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Analyses of woven hemp fabric characteristics for composite reinforcement

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The potential of plant fibres in composite material components can be enhanced by applying hemp fibres for fabrication of composites with aligned fibres. Fibre alignment can be enhanced by converting it into yarn. Applying fabric instead of yarn not only could enhance the fibre alignment but also could enhance the reinforcement handling during the composite fabrication. This paper presents a detailed characterisation of the woven hemp fabric. Two different batches of fabric with a similar quality were analysed to seek the difference between them. Both fabrics possessed similar physical properties as they were intentionally designed to have balanced properties in warp and weft direction. There was also a slight difference in their thermal behaviour but the differences between both fabrics allow their chemical compositions to be measured. These measured chemical compositions reflect their fibre density and mechanical properties. In terms of mechanical properties, their behaviours and properties were slightly different but via the inferential statistics, both fabrics were proven to have similar tensile strength and tensile modulus. The total cover factors for both fabrics were similar with 66% of fabric sheet that were covered by yarn and presumably could give good penetration of resin in composite fabrication. The findings of this study conclude that both woven hemp fabrics can be used and is suitable for composite reinforcement.

1. Introduction

Due to the growth of environmental awareness, the search for new materials at affordable costs is highlighted. The focus has rapidly changed to develop, create and innovate eco-friendly materials, which eventually introduced several new terms such as renewable, sustainable and bio-based materials in material scientists' vocabulary [1–3]. The utilisation of natural fibres from plants as reinforcements in composite materials is kind of remedy to fulfil the new direction above. These kind of materials have existed for quite some times and the current application of plant fibres in composites is mainly for non-load bearing components in many fields especially in the automotive and building industry [4–6]. This circumstance is primarily driven by lower price of natural fibres, a demand of environmental awareness and to a lesser extent, by the reinforcement effect of the natural fibres. Furthermore, its availability, complete data and sustainability seem promising to be used as raw materials [7].

Apparently, it is now the phase to entice industrial consideration to the use of natural fibres in composite components as a natural alternative to the traditionally synthetic and man-made fibres. One of the main problems is controlling over the fibre orientation to ensure that the mechanical properties of the fibres are most efficiently utilised and that the maximum fibre content is high. In the textile industry, there are wide range of techniques to align plant fibre including converting the natural fibres into yarn [4,8]. However, the established method of fabrication limits the usage of yarns in composite application. Utilisation of textile fabric in composite as reinforcement is well recognised for high-performance fibres considering their advantages on high strength, good fibre orientation and fibre distribution and more importantly easy to handle during composite fabrication. In the case of natural woven fabric, there is less work reported on their utilisation especially when considering the type of natural fabric to be used as reinforcement in composite material [3].

Not all of the natural fibres can be converted into fabric because some of them can be considered new, and their extraction method cannot produce fine and clean fibres. In order to convert the fibres into woven fabric, fibres need to go through a long process from

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spinning to weaving and this necessitates good, smooth and clean fibres. Another method of producing fabric is by converting the fibre into a non-woven fabric. However, its fibres are scattered, bulky sheets, less flexible and possess lower mechanical properties as compared to woven fabric [3].

Several fibres such as jute and hemp were established in woven fabric and they possess good properties as reinforcement in composite materials. However, their properties can be varied due to different weathering conditions during plant growth and this factor cannot be controlled. Even in one quality of woven fabric production, the raw materials (fibres) cannot be guaranteed to come from similar source. This can create the variation in the fabric properties that later could affect the composite properties. Therefore, a study to characterise a different fabric batch in similar quality is needed to assess how far the differences in their properties.

There are few studies on the properties of natural woven fabric for composite utilisation and many of them only relied on the information given by the supplier. Therefore, in this study, the properties of hemp fabric in two different batches with a similar quality have been characterised with respect to; (i) fabric physical properties, (ii) thermal and chemical composition analysis, (iii) fibre density, (iv) fabric appearance structure, and (v) mechanical properties. Statistical analysis, both in descriptive and inferential using analysis of variance (ANOVA) in certain topic and section depending on the priority were also conducted in order to seek the significant differences between the average results and the suitability of both fabrics in composite fabrication.

2. Material and method

Two (2) batches of commercial woven hemp fabric were investigated and supplied by Hemp Wholesale Australia. These batches were bought with a time interval of about three (3) months. According to the specifications provided by the supplier, the two fabrics have equal nominal properties. The weight of fabrics is 271 g/m^2 and due to this it can be categorized as 'heavy fabric' in textile term.

