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TEXTILE TECHNOLOGY

History and Experiences with Small-Scale SampleEvaluations of Cotton, and Potential for Improvement

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ABSTRACT

The origin of the Small-Scale Spinning Test, which is used to characterize the quality of samples of cotton weighing between 15 and 30lbs (6.8 and 13.6 kg), lies in the annual cotton crop assessments performed by the USDA's Agricultural Marketing Service and the Textile Research Center of Texas Tech University. Each program of evaluation involved thorough testing of the raw cotton followed by the ring spinning of at least two yarns by the ring spinning route. The machinery used was of industrial size to emulate production conditions. The Small-Scale Spinning Test advocated by the USDA's SRRC has been extended to include fabric manufacture, yet condensed by a need to conserve space that has required the elimination of one drawframe from the sequence of machines employed.

The objectives of this study are three-fold;

- **to describe the evolution of the Small-Scale Spinning Test, and its execution,**
- **to examine the importance of the drawframe in the process, and**
- **to identify a new method of operation in which setup errors are minimized when the same machine is used to perform both passes of drawing.**

The use of 27tex (Ne22) yarn throughout more than 60 years of small-scale evaluations is noted. Control of linear density throughout processing is critical to minimize waste and machine downtime. Benefits can accrue from the use of autolevelling for both passes of drawing, and reducing the chances of error by eliminating four of the five changes previously required, as well as decreasing machine downtime.

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INTRODUCTION

The new millennium coincided with the advent of increased interest in the evaluation of small quantities of cotton. Rising imports of cheaper textiles into the United States reduced the domestic consumption of cotton by half in the decade 1997 to 2006 [Adams, 2002; Anonymous, 2008] causing a spate of textile mill closures that exceeded 215 from 1997 to 2002 [ATMI et al, 2002]. This sudden collapse had been preceded by the more gradual demise of the domestic textile machinery industry, which probably began in the 1960s, and was caused by the influx of more modern technology manufactured primarily in Europe and Japan.

For the cotton research program at the Southern Regional Research Center (SRRC) of the Agricultural Research Service (ARS) of the United States Department of Agriculture (USDA), these changes had an influence on the program's direction; there was little rationale for the continued existence of research into machinery or process development. The diminished demand for cotton in the US meant that greater efforts were required to ensure that US cottons would be competitive in international markets. Thus, in 2004, the three cotton research units at SRRC were reorganized into two, one of which was named Cotton Structure and Quality Research Unit (CSQRU). The research thrust of CSQRU was, and is, to identify those properties of cotton that need to be quantified and the development of instruments and procedures to do so.

One immediate benefit of reorganization was the establishment of centralized testing in the form of the Fiber Quality Evaluation Laboratory (FQEL). In addition to the textile testing facilities of the three previous research units, the FQEL acquired the machinery of the textile pilot plant to be used to produce specified yarns under standard processing conditions, minimizing variation between lots.

Three levels of sample processing can be considered within the auspices of the FQEL, which can be described as micro-spinning, mini-spinning, and small-scale spinning. In the simplest terms, the three differ by catering to quantities that differ by about one order of magnitude. Studies have been performed to demonstrate the association between the properties of yarn produced from the different levels of processing [Krifa and Ethridge, 2003; Price and Meredith, 2004; Krifa *et al*, 2007], since the object of such tests is to be able to estimate performance under industrial conditions from the products of each protocol. Micro-spinning involves the processing of 50 – 100g (ca. 1.5 – 3.5 oz) of raw cotton into yarn of about 27 tex (Ne 22), and utilizes special machinery and techniques that are adaptations of industrial processes, although the processing principles are the same [Landstreet, *et al*, 1962]. Fiber and yarn properties are determined and sufficient yarn may be produced to knit a small swatch of plain knit fabric. Mini-spinning is conducted with a quantity of raw cotton of 750 – 2000g (ca. 1.5 – 4.5lb), with the potential of producing three yarns by both ring and rotor spinning techniques. Sufficient yarn can be produced to provide a homogeneous woven or knitted fabric. Conventional cotton processing machinery can be used with a procedural modification, namely, the elimination of the opening line to eliminate the danger of significant loss of sample [Price *et al*, 2001]. The utilization of machinery developed for micro-spinning is also a possible alternative for mini-spinning. Fiber, yarn and some fabric properties, can be obtained by this test.

