Preparation and Properties of Split Microfiber Synthetic Leather

Baobao Zhao[1], Yao Qian[1], Xiaoming Qian[1], Jintu Fan[2], Fan Liu[1], Yongchao Duo[1]

[1]Tianjin Polytechnic University, School of Textile, Tianjin, Tianjin CHINA

[2]Cornell University, College of Human Ecology, Ithaca, New York UNITED STATES

Correspondence to:
Xiaoming Qian email: qianxiaoming@tjpu.edu.cn

ABSTRACT

A split microfiber synthetic leather using split microfiber nonwoven as the base and waterborne polyurethane（WPU）coating as the polymer coating was prepared by a dry transfer-coating method. First, the nylon/polyester (N/P) split microfiber nonwoven was manufactured, and the structure and properties were investigated. FESEM analysis indicated fiber diameter size was between 2.2~5.5 μm, and performance attaributes met the demands of textiles-nonwovens for synthetic leather. Then the effect of coating-forming temperature, foaming agent concentration and foaming ratio on the structure and performance of WPU coatings were systematically studied. Finally, the structure and properties of the split microfiber synthetic leather were analyzed. The results showed that the split microfiber synthetic leather arranged in a three-layer configuration, and its air permeability, tensile strength, elongation at break, tear strength, peeling strength and creasy recovery angle were better than knitted synthetic leather and real leather.

Keywords: split microfiber, waterborne polyurethane, microfiber synthetic leather, water vapor permeability, tensile strength

INTRODUCTION

Microfiber synthetic leather consists of a three-dimensional reticulated nonwoven fabric skeleton and a porous polyurethane matrix. It is becoming increasingly popular owing to the highly realistic leather-like appearance and touch, excellent wear comfort, mechanical strength, chemical resistance, thermal resistance, quality homogeneity, and shape stability that is comparable or even superior to genuine leather [1,2]. However, there is inevitably organic solvent pollution and residue in the manufacture of microfiber synthetic leather, such as N,N-dimethylformamide (DMF), which limits development and industry application [3,4]. Therefore, it is necessary to find ways to reduce pollution in this field.

Bicomponent spunbond technology is one example of a nonwoven manufacturing method capable of direct conversion of a polymer into a microfiber nonwoven material [5]. Depending on the component distribution within the cross-sectional area, biocomponent fibers can be classified into side-by-side, core/sheath, islands-in-the-sea, hollow segmented pie and solid segmented pie [6]. Hollow segmented pie fiber is usually split by mechanical treatment (needle punching, hydroentangling, ultrasonic, stretching), and linear densities range from 0.075-0.175 D, similar to collagen fibers in genuine leather [7,8]. Hollow segmented pie fibers have several advantages over islands-in-the-sea fiber, including being thinner, non-polluting, higher mechanical properties and are easier to process. Despite the extensive work on the application of hollow segmented pie microfibers, little effort has been mde to prodcue microfiber synthetic leather from them [9,10].

Waterborne polyurethane (WPU) is a newly developed polyurethane system in which water is used as the dispersion medium as a replacement for conventional organic solvents, reducing the release of volatile organic compounds (VOCs), which contribute to environmental protection [11-13]. Moreover, WPU possesses some advantages, such as good film reforming properties, ease of processing, abrasion resistance, and non-toxicity [14,15], and has been widely used as a coating for leather[16]. However, because WPU coating can't achieve a highly microporous structure by wet processing, the water vapor permeability and tensile strength of WPU coated synthetic leather are always worse than those of leather coated with solvent based PU [17-20]. Mechanical foaming technology of WPU is a new method of regulating coating structure, and is attracting more and more attention. WPU foam

technology is not widely used in the synthetic leather industry because factors such mechanical foaming theory are not well understood.

The aim of the present work is the fabrication of a high performance microfiber synthetic leather for apparel which is environmentally friendly. To realize this goal a nylon/polyester (N/P) split microfiber nonwoven was manufactured, and its structure and properties were investigated. Then, the effects of coating-forming temperature, foaming agent concentration and foaming ratio on the structure and performance of WPU coatings were investigated systematically. Finally, the split microfiber synthetic leather using a split microfiber nonwoven as the base and a WPU coating was prepared by dry transfer-coating. The structure and properties of the split microfiber synthetic leather were analyzed.

