The energy-absorbing characteristics of filament wound hybrid carbon fiber-reinforced plastic/polylactic acid tubes with different infill pattern structures

MA Quanjin[1, 2], Idris M Sahat[1], Mohd R Mat Rejab[1, 2], Shukur Abu Hassan[3], Bo Zhang[2], Mubin NM Merzuki[1]

[1]Faculty of Mechanical & Manufacturing Engineering, Universiti Malaysia Pahang, Pahang, Malaysia

[2]School of Mechanical Engineering, Ningxia University, Yinchuan, China

[3]Centre for Advanced Composite Materials, Faculty of Engineering, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia

Corresponding Author:

Mohd R Mat Rejab, Universiti Malaysia Pahang, Pekan 26600, Pahang, Malaysia.

Email: ruzaimi@ump.edu.my

Ma Quanjin, Universiti Malaysia Pahang, Pekan 26600, Pahang, Malaysia.

Email: neromaquanjin@gmail.com

ABSTRACT

The study aims to investigate the effect of different infill pattern structures on the energy-absorbing characteristics of single filament wound carbon fiber-reinforced plastic tubes, single polylactic acid and hybrid carbon fiber-reinforced plastic/ polylactic acid tubes under quasi-static axial compression condition, which were fabricated using filament winding and additive manufacturing techniques. Five infill pattern structures of single polylactic acid tubes and hybrid tubes were studied and compared on their energy-absorbing characteristics, which referred to normal, triangle, square, hexagonal and tetrahedral patterns. It concluded that the effect of the infill pattern structure had a significant influence on energy-absorbing characteristics of single polylactic acid and hybrid carbon fiber-reinforced plastic/polylactic acid tubes. For pure polylactic acid tubes, the triangle infill pattern tube represented the highest values of energy absorption (*EA*) of 0.75 kJ, specific energy absorption (*SEA*) of 28.50 J/g, compressive strength and modulus of 69.72 MPa and 1.40 GPa, yield strength of 27.80 MPa, peak crushing force (F_{peak}) of 23.13 kN and mean crushing force (F_{mean}) of 18.82 kN. For the hybrid carbon fiber-reinforced plastic/polylactic acid tube, tetrahedral infill pattern tube showed the highest values of *EA* with 0.99 kJ, *SEA* with 29.66 J/g, F_{peak} with 22.68 MPa and yield strength with 29.91 MPa. Energy absorption interaction ($EA_{interaction}$) and interaction ratio (φ_e) of all specimens were evaluated, which showed that the tetrahedral infill pattern tube recorded the highest of all hybrid tubes with 259.92 J and 35.72 %. The result revealed that the

tetrahedral pattern displayed better crashworthiness in terms of crushing force efficiency (*CFE*), *EA* and *SEA* in the hybrid structure, which had greater potential to apply as energy absorbers. Moreover, triangle and square infill patterns of hybrid tubes provided the negative interaction effect results, which conducted lower energy-absorbing characteristics compared to individual tubes, respectively.

KEYWORDS

Carbon fiber-reinforced plastic; Hybrid carbon fiber-reinforced plastic/polylactic acid tube; Infill pattern structure; Energy-absorbing characteristics