A METHOD FOR ESTIMATING THE SPINNING POTENTIAL YARN (SPY) NUMBER FOR COTTON SPUN ON THE ROTOR SYSTEM

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Abstract

A test for determining spinning potential of cotton fibers on the rotor spinning system is proposed. It is based on the minimum twist required to rotor spin a fixed yarn size. Using known mathematical relationships inherent in the physics of yarn formation, the minimum twist results are transformed into the theoretically finest yarn count that may be spun commercially. The validity of these conclusions is empirically tested and verified on twenty different cotton samples. Implications about the effects of some key fiber properties on rotor spinning performance are clarified.

Introduction

A "spinning potential yarn number" (SPY) test for cotton fibers spun on the ring system was developed and applied during the 1950's and 1960's [2,3,6]. The test was codified in ASTM standards (no. D2811) in 1960[1].

This paper contains a preliminary report on a procedure for a SPY test for cotton spun on the rotor system. After a brief review of the SPY test for ring spinning , a SPY test method applicable to rotor spinning technology is explained. Then laboratory procedures are described and results are given. These results were followed by full-fledged spinning runs that verified the accuracy of the estimated SPY numbers. Finally, some useful implications about the impact of fiber properties on rotor spinning performance are discussed.

The Existing SPY Test for Ring Spinning [6]

The existing test procedure to determine the SPY for ring spun cotton requires selecting a yarn number (based on subjective judgment), then spinning the fiber on 96 spindles for a 15-minute warm-up period, followed by a 1-hour test run. If the number of end breaks during the 15-minute warm-up is less than 4 or greater than 20, the frame is stopped and a different yarn number is selected. This trial-and-error procedure is repeated until breakage is in the 4-to-20 interval. Then the 1-hour test run is completed and the final spinning potential yarn number is estimated as follows:

- The English yarn count (Ne) is determined from actual spinning tests and is adjusted for deviation from the nominal (i.e., the targeted) yarn count, as well as for deviation from the standard traveler number and twist.
- The yarn count is adjusted to a level that theoretically reduces the actual number of end breakages to zero; this is the final SPY number.

The formula used to compute the SPY is the following:

$$\begin{aligned} SPY &= 2(Na) - (Nn) - 0.2B \\ &= Na - e - 0.2B \qquad (1) \end{aligned}$$

where

SPY ≡ Spinning potential yarn number (expressed as English yarn count, Ne)
Na ≡ Actual yarn count
Nn ≡ Nominal yarn count
B ≡ Number of spindles with end breakage
e ≡ Nn - Na ≡ error in actual yarn count

Two observations should be made about equation (1):

- Neither the formal nor the informal record on development and application of the ring SPY test contains explanation or justification of the term -0.2B in equation (1). Since there is no theoretical justification, it must be surmised that it was determined by empirical testing done during the 1950's. Therefore, prudence would demand that its empirical validity be verified on modern ring spinning frames.

- It is also not explained in the literature why the actual yarn count (Na) is doubled but the nominal yarn count (Nn) is not. The second line of equation (1) was added to indicate that the formulation results in an adjustment for the failure to always spin the exact yarn count targeted in the test procedure.

It is also noteworthy that the test procedures for the ring SPY number pose some inherent ambiguities and dilemmas. In particular, its trial-and-error approach based on yarn sizes is inconsistent with fixed machinery settings, all the way from opening through spinning. If the yarn number is altered substantially from operator expectations, machine settings may become sub-optimal, sliver weights may cease to be optimal, etc. A superior test procedure would be one that allowed the designated machine settings to be optimized regardless of the SPY number ultimately obtained. This was a fundamental consideration in development of a SPY test for rotor spinning.

A SPY Test Method for Rotor Spinning

An obvious starting point for a rotor SPY test is with the fact that, in order to spin continuously, the dynamic

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strength of the yarn must be greater than the spinning tension. An illustration of the yarn formation zone of a rotor spin box is shown in Figure 1. Yarn strength at the peeling point (A) must exceed the spinning tension or most end breakage will occur at that point. End breakages may occur at other points; however, they can be attributed to machine settings and will not be considered for this study.

