

REZUMAT – ABSTRACT

Aplicarea nano-TiO₂ la incleierea firelor din amestec cu fibră Kapok

A fost investigat gradul de utilizare a tipului Rutil de nano-TiO₂ ca auxiliar în incleiere pentru a îmbunătăți calitatea firelor în amestec cu fibra obținută din Kapok. În primul rând, TiO₂ cu o calitate diferită a fost adăugat la incleierea tradițională, iar patru tipuri de fire în amestec cu fibră obținută din Kapok au fost incleiate cu amidon. Apoi, au fost testate rezistența, alungirea, rezistența la abraziune și pilozitatea firelor incleiate. În final, a fost analizat efectul conținutului de TiO₂ asupra performanței firelor. Rezultatele demonstrează că utilizarea TiO₂ ca agent de incleiere este favorabilă creșterii rezistenței, pierderii de alungire, rezistenței la abraziune și pilozității firelor incleiate. Iar atunci când raportul dintre TiO₂ și amidon este de 1,5%, proprietățile firelor incleiate sunt excelente.

Cuvinte-cheie: TiO₂, dimensiune, Kapok, rezistență, rezistență la abraziune, pilozitate

Application of nano-TiO₂ in sizing of kapok blended yarn

The usability of Rutile type nano-TiO₂ as the auxiliary in sizing was investigated in order to improve the quality of kapok blended yarn. First, TiO₂ with different quality was added to the traditional size, and four kinds of kapok blended yarns were starched. Then, the strength, elongation, abrasion resistance and hairiness of the sized yarns were tested. Finally, the effect of TiO₂ content on the performance of the yarn was analyzed. The results demonstrate that using TiO₂ as sizing agent is favorable to the increase in strength, loss in elongation, abrasion resistance and hairiness of sized yarns. And, when the ratio of TiO₂ to starch is 1.5%, the properties of the sized yarn are excellent.

Keywords: TiO₂, size, kapok, strength, abrasion resistance, hairiness

INTRODUCTION

Rutile type nano-TiO₂ is a new non-toxic, pollution-free, non-flammable and environment friendly inorganic textile sizing agent. Its principle is to combine the active groups of the nanoparticles with the hydrophilic groups in the size liquor and the hydroxyl groups in the fibers, thus strengthening the combination of the starch and the fiber. At the same time, the other functional components have good film forming and permeability [1]. Therefore, nano-TiO₂ can play a role in sticking hairiness and improving yarn strength. At present, there are few studies on nano-TiO₂ as sizing auxiliaries. Only Zhang Chi [2] studied the effect of the amount of nano-TiO₂ on the performance of the slurry.

In the kapok blended yarn, the kapok fiber is short [3], so it is easy to form hairiness on the surface of the yarn, which causes the friction between the yarns and the high breakage rate in the weaving process. Therefore, the main sizing task of the kapok blended yarn is to attach the hairiness, increase the wear resistance and improve the yarn strength [4–6]. Accordingly, in this study, nano-TiO₂ was used as an auxiliary in sizing of kapok blended yarn. The effect of TiO₂ content on yarn properties will be explored, and the optimum content of TiO₂ will be determined to achieve optimal yarn performance.

EXPERIMENTAL

Materials and instruments

Yarn: 1# kapok/cotton 30/70 18.2 tex
2# kapok/cotton 30/70 14.6 tex
3# kapok/cotton 20/80 11.7 tex
4# kapok/cotton/tencel 30/50/20 19.4 tex

Size recipe: Polyvinyl alcohol (PVA) 1799, Denaturated Starch, Rutile typenano-TiO₂ (20–30 nm), Wax disk

Instruments: GA392 Single Yarn Sizing Machine, YG020B Electronic single yarn strength tester, Y731 Holding machine, YG171B-2 Yarn hairiness tester, JJ-1 Electric Blender, HH-2 Thermostat water bath, HJ-4A Magnetic Stirrer, Ultrasonic Cleaner and Electronic balance.

