A NEW APPROACH TO MEASURING COTTON SPINNABILITY LIMITS

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Abstract

The spinnability limit of a cotton fiber with given properties refers to the finest possible yarn count that can be produced below a tolerance threshold of yarn ends down. This threshold usually depends on the expectations and on the production conditions of each spinning mill. Traditionally, the spinnability limit is measured by monitoring the end-breakage rate while spinning increasingly finer yarns. This study evaluated a new methodology that determines the spinnability limits based on yarn quality criteria. The new methodology enabled prompt and valid determination of spinnability limits. Two spinning methods were tested with a range of cotton and cotton/polyester laydowns. Results show a significant impact of both the spinning process and the blend composition on the spinnability limit.

Introduction

Today, cotton breeding and biotechnology efforts are increasingly emphasizing fiber quality in addition to yield. As a result, fiber quality of U.S. cotton has undergone significant improvements in recent years. For instance, in 2003 the average staple of all cotton classed reached or exceeded 35 at only three classing offices when in 2004 this average reached or exceeded 35 at seven classing offices (Robinson, 2005). The most striking quality improvement is seen in classing offices serving West Texas. From 2000 to 2006 the most remarkable change was in the HVI fiber length, which went from an average of 1 inch (32 32nds) to over 1⅛ inch (36 32nds). The HVI strength also increased from an average 27 grams/tex to over 29 grams/tex (Krifa and Ethridge, 2007).

In addition to the evolution of fiber properties, spinning technology has also evolved and new spinning methods (air jet, vortex, compact spinning) have emerged with new demands on fiber quality. As a result of this evolution, the interactions among fiber properties, machine parameters and processing performance have also changed and in most cases have become more complex and less readily predictable. The complexity of predicting these interactions is even more apparent when multiple instruments yielding a wide range of quality parameters are used to measure fiber properties. Often, the massive amount of data and the intricate interactions between the various parameters represent major deterrents preventing the useful prediction of cotton spinnability. According to Langenhove and Sette (2002), no mathematical models exist that predict spinnability because of the vast amount of fiber properties, yarn characteristics and the multiple complex interdependences between process parameters.

Traditionally, the spinning process is evaluated through monitoring the end-breakage rate (Graham and Taylor, 1978). In other words, the spinnability limit is defined as the finest count yarn that can be produced below a tolerable threshold of yarn breakage rate (Krifa and Ethridge, 2004). Under normal spinning conditions the low frequency of yarn ends-down requires long tests to obtain an accurate measurement of cotton spinning performance. The ASTM standard method D2811-77 (1991) describes four different options for testing cotton spinnability with the number of spindle hours running from 84 (small laboratory scale) to 25,000 (mill scale). The laboratory scale option is presented as a rough screening method. Early investigation by Ruby and Parsons (1949) suggested a minimum number of 5,000 spindle hours to achieve acceptable accuracy under controlled testing conditions. All these methods rely on the number of ends-down as the only criterion of spinning potential although it appears intuitive that the spinning performance should capture both the suitability of a given fiber to be spun with few ends-down and its potential to yield a yarn with acceptable quality levels.

An approach to spinnability that captures the quality component was first reported by Krifa and Ethridge (2004). The authors demonstrated that the spinning limit can be determined based on yarn quality criteria with sufficient accuracy after relatively short spinning tests when compared to the end breakage criterion. As the yarn quality criteria, the number of yarn thin places was chosen for two reasons. First, for the finer count yarns the number of thin places is the most sensitive yarn defect (Krifa and Ethridge, 2004). Second, thin places are often cited as the most quality and process disrupting yarn faults.

Krifa and Ethridge (2004) found the relation between thin places and ring spun yarn count to be segmented, with one linear segment covering the coarser range of yarn count and one curvilinear segment on the finer range. The linear segment of the relation covers a range where the number of thin places increases slowly as the yarn gets finer, and the curvilinear segment corresponds to a steep increase rate of thin places with yarn fineness. More recent studies corroborated the authors' approach of incorporating yarn quality criteria into the spinnability limit methods. For instance, Lappage (2005) demonstrated that the end breakage rate variation was consistent with the frequency of thin places.

The fundamental objective of this study is to expand the new spinnability concept to various fiber blends and spinning conditions. In what follows, we examine the yarn count-thin places relation for different laydown compositions and different spinning processes using the linear-quadratic model developed by Krifa and Ethridge (2004).

Material and Methods

Five laydowns were constituted using one medium-staple cotton bale and two types of polyester with different levels of fineness.