The strength of a yarn (S) may be determined from the following formula:

$$S = \beta \cdot \mu \cdot M \cdot t \qquad (2)$$

where

β ≡ a constant resulting from multiple machine factors
μ ≡ fiber surface friction
M ≡ linear density of a yarn in tex (number of fibers in a cross section of yarn)
t ≡ twist multiplier in the twist zone

As indicated above, the minimum possible value of S (call it $S_{\min}$) is that value required for the spinning process to continue without an end breakage. Thus, $S_{\min}$ provides an indication of the spinning limit for a specified type of fiber under specified spinning conditions.

The next step requires the information illustrated in Figure 2; namely, that $S_{\min}$ can be estimated either: (1) by determining the minimum twist ($t_{\min}$) for a fixed yarn number (M_o), or (2) by determining the minimum yarn number ($M_{\min}$) for a fixed twist (t_d). (Note: The notation t_d is used, instead of t, because it is assumed to be equal to the official twist multiplier recommended by the spinning machine manufacturer.) Appropriate estimation equations are the following:

$$S_{\min} \cong \beta \cdot \mu \cdot M_o \cdot t_{\min} \cong \beta \cdot \mu \cdot M_{\min} \cdot t_d \qquad (3)$$

It follows that

$$M_{\min} = M_o \cdot \left(\frac{t_{\min}}{t_d}\right) \qquad (4)$$

Because of multiple changes in spinning parameters from one yarn count (or twist) to another yarn count (or twist), the calculation for the potential yarn tex must be adjusted according to the following empirical formula:

$$M_{\min} = a \cdot M_o \cdot \left(\frac{t_{\min}}{t_d}\right) + b \qquad (5)$$

The commonly used English yarn count (Ne) is inversely related to $M_{\min}$; therefore, to find the maximum yarn count ($Ne_{\max}$), the following formulation is used:

$$\text{SPY} \equiv Ne_{\max} = \frac{591.33}{a \cdot M_0 \cdot \frac{t_{\min}}{t_d} + b} \qquad (6)$$

where the a and b are constants which capture the effects of variations accompanying changes in yarn sizes, such as: peeling tension, frictions between yarn and machine parts (e.g., rotor grooves, navels, etc.), levels of machine twist, changes in yarn density and torsion rigidity, etc.[4,5]

As a practical matter, a value for $t_{\min}$ cannot be exactly determined. It must be approximated, as it is in the ring SPY procedures, by limiting the end breaks to a small (and virtually linear) interval. Experimentation in ITC laboratories resulted in selection of an interval between 2 and 4 end breaks during a 15-minute spinning run. The twist that meets this criterion is called the "observed minimum twist" and denoted as t_{min}.

After t^1_{min} is determined, a 1-hour spinning run is done and the fiber-related end breaks (B) are counted. The formula for estimating t^1_{min} was determined to be the following:

$$t_{\min} = t^1_{min} - 0.04B \qquad (7)$$

where the coefficient for B was determined by successively increasing the twist multiplier in spinning of cotton fibers until accurate regression estimation of the relation between end breaks and twist multipliers could be achieved.

Using equation (7) and realizing that M_o and t_d will be assigned fixed values, equation (6) may be rewritten as follows:

$$\text{SPY} \equiv Ne_{max} = \frac{591.33}{d\,(t^1_{min} - 0.04B + b} \qquad (8)$$

where $d = \frac{a \cdot M_o}{t_d}$

The foregoing discussion reveals that, through as process focused on minimizing the twist multiplier for a fixed yarn size, an estimate of the SPY number relevant to rotor spinning is obtained. Once the experimental constants a and b are empirically determined and are used with the procedure described, the many complications associated with variations in yarn sizes do not impose on the execution of this SPY test procedure.

