Machinability of Bio-composites: Prospects and Challenges

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Abstract

The exceptional inherent properties of natural fibre reinforced polymer (FRP) composite materials and their bio-based hybrid counterparts have contributed to extensive engineering applications. These properties include, but are not limited to, acoustic, biodegradability, renewability, sustainability, corrosion and wear resistance. However, the abrasive, heterogeneous and anisotropic nature of bio-composites make their drilling a serious challenge; liable to many drilling-induced damage (DID). Therefore, a comparative experimental study on conventional and non-conventional drilling of bio-composites was conducted on hemp, flax and hybrid carbon/flax fibre/polycaprolactone and vinyl ester bio-composite laminates, designated as HFRP, FFRP and C-FFRP samples, respectively. Similar manufacturing methods and process parameters/conditions were used for their fabrication and drilling, respectively. The conventional drilling technique (CD) technique involved the use of high-speed steel (HSS) twist drill/hole diameter of 10 mm, while non-conventional drilling (NCD) technique included abrasive waterjet (AWJ) and ultrasonically-assisted drillings (UAD). From the results obtained, it was evident that NCD technique (especially UAD) performed better than the CD in terms of reduced DID responses, mainly delamination and surface roughness. This was attributed to the lowest feed rate of 2.55 mm/min used and intermittent, vibro-impact character of the operation of UAD that produced the lowest thrust force, which determined the lowest delamination damage on bio-fibre/vinyl ester (VE) samples. However, poor hole quality was observed with bio-fibre/polycaprolactone sample, due to melting of the bio-resin/polycaprolactone (PCL). The UAD process zone temperature was higher than that of CD, causing the melting of PCL matrix with a very lower melting temperature of 60 ^{o}C. In addition, the AWJ drilling exhibited lower DID response than the CD, but not better than the UAD technique. The minimum surface roughness was obtained with AWJ drilling, due to the absence of heat and presence of combinatory material removal mechanisms of shearing, erosion, polishing and micromachining performed by the correct choice of abrasive garnet (180 μm) used. The main setback of AWJ drilling was an entanglement of abrasive particles of different sizes, which supported delamination phenomenon, especially with hybrid (C-FRP) samples. Therefore, application of these techniques depends on selected drilling parameters, acceptable values of DID responses and nature of bio-composites, as load-bearing and structural materials. Summarily, the results obtained within the scope of this investigation are very germane to automotive, aerospace, marine, among other FRP composite-based manufacturing industries, as quest to enhance properties of natural FRP composites and their machinability continues.

Keywords: CD), NCD, UAD, AWJ, process parameters, drilling techniques, DID, delamination, surface roughness.