The Flame-Retardant Performances of Blending Fabrics of Fire-Retardant Viscose and Polyacrylonitrile Fibre with Different Blending Ratio

Ailing Tao, Shulin Zhao, Liu Chao
School of Textiles, Tianjin Polytechnic University Tianjin, China, 300160
*Email: peach*1986@163.*com*

Abstract: This article used the fire-retardant viscose and the PANOF (polyacrylonitrile fibre) to blend, and wove the flame-resistant fabric with different blending ratios, then tested and analyzed the flame-resistant performance with the Vertical Flammability Test and the Limiting Oxygen Index （LOI） method. The experimental results are that the blending fabric of the fire-retardant viscose and the PANOF has the good fire resistance. When the contention of PANOF is increasing, the performance of spinning will reduce. It is of an important practical significance to develop flame-retardant fabric.

Keywords: Fire-retardant viscose; PANOF; Fabric blending ratio; Blend fabric; Fire resistance

1 Introduction

Fire–retardant viscose: its main element is cellulose, and internal macromolecules are format silicate molecular network and a lot of chemical combination water. The physical and mechanical properties are similar with ordinary viscose fibers, its not only has a better hygroscopic and easy to dye, but also acid and alkali-resistance and moth-proofing [1].Fire-retardant viscose has good fire resistance performance (limiting oxygen index LOI values> 28%), ignited a long time, heat release rate, effective heat of combustion and smoke release ratio are lower than ordinary viscose fiber, structure of burning residue is combustion.

PANOF: polyacrylonitrile fiber is made of heating oxidation in air, its structure is stable, and has excellent flame resistance performance (Limiting oxygen index LOI value > 50%) and chemical resistance [2]. But PANOF has low strength, poor cohesive force and any other shortcomings. So the spinnability is inferior, anti-friction and tenacity is low. It will be appeared hair entanglement in weaving process, we can use its good hygroscopic, and by increasing the workshop relative humidity made the pin feather absorption in yarn, made the shed clear and removes static effectively.

The fire-retardant viscose and PANOF were adapted to spinning to combination yarn with the different blending ratios, and then wove fabric, and the fire-resistance properties of the fabric were studied. Under the past experiences and theoretical basis for fiber, blended yarn, and physical properties of fabrics and fire-retardant properties were systematically studied and explored, the process of spinning, weaving and fire resistance performance are analyzed and discussed.

2 Experimental materials

2.1 Materials

Fire－retardant viscose and PANOF. The properties of fire-retardant viscose and PANOF are shown in Table 1.

Table 1 the properties of materials

Materials	Fineness/dtex	Length/mm	LOI/%
Flame-retardant viscose	1.65	38	29.3
PANOF	2.2	51	50.5

2.2 The design and spinning processes of yarns

2.2.2 The designing of yarns

According to the blending ratio of fire-retardant viscose/PANOF, which is 100/0, 80/20, 65/35, 50/50, 35/65, 20/80, 0/100, 7 kinds of ply-yarn were spun with the linear density for 20/2 Tex.

2.2.3 Spinning process and points

The spinning process: Opening and blending → Carding (carding frame A186F) → Drawing(double drawing with drawing frame A272F)→Roving(roving frame FA401)→Spinning(spinning frame FILA010) → multifunctional twisting frame (TH01)

PANOF has large rigidity, less crimping, easy break, and low cohesive force, so adding 5% antistatic agent to the raw materials in the opening process to reduce electrostatic. At the same time it adopted the slowly attack and combing which instead of blowing in order to reduce the fiber damage. When lapping, the weight roller of carding frame should make heavier to prevent the lap fracture and stick. As the fiber length is long and fluffy, it is easy to present the phenomenon of block coiler and bell block so it should decrease the sliver weight in the carding process. And adopt larger feeding

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plate length and lower licker-in speed to prevent excessive fiber damage. The drawing process adopts double drawing with six slivers compounded, heavy weight and big holds distance. During the drawing will appear wound round roller phenomenon, that be improved by adding oil and increasing workshop relative humidity. In order to reduce the accidents of roving elongation, we should using bigger multiplier in roving process. Using spinning process route of "heavy pressure, big space, greater the drafting" [3].