Small-scale sample evaluations typically utilize 7.0 - 14 kg (ca. 15 - 30 lb) of raw cotton, and permit the production of greater quantities of yarn and potentially larger areas of fabric, if required. The increased quantity of cotton provides significant security against accidental loss, and some indication of processability such as an estimate of spinning performance, may be expected together with fiber, yarn and fabric data to characterize the cotton sample.

The three objectives of this study are

- to describe the evolution of the Small-Scale Spinning Test, and its procedure,
- to examine the importance of the drawframe in the process, and
- to identify a new method of operation in which setup errors are minimized when the same machine is used to perform both passes of drawing.

THE SMALL-SCALE SAMPLING PROTOCOL

The protocol used in the FQEL at SRRC for the processing of small-scale samples has its origins in the annual cotton fiber and processing tests studies conducted by the Agricultural Marketing Service (AMS) of the USDA, in Clemson, SC [USDA AMS, 1948-89] and by the Textile Research Center (TRC) of Texas Tech University, Lubbock, TX [TRC, 1981-92]. (The Textile Research Center was renamed the International Center for Textile Research and Development (ICTRD), then the International Textile Center (ITC) and now, quite recently, the Fiber and Biopolymer Research Institute (FBRI)). Both organizations performed annual evaluations of cotton crop quality for the textile industry as a whole. The AMS studies, begun in 1948 and continued until about 1989, provided data from the testing of raw cottons and certain yarns that were spun from them. The cottons were collected from selected gins throughout the area of US cotton production. In most studies, the yarns that were spun were carded yarns of 27 tex (Ne 22) and 16.4 tex (Ne 36), and combed yarns of 16.4 tex (Ne 36) and 11.8 tex (Ne 50). Equations, particularly for yarn properties, were derived by regression on selected fiber properties, which provided an insight into the utility of the fiber tests that were available at that time. In addition, an assessment of the quality of the crop was made.

The program was subsequently revised to provide a survey of leading cotton varieties, a program that ended with the evaluation of the crop of 1994 [USDA AMS, 1995]. The studies were performed with different, contemporary textile machinery at higher speeds to produce yarn from the most popular cotton cultivars that were grown in the various cotton growing areas of the United States. Three yarns were rotor spun 59 tex (Ne 10), 37 tex (Ne 16), and 27 tex (Ne 22), and three yarns were ring spun from carded stock, namely, 27 tex (Ne 22), 16.4 tex (Ne 36) and 11.8 tex (Ne 50) yarn. In addition, the ring yarns of the same linear density were spun from combed cottons grown in the Far West area (Arizona and California) that would allow additional information to complement the database of the annual Acala Cotton Board variety trials performed in that decade. (The Acala Cotton Board has been superseded by the San Joaquin Valley Cotton Board.)

The annual evaluations performed at the TRC/ITC were performed to demonstrate the quality of Texas cottons. These crop studies began about 1979 at a time when both High Volume Instrument (HVI) testing and rotor spinning were becoming established, serving a very useful purpose in introducing HVI data and Texas cotton quality to a rotor-spinning market. Initially, rotor yarns of 59 tex (Ne 10), 37 tex (Ne 16), and 27 tex (Ne 22) were spun from two designs of machine, which was extended to include 98 tex (Ne 6). When automated piecing was introduced on rotor spinning machines the range of yarns was changed, eliminating 98 tex (Ne 6) and 37 tex (Ne 16) yarns, and introducing 19.7 tex (Ne 30) yarn to the range. Ring yarns of 37 tex (Ne 16), 27 tex (Ne 22) and 19.7 tex (Ne 30) yarn were spun throughout. The range of yarns spun reflected the application of rotor spinning technology to the production of coarser yarns, and the ring yarns provided a range that defined a spinning limit for certain qualities of Texas cotton. Higher production speeds with rotor spinning machines made finer yarns economically feasible so finer rotor yarn data were made available, and direct comparisons could be made between yarns produced by different spinning technologies and different designs of machine. It is noteworthy that yarns of 27 tex (Ne22) are common to evaluations of carded cotton in both AMS and ITC evaluations. Typically, nine yarns were spun from about 13 kg (ca. 29 lb) of raw cotton taken from a commercially-produced bale. The raw cotton was converted to feedstock for spinning with machinery used in the cotton industry, at running specifications that were within the expected ranges for the state of the technology. Fiber samples, captured from the bale, and the batt supplied to the card, were tested using a comprehensive range of HVI and ‘individual’ instruments. The latter were a group of manually operated instruments that included the Stelometer, Digital Fibrograph, and Shirley Analyzer. Waste was collected from the various cleaning points in the blowroom, and expressed as a percentage of the total weight of collected material. From time to time, the data were used in regression analyses to study the influence of fiber properties on yarn properties. The reports of the evaluation were circulated to interested parties in commerce and industry, and the protocol formed the basis for many studies performed at the ITC.