According to the specifications given by the supplier, the fabrics were produced by 100% yarn hemp in both warp and weft with the similar yarn linear density (yarn size) of 100 tex (g/1000 m) for each direction respectively. The yarns were converted from cleaned hemp fibre into yarn through spinning processes and the twist given was 430 twists per meter. These yarns were then converted into fabric via weaving processes and the fabrics were woven by employing loose plain weave (taffeta) structure. Fig. 1 shows schematic diagram of plain weave fabric structure. As referred to plan view, the vertical yarn is known as warp while the other direction is weft. The plain weave structure can be categorized by observing the warp yarn which alternately and repeatedly goes over and under the weft yarn.

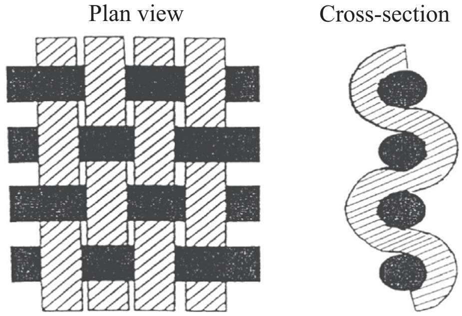

Fig. 1. The plain weave fabric structure in plan and cross-section views [9].

Other than that, the supplier did not give much data. Therefore, further investigation was needed to characterise these two batches hemp fabrics. For comparing purposes, the two batches of hemp fabrics will be denoted as Fabric A and Fabric B (the batch bought after three months). Fig. 2 shows the heavy weight 100% plain woven hemp fabric used in this work.

2.1. Fabric characterisation

Woven hemp fabrics are characterised for their weight, thickness, fabric density or fabric count while their yarn was characterised for its yarn size (linear density) and crimp (for warp and weft). All tests have been done employing several textile materials standard methods. These standard methods are commonly used in textile industry for characterisation as well as product quality determination purposes. Table 1 shows the standard methods used to characterise both woven hemp fabrics.

Yarn spacing is normally related to the fabric compactness and this could affect the fabric properties significantly. Yarn density in fabric is generally known as 'fabric density' or 'fabric count'. By employing ASTM: D3775 standard method, fabric was placed on a smooth surface and the number of warp and filling yarns were counted using a pick counter in a 2 cm length and the result is pronounced as; total warp yarn × total weft yarn, per 2 cm.

Fabric weight was analysed in accordance to ASTM: D3776. Five (5) specimens were needed for this analysis and three (3) readings were taken from each specimen to get an average of fabric weight. The weight was measured in gram per square meter (g/m^2).

Fabric thickness was measured according to ASTM: D1777. Twenty (20) randomly selected locations were used to obtain the average value. This is to make sure the precision value which covers and represents the thickness of a sample since the sample is hemp fabric which has a lot of thick and thin places. The thickness values were taken in millimeter (mm).

ASTM: D3883 was used to measure yarn crimp. Parallel lines were marked in the warp direction 20 cm apart (this is the distance of the yarn in the fabric, Y1 = 20 cm). A cut of 30 cm was made along the filling yarn, which crossed the parallel lines. Several yarns from one edge were unraveled. The next ten (10) yarns were carefully unravelled for measurement. Each yarn was pulled taut without exerting extreme force and the extended length between the two marks was measured as Y2. The yarn crimp, C, is calculated as shown below in Eq. (1).

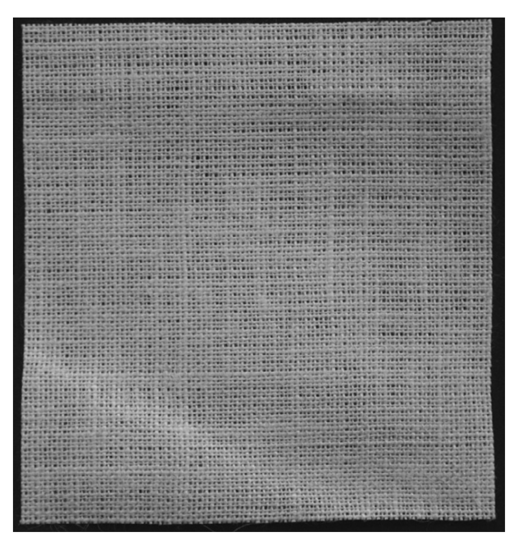

Fig. 2. Woven hemp fabric used for this work.