- Laydown 1: 100 % medium staple cotton with Micronaire 4.0, UHML (upper half mean length) 1.1 inch, Uniformity index 82.4 %, and Strength 28.9 g/tex.
- Laydown 2: Cotton / Polyester blend, 70/30%, with polyester 1.5 inch long and 2.25 denier fineness. Intimate blending was processed from feeding hopper.
- Laydown 3: Cotton / Polyester blend, 70/30%, with polyester 1.5 inch long and 2.25 denier fineness. The polyester was added after the cotton went through the fine opening to prevent breakage of polyester fibers.
- Laydown 4: Cotton / Polyester blend, 70/30%, with polyester 1.5 inch long and 1.5 denier fineness. The polyester was added after the cotton went through the fine opening.
- Laydown 5: Cotton / Polyester blend, 70/30%, with polyester 1.5 inch long and 1.2 denier fineness. The polyester was added after the cotton went through the fine opening.

Each fiber lot (100% cotton and blend-preparation combinations) was processed through drawing, roving and ring spinning. Fibers were spun into a range of medium-fine to fine yarn counts (> 36 Ne). Each sample was spun with both conventional and compact ring spinning frames using the same roving lots. Spinning was started at 36 Ne and continued to finer yarn count up to 90 Ne or until spinning was impossible due to excessive ends-down, whichever occurred first. The yarn samples were tested for evenness using a Uster® Tester 3.

Results and Discussion

As mentioned above the previous study used a linear-quadratic fit to model the relationship between the yarn count and the number of thin places (Krifa and Ethridge, 2004). In this study, we apply the same model to the results obtained with the various blends and spinning processes.

Figure 1 depicts the scatter plots relating the number of thin places to yarn count for the five laydowns spun on the conventional ring spinning frame. The five laydowns are represented by different point markers. Figure 2 shows a similar representation of the data obtained on the compact spinning frame.

The results show the same curvilinear pattern for all of the laydowns in this study. For all the laydowns, the number of thin places increases slowly for coarse yarn counts, then more rapidly as the yarn gets finer. Once we get to the finer yarn counts, a separation can be seen between the blends of different polyester fineness mixed with cotton. The blends with coarser polyester fibers (laydowns 2 and 3) did not demonstrate a significant difference from the 100% cotton (laydown 1). On the other hand, the addition of the finer polyester fiber (laydowns 4 and 5) appears to affect the relationship. It is apparent from the Figures that the scatter plots representing these two mixes (laydowns 4 and 5) stray significantly toward lower thin places counts from that representing the 100% cotton. In addition to laydown composition, two different blending methods were applied to laydowns 2 and 3 (see above). There was no significant indication of a difference between these two blending methods.

