The Retraction Investigation of Yak Hair Fiber during Roller Stretching

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Abstract: This paper mainly investigates the retraction phenomenon of yak hair fiber when stretched. To study the retraction of yak hair fiber with different stretching ratio and the effect of setting reagent, the samples were stretched by a self-made device, including force and position sensor. The retraction curves of yak hair fiber stretched with different drawing ratio up to 90% and different process phases, including stretching, first setting and second setting, were analyzed respectively. The results showed that there is rapid retraction in the early stage when the gripping force was lost, and the retraction velocity of stretched yak hair increased gradually with the stretching ratio increasing. Meanwhile, it was also found that the setting process could result in the reduction of the retraction quantity of stretched fiber evidently. In addition, the stress decay curve of yak hair fiber stretched 30, 60 and 90%, according to different process phase, were investigated likewise. The results for the stress decay of yak hair fiber bundles showed that the stress decay curve exhibited an exponential diversification and the velocity of stress decay had same results with the length retraction of yak hair fiber stretched.

Keywords: roller stretching, yak hair fiber, retraction, stress decay, slenderization, retraction

1. Introduction

Yak hair, a rare resource of speciality animal fiber, is mainly produced in China. The yield of yak hair is about 410,000 tons per year, and there into only 10,000 tons is fine yak hair. The yak fleece contains lots of coarse hair, which is thick and stiff [1, 2]. Consequently, decreasing the diameter of fiber will be a significant way to improve the economic value of yak hair.

The stretching slenderization is one of effective modification methods on animal fibers, which processes fibers with chemical treatment and physical drawing [3, 4]. Now, the method to slenderize fiber is mostly multi-roller stretching [3-5]. Since coarse yak hair fiber bundle were stretched under untwisted condition, the gripping force couldn't be kept all through the process during multi-zone roller stretching [5]. Hence, the fiber retraction would be inevitable during stretching, and this phenomenon would result in an uncertain fiber length finally. By far the research to stretch coarse yak hair fiber mainly focuses on the structure and property of fibers after stretching and process parameters [6-8]; however there is no report about the retraction during stretching. In order to improve the parameter setting of stretching process and make the length of stretched fiber controllable, it is necessary to study the retraction phenomenon of coarse yak hair fiber during the roller stretching.

The aim of this study is to explore the retraction phenomenon of coarse yak hair fibers after stretching by means of analysis with length retraction curves and stress decay curves of fiber bundles, which was stretched with different drawing ratio and different process phases, including stretching, first setting and second setting. The maximum stretching ratio of coarse yak hair fibers is 90% in this experiment.

2. Experimental Section

2.1 Materials and Reagents

The untwisted fiber bundles of coarse yak hair used in this study was from Tibet, China and the average fiber diameter is 110 μm. Five hundred fibers in each sample are carded to be orderly using a comb, and cut

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into a section with a length of 60 mm from central position. Pretreating agent and two setting agents were used during stretching slenderization, which were invented by our lab.

2.2 Treatment

The fiber bundles of coarse yak hair were grasped at both ends of that and kept straight on a special clamper, made by us. The stretching slenderization of coarse yak hair was done by the following processes: firstly, in order to break some of the disulfide crosslink in coarse yak fibers, the fiber bundles were pretreated in a sodium bisulfite solution with a concentration of 5% for 10 min. Then we set the clamper with fiber sample into a stretching apparatus, the samples were stretched 30%, 60%, 80% or 90% longer than their original length respectively in an 85°C steaming chamber at the strain rate of 0.20 min-1 with the laboratory stretching apparatus invented by us, which was equipped with force and position sensor. After that, the samples stretched were set with two different setting agents for 3 and 2 min, respectively. In this investigation, the length retraction measurement and stress relaxation test of the coarse yak hair fibers were carried out in different experiments respectively.

2.3 Retraction Measurement

The fiber bundles of coarse yak hair, stretched with different ratio according to above treating method, were relaxed immediately by removing the clamper at both ends of fibers after different process phases, like stretching, first setting and second setting, respectively. After that, ten fibers were taken randomly from each samples stretched and measured their length along with time for up to 240 min after fiber was relaxed. The final data obtained is the average value of ten fibers.

2.4 Stress Relaxation Test

The stress decay test of fiber bundles were performed by means of the stretching apparatus with force and position sensor. While stretching, the data of stress and strain were recorded synchronously by computer. After different process phases, including stretching, first setting and second setting, the length of fibers was kept constant and the stress decay data was monitored for up to 20 min. To avoid the breakage of the fibers, the maximum stretching ratio was 80% for the stress relaxation test. During the stress-relaxation test, the coarse yak hair fiber bundles were under steaming for the entire duration. Finally, we derived the stress decay curves using Origin version 7.5 (Microcal Software, Inc., Northampton, MA) according to these data.

2.5 Retraction Rate

The retraction rate of the fibers after relaxing was calculated according to the following equation:

$$R_t = \left(1 - L_t / L\right) \times 100\% \quad (1)$$

where Rt (%) is retraction rate of the fibers after eliminating clamper at t min. L_t (mm) is the length of the fiber samples after t min. L (mm) is the length of coarse yak hair fibers before shrinkage, which was stretched at a certain ratio.

2.6 Characteristic Values of Stress Decay Curve

To compare the stress decay of coarse yak hair fiber bundles extended in stretching ratio, several characteristic values were derived from the curves of that the same, i.e. initial stress σ0 (cN), equilibrium stress σe (cN), equilibrium time t_e (s), and decay rate D (%•s^{-1}). The initial stress σ_e indicates the stress value before relaxing. The equilibrium stress σe and equilibrium time t_e are expressed as the stress and time respectively when the stress decay curve reaches an equilibrium state. In addition, the decay rate D could be expressed with stress decay percentage of the samples per second in initial 10 seconds, thus it may be calculated by the Eq. 2:

$$D = \frac{\sigma_0 - \sigma'}{\sigma_0 \times 10} \times 100\% \quad (2)$$

where σ' is the stress value when decayed at 10 seconds.

All characteristic values have been illustrated in Figure 1.