EXPERIMENTAL

Materials

Polyester (PET, FC510) with a density of 1.38 g/cm^3 was purchased from Yizheng Chemical Fiber Co., Ltd.,Jiangsu, China. Nylon 6 (PA6, 1013B) with a density of 1.15 g/cm^3 was received from UBE Co., Ltd., Ube Japan. Waterborne polyurethane (WPU, Leasys 3458, 50% solid content in distilled water) was obtained from Wanhua Chemical Co., Ltd., Shandong China. Disodium monolauryl sulfosuccinate (Hr) (used as the foaming agent) and ammonium stearate (Ht) (used as the foam stabilizer) were supplied by Yantai Daocheng Chemicals Co., Ltd., Shandong China. Levelling agent (SR-103) and thickener were purchased from Swiwellrebon Chemical Co., Ltd., Guangdong China and Yantai Daocheng Chemicals Co., Ltd., Shandong China, respectively.

Preparation of Microfiber Nonwoven

The microfiber nonwoven was produced by spunbonding and hydroentangling [7]. A mix of 70% PET and 30% PA6 was fed into the extruder hopper, melted, filtered and extruded through a spinneret with a 16-segmented pie cross-section. The 16-segmented pie filament fibers were cooled, drawn and deposited on the conveyor. After deposition the was bonded by high-speed water jets.

Preparation of WPU Coating

The WPU coating was prepared by mechanical foaming. First, WPU (19.4 g), levelling agent (0.3 g) and thickener (0.3 g) were put in a 500 ml three-necked flask, and Hr and Ht were added to the flask to obtain solutions. Second, the solutions were stirred to different foaming ratios. Solutions were cast using a casting knife with a thickness of 0.3 mm onto a smooth glass at room temperature and dried at different temperatures. The coating-forming temperature, foaming agent concentration and foaming ratio were optimized via single-factor experiments. The efficiency was determined by measuring the water vapor permeability and tensile strength.

Using a foaming agent concentration of 4%, and the foaming ratio was 150%, samples were produced at coating-forming temperatures of 40, 60, 80, 100 and 120°C. Using a coating-forming temperature of 80°C, and a foaming ratio of 150%, samples were made with foaming agent concentrations of 0, 2, 4, 6, 8 and 10 percent. Using a coating-forming temperature of 80°C and a foaming agent concentration of 8%, samples were produced with foaming ratios of 100, 150, 200, 250%, 300 and 350 percent.

Preparation of Split Microfiber Synthetic Leather

The split microfiber synthetic leather was prepared according to the method of Zhao, et al [21]. The procedure is shown in *Figure 1*.

Characterization

The surface and cross-sectional morphologies of the microfiber nonwoven, WPU coating and split microfiber synthetic leather were examined by field emission scanning electron microscopy (FESEM, JSM-5900LV, JEOL, Japan).

The air permeability of the microfiber nonwoven and split microfiber synthetic leather was determined using an Automatic Air Tester (YG461H, Ningbo Textiles Instrument Co., Ltd).

The water vapor permeability of the microfiber nonwoven, WPU coating and split microfiber synthetic leather was determined according to GB/T 12704.2-2009 using a Fabric Water Vapor Permeability Measuring Instrument (YG (B) 216-°C, Wenzhou Darong Textile Instrument Co., Ltd).

The tensile strength and elongation at break of the microfiber nonwoven, WPU coating and split microfiber synthetic leather were determined according to QB/T 2710–2005 using a Tensile Tester (Instron 3369, America Instron Co., Ltd).

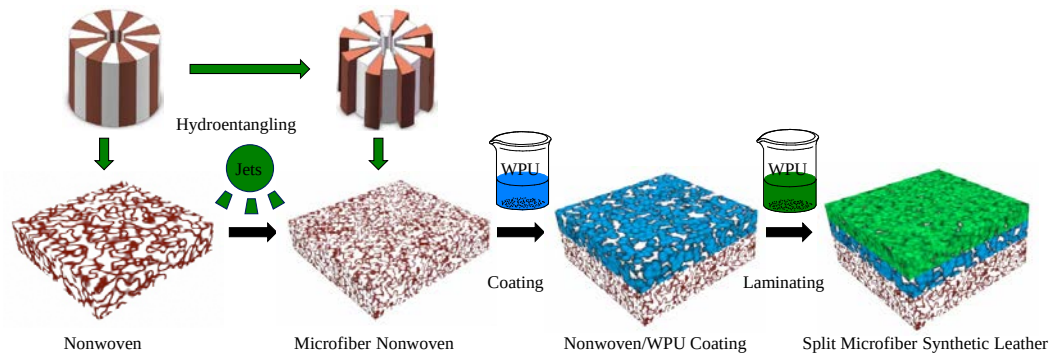


FIGURE 1. Preparation procedure of split microfiber synthetic leather.

