

## Hybrid natural fibre reinforcements and preregs for thermoplastic composites with improved performance and properties

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The interest for natural fibre-reinforced composites has recently grown due to the increasing environmental concerns and the rather good mechanical properties that they exhibit. Presently several natural fibre alternatives have been introduced for use in commercial applications, mainly in semi-structural applications such as car interior panels. One main disadvantage is still the poor commercial availability natural fibre reinforcements which are tailored for the use in structurally demanding applications. Another challenge is the fact that natural fibres are available as short staple fibers, which must be spun to yarns with rather high yarn twist. This will result in that the individual fibre direction will not be in the loading direction, and secondly the twisted yarn will be difficult to impregnate leading to porosity. The fibre impregnation is of particular importance when thermoplastic resins are used in the composite. Porosity is difficult to avoid in natural fibre composites and has influence on the composite properties, yet how to control the porosity has so far only received limited attention. Thus, research on how to decrease the amount of porosity is warranted.

In this paper we will address these challenges, by presenting results from an ongoing project, where we manufacture hybrid yarns composed of thermoplastic fibres and hemp staple fibers. Composites have been manufactured from two different polylactic acid (PLA) - hemp hybrid yarns, one type composed of commingled PLA and hemp low TEX yarns, and one type composed of commingled spun PLA and hemp staple fibers. In the yarns the twist was kept as low as possible, by stabilizing the yarns by a co-wrapping with a very low TEX PLA filament. Laminates were fabricated with 30 weight-% hemp and 70 weight-% PLA using compression moulding, and the yarn orientation was varied (0°, 45° and 90° off-axis angle). Mechanical tests and morphological characterisation were carried out to investigate the effect of the different off-axis angles on the mechanical properties, and the effect of yarn structure on porosity, which is related to resin-fibre impregnation. We studied also the effect of alkali treatment of the hemp fibres on the composite characteristics.

The results showed that the yarn structure has an effect on porosity; it was between 6 – 9 vol-% for the commingled PLA and hemp low TEX yarns, while it was 1 – 3 vol-% for the spun PLA and hemp staple fiber yarns. The tensile properties were improved when the hemp fibre was alkali treated. The alkali treated hemp/PLA yarn gave maximum improvement in mechanical properties compared to untreated hemp/PLA yarn. The best overall properties were achieved with aligned alkali treated hemp/PLA yarn leading to a tensile strength of 77.1 MPa, Young's modulus of 10.3 GPa, flexural strength of 100.9 MPa, flexural modulus of 7.1 GPa, and impact strength of 18.8 kJ/m<sup>2</sup>. The results showed also that the mechanical properties of the composites were highly affected by the fibre direction. Tensile, flexural, and impact values of the composites showed the decreasing trend for off-axial composites compared to 0° axial-oriented composite.

In order to improve the the impact strength of the PLA composites, we also introduced Lyocell (a regenerated cellulose fibre) in the form of a non-woven fabric in the composite. Lyocell has high elongation at break and will improve resin wetting and tenacity of the Lyocell fibres. The composites were fabricated with 30 weight-% nonwoven Lyocell prepreg using compression moulding. The results showed that combination of hemp and Lyocell in a PLA composite can improve the impact, tensile, flexural properties compared to a composite without Lyocell.