Study on Creep Property of Vortex Spun Yarn

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Abstract: Based on the Hook's law for infinitesimal strains and Newton's law for infinitesimal rates of strain, the creep property of vortex spun yarn is studied by generalized Maxwell model connected in a row to a Hook's spring. The results show that this model can effectively explain the creep property of vortex spun yarn. For different creep test conditions, firstly, the creep elongation increases sharply with the prolongation of creep time, and then slows down after a constant elongation period. The maximal creep elongation after being stressed by a constant force value increases with the increase of the elongation rate. When the tensile level is higher, the maximal elongation is larger under a constant elongation rate. Moreover, the maximal creep elongation is larger for a finer vortex spun yarn.

Keywords: Murata Vortex spinning (MVS), vortex spun yarn, viscoelastic model, creep properties.

1. Introduction

In Murata Vortex Spinning, the open-end fibers inverted at the inlet of the hollow spindle are twisted by the high speed whirled airflow and made into MVS yarn [1, 2]. The flow law of air current in nozzle block of Murata vortex spinning was investigated by Guo et al. and Zou et al. [3-5]. The twist strength of high-speed whirled airflow action on the vortex spun yarn is regarded by the following functions: (1) the number of jet orifices, the jet angle, the inner diameter of the jet orifice and the nozzle block, (2) the distance from the inlet of the nozzle block to the inlet of the hollow spindle, (3) the projective height of open-trail-end fibers twined over the top exterior of the hollow spindle, (4) the vortex spun yarn diameter, (5) the velocity at the exit of the jet orifice (i.e. corresponding to nozzle pressure) [6]. The reason of generating yarn thin places of Murata vortex spinning was explained by Zou et al. [2]. The relationship between properties of vortex spun yarn and process parameters were discussed experimentally by previous researchers [7-9]. The relaxation mechanism of vortex spun yarn is studied by four element model [10]. This study focused on the creep properties of vortex spun yarn.

2. Experimental

2.1 Materials

The blend vortex yarns made from 85/15 white cotton/colored cotton (Sample 1: white cotton/colored cotton 85/15, 18.2 [tex]) and 70/30 bamboo pulp fiber/ comb white cotton (Sample 2: bamboo pulp fiber/ comb white cotton 70/30, 18.2 [tex] and Sample 3: bamboo pulp fiber/ comb white cotton 70/30, 32.4 [tex]) were spun by Murata vortex machine. The fiber properties of colored cotton, white cotton as well as bamboo pulp fiber are listed in Table 1. The process parameters of different samples are listed in Table 2.

Table 1 Fiber properties

Fiber Type	Upper quartile length [mm]	Fiber length [mm]	Fineness [dtex]	Fineness Micr-onaire	Tenacity [cN/dtex]	Elon-gation [%]
Colored cotton	26.8	-	1.46	3.14	1.9	5.7
White cotton	29.3	-	1.74	4.81	2.83	13.6
Bamboo pulp fiber	-	40.1	1.56	-	2.21	19.3

2.2 Creep tests

Creep tests were carried out on test samples such as Sample1, Sample 2 as well as Sample 3 subjected to creep for 300 seconds at different test conditions. Creep elongation properties of yarns were measured by the YG061 electronic single-yarn tensile tester. Tests were conducted in a conditioned atmosphere of 20±2℃ and 65%℃±2% relative humidity. 10 tests per sample were performed. For all tests, an ample gauge length of 500 [mm] was chosen. The pre-tension for measuring creep elongation was 0.5 [cN/tex].

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Table 2 Yarn formation process parameters

Yarn type	Sample 1	Sample 2	Sample 3
Delivery speed [m/min]	320	400	400
Total draft	129	218	128
Main draft	40	35	30
Nozzle type	75, Holder 130d, 9.3	75, Holder 130d, 8.8	75, Holder 130d, 8.8
Hollow spindle [mm]	1.4	1.4	1.4
Feed ratio	1	0.96	0.96
Take up ratio	0.99	1.013	1.013
Air pressure [MPa]	0.4	0.6	0.6
Distance between front roller and spindle/N2 nozzle [mm]	19	20	20
Yarn count [tex]	18.2	18.2	32.4

