CAMX 2019

23-26 September 2019, Anaheim, California

Analysis on Part Distortion and Residual Stress in Big Area Additive Manufacturing with Carbon Fiber-Reinforced Thermoplastic using Dehomogenization Technique

Seokpum Kim[1], Harsh Baid[2], Ahmed Hassen[1], Abhishek Kumar[3], John Lindahl[1], Christine Ajinjeru[4], Chad Duty[4], Pritesh Yeole[4], Uday Vaidya[4], Frank Abdi[2], Lonnie Love[1], Vlastimil Kunc[1]

[1]Material Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge, TN 37830
[2]AlphaSTAR Corporation, Long Beach, California 90804
[3] Mechanical and Industrial Engineering, Northeastern University, College of Engineering, Boston, MA 02115
[4]Mechanical, Aerospace and Biomedical Engineering, the University of Tennessee, Knoxville, TN 37996

Part distortion and bottom surface warpage often occur in extrusion-based additive manufacturing. The undesirable deformations during the printing process are due to residual stresses caused by material shrinkage. Analysis on residual stress and deformation requires accurate thermo-mechanical material properties. Polymer composites reinforced with short fibers have intrinsic inhomogeneities with non-uniform fiber orientation. Therefore, homogenized macro properties may not accurately represent the progressive damage behavior or distortion. In this study, fiber orientations in Acrylonitrile Butadiene Styrene (ABS) reinforced with 20%wt carbon fiber are calculated using a de-homogenization technique. Thermal expansion coefficients in multiple directions are obtained from Thermo-Mechanical Analysis (TMA) tests. Temperature dependent stiffness is measured, and temperature dependent strength is estimated. Thermal conductivities in multiple directions and thermal capacity are measured. The calibrated thermo-mechanical properties of the composite with de-homogenized technique are used to analyze the residual stress and distortion of a 4 ft-wide wall printed in the Big Area Additive Manufacturing (BAAM) system. For experimental measurement on the wall printing, Infra-Red (IR) camera captures the temperature field, and Digital Image Correlation (DIC) camera captures the deformation field. Linear Variable Differential Transformer (LVDT) is installed to measure the warpage at the bottom surface. The experimental data are compared to the numerical analysis results. The temperature profile and the distortion profile from experiment are close to the simulation results. Damages due to residual stress and distortion are analyzed.

Keywords: (1) ICME, (2) ABS-CF, (3) FDM, (4) Effect of Manufacturing Defects, (5) Nano-Micro Mechanics, (6) Scatter, (7) Sensitivity, and (8) Uncertainties