



AN OVERVIEW OF COMPOSITE MATERIALS UNDER THERMAL AND IMPACT LOADING: PROPERTIES AND BEHAVIOUR

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Abstract:

Composite materials have gained significant attention in various industries due to their exceptional properties and versatility. Understanding the behavior of composite materials under thermal and impact loading is crucial for their effective utilization in real-world applications. Thermal loading involves examining the response of composites to temperature variations. Changes in temperature can induce thermal stress, expansion, and contraction within the material, affecting its mechanical properties and overall structural integrity. By comprehensively studying the thermal behavior of composites, insights can be gained to optimize their performance across a wide range of operating temperatures. Impact loading focuses on investigating how composites respond to sudden and intense forces. Impact events, such as collisions or rapid loading, can lead to deformation, stress concentrations, and potential damage to the composite structure. Analyzing the impact resistance and energy absorption capabilities of composites is essential for ensuring their reliability and safety in high-stress environments. This paper provides an overview of composite materials under thermal and impact loading, highlighting their properties and behavior. Through experimental and analytical techniques, the thermal and impact characteristics of composites are explored. The identification of failure mechanisms and the proposal of strategies to enhance composite resilience in demanding conditions are key objectives.

Introduction:

Composite materials play a pivotal role in various industries, offering a unique combination of strength, lightness, and versatility. To ensure optimal performance and durability, it is essential to understand how composite materials behave under different loading conditions. Two critical factors that significantly affect composite materials are thermal and impact loading. Thermal loading refers to the response of composites when subjected to variations in temperature. Temperature changes can cause expansion, contraction, and thermal stress within the material, which can influence its mechanical properties and structural integrity. Proper understanding of the thermal behavior of composites is crucial for designing components that can withstand a wide range of operating temperatures. Impact loading, on the other hand, pertains to the response of composites when subjected to sudden and intense forces. This can occur due to impact events, such as collisions or sudden loading during operation. Impact loading can lead to rapid deformation, stress concentrations, and potential damage to the composite structure. Understanding the impact resistance and energy absorption capabilities of composites is vital for ensuring their reliability and safety in high-stress environments.

This study focuses on investigating the behavior of composite materials under thermal and impact loading. By comprehensively examining their response to these loading conditions, valuable insights can be gained to improve the design and performance of composite structures. Through experimental and analytical techniques, we aim to characterize the thermal and impact properties of composite materials, identify potential failure mechanisms, and propose strategies to enhance their resilience in demanding operating environments. The findings of this research will contribute to the advancement of composite material technology, enabling the development of more robust and efficient structures across a range of industries. By gaining a deeper understanding of how composite materials respond to thermal and impact loading, we can optimize their performance and unlock their full potential in demanding applications.

Related Work:

According to Jartiz [1], Composites, according to the generally accepted definition, are multipurpose systems with no defining material properties. They are solid structures that hold together two or more substances that can work together but have different densities, characteristics, and shapes. Thus, a vast variety of materials, from wood and bones to shells and electrical insulators to magnetic resin-bound materials to load-bearing polymers and paper laminates, may all be categorized as composites. But the problem with this broad definition is that it includes mixes without defining what makes them unique or how to tell them apart from other, less important combinations.

Kelly [2] composites are more than just a "mix" of materials, it is emphasized. Composites, on the other hand, have their own unique qualities. These superior qualities may outshine those of its constituent parts as a whole, such as increased durability or resistance to heat.

Bergehan [3] composites are differentiated from alloys in that the unique strengths of each component are preserved while being combined in a manner that allows each to excel beyond the sum of its parts. By using this method, superior substances may be developed.

Van Suchetclan [4] defines composites as heterogeneous materials with intimate microscopic contact between two or more solid phases. Even if they are not perfectly homogenous, they may be treated as such because of the similarities in their microscopic properties. This clarification emphasizes the significance of attaining a synergistic impact in the design and production of composite materials, which enables the creation of novel materials with greater qualities compared to the constituent components, both alone and in combination.