2.3 Fabric weaving process and design

The fabric weaving process: winding→warping→sizing→weaving.

Seven samples by 2/1 ↗ twill-weave, warp into the use of 3per dent, using the three harness [4]. The fabric of the yarn number is 19×2tex, breadth for 40cm. According to the process of weaving, using each blended ratio (100/0 80/20 65/35 50/50 35/65 20/80 0/100) blended ply-yarn woven into the fabric samples A_1, A_2, A_3, A_4, A_5, A_6, A_7. The yarn was used is ply-yarn with S-twist. The standards of samples fabric is show in table 2.

Table 2 the density of samples

samples	warp count/root·10cm^{-1}	weft count/root·10cm^{-1}	fabric set/g·（m^2）$^{-1}$
A_1	270	103	193.26
A_2	272	108	196.65
A_3	276	106	199.59
A_4	268	111	191.43
A_5	273	105	195.18
A_6	275	102	197.29
A_7	272	113	199.98

3 Experiment of fire-retardant

3.1 Introduced of the fire- retardant experimental method

3.1.1 Vertical Flammability Test

Used to determine the burning breadth (carbonized area and damaged length) after flame time、smoldering time of materials. The method is made a definite dimension specimen in prescriptive case burning with the fire twelve seconds, then remove the flame and determined the burning time, smoldering time, after flame time, according to provisions method to detect length (carbonized length)[5]. This is a basic method of testing standards, our GB5455-1997; strict standards applicable to all kinds of fabric test.

3.1.2 The Limit oxygen index method

As the limit oxygen index method, means on the stipulated experimental condition, the minimum concentration of oxygen volume on the oxygen and nitrogen mixture gas which can keep the materials just burning, with the LOI said. Tests on the oxygen index tester. Method is made a definite dimension specimen be placed on sample folder in the combustion cylinder, adjust oxygen and nitrogen with certain proportion, Use specific ignition lit specimen， burning certain time or damaged length from extinguish, At this time of oxygen, nitrogen flow from the table detected oxygen values, that is the LOI of sample [6]. Our standard GB5454-1997 Provisions sample just burning 2 minutes from extinguish or damaged length just needed oxygen for 40mm needed percentage of oxygen just as the LOI of the sample.

3.2 Experimental instrument and sample preparation

3.2.1Vertical burning experiment

Experimental apparatus: LFY-26C vertical flame retardant determinator.

Execution standard: GB5455-1997.

Sample balance: 20°c± 2°c, the relative humidity of 65% ± 3% and balance of 8-24 hours remove and placed in sealed containers under test.

Sample size: 300mm×80mm.

Hammer quality: 113.4 g.

3.2.2 Limiting Oxygen Index （LOI）experiment

Experimental apparatus: burning tester ON – 1.

Execution standard: GB5454-1997.

Test method: the percentage of oxygen just at the damaged length of 40mm.

Sample balance: 20°c± 2°c, the relative humidity of 65% ± 3% and balance of 8-24 hours remove and placed in sealed containers under test.

Sample size: 150mm x 65mm, respectively draw a straight line at the places about 40mm from each end.

Ignition: butane ignition.

4 Results and analysis of the fire-retardant performance

4.1 Experimental results and analysis of the vertical combustion method

We just test the warp direction burning because the combustibility of the latitude and longitude is the same. The vertical combustion of 7 samples vertical burning situation is shown in Table 3.