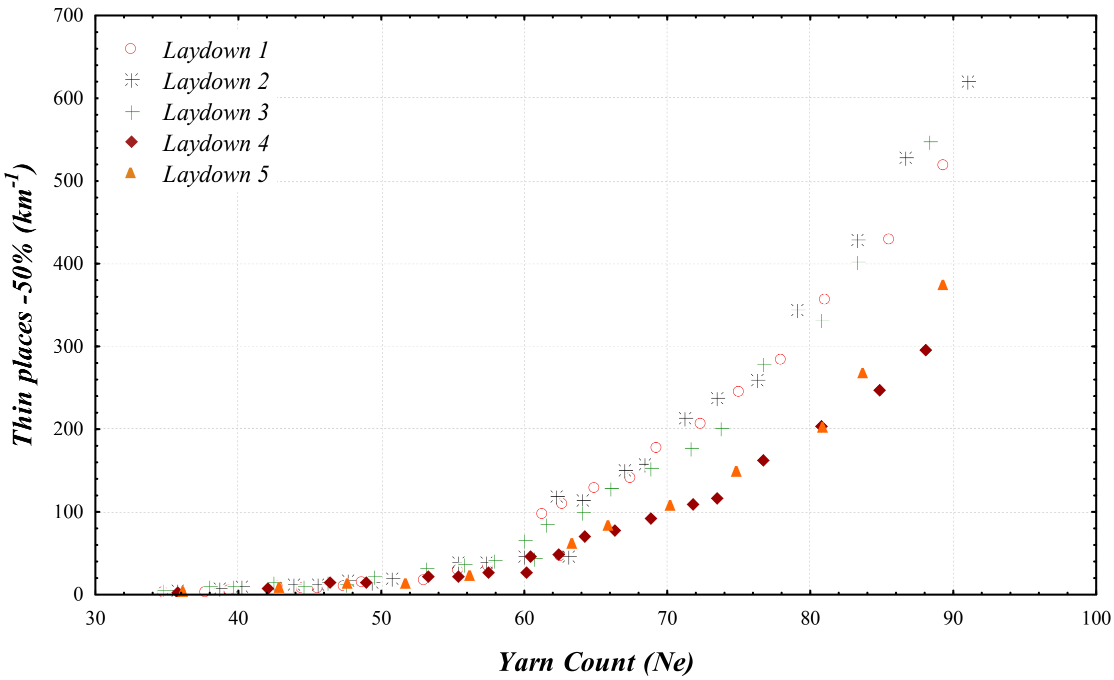

Figure 1: Thin places vs. yarn count for the 5 laydowns – conventional ring spinning.

The compact spun yarn demonstrated the same trend among the five laydowns as the conventional ring spun yarn (Figure 2). The rate of increase of thin places was also low for coarse yarn counts. With the increase of yarn fineness we see a rapid increase of the number of thin places. Once again, there appears to be a significant impact of the addition of the finer polyester, no impact of the coarse polyester and no significant difference between the laydowns processed with two different blending methods.

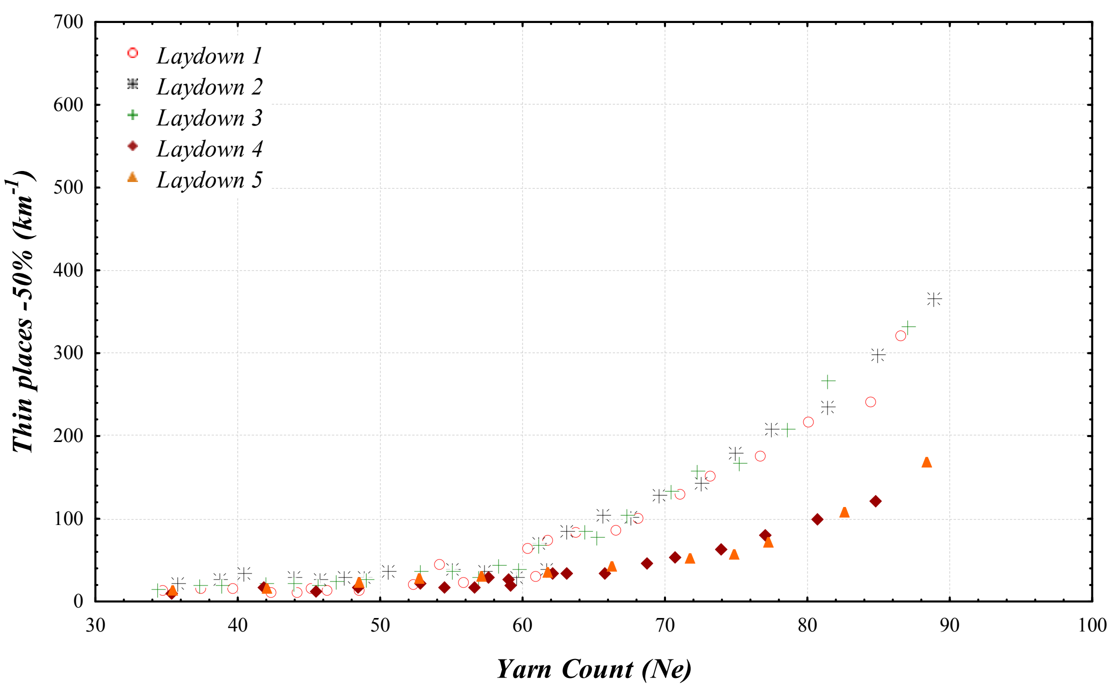

Figure 2: Thin places vs. yarn count for the 5 laydowns – compact ring spinning.

In general, there was a decline of the number of thin places with compact ring spinning. This decline is apparent when examining the range of fine yarn counts. For instance, when considering the finest yarn count, the first three laydowns show numbers of thin places that went down to 400 from 600. For the other two laydowns (4 and 5) this number went down to 200 from 400.

The observations made above based on the number of thin places suggest significant differences in spinnability among fiber mixes and spinning conditions. However, the spinning limit as defined by Krifa and Ethridge (2004) is not the absolute number of thin places. Rather, it is the break point at which the slope of the thin places-yarn count curve changes from linear to curvilinear. The linear segment of the curve illustrates a spinning range where the number of thin places is limited to a low level. Beyond this linear segment, the number and the variance of thin places increase very rapidly.

