their superior strength, stiffness, and toughness. Hybrid nanocomposites, which utilize a combination of nanoparticles, have shown even greater potential in enhancing the properties of composites. Carbon/glass reinforced epoxy hybrid nanocomposites have garnered significant attention for their potential applications in aerospace, automotive, and marine industries[9]. In conclusion, the development of hybrid nano-composites offers exciting opportunities to create materials with superior properties and performance, tailored to meet the demands of specific applications. Continued research in this area has the potential to lead to new breakthroughs in materials science and engineering, and accelerate the adoption of hybrid nano-composites in industry[10].

### **IV. SYNTHETIC FIBER REINFORCED COMPOSITES**

Synthetic fiber reinforced composites have gained immense popularity in the field of engineering due to their superior mechanical properties compared to traditional materials. They are widely used in various industries such as aerospace, automotive, and marine due to their lightweight, high strength-to-weight ratio, and excellent fatigue resistance. Among the synthetic fibers used for reinforcement, carbon and glass fibers are the most common. Carbon fibers are known for their high strength and stiffness, while glass fibers are valued for their low cost and ease of processing. Hybrid composites, which utilize a combination of carbon and glass fibers, have also been developed to combine the advantages of both materials. In recent years, the use of nanocomposites in synthetic fiber reinforced composites has gained significant attention[11]. Nanocomposites are composite materials that incorporate nanoparticles into the matrix material, resulting in enhanced mechanical properties such as increased strength, stiffness, and toughness. Hybrid nanocomposites, which utilize a combination of different types of nanoparticles, have shown even greater potential in enhancing the properties of synthetic fiber reinforced composites. Carbon/glass reinforced epoxy hybrid nanocomposites are one of the most widely studied hybrid nanocomposites due to their potential in aerospace, automotive, and marine applications. One of the key factors that affect the performance of these composites is their impact strength, especially in low

velocity impact scenarios. Therefore, understanding the impact strength of these hybrid nanocomposites is important for optimizing their performance and designing structures that can withstand impact loads[12].

## **V. NATURAL FIBER REINFORCED COMPOSITES**

Natural fiber reinforced composites have been gaining increasing attention due to their eco-friendliness and biodegradability. These composites are made by combining natural fibers such as flax, hemp, jute, or sisal with a matrix material such as epoxy or polyester resin. They offer several advantages over synthetic fiber reinforced composites, including lower cost, lower density, and a renewable and sustainable source of raw materials. Natural fiber reinforced composites have been found to exhibit good mechanical properties, such as high stiffness and strength, as well as good thermal and acoustic insulation properties. However, their impact strength is typically lower than that of synthetic fiber reinforced composites. Nonetheless, recent studies have shown that the impact strength of natural fiber reinforced composites can be improved by using hybrid combinations of natural and synthetic fibers, as well as by modifying the surface of the natural fibers to enhance their adhesion to the matrix material[13]. While natural fiber reinforced composites have potential applications in several industries, including automotive and construction, their use is still limited due to certain challenges, such as moisture absorption and dimensional instability. Nonetheless, ongoing research is exploring ways to overcome these challenges and to improve the performance and durability of these composites[14].

## **VI. HYBRID COMPOSITE**

Hybrid composites are composite materials made from a combination of two or more different types of fibers or reinforcements in a single matrix. Hybridization is a technique to tailor the properties of composite materials to meet specific design requirements. By combining different types of fibers or reinforcements, the resulting composite can have a unique set of properties, which can be beneficial for certain applications[15].

In recent years, hybrid composites have gained significant attention due to their superior properties compared to their single-component counterparts. Hybrid composites have been studied for various applications, such as in aerospace, automotive, and marine industries, where lightweight and high-performance materials are required[16].

One such hybrid composite is the carbon/glass reinforced epoxy hybrid nanocomposite, which combines carbon fibers and glass fibers in an epoxy matrix with nanoparticles. This hybrid composite has shown improved mechanical properties, including stiffness, strength, and toughness, compared to single-component carbon or glass reinforced composites[17].

Understanding the impact strength of carbon/glass reinforced epoxy hybrid nanocomposites is essential for optimizing their performance and designing structures that can withstand impact loads. Low velocity impact is a common scenario in various industries, and the impact resistance of composites is critical in such situations. Therefore, a review of the low velocity impact strength of carbon/glass reinforced epoxy hybrid nanocomposites is

necessary to analyze the effects of different processing techniques and nanoparticle types on their impact strength[18].

## **VII. HYBRID NANO COMPOSITES**

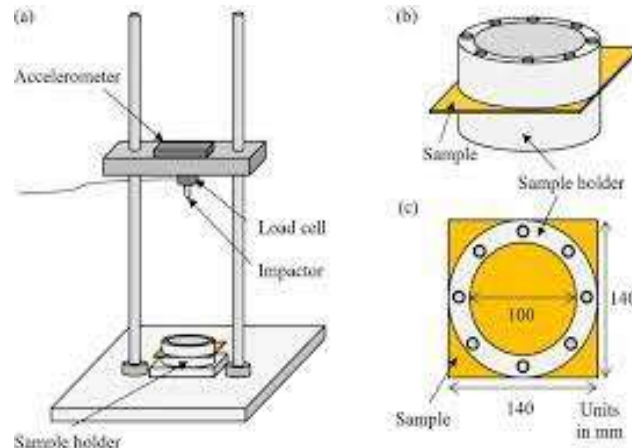
Hybrid nanocomposites are a subclass of composite materials that combine two or more types of nanoparticles to produce materials with enhanced mechanical properties. The addition of nanoparticles to the matrix material can lead to improvements in strength, stiffness, toughness, and other properties, making them attractive for various engineering applications[19].