Although evaluations were conducted with similar quantities of cottons on previous occasions, the first SRRC study that produced yarns capable of direct comparison with those produced in crop studies performed by AMS and TRC/ITC was performed in 1996 [Meredith & Price, 1996] and repeated in 1997. Similar procedures were used to those performed at TRC/ITC; commercially-sized machines were operated at technologically representative speeds to produce yarns that were characterized in terms of their mechanical properties. The properties of the yarns were used for analysis with data provided by fiber samples. The sequence of machines used in these two studies is shown in Figure 1, and is essentially the same as that of the small-scale evaluation protocol of the FQEL except for the use of an earlier version of the rotor spinning machine. This later protocol added the collection of fiber samples from a few more collection points in the blowroom and the production of fabric using 27 tex (Ne22) yarn spun from residual cotton sliver. In 2004, the protocol offered the knitting of a plain fabric using an FAK knitting machine with a cylinder diameter of 254 mm (10 in.). Woven fabric could also be produced, weaving the yarn as filling across a common warp in either plain or sateen construction [Delhom *et al*, 2005]. Recent machinery acquisitions (2008) permit less wasteful means of producing an area of stable homogeneous fabric from yarn spun in the small-scale sample protocol that is sufficient for testing. The CCI sample weaving system manufactured by CCI Tech, Inc, Taipei, Taiwan, produces about 2 m (2.2 yd) of woven fabric from about 0.2 kg (0.44lb) of yarn. A double-jersey machine has also been added to the set of available machines to permit production of a short length of relatively stable knitted fabric for testing and inspection.

PRACTICES IN SMALL-SCALE SAMPLE PROCESSING

Procedure: The evaluation of small-scale samples utilizes the sequence of machinery shown in Figure 1 following the solid line. A subsample of cotton for fiber testing is taken from the lot of raw cotton (the ‘bale sample’). While the cotton is being processed, other subsamples may be taken immediately after each major cleaning point (inclined cleaner and fine opener, respectively), the reserve chamber of the feeder to the line of cards (Crosrol Twin-Feed Unit), and the batt of cotton being fed to the card. In collecting the sub samples of the product from the inclined cleaner and the fine opener, the cotton is captured by opening the output duct thus reducing the airflow at the doffing point of the machine. This could introduce a bias in the test data.

Further subsamples of the cotton may be collected from the product of subsequent stages in processing (sliver, roving, and yarn). Approximately 100g (ca. 0.2 lb) is collected at each point, which is sufficient for tests with the Uster AFIS Pro instrument. More can be collected to fulfill the needs of other tests that may be needed. There is sufficient reserve capacity in the Crosrol Twin Feed unit to collect larger quantities without starving the chute to the card, provided that no more than 800g (ca. 1.75 lb) is collected at any instant.

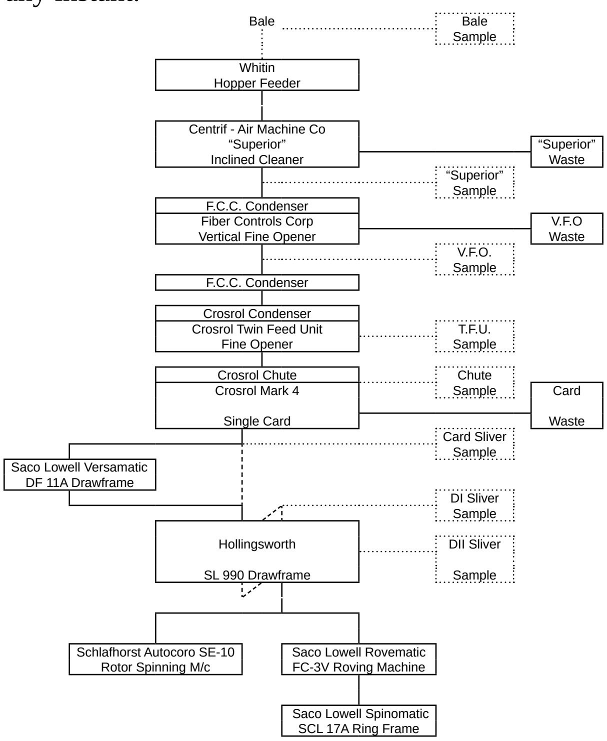

Figure 1: USDA ARS FQEL Small Sample Protocol

The collection of sub-samples has to be made within a period of about 8 minutes when processing a 7kg (ca.15lb) sample. Ideally, they should be collected at random intervals while the cotton lot is in process. In reality, sufficient cotton is garnered at one time except for the collection of batt sub-samples.

