Structure Matters: Maximising the Performance of 3D Woven Fabric Composites

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Abstract

The mechanical properties of a 3D woven fabric reinforced composite highly depend on its structural parameters such as stuffer to binder ratio, filler density, binding step and binding depth. By tuning these parameters, one can achieve the best property in the composite. It is well established that a yarn highly oriented in the direction of the applied load bears the maximum and performs best. However, there is a requirement of structural integrity, which prohibits the usage of all straight yarns. In a 3D woven fabric, binder yarns fulfil this purpose, i.e. to hold the straight stuffer and filler yarns in their respective places. Therefore, the arrangement of binder yarns plays a significant role in deciding the mechanical properties of a 3D woven fabric composite. A higher stuffer-to-binder ratio provides a greater number of straight yarns in the structure at the cost of poor structural stability due to a lower number of binding points. A higher filler density yields more straight yarn and greater structural stability at the cost of reduced resin penetration. A higher binding step and lower binding depth result in lower crimp of the binder yarns and reduce the structural stability. Therefore, this research attempts to find out the best combination of these structural parameters for various mechanical properties of 3D fabric reinforced composites. Ultra-high molecular weight polyethylene (UHMWPE) multifilament yarn was used to weave the 3D fabric preforms. The stuffer-to-binder ratio, filler density, and binding step were varied at three levels, and binding depth at four levels. A total of 24 fabrics were manufactured with these parameters. Epoxy resin was used as the polymer matrix, and the composites were fabricated in a compression moulding machine. Mechanical properties of composites, such as tensile, flexural, low velocity impact, shear strength and dynamic mechanical properties were evaluated. The results reveal that 3D fabric structural parameters, namely binding step and binding depth decisively influence the properties of 3D fabric composites.

Keywords: 3D woven fabric composite, stuffer to binder ratio, filler density, binding step, binding depth, mechanical properties

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