Hollow Porous Polypropylene Fibers with Polyvinyl Alcohol by Melt Spinning

Chin-An Lin[a], *Hsiao-Chi Tsai[a], Ta-Chung An[a,b], Chi-Che Tung[a]

[a] *Graduate Institute of Textile Engineering, Feng Chia University, No. 100 Wenhwa Rd., Seatwen, Taichung 407, Taiwan (R.O.C.)*
[b] *Taiwan Textile Research Institute, 6, Chen-Tian Road, Tu-Chen City, Taipei Hsien 236, Taiwan (R.O.C.)*

Abstract

Polypropylene/Polyvinyl alcohol blended fiber was melting spun using a water soluble polyvinyl alcohol as a micro-porous agent. By the hot water reduction method, micro-voids were generated inside and on the surface of fiber. Making use of these voids could improve the moisture adsorption of polypropylene fiber. We found that the polyvinyl alcohol could be moved mostly at a reduction time of 60 minutes. From the analysis of moisture adsorption, the moisture content was beyond 5%. In this study, the moisture adsorption of conventional polypropylene fiber was effectively improved; water was applied as a solvent to move polyvinyl alcohol material, which is a potential reduction method in environment protection.

Keywords: Hollow porous fiber, Polypropylene, Polyvinyl alcohol,

Introduction

Synthesize fiber was poor in absorption of perspiration. It seemed that the clothes made of synthesize fiber could not absorb sweat.

Many studies on how to improve synthesize fiber in its absorption of moisture and perspiration had been done by scholars.[1] The methods of improve- ment included: materials' reformation of properties in polymerization, changes of synthesize fiber in structure, and knitting methods in composing fabric with fiber.

Changes of fiber in structure: Micro-porous fiber could be used to make the micro-porous capillaries on the surface of fiber produce adsorption property to water molecules. In becoming micro- porous, synthesize fiber could increase in some functions, such as heat insulation, absorption of moisture and perspiration. For the synthesize fiber hard to be dyed, the micro pores in the fiber could also provide dye molecules to produce physical adsorption with fiber. Thus the dyeability of synthesize fiber was improved, and the application and value-added of synthesize fiber would be greatly increased, too.

In addition, micro-porous synthesize fiber and hollow-type fiber were combined to spin hollow micro-porous fiber that was often used as fabric with good absorption of moisture and perspiration. Besides being used to make the clothes with absorption of moisture and perspiration, this hollow micro-porous fiber could also be applied to filter material.

For non-woven filter material, filtering could be realized by fiber gap; moreover, the micro pores in the fiber could even filter smaller particles, which greatly heighten the efficiency of this filter material.

Polypropylene was a kind of plasticizing material with good resistance to chemicals and rubbing. It was low in price and rich in materials. On the other hand, it had a density of about $0.90\sim0.92 g/cm^3$, the lowest among chemical fibers.[2]

Polypropylene in textiles had the following advantages: resistance to oily stain, resistance to bio- logical attack, easy washing, good elastic recovery etc.

After it was spun into fiber type, polypropylene put up the properties of low moisture-absorption and hardness in dyeing because it was non-polar compound whose polymer chain lacked the dye sites that could be combined with dye molecules. So polypropylene was seldom applied to the fabric for clothes. If poly- propylene fiber could be enhanced in absorption of moisture and dyeing, it would be greatly increased in quantity to produce the fabric for clothes. The polypropylene fiber with low density could make the fabric for clothes lighter.

At the same time, polypropylene had a good resistance to chemicals, so as filter material, it was hard to produce chemical reaction with solution in the process of filtering.

In this study, we mainly discussed how to obtain the hollow micro-porous polypropylene fiber with the spinning method of blending two kinds of polymer.

In the light of the slightly miscible relation, polypropylene and polyvinyl alcohol were blended and the content of polyvinyl alcohol was made less than that of polypropylene. With the high shear force blend effect of spinning machine, polyvinyl alcohol was uniformly scattered in polypropylene. Then polyvinyl alcohol was removed with hot water by dissolving action. Thus micro pores would come into being in the fiber.

Experimental Method

Experimental materials: polypropylene, poly- vinyl alcohol.

At first, plasticizers were utilized to improve the thermol properties of polyvinyl alcohol and strengthen its fluidity at high temperature, which could reduce the factors that polyvinyl alcohol was first decomposed because of heat to produce melt blend spinning between polyvinyl alcohol and polypropylene.

The plasticizers of polyvinyl alcohol were mainly polyatomic alcohol, like ethylene glycol, glycerin etc.[3] In this study, we chose glycerin as the plasticizer of polyvinyl alcohol due to its higher boiling point to strengthen the stability of materials in processing.[4]

The polyvinyl alcohol containing plasticizers and the material of polypropylene were blended and then made into fiber through melt spinning. Next, hot water was used to dissolve and remove the components of polyvinyl alcohol in the fiber. Finally micro-porous polypropylene fiber could be obtained.

The spinneret was designed as double-C-shaped spinning orifice and the same blend materials were used to implement melt spinning. Thus hollow micro-porous polypropylene fiber could be produced.

