World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:15, No:01, 2021

In-Process Integration of Resistance-Based, Fiber Sensors during the Braiding Process for Strain Monitoring of Carbon Fiber Reinforced Composite Materials

Authors : Oscar Bareiro, Johannes Sackmann, Thomas Gries

Abstract : Carbon fiber reinforced polymer composites (CFRP) are used in a wide variety of applications due to its advantageous properties and design versatility. The braiding process enables the manufacture of components with good toughness and fatigue strength. However, failure mechanisms of CFRPs are complex and still present challenges associated with their maintenance and repair. Within the broad scope of structural health monitoring (SHM), strain monitoring can be applied to composite materials to improve reliability, reduce maintenance costs and safely exhaust service life. Traditional SHM systems employ e.g. fiber optics, piezoelectrics as sensors, which are often expensive, time consuming and complicated to implement. A cost-efficient alternative can be the exploitation of the conductive properties of fiber-based sensors such as carbon, copper, or constantan - a copper-nickel alloy – that can be utilized as sensors within composite structures to achieve strain monitoring. This allows the structure to provide feedback via electrical signals to a user which are essential for evaluating the structural condition of the structure. This work presents a strategy for the in-process integration of resistance-based sensors (Elektrisola Feindraht AG, CuNi23Mn, Ø = 0.05 mm) into textile preforms during its manufacture via the braiding process (Herzog RF-64/120) to achieve strain monitoring of braided composites. For this, flat samples of instrumented composite laminates of carbon fibers (Toho Tenax HTS40 F13 24K, 1600 tex) and epoxy resin (Epikote RIMR 426) were manufactured via vacuum-assisted resin infusion. These flat samples were later cut out into test specimens and the integrated sensors were wired to the measurement equipment (National Instruments, VB-8012) for data acquisition during the execution of mechanical tests. Quasi-static tests were performed (tensile, 3-point bending tests) following standard protocols (DIN EN ISO 527-1 & 4, DIN EN ISO 14132); additionally, dynamic tensile tests were executed. These tests were executed to assess the sensor response under different loading conditions and to evaluate the influence of the sensor presence on the mechanical properties of the material. Several orientations of the sensor with regards to the applied loading and sensor placements inside the laminate were tested. Strain measurements from the integrated sensors were made by programming a data acquisition code (LabView) written for the measurement equipment. Strain measurements from the integrated sensors were then correlated to the strain/stress state for the tested samples. From the assessment of the sensor integration approach it can be concluded that it allows for a seamless sensor integration into the textile preform. No damage to the sensor or negative effect on its electrical properties was detected during inspection after integration. From the assessment of the mechanical tests of instrumented samples it can be concluded that the presence of the sensors does not alter significantly the mechanical properties of the material. It was found that there is a good correlation between resistance measurements from the integrated sensors and the applied strain. It can be concluded that the correlation is of sufficient accuracy to determinate the strain state of a composite laminate based solely on the resistance measurements from the integrated sensors.

Keywords : braiding process, in-process sensor integration, instrumented composite material, resistance-based sensor, strain monitoring
Conference Title : ICSM 2021 : International Conference on Smart Materials
Conference Location : Zurich, Switzerland
Conference Dates : January 14-15, 2021