From the dates of the Table 3 it shows that the damaged length decreases gradually and the fabric fire resistance increases with PANOF contention increases. But when the proportion of PANOF gets up to 100%, the damaged length is increasing, the reason is that the pure

PANOF yarns have a number of hair feathers and the decreasing of fabric density made the fire resistance reduces. When the blending ratio of fire-retardant viscose and PANOF is 20/80, the damaged length of fabric is shortest, and flame retardant properties are better. From the three indexes investigation (damaged length, smoldering time, renewal burning time), sample A_3, A_5, A_6 have better flame retardant, it can effectively reduce the risk when dressing in the actual.

Table 3 the illustration to vertical flame test results

Specimen	Damaged length (cm)	Smoldering time(s)	Renewal burning time (s)	Flaming Characteristics
A_1	13.8	0	0	Almost no shrinkage, charring, charred larger, acrid smoke, charring layer no holes but more brittle.
A_2	12.3	0	0	Almost no shrinkage, charring, charred larger, acrid smoke, charring layer no holes but more brittle.
A_3	8.8	0	9.3	Almost no shrinkage, charring, charred area is relatively small, pungent smoke, charring layer more solid, no holes.
A_4	All damaged.	0	12.3	Almost no shrinkage, carbonization, the largest area burned, acrid smoke, charring layer no holes but more brittle.
A_5	7.6	0	3.2	Almost no shrinkage, charring, charred area is relatively small, smoke more, pungent, carbonized layers are better than solid, no holes.
A_6	5.1	0	0	Almost no shrinkage, charring, burning of the smallest, smoke more, pungent, carbonized layer of solid, no holes.
A_7	10.1	0	0	Almost no shrinkage, charring, burning an area of small, smoke large, pungent, carbonized layer no holes but more brittle.

4.2 Experimental results and analysis of the limit oxygen index method

Each kind of cloth takes six along the latitude and longitude, do the limiting oxygen index test. According to GB/T 5454-1997 limit oxygen index by formula LOI = CF + Kd[7] calculated the LOI of fabric with different blending ratios as shown in table 4.

Table 4 the fabric LOI value calculation results

specimen	A_1	A_2	A_3	A_4	A_5	A_6	A_7
LOI（%）	27.83	30.25	32.4	35.20	37.95	40.56	43.31

From the Table 4 it can be obtained that with the increase of blending ratio of PANOF, the fabric's LOI and flame retardant properties was increased. But the LOI of pure fire-retardant viscose fabric and pure PANOF fabric is lower than what of their corresponding fibers which is due to the fiber damaged in spinning and weaving process mated the flame-retardant reduce. With the blending ratio of PANOF increasing, the yarn hairiness increase gradually, the rate of twitty yarn increase, the fabric appearance and properties are reduced. It should choose the appropriate process and blending ratio to meet the fabric performance of people required.

5 Conclusion

Through the analysis of the experimental process and experimental results, the four conclusions were shown as following:

5.1 PANOF has good oxidation stability, but the material has low tenacity, less crimping cohesion pressure and spinnability, exist some difficulties in spinning process, and high ends when weaving. Fire-retardant viscose has good hygroscopic、permeability、spinnability and superior properties serviceability. So in the spinning and weaving process should be according to the characteristics of materials, selecting the appropriate process principle, in order to make processing can smoothly.

5.2 The flame-retardant of the combination fabric with fire-retardant viscose and PANOF is strengthened with the percentage of PANOF increases. With vertical combustion method of measured fabric renewal burning time and damaged length is not as fiber ratio decreased, but has certain fluctuations**.** This is because the fiber was damaged in the opening and carding process increased hairiness and dense error of fabrics affected it, and any other factors. In the actual production should choose the suitable spinning process and fabric density, to obtain the best flame retarding.

5.3 The LOI of fabrics rose with PANOF percentage, the higher content of PANOF the better flame-retardant of fabrics. Considering fabric performance, when the

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fire-retardant viscose and PANOF blending ratio is 35/65, the fabric not only have good fire resistance performance but also can satisfy the human requirements in aspects of serviceability. Suitable for high temperature fire retardant garment production under the conditions of the optimal design.

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