Hemp/PLA Co-Wrapped Hybrid Yarns For Structured Thermoplastic Composites,” Nordic Polymer Days, Helsinki, Finland, May 29-31, 2013

***Abstract:***

In recent years, natural fibre-reinforced polymer composites have been attracting attention from the viewpoint of reducing the impact on the natural environment. Currently, the use of thermoplastic resins in composites is clearly of higher potential than the use of thermoset. There are many thermoplastic polymers derived from renewable raw materials, which are also biodegradable. Polylactic acid (PLA) is one such candidate, and it shows rather good properties that are suitable for applications that do not require long-term durability or elevated mechanical performance at higher temperatures. In order to make their possible use in many technical applications more attractive, the mechanical properties of the PLA can be enhanced by using reinforcements. Hemp fibres can be considered to be a good choice for reinforcing polymer composites, due to their high stiffness, strength, and aspect ratio. Highly ordered textile reinforcements, such as interlaced woven fabrics and unidirectional fabrics made from natural-fibre yarns, perform considerably better than random non-woven mats in natural-fibre composites. At present, the commercially available plant-fibre yarns are not intended for structural composites, but for textiles, which have entirely different demands on the yarns. Thus, work is needed to tailor-make the best plant-fibre yarn for reinforcement of composites. This also includes investigation of the possibility of combining plant-fibre yarns with the matrix polymer in fibre form into one hybrid yarn (a composite preform), and how to do it (twisting or blending). It is well known that fibres provide the highest strength and stiffness when they are continuous and aligned in the direction of the applied load. Natural fibres are naturally discontinuous and conventional spun staple yarns tend to be highly twisted, which leads to fibre misalignment and poor resin wet-out. The structured natural-fibre composites reported so far are based on twisted yarns produced by long-established conventional spinning methods, mainly ring spinning.

In this paper, we report our work on improving the orientation of hemp fibres in composites by using our recent development of co-wrapped yarn structures. This novel co-wrapped yarn consists of low twist and very fine hemp yarns next to PLA filaments in the core part, which are wrapped by PLA filaments. By varying the composition of hybrid yarn, it is possible to vary the hemp fibre content from 10 to 45 wt %. An exciting recent advancement has been a new family of aligned natural-fibre reinforcements, which has overcome these issues by using low twist yarns. We also report the influence of fibre content and wrap density (number of wraps per unit length) on the properties of composites. Before compression moulding, multilayer 0/90 bidirectional hybrid yarn prepregs were prepared by winding the hybrid yarn around a steel rectangular frame.

We investigated the mechanical and thermo-mechanical properties of hemp-reinforced PLA composites. Compared to neat PLA, the tensile and flexural modulus and the strength of the PLA-hemp composites were significantly higher as a result of the increased fibre content. Impact strength of the composites decreased initially up to 10 wt % fibre loading, but even higher fibre loading caused an improvement in impact strength. From the DMTA results, it is evident that incorporation of the fibres gives a considerable increase in storage modulus and a decrease in tan δ values. These results show the reinforcing effect of hemp on PLA matrix. From the general trend in the results obtained, it can be affirmed that co-wrapped hybrid yarn with lower wrapping density leads to lower mechanical properties in the composite. The study performed with DSC revealed that the glass transition temperature and the crystalline melting point of PLA were not affected significantly after reinforcement with hemp. The crystallisation temperature of the hemp-reinforced PLA composites decreased compared to pure PLA, which indicates that the hemp fibres hinder the migration and diffusion of PLA molecular chains to the surface of the nucleus in the composites. No noteworthy differences in calorimetric data from DSC for composites were observed between the hybrid yarn preforms with different wrapping density. Future work will concentrate on efforts to evaluate the biodegradability of these developing and promising composites.