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Potentials of Alpaca Fibre as a Renewable Material Substitute for Agro-mechanical Applications: An Exploratory Study

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Abstract.

In recent years, efforts are being made to develop alternative and renewable source of materials for engineering and industrial applications. Alpaca wool is a renewable bio-based material that is mainly produced in South and North America. In this study we observed the micro-structure and tested the stress behaviour of alpaca wool under continuous and cyclic loading conditions to determine the feasibility of its utilization as an alternative material for a number of industrial applications.

We observed significant variations in the diameters of the fibres under the scanning electron microscope (ESEM). The fibre under continuous loadings also exhibits elastic behaviour as the loading increases until either the sample breaks or the end of the testing capability is reached. Under cyclic loadings, the samples never broke and we observed rebounds in the stress-strain behaviour of the wool. The preliminary results showed that it has lots of potentials for static applications while further tests are being carried out to determine the feasibility of its utilization for other areas of agro-mechanical applications.

Keywords. Mechanical properties, Physical properties, Alpaca wool, Tensile properties, Stress-strain behaviour, Natural fibres, Bio-based materials

1.0 Introduction

A renewable material has been defined as a substance derived from a living tree, plant, animal or ecosystem which has the ability to regenerate itself while a biodegradable material is a substance that will decompose in a natural environment (CISRO, 2009). In the last few decades, efforts have been intensified to find/develop biodegradable and renewable materials as artificial materials' replacements for industrial applications. Natural fibres are considered as potential substitutes for synthetic reinforcing fibres especially those that are being used in thermoplastic and thermosetting composites' applications. The growing interests in the use of natural fibres have been attributed to increasing sustainability consciousness, desire for biodegradability of materials at their end-of-life and increasing stringency in environmental regulations in many parts of the world. In addition, if managed properly, these renewable materials will not be depleted and they may have reduced net emissions of CO_2 across their life cycle compared to materials from fossil fuels. Furthermore, it has been noted that the stiffness and strength characteristics of natural fibres are comparable to the commonly used synthetic reinforcing fibres like fibreglass (Johnson, 2007; Maistry, 2009; Romhany, Karger-Korcsis and Czigany, 2003).

Figure 1: Huacaya alpacas

Source: http://www.chimneyhillinn.com/images/alpaca-buddies.jpg

Figure 2: Suri alpaca

Source: http://www.bonnydoonalpacas.org/suri.html

Alpaca fibre is a natural fibre harvested from Alpaca, an animal that is traditionally raised as fibre producing livestock. Alpaca fibres come in various colors but majority are whitish. They are sheered much like sheep and the fibre is combed, carded, and after a basic cleaning process it is ready to spin. Shorn every year, an alpaca will produce a fleece that weighs between two and four kilogram; the staple length—the length of the sheared locks without stretching or disturbing the crimp—is between ten and twenty centimetres (Illawarra, 2004; Quiggle, 2000; Wikipedia, 2008).

Alpacas are environmentally friendly. They have padded feet without hooves, doing little damage to their terrain. While still small in numbers in United States and Canada, alpacas are a growing agricultural business and one that is uncommonly earth friendly (Illawarra, 2004; Quiggle, 2000; Wambua, Ivens and Verpoest, 2003; Wikipedia, 2008). The world alpaca fibre production is around

5,000 tonnes. Peru is the largest producer of alpaca with 90% share of the world market (Local Harvest, 2009).

Characteristics of Alpaca Fibre

Alpaca fibre is a soft, durable, luxurious and silky natural fibre. In physical structure, the fibre is somewhat akin to hair, being very glossy. Although it is similar to sheep's wool but it is warmer and not prickly as sheep's wool. Alpaca wool was so highly prized by the Incas for its luxurious softness and durability that they reserved it for the noble class (Quiggle, 2000).

The most valued attribute of alpaca fibre is its handle, or how it feels to the touch—creamy, silky, soft. While many factors affect the handle, the diameter of the fibre (fineness) is most important and is measured in microns. (A micron measures one-thousandth of a meter; to get a sense of what that looks like, consider that most human hair measures about 64 microns). The fibre used to make most alpaca yarn available to knitters ranges from the ultra-luxurious royal baby, which is never more than 18 microns, to super-fine, which averages 25.5 microns. Alpaca is also valued because it is extremely strong, very warm, drapes beautifully, takes dye extremely well, and is not prone to pilling (Illawarra, 2004; Quiggle, 2000; Wikipedia, 2009).

