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Evaluating the Softness of Animal Fibers

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ABSTRACT

Softness is an important property of textile fibers, animal fibers in particular. At present, there is no reliable method for objective evaluation of fiber softness. This paper examines a simple technique of objectively evaluating fiber softness, by pulling a bundle of parallel fibers through a series of pins. Softer fibers of lower bending rigidity and smoother surfaces should result in a lower pulling force. Alpaca and wool fibers have been used in this study to validate this technique and the results suggest that the pulling force measurement technique can reflect the difference in fiber softness.

Introduction

A soft textile material should have properties of a smooth surface or texture, be pleasant to the touch and very flexible [2]. Most studies on the softness or handle of textiles focus on the surface and compressibility of fabrics. Studies on the softness of wool fibers have used either subjective assessment (i.e. tactile appraisal) [5,10,12,15] or resistance to compression (RtC) measurement as the objective evaluation tool [15].

Resistance to compression (RtC) method is an objective way to reflect fiber compressibility. Wool of greater RtC is generally harsher [13,15]. Previous study has also indicated that the compressibility of knitted fabrics increases and the fabric bending rigidity decreases as loose fiber RtC decreases [9]. Fabric stiffness also decreases with the reduced loose fiber RtC and staple crimp. However, the current RtC test method is highly related to fiber crimp and curvature. It is not suitable for low-curvature fibers such as alpaca fiber, and is not a good softness indicator for fibers of different types with varying diameters [8]. For instance, a very fine fiber with a high curvature usually has much higher RtC value than a much coarser fiber with a low curvature, even though the fine fiber is much softer than the coarser one.

When assessing fabric handle subjectively, the assessor usually strokes the fabric surface with one or several fingers [1] and squash the fabric gently in hand. Therefore the perception of such handle includes complex parameters of compression, tactile sensation and textural effect. The fabric thickness and weight also contribute strongly to subjective evaluations of softness and smoothness of a fabric [3]. Wool classers have used a similar technique to subjectively evaluate the softness of wool fibers also. They usually rub bundles of wool fibers between two fingers or palms, and squeeze the wool to various degrees [15]. They then assess the fiber surface roughness and compressional properties in order to grade fiber softness. However, such assessment is high subjective in nature.

Therefore, it is necessary to develop a new technique for evaluating fiber softness. This paper examines a simple technique of objectively evaluating fiber softness, by pulling a bundle of parallel fibers through a series of pins. We have discussed the theoretical basis for this approach, and constructed an experimental rig to evaluate the effectiveness of this approach in discriminating against alpaca and wool fibers. For a given fiber diameter, we know that alpaca fibers are much softer than wool fibers. The reason for this apparent difference in softness between alpaca and wool is beyond the scope of this study. Suffice to say that the smoother surface of alpaca fibers is one of the main factors that contribute to their softness. Early studies [6,7] have reported that the directional frictional effect of alpaca and wool fibers (of same diameter at 22.0μm) tested over a cattle horn rod is 0.22 and 0.40 respectively. Our measurements on fiber scale heights and scale frequency also indicate that alpaca fiber has more scale ends and a lower scale height than wool [8].

Theoretical Considerations

For simplicity of explanation, we consider the simple case of a fiber bending over 3 pins of equal diameter D, as indicated in Figure 1.

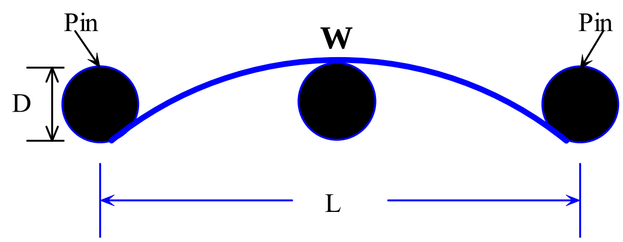

Figure 1. A fiber bending over 3 pins

Assuming the bending is within the elastic limit of the fiber, the concentrated load *W* at the centre should be [4]:

$$W = \frac{48EIy_{\max}}{L^3} \qquad (1)$$

Where:

$\boldsymbol{E}$ = Young's modulus of the fiber

$\boldsymbol{I}$ = Moment of area of the fiber cross-section (I = $\frac{\pi d^4}{64}$, where d is the diameter of a fiber with circular cross section) [11]

$\boldsymbol{y_{max}}$= D (Pin diameter)

$\boldsymbol{L}$ = Distance between pins

If we attempt to pull the fiber out of the pins, we will have to overcome the frictional resistance between the fiber and the pins. As the concentrated load *W* increases, a higher force will be required to pull the fiber. According to equation 1, *W* is a function of the fiber's bending rigidity (*EI*). Similarly, if the fiber surface property changes, the force required to pull the fiber out of the pins will also change, and a smoother surface will offer less frictional resistance and hence a lower pulling force will be required. Smut and Slinger reported that against-scale friction also contributed to the tactile properties (handle) of loose wool and mohair [14].