The break point between the two zones was estimated using the linear-quadratic model (Krifa and Ethridge, 2004). The fits are shown for the two extreme laydowns (with the lowest and highest break points) on Figures 3 and 4 for conventional and compact spun yarns, respectively. A summary of the break point estimates is also shown in Table 1.

For conventional ring spinning, the break point value ranged from 44.9 Ne (laydown 1) to 53.7 Ne (laydown 5). On the other hand, the break point range in compact spinning was 44.1 Ne (laydown 1) to 69.01 Ne (laydown 5). These break points are clearly pointed out on both Figures 3 and 4 with vertical lines.

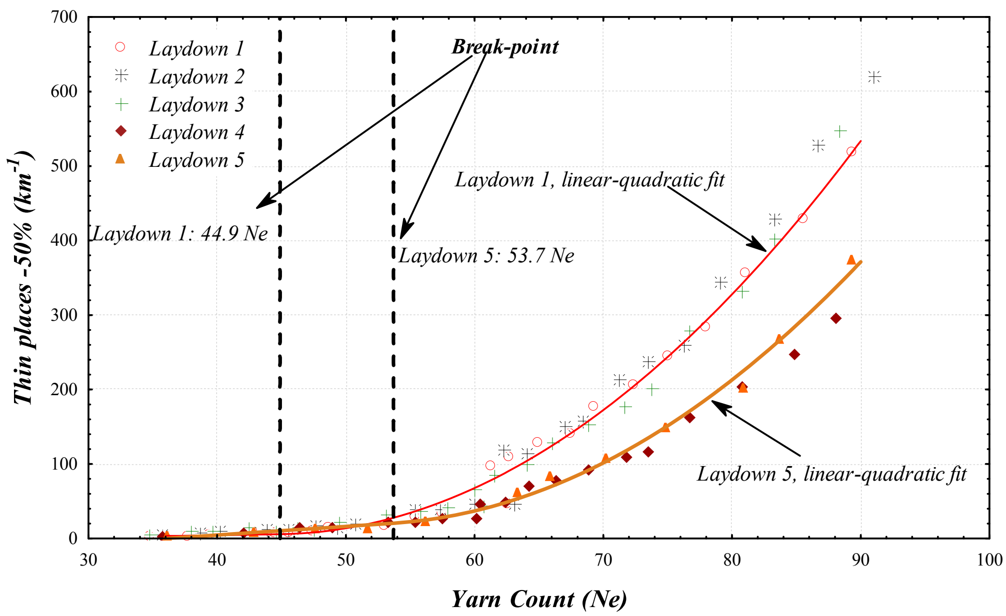

Figure 3: Linear-quadratic fit – conventional yarn.

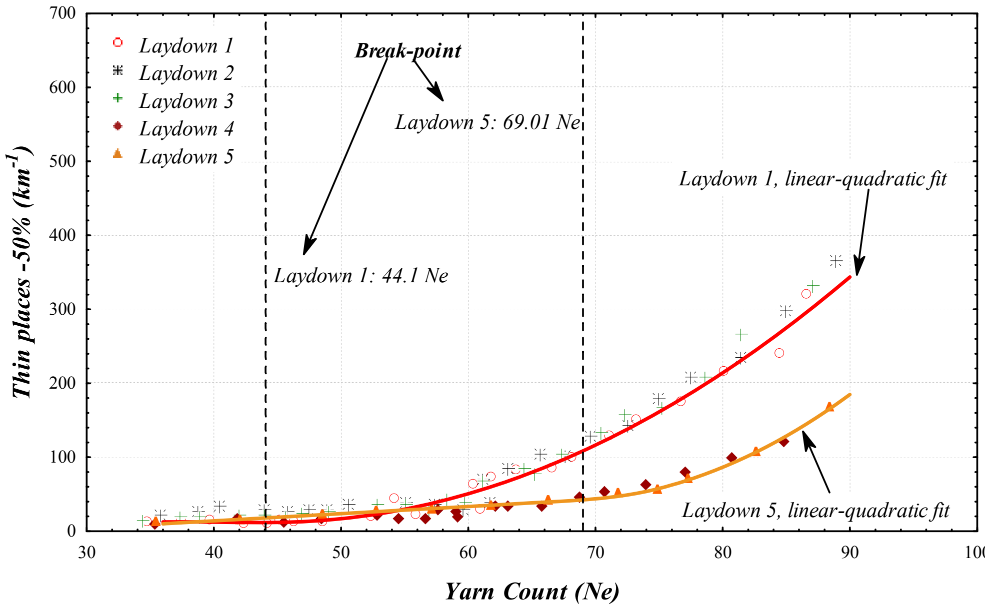

Figure 4: Linear-quadratic fit – compact yarn.