Experimental scheme

In order to explore the effect of TiO₂ on the sizing effect, the proportion of TiO₂ to starch is set as a single variable and other conditions remain unchanged. The experiment project is showed in table 1.

Size mixing

Dilute TiO₂ powder into 20% suspension with water. In order to promote the dispersion of TiO₂ powder, a small amount of sodium chloride was added. Then, the suspension was oscillating for 90 minutes in an Ultrasonic Cleaner and then stirred in a Magnetic stirrer for one hour.

Table 1

No.	Solid content	PVA : Starch	Proportion of TiO ₂ to starch	Content of wax disk
i-1	9%	3:7	0%	4%
i-2	9%	3:7	0.5%	4%
i-3	9%	3:7	1.0%	4%
i-4	9%	3:7	1.5%	4%
i-5	9%	3:7	2.0%	4%
i-6	9%	3:7	2.5%	4%
i-7	9%	3:7	3.0%	4%

Notes: i = 1, 2, 3, 4 (1, 2, 3 and 4 is the yarn 1#, 2#, 3#, 4# respectively)

Heat the beaker with some water in a thermostat water bath. When the water temperature reaches about 30°C, add a certain amount of starch and stir for ten minutes, then add PVA, stir for five minutes, then add the wax disk, and continue to stir and heat up. When the temperature reaches 50°C, add the prepared TiO₂ solution, continue to heat up to 95°C and stir at the temperature for 1.5 hours.

Sizing

A GA392 Single Yarn Sizing Machine was used to size kapok blend yarns at a speed of 49 m/min. The size liquor was shifted into the sizing box on the machine. The yarns were impregnated with the size at 95°C and squeezed with a pair of weighted roller. Finally, the yarns were dried in a pre-dry unit with 75°C, then dried in the cylinder drying unit with 95°C.

Measurement of sized yarns

Strength and elongation

YG020B Electronic single yarn strength tester was used to measure tensile strength and elongation of sized yarns at 65% relative humidity and 20°C with a speed of 500 mm/min under a test length of 500 mm. For each sample, 100 pairs of the strength and elongation readings were recorded and their mean values were adopted to calculate the increase in tensile strength and loss in elongation from equation (1) and (2) [7].

$$\text{Increase in tensile strength/\%} = \frac{S - S_0}{S_0} \times 100 \quad (1)$$

$$\text{Loss in elongation/\%} = \frac{E_0 - E}{E_0} \times 100 \quad (2)$$

Where S and S_0 are the mean values of tensile strength of sized and raw yarns; E and E_0 are the mean values of the elongations of sized and raw yarns, respectively.

Abrasion resistance

Abrasion resistance of sized yarns was evaluated in average number of abrasion cycles to break. The number of abrasion cycles was measured by Y731 Holding machine with a speed of 100 times/min. Each sample was tested 30 times, and average number of abrasion cycles was calculated.

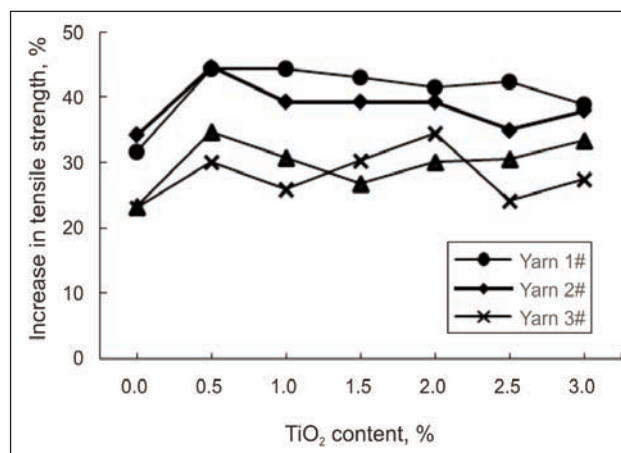
Hairiness

Hairiness of sized yarns was evaluated in term of the hairiness index, which was the number of hairiness per meter of yarn obtained by YG171B-2 Yarn hairiness tester. Each sample was tested 10 times, and the average number was calculated.

