Experimental and numerical investigation on multi-pass laser cutting of natural fiber composite

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Abstract

In this paper, an experimental and numerical investigation of low power laser cutting of cotton fiber laminate (CFL) is presented. CFL is very useful for electrical insulation applications at low voltages, and usually used in gears, spacers and coil supports in turbine generator. Analysis of Variance (ANOVA) along with Taguchi experimental design is conducted to determine the optimum levels of all input parameters; it is observed that heat affected zone (HAZ) and kerf width are largely affected by the cutting speed and least affected by the stand-off distance (SOD). Detailed examination using SEM micrographs shows protruding fibres due to the polymeric matrix vaporization under laser processing. Additionally, it was noted that multiple beam passes produce a greater fiber pull-out than a single beam pass. In order to understand the underline physics, detailed numerical simulation of the problem is also performed in order to predict formation of heat affected zone (HAZ), kerf width and thermal residual stress. Owing to fatigue, higher values of residual stresses result in cracking, delamination and failure. Using Abaqus software, user defined routines for defining laser beam profile and material removal are carried out for determining temperature gradient and cut characteristics. The approach for material removal uses element deletion based on temperature-dependent Hashin failure criteria when the fibers lose their

strength at ablation point. The numerical results match reasonably well with the experimental measurements of HAZ and kerf width using the temperature dependent material removal approach.

Keywords: Cotton fiber laminate, low power laser, cutting, Taguchi experimental design, finite element modelling

Nomenclature

h_c	Convection Factor
ε_{em}	Emissivity
σ_{SBc}	Stefan-Boltzmann Constant
T_s	Surface Temperature
T_0	Initial Temperature
A	Absorptivity
P	Beam Power
R	Beam Radius
Z_0	Initial Beam Position
V	Beam Velocity
X^T	longitudinal tensile strength
X^C	longitudinal compressive strength
Y^T	transverse tensile strength
Y^C	transverse compressive strength
S^L	longitudinal shear strength
S^T	transverse shear strength