Swelling and Shrinking Behavior of Lyocell Fibers

Nobuo Donkai[(1)], **Hiroari Sasaki**[(1)], **and Katsuji Kasahara**[(2)]

(1) Niigata Women's College, 471, Ebigase, Niigata, 950-8680, Japan
(2) Industrial Research Institute of Niigata Prefecture, 2-7-3, Gakkoccho, Mitsuke-shi, Niigata, 954-0052, Japan

Abstract

Swelling behaviors of Lyocell and Polynosic fibers are investigated by measuring fiber sizes in ferric sodium tartrate complex (FeTNa) and NaOH solution. They showed an anisotropic swelling behavior, i.e., a large expansion in a radius and small shrinking in a longitudinal direction. Birefringent structure was maintained in Lyocell fibers in the swollen state but not in Polynosic fibers for both solvent systems.

Introduction

Lyocell fiber is well known to fibrillate easily with mechanical actions in the wet state. By taking advantage of the fibrillation, a finishing process has been invented and developed to create the specific soft fabric surface, namely "peach skin". On the other hand, procedure giving fibrillation resistance has been strongly requested and chemical cross-liking is often performed for this purpose. The proper swelling treatments of Lyocell fibers with cellulose solvent can be also expected to prevent the fibrillation, because the part of cellulose molecules swollen with the solvent will coagulate and bound fibrous parts (or micro-fibrils) when it is replaced in a non-solvent system. Based on above consideration, we investigated the effects of swelling treatment on Lyocell fibers with the ferric sodium tartrate complex (FeTNa) formed in sodium hydroxide solution and found the optimized condition to give apparent improved fibrillation resistance [1].
In this report, swelling behaviors of Lyocell fibers are investigated in detail for not only the FeTNa but also NaOH solution system by referring the behavior of Polynosic fibers in the same systems.

Experimental

The samples used here are commercial Lyocell and Polynosic fibers after washing with distilled water, ethyl ether, and methanol. The FeTNa complex solution, $[Fe(III)(C_4H_3O_6)_3]Na_6$, was prepared by mixing $FeCl_3$, tartrate dihydrate, and NaOH (0.12/0.432/2.22 in mole ratio) in cold water. Observation of swelling behavior of fiber samples were performed by using a video recorder under an optical microscope focusing on short fibers in a narrow glass tube filled with the solvent. Polarized optical microscope was also utilized to observe the birefringence of the swollen fibers. Neutralization of the treated samples was carried out with 1% H_2SO_4 solution.

Results

Swelling process for the size of various cellulosic fibers in FeTNa solution are shown in Fig. 1. Lyocell and Polynosic fibers seem to be equilibrated in a period of 15 min. Expansion in radius and shrink in longitudinal fiber direction are obviously observed for all spun cellulosic fibers, while viscose rayon fiber exhibited the smallest change in the size nevertheless the largest content of amorphous part. Under the assumption that all cellulosic fibers used here have a columnar structure, the calculated volumetric changes are plotted in Fig. 2 and summarized in Table 1 in comparison with the volume change evaluated chromatographically [3] in water.

Table 1 Volume ratio of swollen (Vswell) and dry (Vdry) fibers

	Vswell / Vdry	
	water	FeTNa
Lyocell	1.68	10.9
Polynosic	1.68	13.8
Viscose	2.01	2.71

Swelling process is generally considered that amorphous part in the fiber may be solvated and/or dissolved first, and following crystal part takes place to swell by solvent. The small swelling change of Viscose fibers is surprising. On the other hand, the large volume change of Lyocell and Polynosic fibers suggests necessity to consider some specific swelling mechanism.