Based on the above discussions, the force required to pull a fiber over a series of pins reflects the combined effect of fiber stiffness, fiber diameter and fiber smoothness. Since fiber stiffness, diameter and smoothness affect fiber softness, we should then be able to use the pulling force to evaluate the softness of fibers. We have constructed a simple experimental rig to test this hypothesis.

Experimental

THE TEST RIG AND TESTING SYSTEM

Figure 2 shows a photo of the experimental set-up. Details of the pin configurations are given in Table I.

Figure 2. Experimental set-up

Table I. Pin configurations

Parameters	Rig setting
Distance between pins (mm)	0.48
Pin diameter (mm)	1.57
Number of pins	10

We use a LLOYD material testing instrument (LR30K type) to test the pulling force (Figure 2). We set the test speed to 300mm/min. As shown in Figure 2, a load cell is attached to the crosshead to sense the pulling force. The force signal is acquired by a laptop computer system. Then, we compute the Specific pulling force (cN/ktex) versus displacement of the fiber bundle (mm) based on the linear density of each test specimen.

BUNDLE SAMPLE PREPARATION

We used alpaca and wool bundle samples to validate the concept of softness measurement.

Sample Scouring: We soaked the greasy alpaca and wool samples into a solution containing 1% (owf) Solpon 4488 at 60°C, gently swayed samples using long handle tweezers for 10 minutes, rinsed twice and dried samples at 60°C in an oven for 4 hours. We then washed the scoured samples again using 100% DCM solution to remove extra grease, and finally dried fibers in the air. We took care to avoid any dissociation of staple structure.

Sample Alignment: We selected a thin bundle of fibers, and used a hand comb (lab type) to comb out the short fibers within the bundle. The bundle tips were then stuck together using a masking tape (approx. $5*5mm^2$) as shown in Figure 3. A hole was poked in the middle of the tape using a needle. Through the hole, the prepared sample was attached to the sensor using a hooked needle (Figures 2 and 4). The specimen was then mounted into the test rig with a pretension of 10mg as illustrated in Figure 4. All specimens were finally trimmed from the tensioned fiber ends to the same length of 60mm before testing.

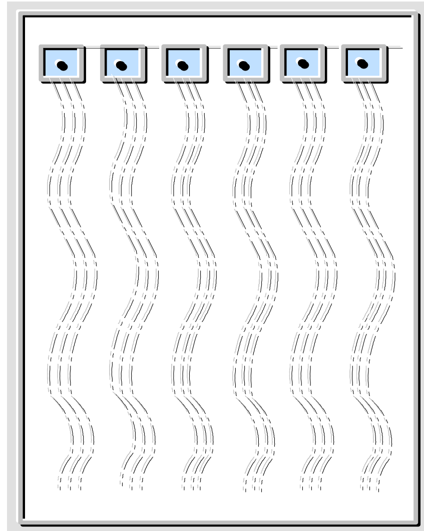

Figure 3. Schematic diagram of prepared specimens of fiber bundles

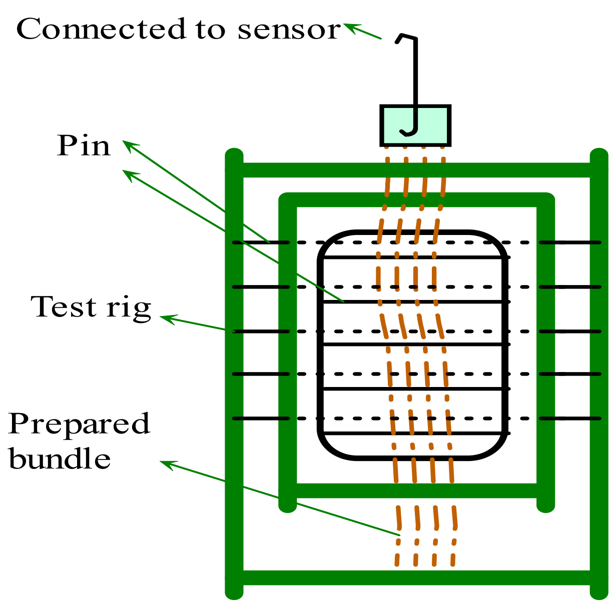

Figure 4. Mounting of the specimens

FIBER DIAMETER AND CURVATURE MEASUREMENT

After the pulling force was acquired by the computer system, we recorded the bundle weight (in mg) for calculating its linear density. Then we allowed the specimen to relax for

24 hours, cut each fiber bundle into 2mm snippets and measured fiber diameter and curvature using an OFDA100 instrument.