Alpaca fibre is valued by the textile industry and high fashion houses for its desirable luxurious softness, warmth without weight, range of natural colour and strength. Alpaca wool is a renewable biomass resource and it is easily obtainable (Local Harvest, 2009).

Besides the reported use of Alpaca wool in the textile industry, there is no record of its utilization for other purpose. But it may have great potential applications as a renewable biodegradable material. However, there are no reported studies of its mechanical properties that may warranty its utilization as a material for industrial applications like in electronics, furniture or automotives to date. The current upsurge in the wave of studies on natural materials and the growing interest in bio-based materials necessitate a study of this material to explore its potential use. In this study, alpaca wool fibre mechanical properties including its stress behaviour and micro-structures were investigated.

2. Experimental Studies

2.1. Sample and its Preparation

The fibres used in this study were obtained from the Natural Fibre Centre of Olds College's School of Innovation. They were neither treated with any chemical nor coloured. They were free of dirt and any physical impurity. Samples of alpaca fibres were first mounted on metallic plates before they were spartan-coated for some minutes to make them feasible and easier to measure in the ESEM. The spartan-coated alpaca fibre samples were then secured on the ESEM mounting frame before being observed and measured in vacuum.

Figure 3 A sample of Alpaca wool

2.2.2 Stress behaviour testing

The test samples were prepared by mounting a strand of alpaca fibre on a paper carrier with a 5mm by 15mm cut out hole. The fibre was glued to the paper with masking tape. The sample is then clamped on an in-house designed testing jig shown in Figure 4. The highly sensitive testing jig is designed to measure load and elongation. The machine can run from 0.008 μm/s to 13.0 μm/s (Le, 1986). The test results were measured and recorded through a computer coupled with a strain gauge conditioner and amplifier.

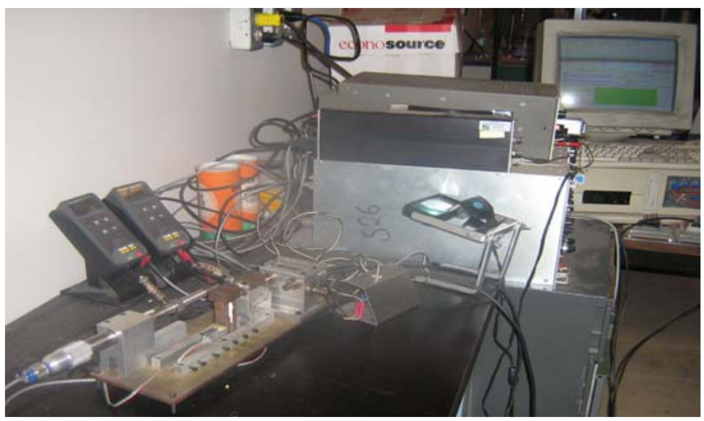

Figure 4 Fibres Stress Testing Jig

3. Results and discussion

3.1 Physical microstructure

A number of observations of mass of alpaca fibres and individual strands of alpaca wool were made in the ESEM. Figure 5 shows the micrograph of a mass of alpaca fibres under the ESEM while Figure 6 shows the microstructure of a single alpaca fibre strand. We measured the diameter of a number of strands of alpaca fibre at different points along their lengths both before and after the stress testing, and we found that they varied from 13.7 to 18.6 micrometer. We discovered that the variation is not regular but it is sporadic. We also observed that each strand has bumps and that they have striations as can be seen in Figures 5 and 6.