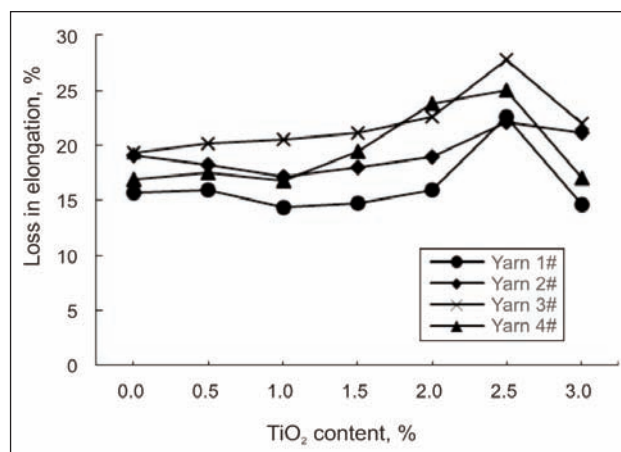
RESULTS AND DISCUSSION

Effect of TiO₂ content on strength and elongation

The increase in tensile strength and loss in elongation of sized yarns were shown in figure 1.



a



b

Fig. 1. Effect of TiO₂ content on the: a – increase in tensile strength and b – loss in elongation

From figure 1, a, it can be seen that the addition of TiO₂ in the size liquor significantly increases the strength of the yarns compared with those without titanium dioxide. This indicates the necessity of adding TiO₂ in the size. Further, with the increase of TiO₂ content, the increase in tensile strength of sized yarns first increases and then decreases slightly. When the ratio of TiO₂ to starch weight is 0.5% to 1.5%, the increase in tensile strength is better for four kinds of yarns.

From figure 1, b, it can be observed that the addition of TiO₂ will affect the loss in elongation of sized yarns. When TiO₂ content is between 0.5% and

1.5%, the loss in elongation changes little; when TiO₂ content is between 1.5% and 3.0%, the loss in elongation increases first and then decreases. Combined with four kinds of yarns, when the ratio of TiO₂ to starch weight is 0.5%, 1.0% and 1.5%, the loss in elongation is better.

Effect of TiO₂ content on abrasion resistance

In order to analyze the effect of TiO₂ content on the abrasion resistance of yarns, the average number of abrasion cycles of the four yarns was summarized to figure 2.

As can be seen from figure 2, the number of abrasion cycles of four sized yarns is increased after adding

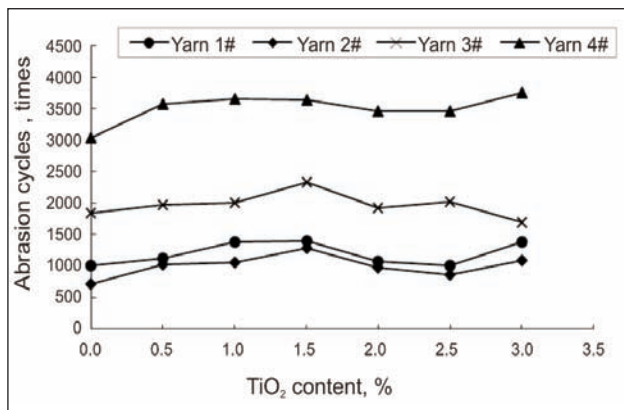


Fig. 2. Effect of TiO₂ content on the abrasion resistance

TiO₂ into the size liquor. And, with the increase of TiO₂ content, the trend of abrasion resistance tends to increase first and then slightly decrease. When the ratio of TiO₂ to starch is 1.5%, the number of abrasion cycles of yarn 1#, yarn 2# and yarn 3# is the maximum, and when it is 1.5% and 3.0%, the number of abrasion cycles of yarn 4# are the maximum. Therefore, in general, when the ratio of TiO₂ to starch is 1.5%, the abrasion resistance of four yarns is the best. Beside, it can be seen that the number of abrasion cycles of yarn 4# is higher than that of yarn 1#, 2# and 3#. This is because yarn 4# contains Tencel, which is different from the other three kinds of yarns.