3. Creep model

The combination of the Hook's spring and the Newton's dashpot can describe the creep elongation properties of textile materials such as fibers and yarns and so on. In this paper, the generalized Maxwell model connected in a row to a Hook's spring shown in Fig. 1 is used to analyze the creep properties of MVS yarns. The mechanical behavior of this model is ruled by Eq. 1 [11] as follows:

$$\frac{\mu_2}{E_2E_3}\ddot{\varepsilon}+\left(\frac{E_1}{E_2}+\frac{\mu_2}{\mu_1}+1\right)\dot{\varepsilon}+\frac{E_1}{\mu_1}\varepsilon = \frac{\mu_2}{E_2E_3}\ddot{\sigma}+\left(\frac{1}{E_3}+\frac{E_1}{E_2E_3}+\frac{\mu_2}{\mu_1E_3}\right)\dot{\sigma}+\left(\frac{E_1}{E_3\mu_1}-\frac{1}{\mu_1}\right)\sigma \quad (1)$$

Where E_1, E_2, and E_3 are the elastic coefficients of Hook's springs, μ_1 and μ_2 are the viscosity coefficients of Newton's dashpots, σ is the stress action on the MVS yarn, and ε is the elongation of MVS yarn under a stress σ.

When a stress $\sigma = \sigma_c$, Eq. 1 can be derived as:

$$\frac{\mu_2}{E_2E_3}\ddot{\varepsilon}+\left(\frac{E_1}{E_2}+\frac{\mu_2}{\mu_1}+1\right)\dot{\varepsilon}+\frac{E_1}{\mu_1}\varepsilon = \left(\frac{E_1}{E_3\mu_1}-\frac{1}{\mu_1}\right)\sigma_c \quad (2)$$

If $A=\frac{\mu_2}{E_2E_3}$, $B=\frac{E_1}{E_2}+\frac{\mu_2}{\mu_1}+1$, $C=\frac{E_1}{\mu_1}$ and

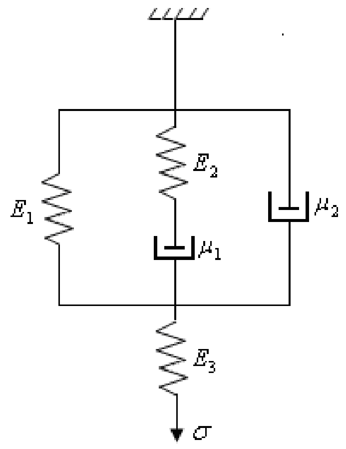

Figure 1 Modified generalized Maxwell model [11].

$D=\left(\frac{E_1}{E_3\mu_1}-\frac{1}{\mu_1}\right)\sigma_c$, the Eq. 2 can be modified as:

$$A\ddot{\varepsilon}+B\dot{\varepsilon}+C\varepsilon=D \quad (3)$$

The general solution of Eq. 3 is expressed by Eq. 4 as follows:

$$\varepsilon(t)=c_0+c_1e^{\left(\frac{-B+\sqrt{A^2-4AC}}{2A}\right)t}+c_2e^{\left(\frac{-B-\sqrt{A^2-4AC}}{2A}\right)t} \quad (4)$$

where t is the time variable, $c_0=\frac{D}{C}=\left(\frac{1}{E_3}-\frac{1}{E_1}\right)\sigma_c$, c_1, c_2 are undetermined coefficients.

When t=0, $\varepsilon(0)=\frac{\sigma_c}{E_3}$ and $\dot{\varepsilon}(0)=\frac{\sigma_c}{\mu_2}$, which are substituted into the Eq. 4, and then the parameters c_1, c_2 can be obtained as:

$$c_1=\frac{\sigma_c}{E_3}-\frac{D}{C}-\frac{\left(-\frac{B}{A}+\sqrt{1-4\frac{C}{A}}\right)\left(\frac{\sigma_c}{E_3}-\frac{D}{C}\right)-\frac{2\sigma_c}{\mu_2}}{2\sqrt{1-4\frac{C}{A}}} \quad (5)$$

$$c_2=\frac{\left(-\frac{B}{A}+\sqrt{1-4\frac{C}{A}}\right)\left(\frac{\sigma_c}{E_3}-\frac{D}{C}\right)-\frac{2\sigma_c}{\mu_2}}{2\sqrt{1-4\frac{C}{A}}} \quad (6)$$

Therefore, the simplified form of Eq. 4 is described by the following equation: