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Flexural behaviour of pultruded jute/glass and kenaf/glass hybrid composites monitored using acoustic emission

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ABSTRACT

The flexural (before and after cyclic loading up to 50% of ultimate load) and indentation behaviour of pultruded jute/glass and kenaf/glass hybrid polyester composites has been monitored using acoustic emission, and compared with that of kenaf fiber composites. In all hybrids, natural fiber content was 40 wt.%, while glass fiber one was 25 wt.%.

Acoustic emission (AE) has been used for real-time monitoring during flexural and indentation loading: the analysis concentrated on AE resuming during reloading (Felicity ratio) and AE activity at low loads during unloading (crack closure effect).

The results show that the introduction of this large amount of reinforcement appears quite effective on jute fiber reinforced laminates, although with a significant effect of fiber architecture, whilst it did not yield comparable results in kenaf fiber laminates. This was attributed to the insufficient fiber impregnation and to the need for improving the control of fiber orientation in the laminate.

1. Introduction

In recent years, plant fiber composites are widely investigated, as materials which are, as demonstrated by Life Cycle Analysis, closer to carbon dioxide neutrality in all phases of their interaction with environment (pre-production, production, service, end-of-life) than glass fiber composites [1,2]. Application of plant fiber composites as semi-structural materials is steadily growing, also in technologically advanced sectors, such as the automotive industry. Here, natural fiber composites are used already, e.g., in door- and boot-liners, seatbacks, etc. [3]. When trying to broaden the field of application of these materials, more stringent mechanical and impact resistance criteria are required. In this respect, the application of glass/plant fiber hybrid laminates can also be pursued with the idea of retaining some environmental benefit, in a material with mechanical properties possibly comparable with those of fiberglass [4,5].

In spite of the growing interest for these materials, fiber selection is still based on economical factors and local availability rather than on materials properties. The complexity and variety of factors involved (e.g., fiber extraction, chemical treatment, ease of producing non-woven mat with the fibers, transportation costs, constant availability of the fiber over the year) would possibly require carrying out comparative studies among composites where only the type of natural fiber used is different, being all other parameters the same.

Kenaf has been long considered as the natural alternative to jute for its higher cropping yields together with similar properties, for example for the production of sacks [6]: as a matter of fact, both fibers are among those used in recent years as a reinforcement in automotive composites [3]. However, comparative studies between composites obtained with these two fibers are still rare in literature and virtually non-existent as regards hybrid laminates with glass fibers. A previous study on mechanical and impact properties obtained when adding 40 wt.% of jute or kenaf fibers in a polypropylene matrix by compression molding, confirmed that the properties of the two composites appear to be very close each other [7].

Pultrusion is a manufacturing process that allows obtaining composite profiles with higher tensile strength, higher reinforcement volume and a more consistent quality than it is possible using hand lay-up technique. All these characteristics make pultrusion a widely adopted technique for the production of glass fiber composites. In recent years, it has also been used in a few occasions to manufacture plant fiber composites with promising results [8–11].

In particular, experiments conducted on hemp fiber composites and E-glass/hemp hybrids showed that adopting pultrusion as the manufacturing method allowed reducing the influence of inherent

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Table 1
Laminates configurations.

Configuration code	Stacking sequence	Fiber content (wt.%)
JC	S/C/J/J/C/S	40 jute + 25 glass
JG	G/J/J/G	40 jute + 25 glass
KCS	S/C/K/C/S	40 kenaf + 25 glass
KS	S/K/S	40 kenaf

J = jute fibers, G = glass fibers, C = chopped strand mat, K = kenaf fibers, S = surface veil.

variability in the properties of natural fiber on the characteristics of the final material [8]. Initial work on pultruded jute fiber composite boards showed their potential as a replacement for wooden frames due to their improved dimensional stability [9]. Another work concentrated on simulating in-service degradation of jute/polyester pultruded composites in different conditions, showing the effect of water uptake and of the presence of salts or acids in solution on the composite properties [10].

This work aims at comparing the flexural properties and characterizing the damage mode of different pultruded jute fiber and kenaf fiber/polyester laminates and their hybrid laminates with E-glass fibers to offer a broader insight into the possibilities of this manufacturing technique when used for the production of plant fiber composites and hybrids. Mechanical tests were monitored using acoustic emission, a non-destructive technique which proved promising also on natural fiber composites and their hybrids with glass fibers [11–13].

