Abstract

Demonstration of Composite Oriented Strand Board (COSB): a Novel Notch-Insensitive Hybrid Carbon/Glass-Fiber Reinforced Polymer Composites with Superior Ductility, Toughness, and Formability

Carbon fiber reinforced composite material is a non-biodegradable cancer-causing hazard material that presents large negative impact to earth environment and human health. There is a critical need for more sustainable solutions for reusing and recycling carbon-composites. Current disposal routes of these materials is buried them in landfills, where they do not degrade for decades. In recent years, commercial aircraft industry has markedly increased usage on carbon fiber reinforced composites to produce lighter and more durable aircrafts. For example, one Boeing-787 airplane contains more than 50% by weight of carbon-composites, which is about 32,000kg. In 2015, Boeing projected a demand of 38,050 new airplanes over the next 20 years. Currently, Boeing and Airbus each manufactures 60 A350XWB and 787 airplanes/month, and generates ~1 million lb of carbon-waste/year from production. Increasing use of carbon-composites will lead to increasing amounts of scraps generated from manufacturing processes. In Boeing's production shops, as much as 40% of carbon-composites eventually become waste in the form of skeletal cutouts (irregular-shape remaining parts after desired raw materials being cut-out). If the entire supply chain is included, the total carbon-waste is close to 4 million lb/year. Dealing with production waste sustainably is hence growing in importance.

In this work, efforts have focused in four steps on converting aerospace carbon fiber reinforced composite scraps into useful reused products. Firstly, a composites oriented strand board (COSB) material (similar to the popular wood OSB products used in construction world) using recycled and reused aerospace-scraps was invented by cutting carbon-wastes into rectangular strands and curing them by state-of-the-art Out of Autoclave (OoA) process manufacturing methods, including Vacuum Bag Only (VBO) and compression molding techniques. Secondly, multiscale Finite Element Analysis (FEA) computer models were developed in ABAQUS, MSC NASTRAN, and DIGIMAT, after which design optimization and parametric fabrication of the COSB were conducted. The results of the FEA models, as well as the invented higher order abstract structural element (HOASE) method were used as fast guidance for further development of COSB. Thirdly, nondestructive evaluation (NDE) including ultrasound C scan, X-ray Micro-CT (XCT), and microscopic study were conducted to reveal COSB's material microstructures such as void morphology, void content, and void distribution. Material property characterization including tensile, compression, 3 point bending (3PB), end-notched double cantilever beam (DCB) interlaminar fracture toughness, compression after impact (CAI) tests were performed to further understand and improve COSB's elastic behavior and failure mechanism. Finally, structural design and optimization of manufacturing process were performed, and COSB's stiffness, strength, strain to failure, toughness, and experimental coefficient of variation (CoV) were further enhanced. COSBs were eventually developed into daily civil products such as COSB skateboards and structural and non-structural parts e.g. COSB hat-stiffeners and hat-stiffened-panels for aerospace unmanned aerial vehicles (UAVs), automotive, and constructional applications. The publications, methods, and products resulted from this work have been widely accepted by industries and have significantly advanced the sustainability of the aerospace industry.