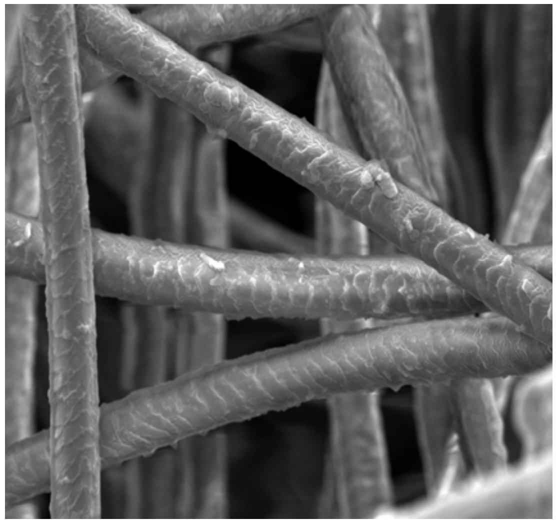

Figure 5 An ESEM micrograph of a mass of alpaca wool

(Magnification: 1000x, Working distance: 17.1mm)

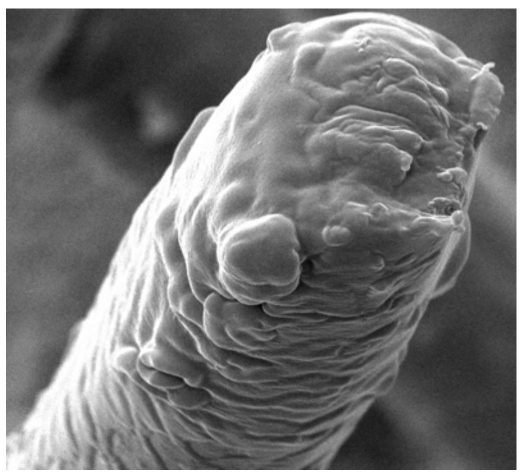

Figure 6 An ESEM Image of one end of an alpaca fibre strand

(Magnification: 3000x, Working distance: 10.3mm)

3.2 Stress behaviour

A number of experimental studies of the stress-strain behaviour of alpaca fibre were carried out. In our study of the fibre behaviour under continuous loading, the fibres were stretched at uniform speed until the stretchable limit permitted by the equipment was reached. This experiment was repeated at different motor speed. Our intent was to determine the breaking point (that is, the ultimate tensile strength), but no breaking was observed. We also tried shorter fibre length but the results were the same. The fibre exhibited plastic behaviour in each case. Figure 7 shows our observations of the stress behaviour of alpaca fibre under continuous loading. We also subjected the fibre to cyclic loading by stopping the stretching electric motor every minute and at different motor speed. We observed rebounds of the fibre strength as shown in Figure 8.

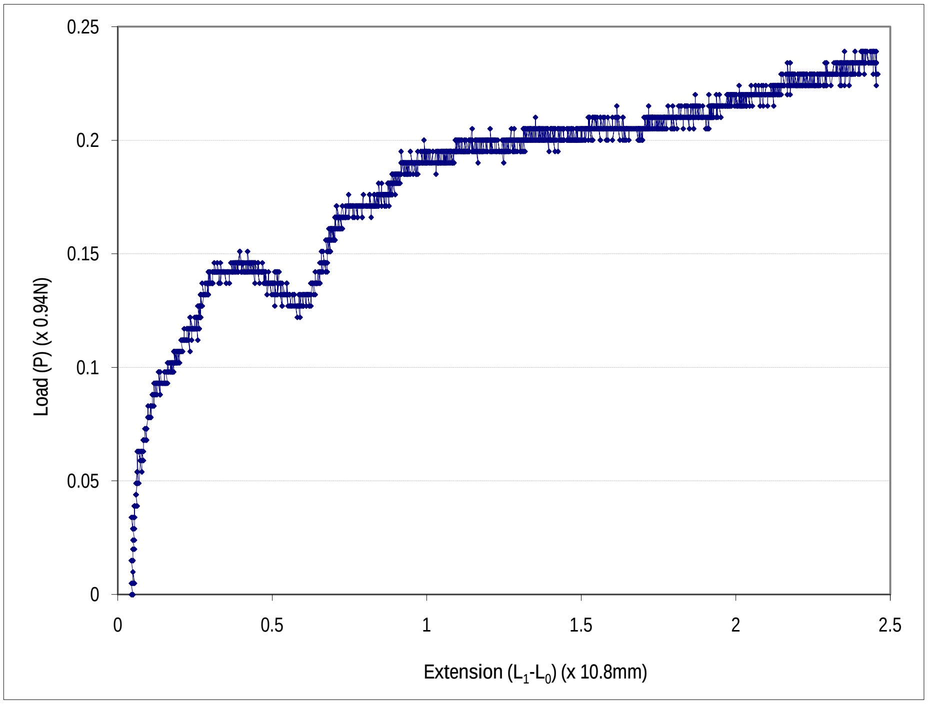

Figure 7 A Typical "Load vs Extension" graph of Alpaca fibre under continuous loading

