Chapter 5

Biaxial and Multi Axial Stress Behavior of Composites Insights and Methodologies

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ABSTRACT

The utilization of fiber-reinforced composites has experienced a significant surge in various industries, such as aviation, marine, civil engineering, and automotive. This is mostly due to their exceptional strength and stiffness. However, the design of these structural components is usually based on the uniaxial test data, which has been found to be insufficient. This is due to the fact that real-world engineering materials often experience complex loading conditions that uniaxial testing cannot depict. To create structures that can withstand multiple loads, one must understand how composites react to biaxial or multiaxial loading. Multi-axial and biaxial loads cause different failure processes than uniaxial loading. The current study examines the behavior of FRP when subjected to biaxial loading. The study encompasses the examination of testing protocols, specimen design, and sensing techniques utilized for the measurement of stress and strains under biaxial loading.

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1. INTRODUCTION

In order to create a material that is unique from each constituent, new materials are created by combining multiple constituents. This combination can happen on a microscopic or macroscale. A composite material is created when various materials are combined in a way that creates continuous regions with a strong bond at the interface. This group includes many materials, both natural and artificial. Bamboo, bones, mortar and concrete mixers, alloys, filled polymers, chopped fiber composites, porous and fractured media, and more are a few examples.

The shape and type of constituent materials determine the nature of a composite. The most common composite form has a binary phase that consists of a continuous phase called the matrix and a discontinuous phase called reinforcement. The reinforcement can be continuous long fibers, short fibers, or particles, and the matrix phase can be metals, polymers (both thermosetting and thermoplastic), or ceramics.

Despite their versatility, composite materials have a limited use in structural applications when compared to traditional metallic materials. This limitation is caused by a number of factors. These include the following:

a) The high costs of processing and materials;
b) The limited opportunities for manufacturing;
c) The complexity of joining;
d) The infrastructure that is required for manufacturing and servicing is still in the process of being developed, and
e) The design methodologies need to be validated due to the lack of test data under complex loading.

Despite the wide and complex range of material groupings studied, only a few material forms and categories are widely available on the market. Fiber-reinforced polymeric composites are currently the most popular type of structural material. Their popularity is attributed to unique advantages such as a high stiffness-to-weight ratio and corrosion resistance. As a result, composites are used in a variety of fields, including the military, civil engineering, and commercial applications such as pipes and water storage tanks. The ability to tailor material properties in specific directions provides designers with greater flexibility and has expanded the use of composite materials. The conventional practice of designing components made of inhomogeneous and anisotropic materials using uniaxial test data has been deemed inadequate. Recognizing this limitation has resulted in a better understanding of how these complex materials behave under biaxial loads [Lamkanfi (2010)].

During their lifetimes, pressure vessels, shafts, and pipes are frequently subjected to multiaxial and biaxial loading. Schen et al. (2006) mention extensive research on biaxial and triaxial loading of isotropic materials, which employs a variety of experimental techniques and test procedures. Similar research has been done on composite materials. However, due to their anisotropic and inhomogeneous nature, studying the multiaxial and biaxial behavior of composites is difficult. This complication calls into question the precision of using uniaxial coupon tests as the sole method of evaluating materials and their mechanical properties. Uniaxial testing alone may provide an inaccurate representation of how these materials will behave in engineering structures [Jones et al. (2001)]. The inability to assess the entire multiaxial (or biaxial) response of composite materials is a major concern. Despite numerous attempts to comprehend their behavior under multiaxial and biaxial stress states, the quality of these efforts has frequently been inadequate.

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