Effect of TiO₂ content on hairiness

The results of the hairiness test for four kinds of yarns were shown in tables 2, 3, 4 and 5, respectively.

In general, the short hairiness of 1 mm to 2 mm is the main body of yarn hairiness, which accounts for about 95% of the total yarn hairiness, and the harmfulness is small, while the proportion of 3 mm and above hairiness is not high, but it is more harmful to the later production [8]. Therefore, take 3 mm and 4mm hairiness as research object. Four kinds of yarn data were summarized in figures 3 and 4, respectively.

It can be observed that for 3 mm long hairiness, the yarn hairiness index decreased significantly after adding TiO₂, especially yarn 1#, 2# and 3#. Moreover, with the increase of TiO₂ content, the hairiness index decreases first and then increases. When

Table 2

	No.	Proportion of TiO ₂ to starch	Hairiness length (mm)						
			1	2	3	4	5	6	7
Hairiness Index (number/m)	01		633.70	155.40	52.90	22.20	16.70	13.40	2.60
	1-1	0%	32.90	6.30	1.10	0.30	0.40	0.20	0
	1-2	0.5%	54.10	3.70	1.00	0.40	0.50	0.20	0
	1-3	1.0%	14.50	1.90	0.60	0.40	0.10	0.80	0
	1-4	1.5%	8.10	0.60	0.10	0.20	0.30	0.10	0.10
	1-5	2.0%	6.90	0.40	0.20	0	0	0	0
	1-6	2.5%	25.30	3.40	0.60	0.10	0.10	0.10	0
	1-7	3.0%	7.30	0.50	0.10	0	0.20	0	0

Table 3

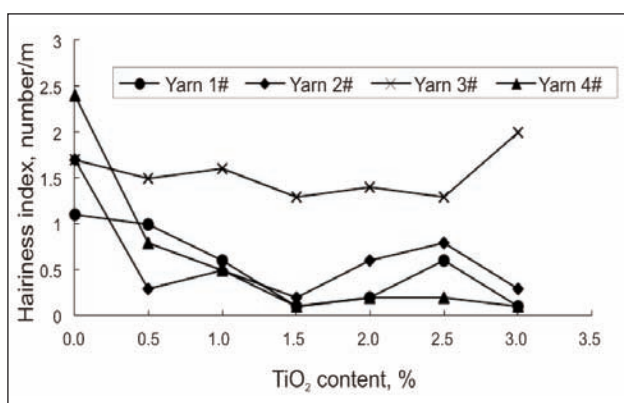
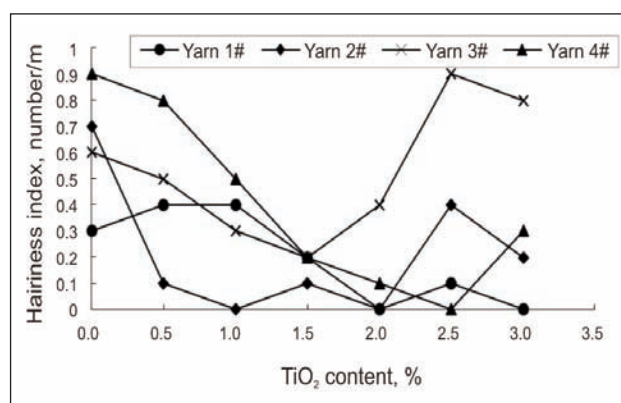
	No.	Proportion of TiO ₂ to starch	Hairiness length (mm)						
			1	2	3	4	5	6	7
Hairiness Index (number/m)	02		950.50	252.40	89.10	45.40	22.10	17.40	4.60
	2-1	0%	18.10	3.50	1.70	0.70	0.70	1.20	0.10
	2-2	0.5%	11.20	0.70	0.30	0.10	0.30	0.30	0.10
	2-3	1.0%	28.80	1.40	0.50	0	0.10	0.20	0.20
	2-4	1.5%	27.00	0.80	0.20	0.10	0.30	0.10	0
	2-5	2.0%	11.30	2.40	0.60	0	0.10	0.40	0
	2-6	2.5%	11.10	1.40	0.80	0.40	0.90	0.70	0.60
	2-7	3.0%	12.80	3.30	0.30	0.20	0.10	0.50	0.20