All the spinning-limit estimates, i.e., the break points for the five laydowns are listed in Table 1. These results are also graphed in Figure 5. The variation in spinning limits among laydowns was higher with compact yarns than with the conventional counterparts. It appears from these results that the blends with finer polyester fibers interacted with the compact spinning better than with conventional spinning. Indeed, the range between the lowest and highest break points (laydowns 1 and 5 respectively) is wider in compact spinning than in conventional spinning. Quite interestingly, the difference between break points obtained with conventional and compact spinning are only apparent for laydowns containing the fine polyester types (laydowns 4 and 5). The break points of the first three laydowns for both conventional and compact spinning were more or less found to be the same. There is a slight increase in break point with polyester blends with the conventional ring spinning. In compact spinning this increase is more obvious especially with the finer polyester fiber blends.

Table 1: Linear-quadratic fit breakpoints for all samples

Fiber	Break-point (Ne) Conventional yarn	Break-point (Ne) Compact yarn
Laydown 1	44.89	44.09
Laydown 2	48.58	48.90
Laydown 3	52.13	49.02
Laydown 4	50.31	53.98
Laydown 5	53.74	69.01

The results above indicate that compact spinning may make better use of finer fibers than conventional spinning does. This result is corroborated by the literature dealing with compact spinning. For instance, Cheng and Yu (2003) suggested that coarser fibers may decrease the effectiveness of the compact spinning system because the suction current is unable to control and straighten individual fibers unless fibers are combed. More recently, Krifa and Ethridge (2006) showed that the effectiveness of compact spinning also depends on a variety of fiber properties including length and length uniformity.

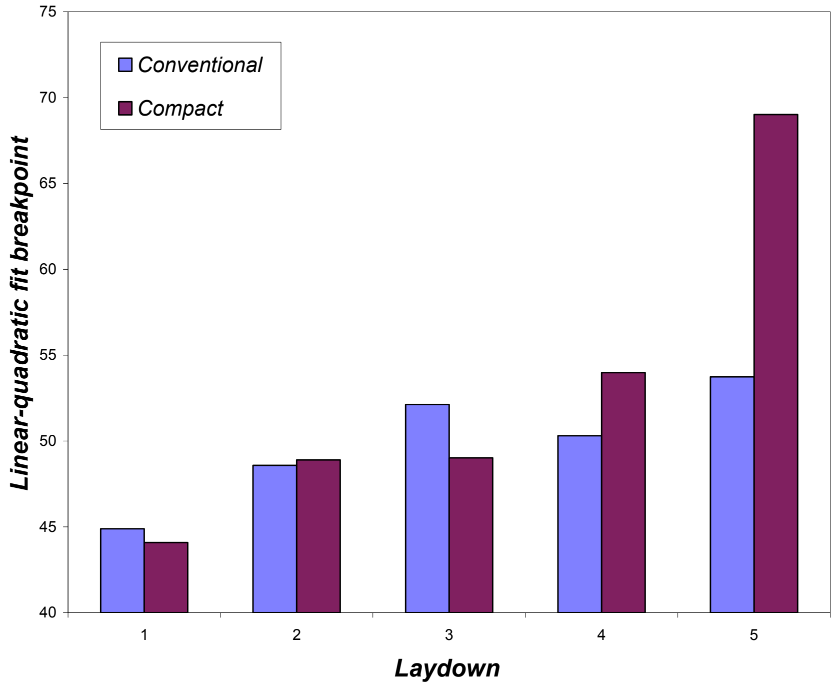

Figure 5: Break points of each laydown for both spinning methods.

Conclusion

In conclusion, this study expands the results of the previously developed model determining the spinnability limits based on yarn quality criteria by including different blends and spinning methods. The spinning limit was defined as the break point between the two segments of a curvilinear relationship of yarn count and thin places. Using this approach the impact on spinnability of blending cotton and polyester of different fineness levels was determined for both conventional and compact spinning. Although there is a trend for a higher spinnability limits when adding polyester with conventional spinning the addition of fine polyester in conjunction with compact spinning appeared to have the greatest impact.

Acknowledgement

The results shown here are part of a research supported by the Texas Department of Agriculture – Food and Fibers Research.

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