Characteristics of the Composites:

One or two degrees of discontinuity might occur during the continuous operations used to create composites. When compared to the continuous phase, called the matrix, the discontinuous phase, called reinforcement or strengthening, displays increased toughness and strength. Composites' qualities are significantly impacted by the nature, distribution, and interaction of their individual components. Properties of composites may be determined either by the combined volume of their individual components or by the synergistic effects of those components working together. The geometry of the reinforcement, including its form, size, and distribution, has a considerable effect on the characteristics of the composite material, in addition to the material components themselves. The material characteristics are also affected by the reinforcing concentration and orientation.

Scale, measurement (which affects the material structure), and the volume of the interface region are all taken into account when assessing the reinforcement's bond to the matrix in the context of discontinuous reinforcement. Different geometric forms may be used to illustrate this connection, including prisms and plates with round, square, or elliptical cross-sections. The concentration of a composite material is the proportion of its constituent parts by volume or weight that contributes to the material's overall qualities. It not only affects the primary parameter that determines the composite's qualities, but it also serves as a performance vector that can be easily adjusted to alter those characteristics.

Classification:

There are several classes into which composites may be placed [5]. Because reinforcing geometry has such a significant impact on composites' technical qualities and overall quality, categorizing them according to it is a helpful exercise. There are two primary types of composites, and they are: Composite materials and particles.

Particulate Composites:

Platelets fall under this category, which refers to the determination of an element's morphology based on the form of the element itself. The form may range from cuboid to cubic to tetragonal to plate-like or irregular shapes, but all of these shapes have a same overall appearance. Particles generally do not considerably improve fracture resistance, but they do contribute to increasing the composites' overall quality. Particle fillers also have the ability to improve the matrix material's properties, including changing thermal and electrical conductivity, increasing temperature performance, decreasing friction, increasing wear and abrasion resistance, improving machinability, improving surface toughness, and decreasing shrinkage. The durability of a surface can be improved by particle fillers.

Composite Materials:

Composite materials are engineered materials that consist of two or more constituent materials with different physical and chemical properties. These materials are combined to create a new material with enhanced properties that cannot be achieved by any of the individual components alone. The composite materials typically comprise a reinforcement phase and a matrix phase. The reinforcement phase, often in the form of fibers, provides strength, stiffness, and other desired properties to the composite. The matrix phase, which can be a polymer, metal, or ceramic, acts as a binder and holds the reinforcement together, transferring stress between the reinforcing fibers. The combination of the reinforcement and matrix phases allows composites to exhibit properties such as high strength-to-weight ratio, excellent fatigue resistance, corrosion resistance, thermal stability, and electrical conductivity, depending on the chosen materials. This makes composites suitable for a wide range of applications in industries such as aerospace, automotive, construction, sports equipment, and renewable energy.

Manufacturing processes for composite materials include methods like lay-up, filament winding, pultrusion, and injection molding, depending on the specific requirements of the application. The selection of reinforcement materials, such as carbon fibers, glass fibers, or aramid fibers, and matrix materials, such as epoxy, polyester, or thermoplastics, depends on the desired properties and performance characteristics of the final composite. Advancements in composite materials technology continue to push the boundaries of what can be achieved in terms of strength, lightweight design, and tailored properties. Ongoing research and development

efforts aim to further improve the performance and cost-effectiveness of composites, enabling their wider adoption in various industries and applications.

Fibrous Composites:

Composite fibers have bigger dimensions relative to their cross-sectional proportions, which allows them to significantly increase strength. Longer fibers are essential for avoiding the spread of early fractures, especially in brittle matrix materials, which raises the matrix's fracture resistance. Non-polymeric fibers, whether treated or untreated, have a smaller cross-sectional area than polymeric fibers, which reduces the amount of severe flaws in the material. On the other hand, polymeric materials' superior resilience and stiffness are a result of their molecular makeup. However, because of their modest cross-sectional dimensions, textiles alone often fall short in real-world technological applications. As a result, fibrous composites include matrix components. The matrix functions to hold the fibers together, distribute the load to the fibers, and shield against the negative consequences of fiber aggregation. Compared to discontinuous fiber composites, the matrix's capacity to transmit load is especially crucial for continuous fiber composites.