One method is to collect the batt sub-sample from the feed plate as the batt begins to be supplied by the chute. This is the most convenient method but there is a danger of including tufts of cotton that unfortunately are likely to remain in ducts, etc., from previous samples. While there is always a danger that they can be released at any time during processing, the greatest quantity is delivered at startup. This has been clearly observed after processing small samples of colored cotton [Price *et al*, 2001].

The desired technique is to collect the batt sub-sample while the card is in production. It is preferable to remove all obvious clumps of cotton that are twisted and entangled as the batt begins to be supplied to the card, and to proceed to complete the startup of the card. During the process of initiating delivery of fiber web from the card, gathering it and supplying the end of sliver to the coiler head, an opportunity is created to lose any contaminating fiber as start-up waste, which is collected as floor sweepings. There is also a delay between the time that sliver begins to be coiled in the can and the instant that the length counter of the card is set. This initial length of cotton sliver will be left as waste at the first pass of drawing as well as a length of sliver surplus to the requirement; a further opportunity for 'foreign' fibers to be removed. When running, small tufts of cotton can be plucked from the batt to provide the quantity required for testing. Caution must be taken to avoid removing too great a quantity, which can create holes of significant size being made in the web that may result in a stoppage of the carding machine (an "end-down"). An interruption in production at the card could lead to increased waste losses, and detectable changes in fiber properties due to fiber damage. Alternatively, a number of strips of convenient length, having the thickness of the batt and about 4 cm (ca. 1.5 in) wide can be taken from the side of the batt between chute and card. This may be preferred since the web density remains essentially constant across its width, as the selvage moves toward the center of the card coinciding with the point in the batt from which a strip was removed. In both cases, removal of fiber from the batt will increase the medium-long term variability in the sliver.

Collection of samples reduces the time available to monitor the performance of the card, in particular, the functioning of the autoleveller with regard to any adjustment of its setting. In reality, the card autoleveller is best left alone and kept at a fixed setting for all lots; constant tweaking of settings is more likely to produce increased variability in the linear density of the sliver by over-correction of deviations. Furthermore, the value of autolevelling at the card is questionable given the small quantities in process do not necessarily provide sufficient time for the system to stabilize. The autoleveller at the card is only capable of correcting long-term sliver variation and the modern draw-frame which follows in the processing sequence is very capable of correcting such weight variation.

Other factors may influence the linear density of card sliver. The history and properties of the cotton prior to processing may influence the density of the batt of fibers presented to the card. Cotton of low Micronaire value that have been compressed in a bale prior to shipment may provide a more dense batt than a cotton of high Micronaire value that has been manually harvested and bagged. Lack of processing time, sample collection procedures, fiber properties and storage history are all factors that could contribute to the variation of sliver linear density within and between sample lots.

Collection of Waste Material from Cleaners: The quantity of waste produced during the production of card sliver from the raw cotton is an indication of the quantity that can be removed from the blowroom and the cardroom of an industrial operation. It is a useful parameter in ginning research and, perhaps to a lesser extent, in breeding research, also. Collection and testing of samples of cotton at various points on the opening and cleaning process, as well as the products from the various preparatory machines, provide information on the variation in cotton quality due to fractionation at each process. In the blowroom, subsamples are taken while the machinery is running. Wastes are collected after processing the sample, as part of the clean up procedure between runs. Product samples (e.g. sliver) are taken from the "packaged" material. All subsamples of cotton and waste collected from the various opening and cleaning machines are weighed to provide an indication of the yields of material in relation to the quantity of cotton supplied. The time taken to perform these duties is a necessary part of the process. Consequently, there is no opportunity to improve sample processing times unless it is decided that such sub samples are not required. However, waste collection times will remain a necessary factor as part of the inter-sample clean-up procedure.

Drawing: The process of drawing is particularly important in the preparation of fiber for spinning. First, it improves the orientation of the fibers relative to the axis of the sliver. While progressing from one pair of rollers to another pair rotating at higher speed, the fibers are individually accelerated and straightened by the restraining forces of the slower moving fiber mass proffered by the input rollers. Second, there is a blending and evening action. About six slivers produced at different times are supplied simultaneously, which also has the benefit of averaging differences in linear density. Third, the drawframe provides the last point for autolevelling, whereby a mechanism is used to determine variations in the input sliver and adjust a speed (typically a pair of delivery rollers) that will correct the deviation in linear density from an average value.