Experimental Procedures and Results

All spinning was done on a Schlafhorst Autocoro SE-9 with the following machine set-up:

Rotor/rpm -------------- G231/100k
Combing Roller/rpm - G174DN/7.5k

Navel ------------------- 8-grove ceramic
Torque Device-------- TS-37
Sliver weight ---------- 55gm/yd finisher drawing

A summary of the procedure used to estimate all necessary parameters treated in the previous section is given below:

1. Creel 24 positions and set length informator; piece up all positions once. Begin running and alter twist multiplier until end breaks fall within the acceptable range of 2 to 4 within a 15-minute run, thus determining the observed minimum twist (t^1_{min}).

2. Clear all rotors, piece up 24 spinning positions, then spin for one hour.

3. Record positions with ends-down and identify cause of break. Count only the fiber-related end breaks (B). Do not piece-up end breaks.

4. Calculate the minimum twist(t_{min}) according to equation (7).

5. Follow through with spinning of successively finer yarn counts in order to obtain estimates of all necessary parameters contained in equation (6).

The above procedure was done for 20 cotton samples with diverse fiber properties. A summary of the fiber properties for the sample cottons, as measured by HVI, is given in Table 1.

Major experimental results for these same samples are summarized in Table 2. These results provide the basis for determining parameter estimates for equation (8) as follows:

$$\mathrm{SPY} \equiv Ne_{\mathrm{max}} = \frac{591.33}{4.054 \cdot (t^1_{min} - 0.04B + 1.692} \qquad (9)$$

While the parametric values given in equation (9) may be subject to further refinements, we believe that they are adequate for deriving the SPY number after t^1_{min}. has been determined for any given cotton sample.

Some Related Conclusions Regarding Impacts of Fiber Properties

Fiber Fineness

Figure 3 demonstrates that the rotor SPY number is inversely related to micronaire values. Thus, the thinner the cotton fiber, the finer the yarn that can be spun. This is because more fibers can be packed into a cross section of yarn, resulting in an increase in the dynamic strength of the yarn.

Fiber Length

Figure 4 illustrates the non-linear relationship between fiber length and the SPY number. The SPY number increases until the fiber length reaches 1.05 to 1.07 inches, then begins to decrease with longer fibers. There is no doubt that such results will vary with the diameter of the rotor used. The 31mm rotor used in this investigation is typical, but it is small enough to cause increased "wrapping" of longer fibers, thereby disadvantaging them in the rotor spinning process.

Fiber strength

The rotor SPY number is insensitive to variations in fiber strength. While this will seem counter-intuitive to many, it follows from the fact that the peeling tension (re. Figure 1) is not great enough to break fibers. Therefore, when an end break does occur at the peel point, it is due to insufficient friction between fibers. This serves to remind that SPY tests have never been useful indicators about the adequacy of yarn strength. Even with ring spinning, which exerts substantially more spinning tension than does the rotor system, the correlation between SPY tests and yarn strengths is poor.

Summary and Conclusion

A theoretical and empirical analysis was done to develop a convenient method for determining the spinning potential yarn number on the rotor spinning system. The proposed test utilizes a fixed yarn size and determines the minimum twist needed to successfully spin yarn. Based on the results, a reliable estimate of the SPY number made. A fundamental advantage of this method is that most of the complicated machine/fiber interaction effects are kept limited by holding the yarn size fixed. Lost time associated with excessive trial-and-error is greatly reduced.

The limited experimental work done with this rotor SPY test leads to the following conclusions:

- The finer the fiber, the higher the SPY number.
- As fiber length is increased, the SPY increases to a maximum then decreases.
- Fiber strength has practically no effect on the SPY number.

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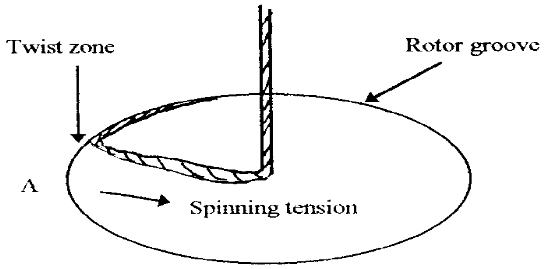