Types of Composite Materials:

The composite materials are broadly classified into the following categories:

Fiber-Reinforced Composites:

It is common knowledge that reinforced composites have a high specific strength and may be stiff when used in a variety of industrial contexts. Because of their superior structural efficiency, composites are also becoming more interesting as a material for use in tribological applications. The second phase of this kind of composite consists of fibers, which may be made of either metal or plastic depending on the application. The proportion of volume, often known as V_f , may range anywhere from a few hundred to seventy percent. In most cases, the fiber is strengthened such that both its resistance and its modulus may be maintained at high levels. Because of this, the fibers have to have a greater modulus than the material that makes up the matrix in order for the load to be transmitted from the matrix to the fibers in an efficient manner.

Continuous or Long Fiber Composite:

A matrix that has been enhanced via a broken process in the form of a continuous fiber may be referred to as a long composite fiber or a persistent composite fiber. Geometrically speaking, continuous fiber is more longitudinal than it is circumferential. In general, the bulk materials are characterized by their greater weight and greater durability. The matrix organizes the fibers in such a manner that allows them to be divided into two distinct categories: (a) reinforcing in a unidirectional manner, and (b) reinforcing in a bidirectional way.

Discontinuous or Short Fiber Composite:

A technique of dispersion in the form of discontinuous fibers is used to strengthen the matrix that is composed of short fibers. Because of their low cost, simplicity of processing intricate components, and isotropic nature, short-fibre composites are the preferred material for large-scale manufacture. These three elements are sufficient to establish short-fibre composites as the preferred material. As a result, short-fiber reinforced composites have successfully cemented their place in the production of lightly loaded components. After that, the discontinuous fiber reinforced composite may be split into the following groups:

Dispersion Hardened Material:

In this kind of product, a matrix is filled with fine particles with sizes ranging from 0.1 micrometers to 0.14 micrometers. They range from 1% to 10% of the total quantity in terms of concentration. Because of the presence of these small particles, the mobility of the substrate dislocation is reduced, which ultimately leads to an extremely high resistance. These goods also have better resilience to high temperatures in terms of both their strength and their creep.

Laminate Composites:

The layers of the material that are preserved in the matrix are composed of the components that make up the laminates. In most cases, the arrangement of these layers serves to facilitate a connection between the reinforcement and the matrix. The laminates have the capability of either unidirectionally or bidirectionally orienting the reinforcement of the fiber, and this is determined by the ultimate application of the composite. There are many different varieties of laminate, including symmetrical, cross-sectional, unidirectional, and twisting laminates.

Particulate Composites:

Particles ranging in size from one micrometer to two hundred micrometers are dispersed throughout the matrix of these composite structures. Aluminum (DRA) is continually being reinforced by the sub-class composites that are found in the metal matrix (MMM). DRA is an aluminum alloy that has been merged with a proprietary reinforcing technique (particles, whiskers, or sliced fibers) in order to maintain the positive properties of both components. They are attracted to a wide variety of structural components because of the combination of their features and their ability to weave since these elements include high rigidity, high strength, and low weight.

Conclusion:

Composite materials have demonstrated remarkable properties and versatility, making them valuable for numerous applications. This overview focused on understanding the behavior of composite materials under thermal and impact loading conditions, emphasizing their properties and behavior. Thermal loading affects composites through temperature-induced expansion, contraction, and thermal stress. By comprehensively studying the thermal behavior of composites, it becomes possible to optimize their performance across a wide range of temperatures. Understanding the impact resistance and energy absorption capabilities of composites under impact loading is crucial for ensuring their reliability and safety in high-stress environments. Through experimental and analytical techniques, researchers can gain insights into the thermal and impact characteristics of composite materials. Identification of failure mechanisms and the proposal of strategies to enhance composite resilience in demanding conditions are vital objectives. These findings contribute to the advancement of composite technology and aid in the development of robust and efficient composite structures. By deepening our understanding of how composite materials perform under thermal and impact loading, we unlock their full potential. Composites offer a unique combination of properties, including high strength-to-weight ratio, excellent fatigue resistance, corrosion resistance, and thermal stability. These qualities make them suitable for diverse industries such as aerospace, automotive, construction, sports equipment, and renewable energy.

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