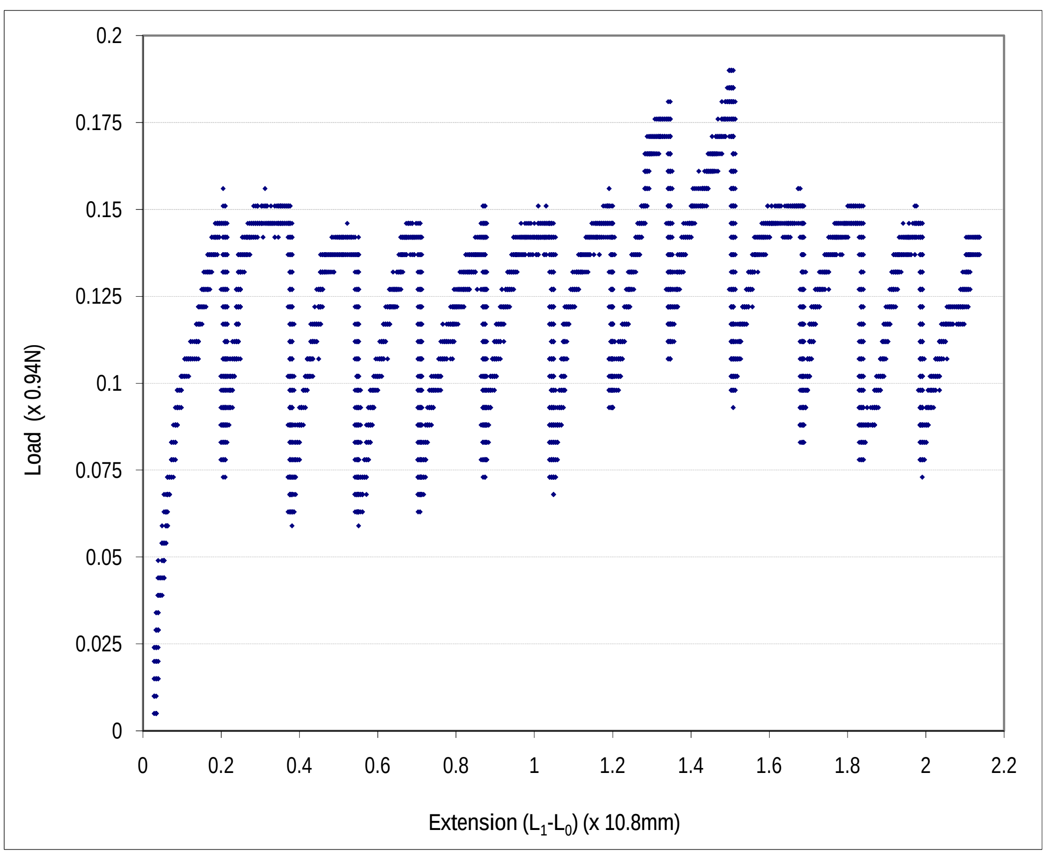

Figure 8 A typical "Load vs Extension" graph of Alpaca fibre under cyclic loading

4. Conclusion

The knowledge of the physical microstructure and stress-strain behaviour of fibres are essential to determining the potential use of the fibre for various industrial applications. Our study of Alpaca fibre revealed variations in the diameters of each fibre strand along its length. We also observed rebounds in the fibre strength under cyclic loading. The plastic and rebound behaviour under relatively high load is a pointer that it is a potential substitute for mam-made fibres in static applications. However, further studies are being carried out to identify specific areas of possible application.

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