Results and Discussions

Figure 5 shows the specific pulling force curves of wool and alpaca fibers. We can see that the specific pulling force profiles are quite different for different fiber types as well as for the same type of fibers of different diameters. The finer fiber has a lower specific pulling force and alpaca fiber has a lower specific pulling force than wool. Considering that finer fibers are softer for a given fiber type and that alpaca fibers are softer than wool for a given diameter, these results do suggest that the pulling force measurement can reflect the softness of fibers. Figure 5 also indicates that different specimens have different displacements, which reflects the variations in fiber curvature. The general trend is that fibers of a lower curvature have a larger displacement.

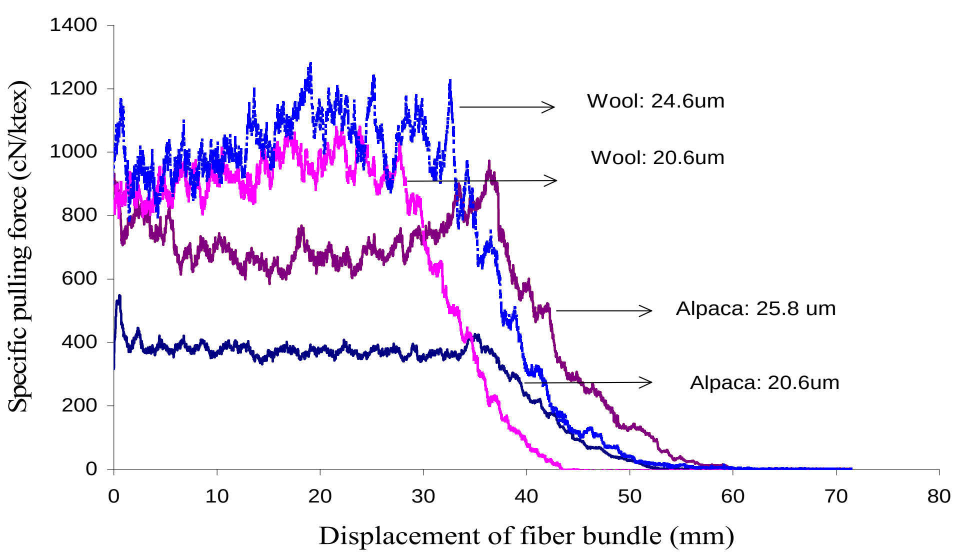

Figure 5. Typical profiles of specific pulling force for alpaca and wool at similar diameter

For each test we take the average specific pulling force in the region of 10-20mm of the displacement for further analysis, since within this region, the specific pulling force is relatively stable. Figures 6 and 7 show such statistical pulling force versus mean fiber diameter and curvature respectively. We can see from Figure 6 that alpaca fiber has a lower pulling force compared to the wool fiber of the same diameter and both alpaca and wool fiber pulling forces increase with the increase of fiber diameter. To achieve the same level of specific pulling force of an alpaca fiber, the wool fiber should be around 12μm finer than the alpaca fiber. It is interesting to note that the linear regression line for the alpaca fibers appears parallel to that for the wool fibers, suggesting that this test method may be able to reveal the intrinsic difference in softness between different animal fibers.

