12th International Conference on Composites Testing and Model Identification
J. Varna (Editor)
Riga, 2024

SUSTAINABLE HYBRID COMPOSITES WITH RECYCLED CARBON FIBERS

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Keywords: Polymer Composites, Recycled Carbon Fiber, Compression Moulding, Mechanical properties, Hybrid Composites

ABSTRACT

The increasing demand for sustainable materials and circular economy has driven significant research into the recycling and the reuse of carbon fibers. Recycled carbon fiber (rCF) reinforced polymers (rCFRP) offer a promising solution by utilizing short rCF to create high-performance composites at a reduced cost compared to polymers reinforced with virgin carbon fibers (vCF).

Currently, as a consequence of the recycling processes used by the industry, long and continuous carbon fibers from manufacturing waste and structures reaching end-of-life become short, recycled fibers. These rCF still possess rather high mechanical properties which however, are slightly lower than properties of vCF [1]. This study aims to show potential of using these discontinuous rCF to design high performance sustainable composites by combining rCF with vCF and/or other reinforcements to produce hybrid composites. To achieve this, the traditional paper-making technique is adapted to manufacture non-woven mats out of short rCF, vCF, and a combination of both. The fibers used in this study have an average length of 12 mm. Mats are produced one at a time by mechanically dispersing the fibers in a container with a solution of water and binding agent, and with the aid of a stirrer. This process promotes the opening of the fiber bundles and transforms them into a network of two-dimensional “dandelion” like architecture (see Figure 1).

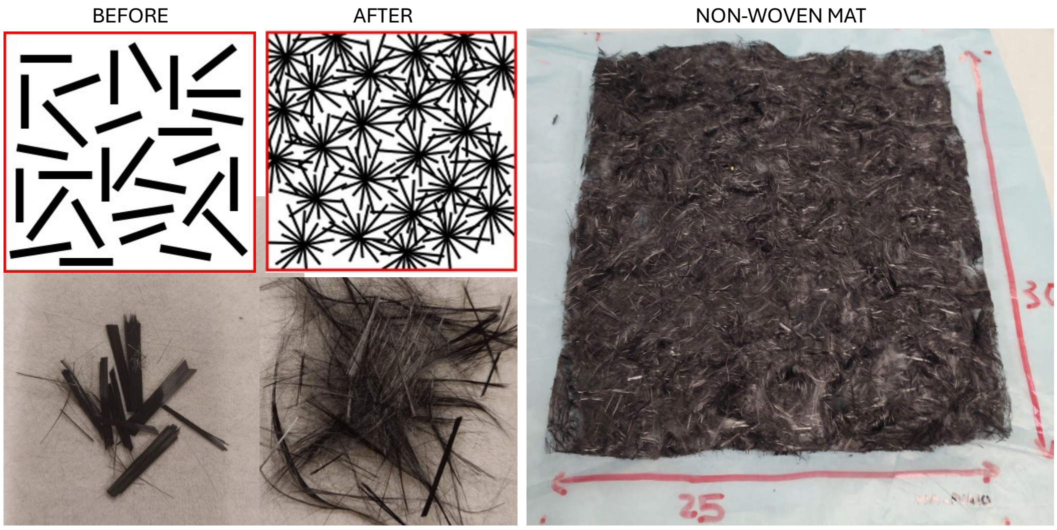

Figure 1: Fibers before and after dispersion (left) and finished vCF non-woven mat (right)

After mixing, the water is removed by draining through a pipe using gravity as driving force, , ensuring minimal disturbance to the fibers. The wet mats are then dried in a fume hood for 24 hours at RT and subsequently in an oven at 120°C for 2 hours to ensure complete moisture removal. Each mat has an average weight of 60-65 gsm and contains a negligible percentage of polyvinyl alcohol, which acts as a binder and improves handleability. These mats are then stacked and compacted at room temperature to form a “non-woven” fabric with randomly oriented fibers (Figure 1 (right)). These fabrics are made with variable content of rCF and vCF to study how different ratio of recycled/virgin fibers affect performance of composite laminates. For each layup and vCF/rCF content combination, two final laminates are produced. One is infused with epoxy resin by vacuum-assisted resin infusion (VARI), while the other is manufactured using compression molding in a lab-scale hot press. Both laminates consist of 8 layers of mats which are either made of single type of fiber (e.g. rCF or vCF) or consist of two types of reinforcements with different fiber contents ratios. This method allows for hybridization at two scales: layer by layer and in-layer (see Figure 2). In case of layer-by-layer hybridization other materials besides vCF can be introduced in the form of unidirectional or woven fabrics.

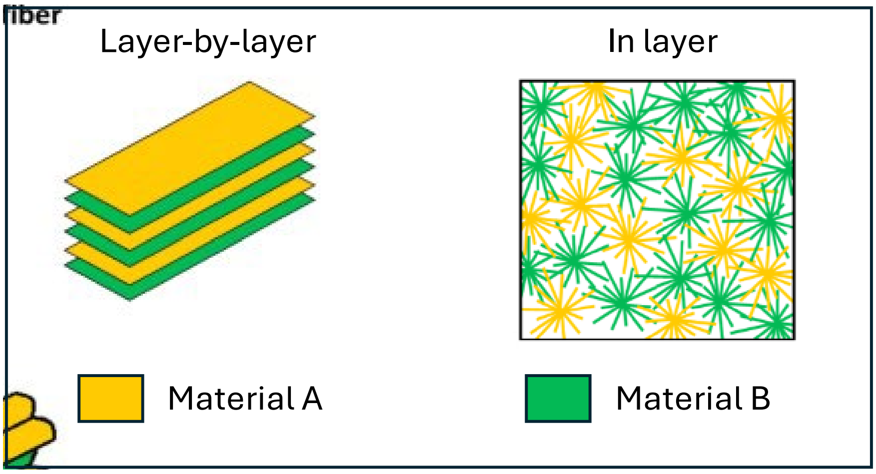

Figure 2: Representation of hybrid reinforcement, layer-by-layer and in layer.

For the quality control purposes, the composite plates are heated in an oven until they reach a constant temperature, and their heat diffusion during subsequent cooling is recorded using a thermal camera. This provides information on possible defects such as resin-rich areas and offers an initial estimation of the quality of the composites. The composite laminates are then characterized to assess their mechanical performance. By testing specimens cut from various locations on the plates, and with different specimen orientations (with respect to the plate geometry), the distribution (evenness) and orientation (randomness) of fibers in the mats can be assessed. The elastic properties of constituents, obtained from datasheets or experimental methods when possible, allows for the use of micromechanics and classic laminate theory (CLT) to predict the properties of laminates with various reinforcement combinations. This is used for design of composites with desired properties.

The study successfully demonstrates the feasibility of using discontinuous rCF in the manufacturing of rCFRP. The comparative analysis and composite characterization objective are to demonstrate that the hybrid composite laminates exhibit promising mechanical performance and have potential for further optimization. The modeling and validation provide a reliable prediction of the laminate properties, supporting the viability of this approach for sustainable composite manufacturing. Future work will focus on refining the manufacturing process and exploring additional reinforcement materials to achieve the performance and suitability of hybrid rCFRP laminates for particular applications.

REFERENCES

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