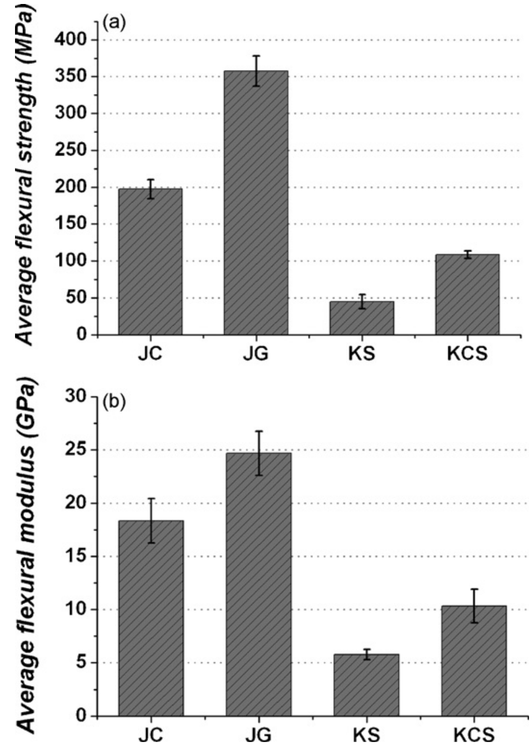

Fig. 1. (a) Flexural strength (avg. and standard deviation) of the different configurations. (b) Flexural modulus (avg. and standard deviation) of the different configurations.

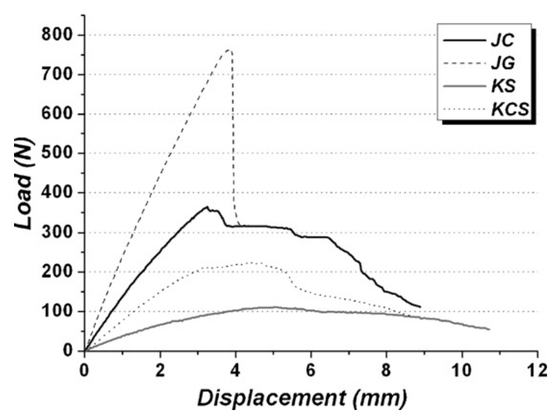

Fig. 2. Typical flexural load vs. displacement curves.

2. Experimental

2.1. Materials

Unsaturated polyester resin Crystic P9901 by Scott Bader (Wollaston, Norths. UK) was used for the production of all laminates. Glass fiber pultrusion roving (G) and chopped strand mat (C) were supplied by Hengshui Yixing Fiberglass Co. Limited (Hengshui, China).

Jute fibers (J) were supplied by Alam Fiber Impex Ltd. and kenaf fibers (K) by the Malaysian Tobacco Board. Both fibers were supplied in twisted roving form: the thread diameter being approximately 1 mm for jute and 2 mm for kenaf.

In some configurations, a protection surface veil (S) was used, which is made of polyester fibers through non-woven process and finished with resin, to obtain layers of 0.2 mm thickness.

2.2. Composite manufacturing

For composite manufacturing, a thermoset pultrusion machine was used at MMFG Composites Sdn. Bhd, Subang Jaya, Selangor, Malaysia.

The continuous fiber rovings were first impregnated with unsaturated polyester resin in a resin impregnation tank. There was a pulling device to pull the jute fibers impregnated with resin through a steel die to obtain the desired shape. Curing process was carried out in a precision machined forming and curing die, so to impart the final shape. The heating time to reach the exothermic peak of the resin (around 50 °C), was 5 min. The tough, low viscosity resin needed no post-curing. The pulling device, which drew the stock through the die, determined also the production speed: this was approximately 100 mm/min. The configurations produced are summarized in Table 1.

2.3. Mechanical testing

Three-point bending tests, according to ASTM D-790 standard, were performed using a 5584 universal testing machine

Table 2
Comparison of the average flexural strength and modulus values in relation to the composite modifications.

Modification	Comparison	Avg. effect on strength (%)	Avg. effect on modulus
Adding E-glass fibers to kenaf fiber composites	KCS vs. KS	+142	+79
Changing E-glass fiber architecture in jute/E-glass fiber hybrids	JG vs. JC	+80	+35
Replacing kenaf with jute fiber in E-glass hybrids	JC vs. KCS	+83	+77