Following industrial practice, the small-scale protocol employed two passes of drawing prior to roving in preparation for ring spinning. Originally, card sliver of 4.25 ktex (60 gr/yd) was supplied [Meredith & Price, 1996], which was reduced to 4.1 ktex (58 gr/yd), then 3.90 ktex (55 gr/yd) sliver in two drawframe passes, but this was changed later to 3.90 ktex (55 gr/yd) for all sliver [Delhom *et al*, 2005]. The first pass of drawing was performed without autolevelling, using the machinery manufacturer's recommendation [Hollingsworth Inc, 1992] of an intermediate draft of about 1.7, feeding six ends and producing six cans of sliver. Originally, this process was conducted with a Saco Lowell Versamatic DF 11A drawframe. The second pass was performed with a Hollingsworth 990SL drawframe, feeding six ends, using the autoleveller and the recommended intermediate draft of 1.4, to produce ten cans from which the required quantity of roving was produced. A nominal main draft of about 6 was employed for both passes of drawframe. The excess of sliver became the feedstock for rotor spinning, thereby minimizing the number of cans in use.

To maximize space utilization, the Saco Lowell DF11A drawframe was removed, since the two passes of drawing could be performed by the newer Hollingsworth 990SL machine that is equipped with an autoleveller, which may be engaged or disengaged. Instead of having one drawframe set up for a particular drawframe passage, one machine was required to perform two processes. On this particular design of drawframe, a change in drawframe pass would therefore require the following:

(a) a change in the Measuring Roll Tension Pulley
(b) a change in Intermediate Draft Change Gears, and probably, at the same time,
(c) a change in nominal Main Draft Gears
(d) toggling the autoleveller ON or OFF.
(e) checking that the Input Sliver Setting is correct.

Note that there is no provision for the alteration of ratch settings according to staple length within the protocol. The time taken for setting up the machine relative to the potential benefits in product quality were not considered to be justified at this scale and potential number of changes.

Whereas the act of changing gears is relatively straightforward with either design of drawframe, the pairs of gears that are required for either intermediate or nominal main draft change can be the same, yet be assigned to different shafts. Thus, there is an opportunity for errors to occur. Incorrectly fitting the nominal main draft gears would only be discovered by direct measurement of the sliver linear density, or the weight of a delivered sliver can, or by the discovery of insufficient or excess sliver remaining in the creel. Mixing the intermediate gears would probably remain undetected until the next gear change; an intermediate draft of 2.21 is possible instead of the required 1.38. The act of forgetting to activate the autoleveller or to use an incorrect sliver setting would also alter the linear density of the product, which can result in premature exhaustion of the sliver supplied to the drawframe.

Control of Sliver Mass: In the event that the yield of card sliver was less than expected, either by insufficient supply or mechanical mishap, it was common practice to determine the amount of cotton delivered to each can by weighing. To expedite the process, cans were labeled and their tare weight noted thereon. Knowledge of the length delivered to the can permitted calculation of the average linear density of the sliver produced. This method avoided the much slower, destructive method of cutting and weighing four one yard lengths of sliver cut using a template, which could be misleading if sliver was not autolevelled. For an accurate assessment, all cans would need to be tested. However, particularly with the small quantities of sliver produced per can (about 1.7 kg, i.e. 3.7 lb), errors could become significant from sources such as contamination of the pre-weighed cans, or underestimation of sliver lengths arising from either machine overfeed or imprecise or inconsistent manual doffing.

With approximately 13kg of cotton (ca. 29lb) there is sufficient material to accommodate such errors; however, when presented with the processing of smaller quantities of cotton within the small-scale protocol, greater care is necessary to have sufficient material to fulfill requirements. Thus, with variable quantities of supplied material, it became standard practice to determine the gross weight of all cans used for carded and drawn slivers to ascertain the weight of product at each process, calculating and adjusting delivered lengths as required for the next process. Inspection of the records provided a means of identifying those cans that consistently held seemingly heavy sliver, which could then be inspected for contamination, cleaned if needed, and reweighed.

