Experimental study to investigate mechanical behaviour of hemp fibre yarn

Sheedev ANTONY [1], Abel CHEROUAT [1], Guillaume MONTAY [2]

1. University of Technology of Troyes, GAMMA3-INRIA 12 rue Marie-Curie, BP 2060, 10010 Troyes, France
sheedev.antony@utt.fr abel.cherouat@utt.fr
2. University of Technology of Troyes, LASMIS 12 rue Marie-Curie, BP 2060, 10010 Troyes, France
guillaume.montay@utt.fr

Abstract

Synthetic fibre composite materials are replaced by natural fibre composites widely in past decades due to their low environmental impact and low cost. Hemp is one of the most available raw materials for the manufacturing of natural fibre composite material in Europe. In this study, an experimental analysis is carried out in order to investigate the mechanical behaviour study of hemp fibre yarn. Hemp fibre yarn specimens were set up and subjected to mechanical tensile test. The mechanical properties were retrieved from the experimental results and these studies show that hemp fibre can be utilised and replaced synthetic fibre in many applications.

Key words: *Natural fibres composites, Mechanical properties, Mechanical testing*

1. Introduction

In the past decades, synthetic fibre composite materials (aramid, carbon and glass fibre reinforced plastics) are widely used in many industries like automobile, aerospace, sports, construction, etc. For example, glass fibres are the most widely used to reinforce composite plastics due to their low cost (compared to aramid and carbon) and fairly good mechanical properties. But they have some significant drawbacks like high-energy consumption, limited recyclability, high cost, etc. Due to these reasons, natural fibres are emerging as the alternative of synthetic fibres in many applications [1,2].

Several kinds of natural fibres are used as reinforcement in composite materials such as flax, sisal, hemp, kenaf, ramie, cotton, jute etc. Many parameters can influence the mechanical behaviour of natural fibres. Mechanical properties of natural fibres do not only depend on the manufacturing or extraction process, but also depend on the growing conditions and the variety of plant where the fibres are extracted.

Hemp straw in Europe is only processed in a so-called total fibre line, producing random non-aligned technical fibre. This is in contrast to flax, processed in long fibre processing lines, which produces a high value aligned, long textile fibre and a technical short fibre in a similar form to hemp. So far, a good number of automotive components previously made with glass fibre composites are now being manufactured using environmentally friendly composites [3].

Automotive manufacturers have utilised these properties for years in interior mats, felts, and textiles. Moreover, natural fibre reinforced plastics have been in production vehicles for almost a decade. The automotive industry's interest in woven, natural fabric–reinforced thermoplastics are increasing due to their excellent mechanical-specific properties and competitive raw materials cost.

The aim of this study is to investigate the mechanical behaviour of hemp fibre composite materials and to deliver a clear idea about the opportunities of hemp fibre as composite material reinforcement in different industries. In order to review the mechanical characteristics of hemp fibre woven fabrics, the investigation start from the hemp fibre single yarns. For further studies, the hemp fibre yarn with different orientation angles will also be studied.

Later the mechanical behaviour of hemp fibre woven fabrics and the hemp polypropylene composite materials will be studied. Finally, the hemp fibre woven fabrics and polypropylene sheets will be added together using thermo-forming process and different shaped parts will be fabricated in order to investigate the behaviour of shaping and forming of hemp fibre fabrics.

2. Material and method

INSTRON 4411 mechanical testing machine with static load 100 N was used for the tensile test of the hemp fibre yarn. The hemp fibre yarn specimen was subjected to tensile test with a crosshead speed of 0.5mm/min and the force vs (see Fig. 1).

Hemp fibre yarns with density of 1.45 g/cm^3 and average diameter of 303.55 µm were used to set up the specimens (Fig.2). The tensile tests were performed on a single hemp yarn by the Single-Strand Method to determine the tensile properties according to ASTM D2256 [3].

Fig 1. INSTRON 4411 mechanical testing machine

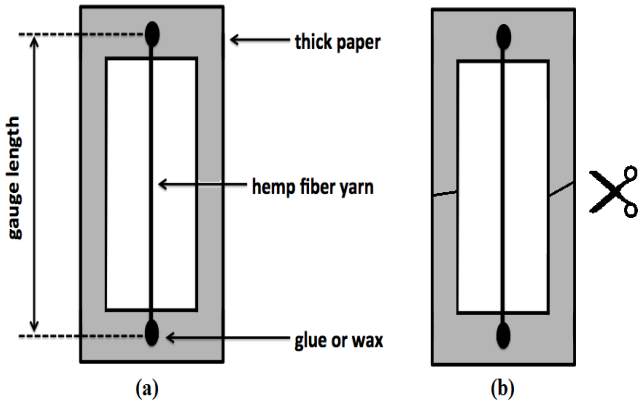

Fig 2. Hemp fibre yarn specimen set up

3. Results

The force vs. displacement curve obtained from the experiment was retrieved and the stress strain curve for each specimen was plotted using the calculated cross sectional area and length of the specimens. Longitudinal strain will not change because it does not depend of the cross section, whereas the tensile stress and the Young's modulus is calculated from the cross section. The average value of fibre section considering a circular cross section along the fibre length.