Results and Discussions

1. Dissolving Action of Polyvinyl Alcohol in Fiber

In the experiment, the mixing proportion of polypropylene and polyvinyl alcohol was 4: 1, which meant the content of polyvinyl alcohol in the fiber was 20 wt%.

The dissolution of polymer was mainly divided into two steps: Step 1, dissolvent infiltrated into the polymer and made it swell; Step 2, polymer structure was disintegrated and polymer chain was separated from other chains because being eroded by dissolvent.[5]

In this study, polypropylene belonged to the polymer that could not be dissolved into water. In the process of experiment, the hot water at the temperature of 70℃ was mainly used to dissolve polyvinyl alcohol. But in the course of blend spinning, polyvinyl alcohol might be coated by polypropylene, which would slow down the dissolution of polyvinyl alcohol.

In order to make certain whether the polyvinyl alcohol in the fiber had been dissolved and how long this process would take in hot water, we explored the dissolving rate of polyvinyl alcohol in the fiber.

In this study, we used the spun fiber as a sample to do the dissolving action, in which we regularly took out the fiber to dry it out and weigh it every 10, 20, 40, 120 min. The results we got were shown in Figure 1.

Along with the extension of time in hot water treatment, the percentage of weight loss of the fiber would gradually increase. About 60 min. later, this percentage tended to be stable.

The percentage of weight loss showed that polyvinyl alcohol was lost from the fiber. As the time of hot water treatment extended, the loss of polyvinyl alcohol would also increase.

When the hot water treatment lasted for 60 min., only a small amount of polyvinyl alcohol was left in the fiber. Therefore, even if the time of hot water treatment was extended, only a little polyvinyl alcohol was dissolved out from the fiber. This was why the percentage of weight loss tended to be stable.

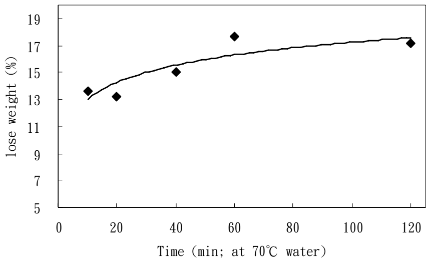

Figure 1: The Percentage of Weight Loss of Fiber

2. The Analysis of SEM

In order to observe the distribution situation of the micro pores in the fiber, we utilized SEM to analyze the section and surface of the fiber. The results we got were shown in Figures 2~5. Figures 2 and 3 displayed the section and surface of the fiber before hot water treatment.

Figures 4 and 5 were the situation after hot water treatment. After the fiber was treated with hot water, there were hollow micro pores appearing on its section and surface, as Figures 4 and 5 showed. In Figure 4, the hollow micro pores were uniformly distributed on the section of the fiber.

While, in Figure 5, the hollow pores on the surface of the fiber emerged like a strip. Polyvinyl alcohol was blended into polypropylene; meanwhile, in the course of spinning, affected by the blend of screw and the formation of spinning orifice, polymer was drawn along the fiber axis. All of these caused the strip-like micro pores on the surface of the fiber.

Furthermore, from Figure 3 showing the picture of the surface before the hot water treatment, we could find that the surface of fiber was not completely smooth. Generally speaking, for the fiber made by melt spinning, its surface was affected by the rubbing of spinning orifices in formation, so the surface would appear smooth.

While, in Figure 3, the surface of fiber made by blend spinning appeared like a strip. Polyvinyl alcohol and polypropylene were slightly miscible polymers, only a very small part of the chain would dissolve with each other and most of polyvinyl alcohol and polypropylene were kept apart; meanwhile, the un- dissolved polyvinyl alcohol and polypropylene each agglomerated alone. This was the reason why the surface of fiber had irregular strips.

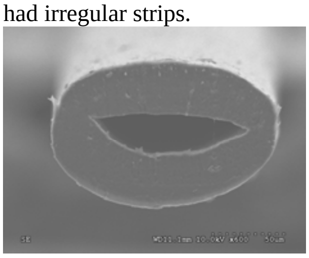
Figure 2: The Section of Fiber (Before Hot Water Treatment)

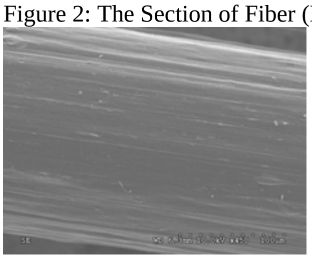
Figure 3: The Surface of Fiber (Before Hot Water Treatment)

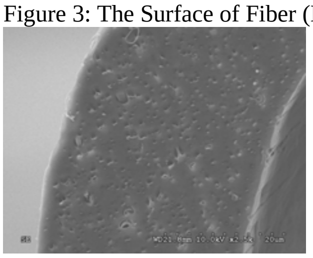
Figure 4: The Section of Fiber (After Hot Water Treatment)

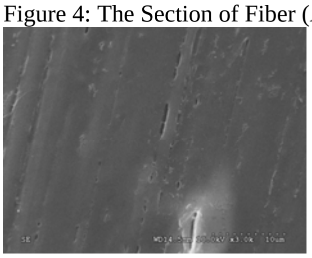
Figure 5: The Surface of Fiber (After Hot Water Treatment)

3. The Analysis of Moisture-absorption Properties of Hollow Micro-porous Fiber

In the analysis of moisture-absorption properties of hollow micro-porous polypropylene fiber made by blend spinning, we first dried out the spun fiber and weighed it 6 hours later. Then we put the fiber at the room temperature for 24 hours to let it regain moisture. Subsequently, we re-weighed it. In this way, we could figure out the water content of the spun fiber.