The tear strength of the split microfiber synthetic leather was performed according to QB/T 2711–2005 using a Tensile Tester (Instron 3369, America Instron Co., Ltd).

The crease recovery angle of the split microfiber synthetic leather was performed according to GB/T 3819–1997 using a Fabric Crease Recovery Tester (YG 541D, Changzhou Textile Instrument Co., Ltd).

RESULTS AND DISCUSSION

Characterization of Microfiber Nonwoven

Figure 2 shows the FESEM images of the fibers and the nonwoven. As shown in *Figure 2a*, the nonwoven consists of microfibers with a three dimensional network structure. *Figure 2b* and *Figure 2c* show the surface and cross-section of unsplit filament fiber. The unsplit filament fiber had a 16-segmented pie configuration, and the fiber diameter size is approximately 24 μm. As *Figure 2d* and *Figure 2e* show, the microfiber diameter size is 2.2~5.5 μm, similar to collagen fibers in genuine leather.

Table I contains the air permeability, water vapor permeability and mechanical properties of the microfiber nonwoven. The density and thickness are 80 g/m^2 and 0.41 mm respectively, which are suitable for garment leather. The air permeability and water vapor permeability of microfiber nonwoven are 82.84 L/(m^2·s) and 3456.19 g/(m^2·24h), respectively. The results are associated with the high capillary effect and high hydrophily of the microfiber and the porous structure of the nonwoven. The mechanical properties indicate that the microfiber nonwoven exhibit tensile strength and elongation at break meet those required for textiles and nonwovens to be used in synthetic leather according to GB/T 24248-2009. These meet the requirements for textiles and nonwovens intended for use as synthetic leather.

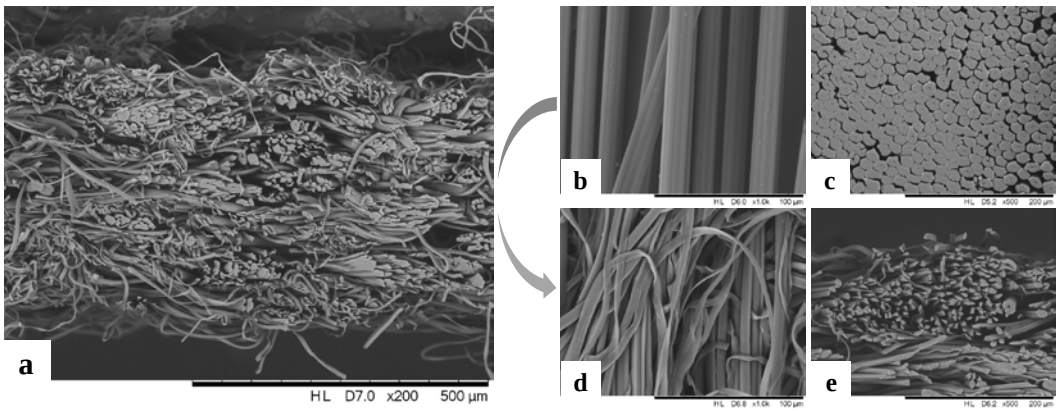


FIGURE 2. FESEM images of fiber and nonwoven for (a) nonwoven, (b) surface and (c) cross-section of unsplit filament fiber, (d) surface and (e) cross-section of split filament fiber.

TABLE I. The air permeability, water vapor permeability and mechanical properties of microfiber nonwoven.