Roving and Spinning: The draft gear for roving is determined by calculating the draft required to produce the 590 tex (1.0 hank) roving specified in the protocol, based on the sliver weight determined by weighing the cans of second pass drawframe sliver. So long as the linear density of the sliver remains under control, the production of roving will be trouble free. If the sliver is too heavy and the draft is not corrected then tension will increase with running time, and roving breaks at the presser bar and bobbin are likely. If the sliver is too light then the roving tension between delivery roll and spindle will decay until control of the textile material is lost, and ends fail due to contact with static surfaces. The quality of roving and subsequent products is compromised when the balance between delivery and take-up by the bobbin is disturbed.

At the spinning machine, the adopted procedure is to use the nominal value of the feedstock to determine the draft required for the yarn number to be spun, and appropriate gears fitted accordingly. Sufficient yarn is spun on five ends for the determination of yarn number (typically 200 meters or yards), and the draft adjusted by ratio and proportion for the production of the sample. In instances when six yarns (three ring spun, three rotor) may be produced, as many as 12 weighings may be performed in determining linear density, in addition to the weighing of at least 17 cans in sliver preparation, not including those that are necessary to determine the weights of product sub-samples and cleaner extracts. If the results of these weight determinations initiate gear or pulley changes, then the total time to produce the required quantities of yarn is significantly increased.

OPPORTUNITIES FOR INCREASED PRODUCTIVITY

In providing a service to cotton breeders, for example, where the quantity of cotton may be limited but the interest may be high in having as thorough an evaluation as possible, minimizing the loss of material becomes very important. Some loss of useful fiber is inevitable due to handling, such as start up and run out losses at the card, piecing losses, etc. but some losses can be avoided. On the other hand, the material needed (and wasted) in the direct method of determining linear density can be avoided if almost total reliance can be placed on the production of drawframe sliver of consistent linear density between different lots of cotton. With such a material, the need to determine the linear density at each production step is ideally eliminated, or at least reduced to one measurement from which other drafts, hence combinations of gears, may be predetermined. Under these conditions, not only is the loss of material reduced, but significant reductions in sample processing time will occur. In essence, reductions in the number of determinations and adjustment of the linear density of the product increase efficiency by decreasing machine downtime.

The critical machine is the drawframe. Earlier, it was shown that there are five potential sources of error that need to be monitored to assure consistent quality of product, when one drawframe is required to perform two passes of drawing where machine specifications are different. These are a change of Measuring Roll Tension Pulley, a change in Intermediate Draft Change Gears, a change of nominal Main Draft Gears, toggling the autoleveller ON or OFF, and checking that the Input Sliver Setting is correct. (Note: Throughout the text, nominal Main Draft refers to the overall draft of the 4-over-4 roller system as determined by the gearing when the autolevelling system is inactive.) If the changes between drawframe setups can be minimized then the likelihood of error is decreased, and there is further assurance of consistency of product quality with a likely reduction in machine changeover time. The importance of the control of linear density at the drawframe is discussed at some length elsewhere (Grover & Hamby, 1960)

Autolevelling: It is normal in industry for the first passage of drawing to be performed without autolevelling. Autolevelling at the second finisher pass is believed to be sufficient; additional autolevelling may increase short term irregularity if the autoleveller's response to a need for adjustment is not quite correct. Also a drawframe with an autoleveller is more expensive, and the outlay is unwarranted if one pass with autolevelling will suffice. If, however, the effects of two passes of autolevelling are not detrimental to product quality, then the likelihood of omitting to activate the autoleveller is removed. It can remain active for both passages.

When card sliver is supplied to the drawframe instead of drawn sliver, a higher measuring zone draft is required to prevent the sliver from sagging and contacting the upper surface of the machine. This is achieved by a simple change of timing belt pulley to alter the measuring zone draft from 0.998 to 1.012. Contact between sliver and a plane static surface is undesirable since it may initiate intermittent shear of the sliver that will not be detected and corrected by the autoleveller.

Draft Gearing: A greater intermediate draft is recommended when drawing card sliver (1.67) than for drawn sliver (1.38) (Hollingsworth Inc, 1992). If one intermediate draft can be used for both passes with no detectable loss in quality, then it would be desirable to do so to avoid gear changes.

It is possible to use the same nominal main draft for the drawframe in both passes. If it is also acceptable to use the same intermediate draft gears for both passes, then no gear box changes are needed and machine downtime is reduced.

The required draft can be calculated using the following relationship, which is essentially a simple statement of constant mass of fiber in and out of the machine:

$$z_i * T_{(i-1)} = T_i * D_i \qquad \text{[Eq. 1]}$$

where $D_i = D_{mi} * D * D_{ci}$
$i = i^{th}$ drawframe pass
D = nominal main draft
D_{ci} = output draft on i^{th} pass.
D_{mi} = measuring roll draft on i^{th} pass
T = linear density (Ktex or gr/yd)
z_i = number of ends of sliver supplied on i^{th} pass.