Likewise, we first washed the polyvinyl alcohol out from fiber with hot water (i.e. hot water treatment at 70℃), then dried it out and weighed it, and finally kept it regaining moisture for 24 hours. Thus, we could also obtain the water content of fiber after hot water treatment.

In the process of study, we took out the samples of fiber before and after hot water treatment respectively three times. The results were shown in Table 1.

From Table 1, it could be known that the water contents of fiber before and after hot water treatment were all above 5%. Compared with the water content of pure polypropylene fiber, these values indicated that the moisture-absorption properties of fiber had been greatly improved.

Therefore, provided that polyvinyl alcohol was used as micro-porous formation agent and combined with polypropylene to make hollow micro-porous polypropylene fiber through blend spinning, the moisture-absorption properties of fiber would indeed be greatly enhanced.

On the other hand, by comparing the water contents of fiber before and after hot water treatment (as Figure 6 showed), we found that the water contents of fiber before hot water treatment were all higher than those after hot water treatment. This was because the fiber contained polyvinyl alcohol before hot water treatment, and polyvinyl alcohol belonged to the polymer with high perspiration-absorption. That was to say, when polypropylene fiber contained polyvinyl alcohol, the perspiration-absorption of polyvinyl alcohol would increase the whole water content of fiber. So the water content of fiber was higher before hot water treatment.

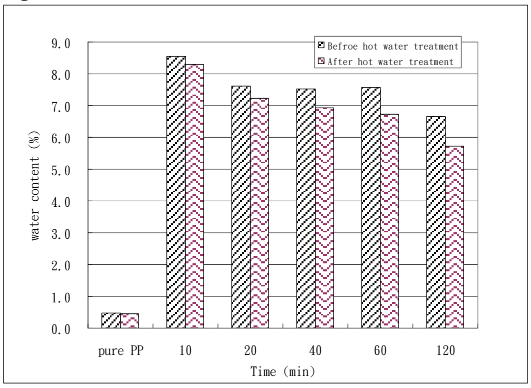

Figure 6: The Comparison of Water Contents of Fiber before and After Hot Water Treatment at 70℃

Conclusions

In the light of its high water soluble, polyvinyl alcohol was used as micro-porous formation agent to make porous polypropylene fiber.

The dissolvent used to dissolve polyvinyl alcohol was water, which could effectively reduce environmental pollution and avoid the harm to the health of working staff.

Through analyzing the time of hot water treatment, we got the mode of blending polyvinyl alcohol into polypropylene. When the time of hot water treatment was about 60 minutes, most of polyvinyl alcohol could be effectively dissolved.

When the polymers in blend system having low miscibility were dispersed by high shear force, polyvinyl alcohol with a smaller content would be separated from polypropylene. Then polyvinyl alcohol agglomerated alone and distributed in polypropylene. After polyvinyl alcohol was dissolved through hot water treatment, disheveled micro pores were left in polypropylene fiber.

In improving the moisture-absorption properties of polypropylene fiber, we, with this blend method, obtained the hollow micro-porous polypropylene fiber that was really greatly increased in moisture- absorption.

Even if the polyvinyl alcohol with high moisture-absorption was dissolved in hot water, the moisture-absorption of polypropylene fiber could also be realized through the capillary action of many micro pores, and the water content of fiber was kept above 5%.

Reference

1. Menachem Lewin and Jack Preston, “High Technology Fibers”, Part. A. Marcel Dekker, Inc. New Tork and Basel.
2. K. J. Saunders, “Organic Polymer Chemistry”, Chapman and Hall (1976)
3. B. E. Aubery, U. S. Pat., 2, 844, 570(1958)
4. Yi-Hung Tu, “Principles of polymerization”, San Min Book Co., Ltd. (1978)
5. Steven B. Warner, “Fiber Science”, Prentice Hall. (1995)

Table 1: The Water Contents of Hollow Micro-porous Fiber

	Water Contents of Fiber Before Hot Water Treatment (%)				Water Contents of Fiber After Hot Water Treatment (%)			
Time of Hot Water Treatment (min)	Sample 1	Sample 2	Sample 3	Average	Sample 1	Sample 2	Sample 3	Average
10	8.14	9.66	7.86	8.55	7.31	7.67	9.91	8.30
20	6.08	10.18	6.59	7.62	5.64	10.85	5.20	7.23
40	8.71	7.24	6.64	7.53	6.29	6.20	8.30	6.93
60	8.81	8.00	5.87	7.56	8.59	3.33	8.28	6.73
120	6.07	5.84	8.03	6.65	7.11	4.83	5.22	5.72
Pure PP	0.54	0.40	0.46	0.47	0.33	0.54	0.49	0.45