ABSTRACT

The popularity of additive manufacturing has been growing over the last few decades. Additive manufactured composites have a wide range of applications in engineering sectors specifically in aerospace structures. In addition to mechanical loads, they are subjected to thermal loads caused by aerodynamic heating. Temperature increases cause changes in material properties, which complicates thermal stress analysis.

This PhD work aims to analyze the influences of various thermal treatments on the mechanical properties, thermal stability, and morphological characteristics of continuous carbon fiber reinforced polymer (CFRP) composites printed using the modified FDM printer. The printed samples were exposed to various thermal modes (prolonged and cyclic) and magnitudes (above- and sub-zero degrees) then were investigated using scanning electron microscope, static tensile testing, and differential scanning calorimetry. It is revealed that the Young's modulus and tensile strength of samples were all degraded after thermal treatment under prolonged temperatures and cyclic temperatures. The samples exposed to thermal cycling at above-zero degrees exhibit higher values of glass transition temperature compared to those subjected to prolonged temperature. Observing the morphological structure on the surface visually revealed a subtle change in the surface morphology before and after thermal treatment at temperatures above zero degrees Celsius. The higher the temperature exposure for both cyclic and prolonged temperature groups at above-zero degrees, the more the damage in the polymer parts.

Hence, it is possible to characterize the thermal, morphological, and mechanical properties of CFRP composites printed by modified FDM printer using NDT and destructive methods. The thermal loading was simulated with specific boundary conditions similar to the experiments where the sample was placed inside the oven chamber. While for the mechanical (tensile) testing loading, the sample's geometry was created with gripping lines to be in accordance with ASTM D3039 standards for tensile tests used in experimental work and surface traction for the applied load. The highest modulus and strength were achieved from the intact sample while the lowest mechanical modulus and strength were obtained in the sample with heat treatment at the prolonged temperature of 145◦C. At high temperatures, matrices soften affecting matrix-dominated properties such as transverse and in-plane shear stiffness and strength. A good correlation between the predictive models and experimental results is obtained. Hence, it is possible to determine the degradation processes of AM CFRP using the combination of experimental and numerical approach.