The "output draft" is mainly the product of calendar and coiler drafts, which was determined by experiment by from the ratio of the total input and output sliver linear densities, divided by the product of the measuring roll draft and the nominal main draft. The output drafts for first passage and second passage through the drawframe were 1.066 and 1.050, respectively. (The respective measuring roll drafts are 1.012 and 0.998, respectively.)

Combining the equations for first and second passes, we obtain

$$D^2 = z^2 * T_c / (D_{c1} * D_{c2} * D_m1 * D_{m2} * T_2) \qquad \text{[Eq. 2]}$$

Substituting the values in equation (2) for the supply of 6 ends of 4.39 ktex (62 gr/yd) card sliver and expecting 3.90 tex (55 gr/yd) finisher drawframe sliver, the required nominal main draft for both passes is estimated to be 6.0. This value defines the draft gearing that will be used for both drawframe passes.

Input Sliver Setting: The Input Sliver Setting (ISS) has a direct relationship to the total sliver weight that is fed to the drawframe. As sliver passes between the measuring rollers (which are of tongue and groove form) variations in mass produce a displacement of the "tongue" roller. This displacement is indicated by the position of the illuminated bead of the display for sliver variation. The input setting is correctly set for the sliver when the bead is in the center of the display, the "zero" position. Variation of the displacement is encoded and the speed of the drafting rolls increased or decreased to correct the mass of sliver.

Figure 2 shows the linear relationship between the ISS and the weight of sliver fed to the drawframe. Note that there appears to be a separate relationship for each passage of drawing. This is probably related to the density of the sliver, determined by the degree of orientation of the fibers. The data were obtained by varying the mass of the sliver supplied, and determining the value of the ISS when the bead was located in the central position. Since the display is graduated in increments of 3% displacement, the central position was identified as the midpoint between the settings which caused the illumination of the -3% and +3% beads.

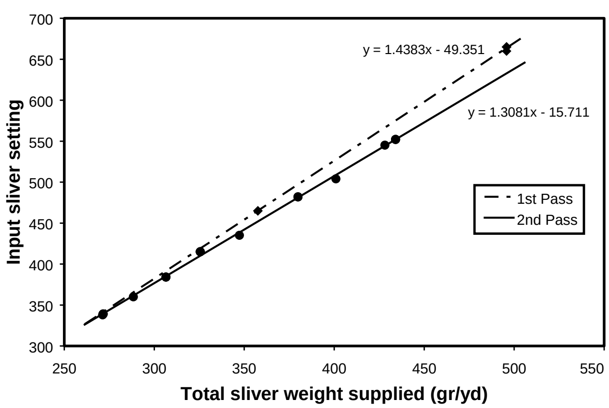

Figure 2: Input Sliver Setting on Sliver Weight Supplied

By defining the central point, the autoleveller seeks to provide sliver as if the machine were being fed with material of the expected linear density and drafted according to the dictates of the gearing. The main drafting system of rollers is increased or decreased in speed by a servomotor when variation is detected to mitigate the variation in mass. The range of operation of the autoleveller is +/- 27%, sufficient to accommodate a temporary loss of an end of sliver supplied, or a doubled end caused by coil entanglement, for example. Although the ideal situation is for the machine to be set so that the bead is always varying around the zero point, the autoleveller can be run at a setting that is displaced from zero, but not at a point where the variability of the input material is such that the autoleveller is operating at the edge of its range. In fact the machine manufacturer does advocate the running the autoleveller in an "off-center" mode in order to adjust for small variations in average linear density [Hollingsworth Inc, 1994]

This feature provides the opportunity to perform two passes of drawing without any alteration of settings to the autoleveller, or changes to the gear box. The only exception is a requirement to change the measuring roll tension to avoid contact between sliver and stationary surface, one item of change instead of five.

RESULTS AND DISCUSSION

To generate empirical equations to be used to determine machine settings, West Texas cotton was opened and cleaned and carded by a Crosrol Mk 4 single card, and Crosrol Mk 4 tandem card. The single card sliver was drawn into first passage drawframe sliver at various nominal main drafts using a fixed ISS. The resulting slivers from the single carded stock were given a second pass of drawing at different combinations of ISS and draft. The linear densities of all the sliver samples were determined by direct measurement, each data point being the mean of at least six 4 yard determinations.

