Experimental Analysis of Bundle Thickness Variation by the Describing Function Method

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1. Introduction

Linear density regularity is one of the important characteristics of fiber bundle and yarns, influencing the process performance and the product quality. Analysis on the variation of bundle thickness for various draft ratios and frequencies is therefore of great significance, because an optimum drafting condition can be obtained by establishing the effect of major process factors on the output. Therefore we analyze the drafting operation by applying the Describing Function, a sort of the frequency response method.

2. Experimental system

To prepare specimens with the thickness variation, we adopt a ring spinning frame as experimental system. The gear head that functions adjusting the draft ratio is removed. The middle and back rolls are geared each other and driven by an AC servomotor by the actuating signals from a computer. Therefore it is possible to generate the draft ratio signal as we want to. We altered draft ratios in form of square wave signals with various amplitudes and frequencies. The thickness of output yarn is obtained by an optical method which measures the yarn thickness by a light beam[2].

3. Results and Discussions

The total system can be described by means of a block diagram as Fig. 1. The output thickness of yarn can be influenced by not only the form of input signal but also the characteristics of actuator and draft mechanism.

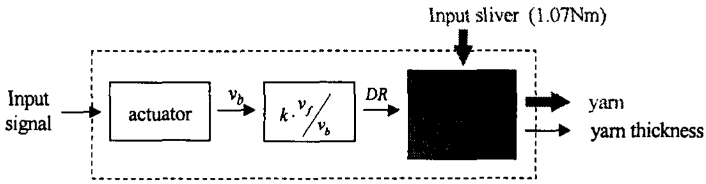

Fig. 1 Block diagram for total system. (v_b, v_f :linear velocity of back roll and front roll)

3.1. Characteristics of the actuator with load

The step response of the actuator for obtaining the characteristic of the actuator including the inertia of the back roll is shown in Fig. 2.

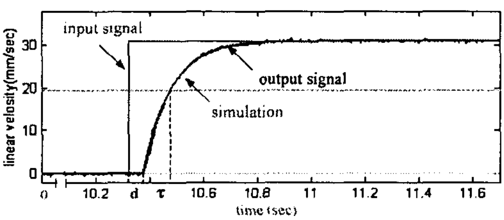

Fig. 2 Step response of the actuator

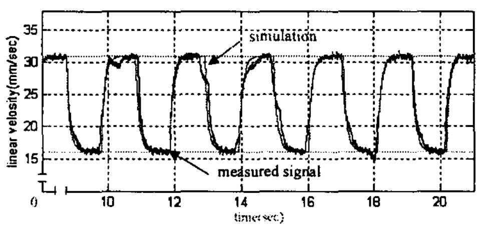

Fig. 3 Square wave response of the actuator

From Fig. 2 we can recognize that this system is the first order system with a time constant of 0.1sec, and a time lag, 0.05sec. Fig. 3 shows the measured signal and simulation results for square-wave response of the actuator with frequency of 2.11cycle/m used for experiment.

3.2. Describing Function of the output bundle thickness for the draft ratio

In a linear system the output depends only on the input frequency. In case of a nonlinear system, however, the output is influenced by the input amplitude additionally to the frequency. Therefore a nonlinear system is analyzed by means of the Describing Function, which compares the amplitudes of input and output signals under a given frequency ω_f.

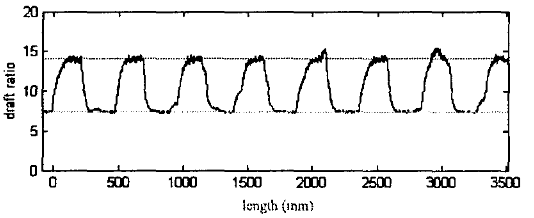

Fig. 4 Input signal of the draft ratio.
(ω_f : 2.11cycles/m, amplitude : 6.76)

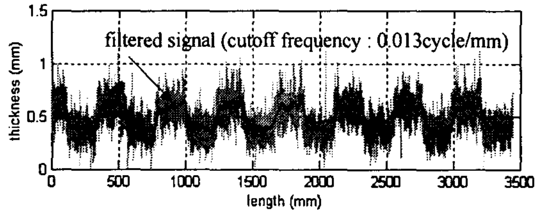

Fig. 5 Thickness response of the output staple yarn
(ω_f : 2.11cycles/m, amplitude : 0.2799mm)

The Describing Function for the fiber bundle dynamics in a roll drafting can then be given, if we get the thickness of output staple yarn for the input draft ratio experimentally. The input amplitudes of total draft ratio are chosen as 2.26, 4.54, 6.76, 10.83, 12.26, and 18.56, while the frequencies of the draft ratios are 0.7147, 1.072, 2.11, and 7.326cycle/m. Fig. 4 shows an input signal of draft ratio with a frequency 2.11cycle/m and an amplitude 6.76. The thickness response of output staple yarn for the input signal shown in Fig. 4 is given in Fig. 5.

Fig. 6 shows the Describing Function for the roll draft system approximated from experiments for various fundamental frequencies. The amplitude of output thickness increases non-lineally to the amplitude of draft ratio, depending on the input frequency.

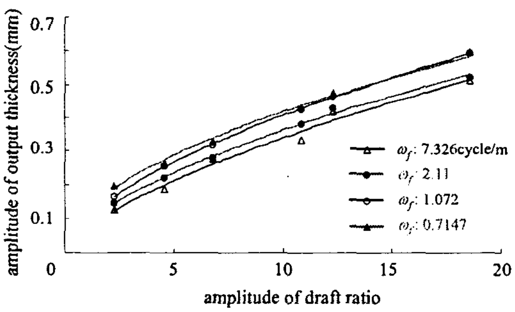

Fig. 6 Describing Function of the roll draft system.

4. Conclusions

In this research we analyzed the bundle thickness variation in a roll draft operation, applying the Describing Function. From the results we can certify that the output thickness maintains the fundamental wave frequency ω_f. The amplitude of output thickness increases non-lineally with the increase of the amplitude of draft ratio. The input frequency showed a little effect on the output thickness in the experimental conditions.

Reference

1. Tames H. Taylor, "Sinusoidal-Input Describing Function Analysis Methods", JUV RESCCE'02 Summer School, 05-09 August 2002
2. Huh, Y., Kim, J.Y., and Suh, M.W., "Analysis of Cross-sectional Variability of Yarn by a Flying Laser Spot Scanning Method", the 6th ATC, Hon Kong, Aug. 22-24, 2001