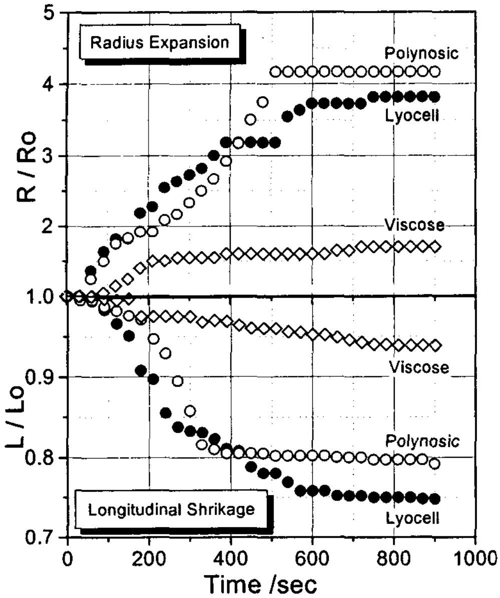

Figure 1 Swelling change in sizes of various cellulosic fibers in FeTNa solutions

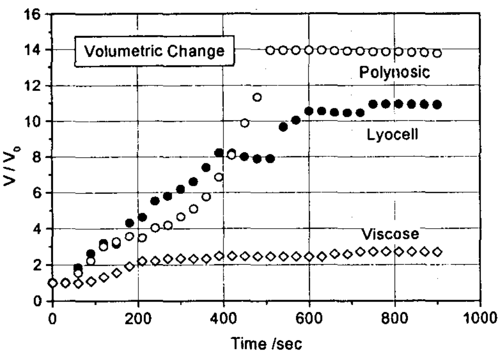

Figure 2 Volumetric Change of various cellulosic fibers in FeTNa solutions

Alkali solution, especially, NaOH solution has been used to improve the cellulosic fiber structure. The swelling speed was, however, too fast to follow with our simple equipment, so that only the radius changes were traced for Lyocell and Polynosic fibers in 2.5M and 5.0M NaOH solution. The results indicate, as shown in Fig. 3, that the radius expansion of Lyocell fiber in 2.5M NaOH solution is almost same as that in FeTNa solution. On the other hand, Polynosic fiber showed more large expansion in 2.5M NaOH solution than that in FeTNa solution. Relating to these observations, birefringent structures were obviously observed for the swollen Lyocell but not for Polynosic fibers in both solvent systems.

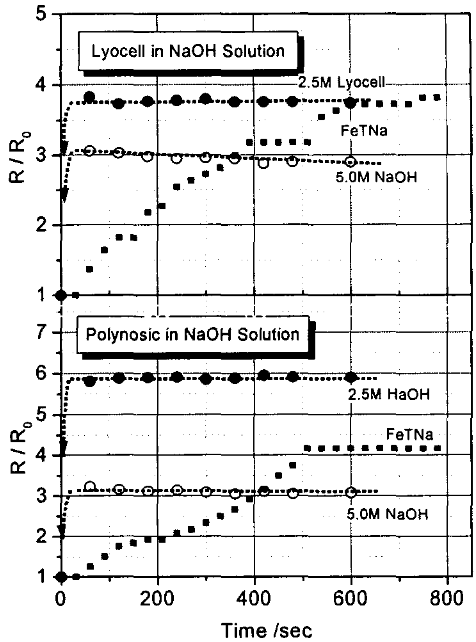

Figure 3 Radius expansion of Lyocell and Polynosic fibers in NaOH solutions.

The neutralized and dried fiber samples obtained after these swelling treatments exhibited apparent twisted structure in the case of Lyocell fibers treated with FeTNa and NaOH solution. The source of twisted structure will be discussed by referring the swelling behavior. Related discussion will be described with a simple schematic model.

Conclusions

The specific swelling behavior of Lyocell fibers, expansion of 3.8 times in radius and 25% shrink in longitudinal direction, was observed, by maintaining optical birefringence properties under a polarized optical microscope. These behaviors have a large potentiality to improve fiber structure.

References

1. L. Valtasaari, *Paperi Puu*, 39, 243-250 (1957).
2. K. Kasahara, H. Sasaki, N. Donkai, T. Yoshihara, and T. Takagishi, *Cellulose*, **8**, 23-28, (2001).
3. K. Kasahara et. al., *Tex. Res. J.*, in press.