Carbon/glass reinforced epoxy hybrid nanocomposites have been extensively studied due to their potential applications in aerospace, automotive, and marine industries. The use of carbon and glass fibers in combination with epoxy resin can provide high strength and stiffness, while the incorporation of nanoparticles further enhances the properties of the resulting hybrid composites[20]. Several processing techniques have been developed for fabricating carbon/glass reinforced epoxy hybrid nanocomposites, including hand lay-up, resin infusion, and autoclave molding. In addition, various types of nanoparticles, such as carbon nanotubes, graphene oxide, and clay nanoparticles, have been utilized to enhance the properties of the composites[21].

The impact strength of carbon/glass reinforced epoxy hybrid nanocomposites is critical for their performance in low velocity impact scenarios, and understanding the factors that influence impact strength is essential for optimizing their design and performance. Therefore, extensive research has been conducted to investigate the impact strength of these hybrid nanocomposites and the effects of processing techniques and nanoparticle types on their properties[22]. Overall, hybrid nanocomposites offer great potential for various engineering applications due to their improved mechanical properties, and carbon/glass reinforced epoxy hybrid nanocomposites represent a promising class of materials for such applications.

## **VIII. LOW VELOCITY IMPACT STRENGTH**

Low-velocity impact refers to a type of impact that occurs at relatively low speeds, typically between 1 and 10 meters per second (m/s). This type of impact is characterized by a relatively low level of energy, which can result in deformation, cracking, or other forms of damage to the impacted material, but typically does not cause complete failure or fracture. Low-velocity impact can occur in a variety of settings, including during transportation of materials, in manufacturing processes, and in sports and recreational activities[23]. Understanding the behavior of materials under low-velocity impact is important for designing structures and materials that can withstand impact loads, as well as for predicting and mitigating potential damage[24].



**Figure 1:** Low Velocity Impact Test of Composites[25]

## VIII. IMPACT TESTING OF FIBER REINFORCED COMPOSITES

Impact testing of fiber-reinforced composites is an important aspect of material characterization as it helps to evaluate the material's ability to withstand sudden loading conditions. The low velocity impact strength of composites is particularly critical in applications where the material is subjected to accidental impacts or collisions. The impact strength is affected by various factors such as the type of fiber, matrix material, fiber orientation, and processing conditions. Therefore, it is necessary to study the impact behavior of fiber-reinforced composites to optimize their performance and ensure their reliability in practical applications[26]. Various test methods such as the drop weight test, falling weight impact test, and instrumented impact test are commonly used for impact testing of composites. These tests provide valuable information on the composite's energy absorption capacity, damage initiation and propagation, and deformation behavior during impact. The test results can be further used to develop analytical models for predicting the impact response of composite structures[27].

In conclusion, impact testing of fiber-reinforced composites is an essential aspect of material characterization that helps to assess the material's performance under sudden loading conditions. The results obtained from impact tests can be used to optimize the design and ensure the reliability of composite structures in practical applications[28].

The impact response of natural fiber reinforced composites is an important area of research that aims to improve the performance of these materials under impact loading. Recent studies have provided insights into the damage mechanisms that occur during low velocity impact and explored various methods to improve the impact resistance of natural fiber composites. These efforts are expected to lead to the development of sustainable, lightweight, and impact-resistant materials for various applications.

## IX. MODES OF FAILURE IN LOW VELOCITY IMPACT

Modes of failure in low-velocity impact refer to the various ways in which a material can be damaged or fail when subjected to an impact at relatively low speeds. Here are some common modes of failure:

- 1. Matrix Cracking:** This occurs when the matrix material surrounding the reinforcing fibers in a composite material is subjected to tension, causing it to crack. Matrix cracking can occur in a localized region around the impact point or propagate throughout the material.
- 2. Fiber Breakage:** The fibers in a composite material can break under tensile or compressive stress, leading to a loss of strength and stiffness. The fiber breakage can be due to the impact itself or as a result of stress concentrations caused by matrix cracking[29].
- 3. Delamination:** Delamination occurs when the layers of a composite material separate from each other, often due to shear stress induced by the impact. Delamination can weaken the material and make it more susceptible to further damage[30].
- 4. Fiber pull-out:** In some cases, the fibers in a composite material can be pulled out of the matrix material without breaking, leading to a loss of load transfer between the fibers and the matrix[31].
- 5. Crush Damage:** This occurs when the impacted region of the material is crushed, leading to permanent deformation and loss of strength[32].

These modes of failure can occur individually or in combination, depending on the material properties, impact energy, and other factors. Understanding the modes of failure is important for designing materials that can withstand low-velocity impact and for predicting the behavior of materials under impact loading.

## X. CONCLUSIONS

In conclusion, this review paper has provided a comprehensive analysis of the low velocity impact strength of carbon/glass reinforced epoxy hybrid nanocomposites. The review has covered the most recent and significant research papers published in this field and has highlighted the key findings and trends observed in these studies. The review has shown that the addition of nanofillers to the hybrid composites has a significant impact on the low velocity impact strength, resulting in increased resistance to damage and improved toughness. The choice of nanofiller, its concentration, and the processing conditions used to prepare the nanocomposite are all critical factors that affect the final properties of the material.

Overall, the review highlights the potential of carbon/glass reinforced epoxy hybrid nanocomposites for applications requiring high strength and durability under low velocity impact conditions. However, further research is needed to fully understand the mechanisms behind the improved performance of these materials, and to optimize their properties for specific applications. In summary, the review paper provides a valuable resource for researchers and engineers working in the field of composite materials and serves as a guide for future studies aimed at developing advanced hybrid nanocomposites with superior low velocity impact strength.

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