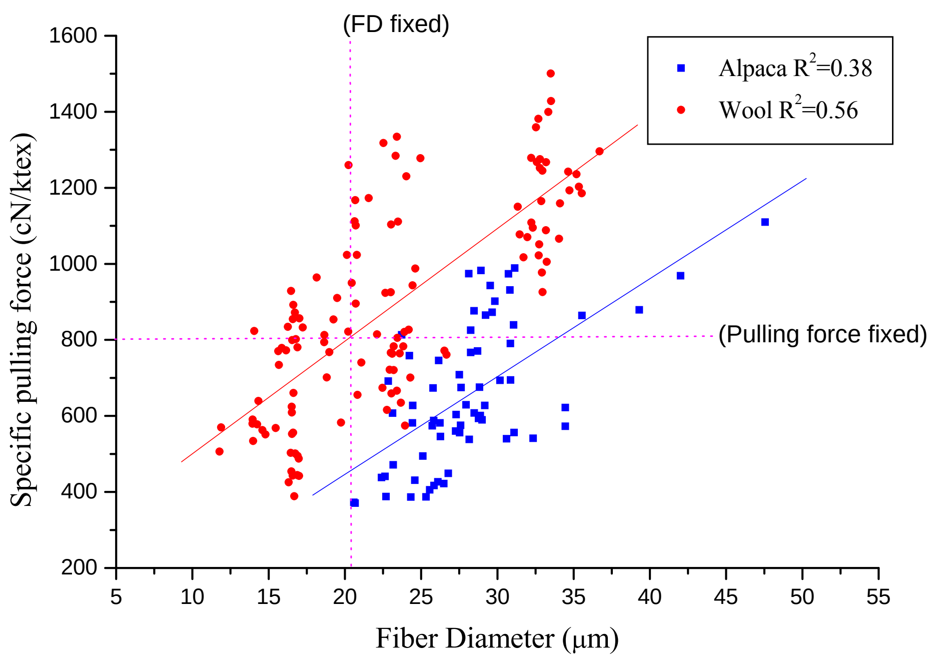

Figure 6. Relationship between fiber diameter (FD) and specific pulling force

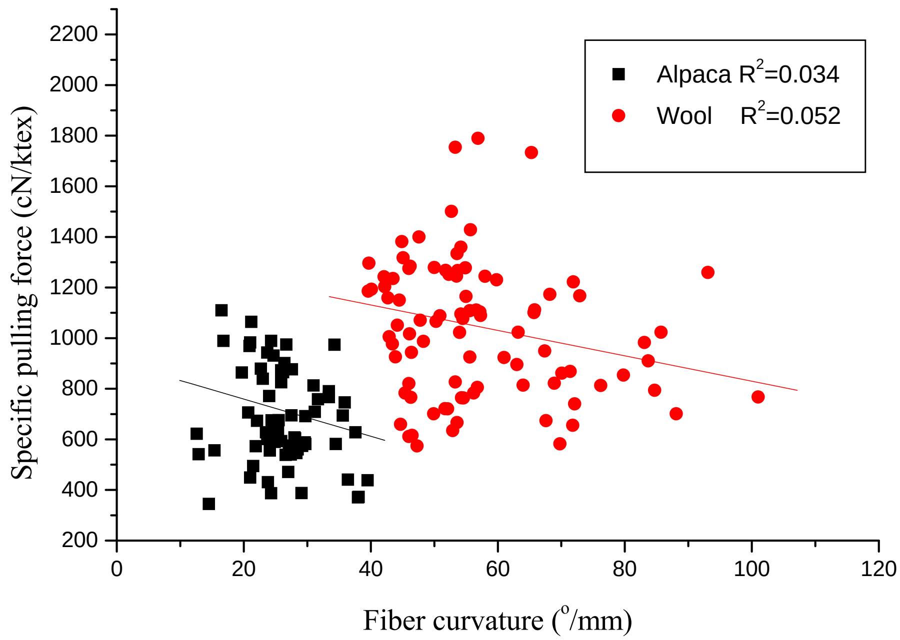

Figure 7. Relationship between fiber curvature and fiber bundle specific pulling force

Results in Figure 7 show that the curvature of alpaca fiber is considerably lower than that of wool, and fiber curvature bears little co-relation with the average specific pulling force, except for the slight tendency that higher crimp (curvature) fiber seems to give a lower average specific pulling force within each fiber group (Alpaca or Wool). In other words, fiber curvature is not a good indicator of fiber softness, as suggested in our earlier work [8].

Conclusion

Many factors affect fiber softness, such as fiber surface properties and mechanical properties. These factors should be considered together for softness assessment. This paper introduced a new testing method for evaluating fiber softness. A testing rig for the softness measurement of fiber bundles was developed in this study.

The experimental results showed that the new softness testing method can achieve good discrimination between fibers of varying levels of softness, such as alpaca and wool, based on the measured specific pulling forces. The specific pulling force reflects the combined effect of fiber surface properties, fiber diameter and fiber rigidity. Fibers with finer microns, lower bending rigidity and smoother surface have a lower specific pulling force and are softer. The effect of fiber crimp or curvature on the specific pulling force or fiber softness is small.

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