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Variation of Warp and Binder Yarn Tension across the 3D Weaving Process and its Impact on Tow Tensile Strength

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Abstract : Modern industry has developed a need for innovative 3D composite materials due to their attractive material properties. Composite materials are composed of a fibre reinforcement encased in a polymer matrix. The fibre reinforcement consists of warp, weft and binder yarns or tows woven together into a preform. The mechanical performance of composite material is largely controlled by the properties of the preform. As a result, the bulk of recent textile research has been focused on the design of high-strength preform architectures. Studies looking at optimisation of the weaving process have largely been neglected. It has been reported that yarns experience varying levels of damage during weaving, resulting in filament breakage and ultimately compromised composite mechanical performance. The weaving parameters involved in causing this yarn damage are not fully understood. Recent studies indicate that poor yarn tension control may be an influencing factor. As tension is increased, the yarn-to-yarn and yarn-to-weaving-equipment interactions are heightened, maximising damage. The correlation between yarn tension variation and weaving damage severity has never been adequately researched or quantified. A novel study is needed which accesses the influence of tension variation on the mechanical properties of woven yarns. This study has looked to quantify the variation of yarn tension throughout weaving and sought to link the impact of tension to weaving damage. Multiple yarns were randomly selected, and their tension was measured across the creel and shedding stages of weaving, using a hand-held tension meter. Sections of the same yarn were subsequently cut from the loom machine and tensile tested. A comparison study was made between the tensile strength of pristine and tensioned yarns to determine the induced weaving damage. Yarns from bobbins at the rear of the creel were under the least amount of tension (0.5-2.0N) compared to yarns positioned at the front of the creel (1.5-3.5N). This increase in tension has been linked to the sharp turn in the yarn path between bobbins at the front of the creel and creel I-board. Creel yarns under the lower tension suffered a 3% loss of tensile strength, compared to 7% for the greater tensioned yarns. During shedding, the tension on the yarns was higher than in the creel. The upper shed yarns were exposed to a decreased tension (3.0-4.5N) compared to the lower shed yarns (4.0-5.5N). Shed yarns under the lower tension suffered a 10% loss of tensile strength, compared to 14% for the greater tensioned yarns. Interestingly, the most severely damaged yarn was exposed to both the largest creel and shedding tensions. This study confirms for the first time that yarns under a greater level of tension suffer an increased amount of weaving damage. Significant variation of yarn tension has been identified across the creel and shedding stages of weaving. This leads to a variance of mechanical properties across the woven preform and ultimately the final composite part. The outcome from this study highlights the need for optimised yarn tension control during preform manufacture to minimize yarn-induced weaving damage.

Keywords : optimisation of preform manufacture, tensile testing of damaged tows, variation of yarn weaving tension, weaving damage
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