Figure 1. Rotor Spinning

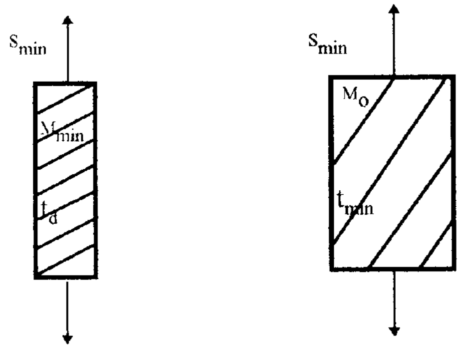

Figure 2. Relation of Yarn Strength to Yarn Number and Twist

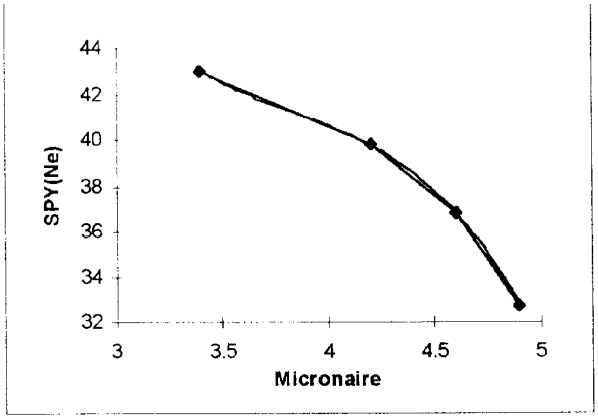

Figure. 3 Effect of Micronaire on SPY

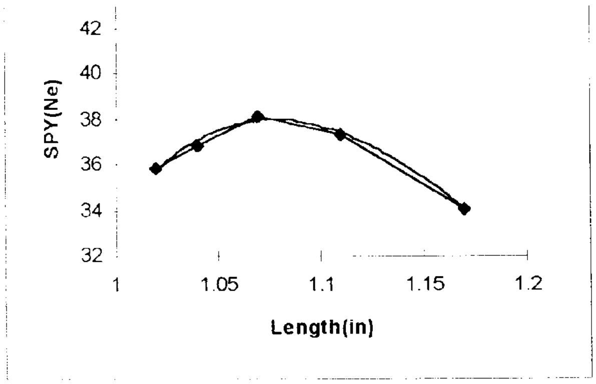

Figure 4 Effect of Fiber Length on SPY Number

Table 1. Fiber Properties

Sample number	Strength (g/tex)	Length (in)	Micronaire Index	Total Trash (No./g)
1	26.5	1.03	3.8	501
2	26.3	0.98	4.7	292
3	28.7	1.00	5.2	850
4	27.7	1.04	4.9	366
5	26.8	1.04	3.4	973
6	29.3	1.01	4.2	553
7	27.8	1.03	5.1	717
8	25.0	1.11	4.3	402
9	30.3	1.05	4.9	254
10	25.4	1.07	4.6	255
11	32.3	1.17	4.5	270
12	32.5	1.2	3.9	973
13	30.8	1.14	3.2	584
14	28.2	1.05	4.2	380
15	27.1	1.04	4.6	629
16	34.4	1.20	3.9	607
17	35.6	1.16	3.9	485
18	31.3	1.09	4.5	252
19	36.7	1.23	3.4	900
20	29.4	1.02	4.7	311

Table 2. Experimental Results

Sample number	t'_{min}	B	t_{min}	SPY
1	3.64	13	3.12	39.85
2	3.82	11	3.38	37.70
3	3.74	7	3.46	38.57
4	4.31	11	3.87	33.26
5	3.35	9	2.99	42.87
6	3.99	11	3.55	36.08
7	3.57	10	3.17	40.28
8	3.90	6	3.66	37.30
9	4.04	12	3.56	35.50
10	3.82	12	3.44	37.80
11	4.22	9	3.86	34.28
12	4.10	13	3.58	35.10
13	3.90	6	3.66	36.94
14	3.57	11	3.13	40.34
15	3.90	9	3.54	36.97
16	4.10	15	3.50	35.10
17	4.36	13	3.84	33.00
18	4.10	13	3.58	35.00
19	4.22	13	3.70	34.00
20	3.99	10	3.59	36.00