Chapter 1
Recent Advances on Smart Lightweight Carbon Fiber/Aluminum Hybrid Composite Structures

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ABSTRACT

Due to the growing demand for lightweight materials in different industries, the selection and hybridization of engineering fibers and metals is becoming a promising solution as it combines the outstanding mechanical, thermal, and weathering-resistance properties from both materials. Due to their lightweight and strong mechanical properties, carbon fiber/aluminum hybrid composite-based structures have become the most dominant materials used by engineers and researchers in the recent two decades. In the present chapter, the recent development on the processing techniques and mechanical performances of these hybrid structures are reviewed in detail. In addition, the applications of these kinds of structural materials in the various industrial sectors including, automobile, aerospace, design of industrial robots, and fire protection are summarized.

INTRODUCTION

Fiber-Metal-Laminates (FML) exhibit superior dynamic mechanical performance combined with small densities. Due to their higher mechanical properties glass fibers, Kevlar, carbon fibers laminates reinforced polymers have been extensively utilized to strengthen metals. However, these fibers reinforced metals laminate provokes a discrepancy in their thermal expansion coefficients and the ability of gal-

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vanic corrosion. To tackle these challenges, the fiber/metal laminate is changed by the incorporation of elastomeric interlayer, which is recommended to deal with these problems.

Aluminum Matrix Composites (AMC) represent a novel generation of light-weight, high-performance aluminum centric materials. The reinforcement of AMC could be achieved by using continuous or discontinuous fibers, in the whisker or particle forms at various volume fractions. The properties aluminum matrix can be tuned to accomplish the requirement of different industries from a suitable combination of matrix, type of reinforcing fibers and joining method. For several decades of intensive research have afforded a large scientific knowledge on the role of fiber reinforcement on the various structural, mechanical, and wear features of this metallic matrix. Recently, this matrix has been used in high-technical, structural and functional applications including aircraft building, defense, automotive, and heat management areas, sports, and recreation. It is worthy to note that research on fiber-reinforced aluminum matrix reached industrial maturity in the developed countries and is currently under the process of further ameliorating their properties (Surappa, 2003).

Owing to the increasing demand for stronger and low density structures in the industry, researchers have made strong efforts on the design of advanced prototypes for fiber-aluminum laminates. Fiber/aluminum hybrid composites produced by interlocking thin aluminum layers with fiber reinforced polymer laminates. By hybridization of the two constituents, aluminum and fiber-reinforced laminate, a combined several advantageous properties of their resulted composites can be offered like, good corrosion resistance, better thermal stability, and improved damage tolerance to fatigue crack growth and impact damage, which represents a critical requirement for aviation applications (Sinmazçelik et al., 2011). Aluminum layers and fiber-reinforced composites could be joined by several mechanically and adhesively techniques. Generally, the adhesively joined fiber/aluminum composites were demonstrated improved fatigue properties relative to those similar mechanically joined ones. The most well-known commercially in service fiber/aluminum laminates are reinforced with aramid fibers such as ARALL, those produced from high strength glass fibers, GLARE, and those strengthened with carbon fibers like CARALL.

Carbon fibers (CF) are materials comprising more than 92 wt.% of carbon and forming a fiber shape. They are very important carbonaceous material demonstrating several superior mechanical performances (tensile strength of 2–7 GPa), better physical, and chemical stability, prominent compressive strength, high Young's modulus of 200–900 GPa, small density in the range of 1750–2200 Kg/m^3, low thermal expansion, higher thermal conductivity that exceeds 800 $Wm^{-1} K^{-1}$. These fibers are much lighter than steel, aluminum, and many alloying components of manganese, zinc, and zirconium, which make them very suitable for reinforcing the different metallic plates such as magnesium or aluminum. For example, double-decker panels fabricated from fibers/epoxy resin face-sheet and aluminum foam core were manufactured as a prospective application significance in the industrial processing field. The carbon fiber was the most extensively used for reinforcing aluminum metal due to its intriguing properties, this includes lightweight and higher mechanical strength, and improved anticorrosion characteristics (Table 1). Therefore, it was widely utilized for manufacturing carbon fiber reinforced polymers (CFRP) laminates.

The production methods to join only CFRP/aluminum composite structures involve adhesive-bonding, self-piercing rivet, bolt, clinching and welding (Pramanik et al., 2017). Excluding adhesive bonding and welding techniques, the other joining processes required the infiltration of aluminum pins over joining parts and thus, surface pre-treatment is not recommended. The selection of suitable joining process primarily depends on the targeted applications. The joining technique can also predominantly influence the inherent mechanical performances of these composite structure, including the friction, impact,

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