BRAIDING MANUFACTURING OF NATURAL FIBRE COMPOSITES

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In line with the global request for reducing environmental impact, natural fibers are increasingly used. The use of this kind of fibers allows to reduce problem of raw materials and a limited amount of conventional energy resources. In particular, among several types of natural fibers, hemp fibers are more and more used as reinforcement in composites thanks to mechanical properties and low cost. Another good characteristic of hemp is associated with the LCA of this plant in particular the ease of cultivation and the fast growing besides the ability to extract heavy metals from the soil. Braiding is a production process known from ancient times. Initially, it was used to realize ropes and only after many years the development of the industry allowed to automate this process. In the last fifty years the braiding reinforcements have been used to realize reinforced plastics and composites materials. The advantage of using the braiding process is to obtain air ducts, automotive shaft and fuel lines with holes and openings inside without having other productive phases and a consequent fibers breakage. Braiding process can be taken into consideration in order to have an automated mechanical system of production of hemp laminates.

The production of an interlacing fabric involves the design of fabric considering the geometry of the braid, the design of composites structures, the final properties, and the design of the braiding machine.

In this Ph.D thesis a Circular braiding process is used with a Circular braiding machine not to obtain tubular pre-forms, but to produce hemp fibers laminate with a high rate. The machine is a Herzog RF1/144-100 and is composed of 144 carriers with a rotary movement; half of this has a rotary in the warp direction, the other half has a rotary in the weft direction, so to obtain an interlacing of fibers.

The thesis is focused on the study of the features of final products, that are influenced by the production parameters and could affect the geometry of the pre-form. One of these parameters is the angle of the interlacing of yarns called braiding angle that combining with the dimension of single yarn is the first parameters to control for the final results.

The first year of the Ph.D was based on the preliminary study of this technology including all kind of machine and all the parameters A design tool that allows to insert the parameters of the production process and the geometrical parameters of the fibers has been developed in order to obtain the final features of the pre-forms. The tool is designed also to have the possibility to realize hybrid pre-forms with two different kinds of fibers or using axial fibers, consequently it evaluates the correct spindle radius and have the correct cover factor.

The study continued in the second years performing an experimental application of the calculation tool so to obtain a defined number of preforms with different braiding angle and different cover factor (that means different volume fraction of fibers)

The braiding angles are chosen and consequently, the laminates realized have the follow angles: +/-30°, +/-60° and +/-45°. With the tool it has been calculated the correspondent spindle radius for each winding. Two kinds of resins have been used as a matrix to obtain different laminates to test; the first one is a thermoset epoxy resin, the second one is a new kind of thermoplastic resin. To produce the laminates was used an infusion process coupled with the study of the process and of permeability for different angles.

Then in the third year, all the laminates are subjected to mechanical tests to evaluate the quality of the used production process and the value of adhesion between the plies. Then simulations of elementary cells are performed to make a comparison between numerical and experimental results in terms of fiber volume fraction and mechanical behavior and obtaining also a different comparison between two different kinds of matrix.

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