Density (g/m^2)	Thickness (mm)	Air permeability ($L/(m^2 \cdot s)$)	Water vapor permeability ($g/(m^2 \cdot 24h)$)	Tensile strength (N)		Elongation at break (%)	
				Perpendicular	Parallel	Perpendicular	Parallel
80.00	0.41	82.84	3456.19	256.81	167.74	63.33	81.25

Optimization of WPU coating

Effect of Coating-Forming Temperature

The coating-forming temperature is a key parameter affecting the water vapor permeability and tensile strength of the WPU coating. Herein, WPU coatings were obtained using coating-forming temperatures of 40°C, 60°C, 80°C, 100°C and 120°C. The effect of coating-forming temperature on the performance of WPU coating is shown in *Figure 3*. The water vapor permeability increased from 3867.14 $g/(m^2 \cdot 24h)$ to 6089.05 $g/(m^2 \cdot 24h)$ as coating-forming temperature increased from 40°C to 120°C. Tensile strength first slightly increased from 2.11 MPa to 2.5 Mpa (80°C) and then decreased to 0.68 MPa (120°C).

Effect of Foaming Agent Concentration

The foaming agent concentration plays a key role in preparation of WPU coating. *Figure 4* shows the effect of foaming agent concentration ranging from 0% to 10% on the water vapor permeability and tensile strength of the WPU coating. The water vapor permeability increased from 3337.10 $g/(m^2 \cdot 24h)$ to 4766.08 $g/(m^2 \cdot 24h)$ (the maximum value) as foaming agent concentration increased from 0% to 8%, and then decreased to 4286.93 $g/(m^2 \cdot 24h)$ as foaming agent concentration reached to 10 percent. The opposite trend was found for the tensile strength values in *Figure 4*. Tensile strength of the WPU coating decreased with increasing foaming agent concentration, reaching a minimum at 8 percent.

Effect of Foaming Ratio

The water vapor permeability and tensile strength are closely related to the foaming ratio. As shown in *Figure 5*, when the foaming ratio increased from 100% to 350%, the water vapor permeability increased from 3686.84 $g/(m^2 \cdot 24h)$ to 6289.05 $g/(m^2 \cdot 24h)$ and the tensile strength decreased from 2.60 MPa to 0.36 Mpa.

Figure 6 displays the cross-section and surface of WPU coating prepared at optimum conditions (coating-forming temperature of 80°C, foaming agent concentration of 8% and foaming agent concentration of 250 percent). The SEM image shows that the WPU coating consists of a sponge-type micropore structure (*Figure 6a)*. *Figure 6 (b-c)* clearly show the presence of micron-sized pores on the surface of the WPU coating. These features indicate that the coating pore structure should yield relatively high water vapor permeability.

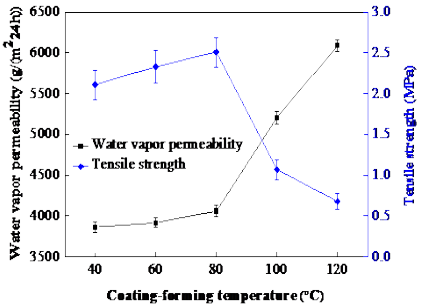


FIGURE 3. Effect of coating-forming temperature on the water vapor permeability and tensile strength of the WPU coating.

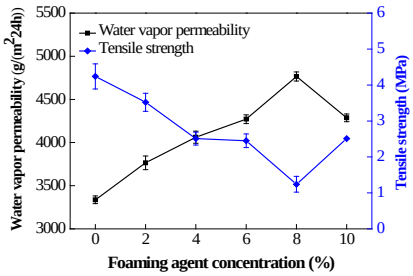


FIGURE 4. Effect of foaming agent concentration on the water vapor permeability and tensile strength of the WPU coating.

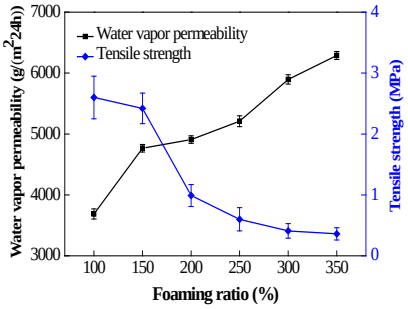
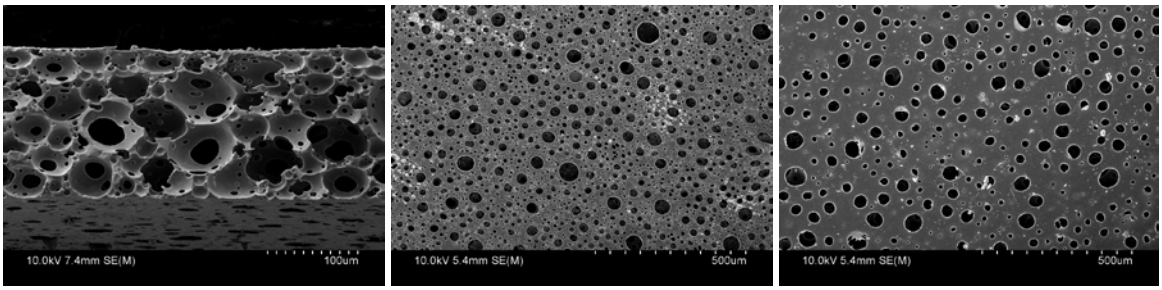