Table 4

	No.	Proportion of TiO ₂ to starch	Hairiness length (mm)						
			1	2	3	4	5	6	7
Hairiness Index (number/m)	03		742.20	106.7	19.70	5.80	3.00	1.80	0.90
	3-1	0%	24.10	1.90	1.70	0.60	0.60	0.40	0.10
	3-2	0.5%	22.20	1.50	1.50	0.50	0.10	0.50	0.10
	3-3	1.0%	10.50	1.40	1.60	0.30	0.50	0.50	0.10
	3-4	1.5%	8.90	3.80	1.30	0.20	0.55	0.30	0
	3-5	2.0%	6.70	1.70	1.40	0.40	0.30	0.20	0
	3-6	2.5%	31.00	5.40	1.30	0.90	0.40	0.20	0.20
	3-7	3.0%	18.70	5.40	2.00	0.80	0.30	0.30	0

Table 5

	No.	Proportion of TiO ₂ to starch	Hairiness length (mm)						
			1	2	3	4	5	6	7
Hairiness Index (number/m)	04		151.60	38.20	20.10	12.30	6.80	7.60	0.90
	4-1	0%	5.30	2.00	2.40	0.90	1.20	1.00	0.10
	4-2	0.5%	5.40	0.80	0.80	0.80	1.10	1.40	0.20
	4-3	1.0%	15.90	0.40	0.50	0.50	0.30	0.30	0.10
	4-4	1.5%	6.70	0.10	0.10	0.20	0.20	0.10	0
	4-5	2.0%	5.70	0.10	0.20	0.10	0	0	0
	4-6	2.5%	10.90	0.60	0.20	0	0.50	0.50	0
	4-6	3.0%	16.30	0.40	0.10	0.30	0.40	0	0

Fig. 3. Effect of TiO₂ content on the hairiness index of hairiness length 3 mmFig. 4. Effect of TiO₂ content on the hairiness index of hairiness length 4 mm

the proportion of TiO₂ and starch is 1.5%, the hairiness index of the four yarns is the smallest.

The variation of 4 mm long hairiness is similar to that of 3 mm. When the proportion of TiO₂ and starch is 2.0%, the hairiness index of yarn 1# and 2# are the lowest; when it is 1.5%, the hairiness index of yarn 3# is the lowest; when it is 2.5%, the hairiness index of yarn 4# is the lowest.

In summary, the addition of TiO₂ has great effect on reducing yarn hairiness. And, when TiO₂ content is 1.5%, the hairiness index of the four yarns are lower.

CONCLUSIONS

Because kapok fiber is shorter, the hairiness of kapok blended yarn is much more and the strength is low. In this study, Rutile type nanometer TiO₂ was applied to the sizing of kapok blended yarns. The observation demonstrates that nanometer TiO₂ exhibits potential use as size agent in kapok sizing for improving the quality of sized yarns. The experimental results show that after adding TiO₂, the tensile strength and abrasion resistance increase, the loss elongation changes, and the yarn hairiness index decreases significantly. And, with the change of TiO₂ content, the

yarn performance also fluctuates. Considering the four properties of the four yarns, when the content of TiO₂ is 1.5%, the yarn has better performance.

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