Figs. 3 and 4 show the hemp fibre yarn specimens before and after tensile test. The obtained result forces versus tensile displacement or stress versus strain is given in Figs. 5 and 6. The maximum stress is about σ_m = 200± 35MPa and the strain failure is about ε_f = 10%. The results also show that the fibre failure and crack occur at a point where the section is smaller than the average global section. So there is a stress concentration phenomena located at the failure point which favours the crack of fibre. Tab. 1 gives the mechanical properties of a single hemp fibre.

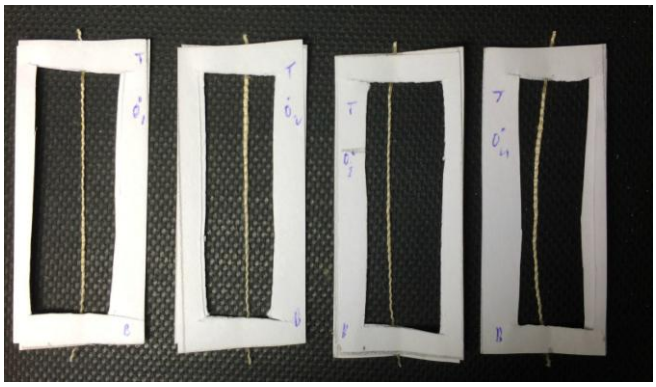

Fig 3. Hemp fibre yarn specimens before test

Fig 4. Hemp fibre yarn specimens after test

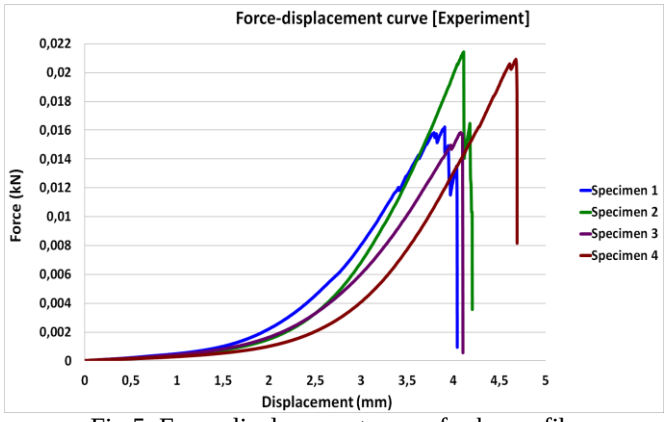

Fig 5. Force displacement curve for hemp fibre yarn specimens

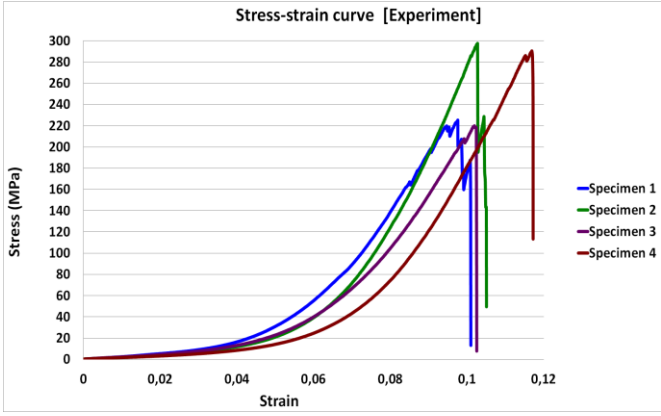

Fig 6. Stress strain curve for hemp fibre yarn specimens

Specimen	Elastic Modulus *E (GPa)*	Tensile Strength σ_m *(MPa)*	Failure Strain ε_f *(mm/mm)*
1	5.01	225.28	0.101
2	7.44	297.54	0.105
3	5.50	219.90	0.103
4	6.45	290.44	0.117
Mean	*6.1*	*258.29*	*0.107*
Standard Deviation	*1.86*	*35.84*	*1.56 10^{-4}*

Tab 1. Mechanical properties of hemp fibre yarn obtained from experiment

4. Conclusion

The result obtained from the experiment result shows that the hemp fibres can be replaced with synthetic composite materials in some application. A detailed numerical analysis is relevant to gain more accurate information about the mechanical properties of hemp fibre yarns.

References

[1] Jauhari, N., Mishra, R., & Thakur, H. (2015). *Natural Fibre Reinforced Composite Laminates–A Review.* Materials Today: Proceedings, 2(4), 2868-2877.

[2] Wambua, P., Ivens, J., & Verpoest, I. (2003). *Natural fibres: can they replace glass in fibre reinforced plastics?.* Composites Science and Technology, 63(9), 1259-1264.

[3] Carus, M., Karst, S., Kauffmann, A., Hobson, J., & Bertucelli, S. (2013). *The European Hemp Industry: Cultivation, processing and applications for fibres, shivs and seeds.* European Industrial Hemp Association (EIHA), Hürth (Germany).

[4] ASTM D2256 / D2256M-10 (2015), *Standard Test Method for Tensile Properties of Yarns by the Single-Strand Method.*