FIGURE 5. Effect of foaming ratio on the water vapor permeability and tensile strength of the WPU coating.

Split Microfiber Synthetic Leather

The split microfiber synthetic leather is in a three-layer configuration, including a fabric layer, a foam layer and a surface layer. The properties of split

the microfiber synthetic leather and other synthetic leathers are shown in *Table II*. The air permeability of the split microfiber synthetic leather is 0.45 L/(m^2·s), tensile strength perpendicular and parallel are 138.40 N and 96.60 N respectively, elongation at break perpendicular and parallel were 72.70% and 101.80% respectively, tear strength perpendicular and parallel were 63.20 N and 88.20 N respectively, peel strength before and after hydrolyzation are 15.86 N and 15.61 N respectively, and crease recovery angle perpendicular and parallel are 149.30º and 151.80º, respectively. All properties are sperior to both knitted synthetic leather and real leather. The water vapor permeability reached 1673.8 g/(m^2·24h), close to that of real leather. Thus, the production of synthetic leather from a microfiber nonwoven may be considered a success.



(a) (b) (c)

FIGURE 6. SEM images of WPU coating prepared by optimal point corresponded to coating-forming temperature of 80°C, foaming agent concentration of 8%, and foaming agent concentration of 250%: (a) overall cross-section structure; (b) top surface; (c) bottom surface.

TABLE II. The properties of split microfiber synthetic leather and other synthetic leathers.

Properties		Split microfiber synthetic leather	Sea-island PU synthetic leather	Real leather	QB/T 2888-2007
Density/ (g·m^{-2})		294.58	289.4	297.33	-
Thicknes/ mm		0.67	0.62	0.74	≤ 0.80
Air permeability/ (L·(m^2·s)$^{-1}$)		0.45	0.39	0.39	-
Water vapor permeability/(g (m^2·24h)$^{-1}$)		1673.8	1272.4	1858.48	-
Tensile strength (N)	Perpendicular	138.4	251.9	63.5	≥35
	Parallel	96.6	85.9	60.7	
Elongation at break (%)	Perpendicular	72.7	54.5	50.5	≥15
	Parallel	101.8	403.6	52.5	
Tear strength (N)	Perpendicular	63.2	49.1	21.8	≥15
	Parallel	88.2	127.4	22.9	
Peeling strength (N)	Before hydrolyze	15.86	5.82	4.13	≥25
	After hydrolyze	15.61	5.72	4.08	
Creasy recovery angle (º)	Perpendicular	149.3	135.9	130.4	-
	Parallel	151.8	151.3	132.5	

CONCLUSION

A split micrifiber nonwoven with a three dimensional network structure was successfully produced by spunbonding and hydroentangling，and the properties meet those required for textiles and nonwovens to be used in synthetic leather according to GB/T 24248-2009. The water vapor permeability and tensile strength of a WPU coating prepared at optimum point coating-forming temperature of 80°C, foaming agent concentration of 8%, and foaming agent concentration of 250% was 5209.09 g/(m^2·24h) and 0.6 MPa respectively. The obtained split microfiber nonwoven and waterborne polyurethane (WPU）coating were used to prepare split microfiber synthetic leather by dry transfer-coating. The properties of the resulting

split microfiber synthetic leather were better than both knitted synthetic leather and real leather, indicating that the application of split microfiber nonwoven to synthetic leather was successful.

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AUTHORS' ADDRESSES

Baobao Zhao
Yao Qian
Xiaoming Qian
Fan Liu
Yongchao Duo
Tianjin Polytechnic University, School of Textile
No. 399 Binshui Xi Road
Xiqing District
Tianjin, Tianjin 300387
CHINA

Jintu Fan
Cornell University
College of Human Ecology
Martha Van Rensselaer Hall
Ithaca, NY 14853
UNITED STATES