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Analyzing the Effects of Bio-fibers on the Stiffness and Strength of Adhesively Bonded Thermoplastic Bio-fiber Reinforced Composites by a Mixed Experimental-Numerical Approach

Authors : Sofie Verstraete, Stijn Debruyne, Frederik Desplentere

Abstract : Considering environmental issues, the interest to apply sustainable materials in industry increases. Specifically for composites, there is an emerging need for suitable materials and bonding techniques. As an alternative to traditional composites, short bio-fiber (cellulose-based flax) reinforced Polylactic Acid (PLA) is gaining popularity. However, these thermoplastic based composites show issues in adhesive bonding. This research focusses on analyzing the effects of the fibers near the bonding interphase. The research applies injection molded plate structures. A first important parameter concerns the fiber volume fraction, which directly affects adhesion characteristics of the surface. This parameter is varied between 0 (pure PLA) and 30%. Next to fiber volume fraction, the orientation of fibers near the bonding surface governs the adhesion characteristics of the injection molded parts. This parameter is not directly controlled in this work, but its effects are analyzed. Surface roughness also greatly determines surface wettability, thus adhesion. Therefore, this research work considers three different roughness conditions. Different mechanical treatments yield values up to 0.5 mm. In this preliminary research, only one adhesive type is considered. This is a two-part epoxy which is cured at 23 °C for 48 hours. In order to assure a dedicated parametric study, simple and reproduceable adhesive bonds are manufactured. Both single lap (substrate width 25 mm, thickness 3 mm, overlap length 10 mm) and double lap tests are considered since these are well documented and quite straightforward to conduct. These tests are conducted for the different substrate and surface conditions. Dog bone tensile testing is applied to retrieve the stiffness and strength characteristics of the substrates (with different fiber volume fractions). Numerical modelling (non-linear FEA) relates the effects of the considered parameters on the stiffness and strength of the different joints, obtained through the abovementioned tests. Ongoing work deals with developing dedicated numerical models, incorporating the different considered adhesion parameters. Although this work is the start of an extensive research project on the bonding characteristics of thermoplastic bio-fiber reinforced composites, some interesting results are already prominent. Firstly, a clear correlation between the surface roughness and the wettability of the substrates is observed. Given the adhesive type (and viscosity), it is noticed that an increase in surface energy is proportional to the surface roughness, to some extent. This becomes more pronounced when fiber volume fraction increases. Secondly, ultimate bond strength (single lap) also increases with increasing fiber volume fraction. On a macroscopic level, this confirms the positive effect of fibers near the adhesive bond line.

Keywords : adhesive bonding, bio-fiber reinforced composite, flax fibers, lap joint
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