From the tandem carded sliver, the first pass was made at four different nominal main drafts to give sliver of linear densities ranging from 3.40 to 5.03 ktex (48 to 71 gr/yd). Each sliver was given a second pass with a constant nominal main draft of 6.02. In all cases (first and second passes), the bead setting was set to the central position by adjustment of the ISS. The second pass slivers ranged in linear density from 3.19 to 4.89 ktex (45 to 69 gr/yd). Output sliver linear density and ISS setting were plotted against the total input sliver weight as shown in Figure 3. The equations shown in the graph were used to determine that finisher drawn sliver of 3.90 tex (55 gr/yd) would result from the supply of 6 ends of 4.11 ktex (58 gr/yd) sliver and an ISS of 437.

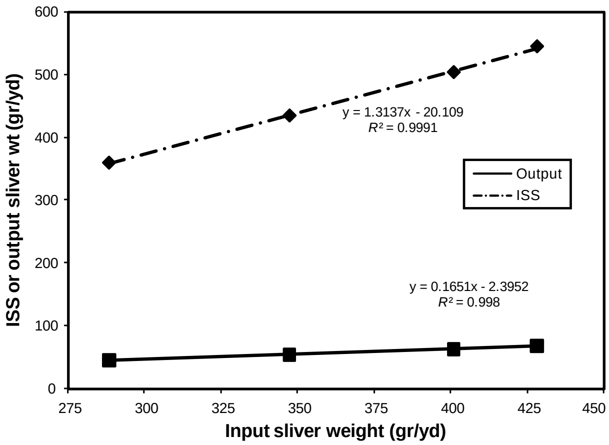

Figure 3: ISS and Output on Input Sliver Weight

Multiple regression equations were derived using all of the data for the output sliver linear density for both first (DI) and second (DII) passes of drawing, and are shown in Table 1. These permit estimation of the output sliver weight from the nominal main draft and the ISS set on the machine. Using a nominal main draft of 6.02 and the ISS of 437, the estimated linear densities of breaker and finisher slivers are 3.48 and 3.88 ktex (49.1 and 54.7 gr/yd) respectively, when autolevelling at both passes.

To demonstrate the performance of the drawframe set up as determined above, two 20 lb (9.1 kg) lots of cotton were opened, carded, and drawn using the drawframe settings above. Breaker drawframe sliver linear densities were 3.49 to 3.52 ktex (49.3 and 49.7 gr/yd), and finisher drawframe sliver linear densities were 3.84 to 3.86 ktex (54.2 and 54.5 gr/yd), respectively. This demonstrates that the estimated and actual linear densities are close to expectation; both measured values lay within 0.6 gr/yd of the estimate for each passage of drawing.

In these examples, the card sliver was about 4.61 ktex (65 gr/yd), a little heavier than planned in the protocol. The autoleveller was catering for sliver 21 to 24 % heavier than that for which it was set. Under these conditions, the adjusted main draft is about 7.9 on the first pass, and 5.5 on the second pass. (The use of “adjusted” in reference to the main draft refers to the change from the nominal main draft as a result of the action of the servomotor in response to position of the measuring rolls.) The reason why the adjusted main draft differs significantly from the nominal main draft is due to the Input Sliver Setting which is set at a value that will provide the required sliver weight on the second passage of drawing, but the setting is lower than required on the first pass of drawing for the autoleveller to operate about the midpoint of its range. Consequently the servomotor is running continually to provide a draft (the adjusted main draft) that is higher than the nominal main draft. However, the draft distribution between first and second passes is similar to current industrial practice, where a higher draft is applied at the first passage than at the second pass [Clapp, 2008]. Provided that there are no unusually thick places, it is estimated that the drawframe will operate satisfactorily with six ends of card sliver with a linear density in the range of 3.26 to 4.68 ktex (46 to 66 gr/yd).

In comparison, to reduce the sliver density at two stages using a nominal main draft of about 6.0, autolevelling at both stages would entail setting the ISS to 520, then 437 for first and second passes respectively. While it is a simple task to alter the ISS, if overlooked or if a number is entered incorrectly, operation of the drawframe will produce either a shortage in the length of sliver remaining in the creel, or a shortage in the length delivered to the cans at the output. To rectify the problem, time is lost and quality compromised by having to divide sliver layers manually, and piece the resultant short lengths to maintain the required number of ends fed to the drawframe. If the ISS is set to 437 on the first pass, sliver of about 3.5 ktex (49.5 gr/yd), is produced and the weight of first pass sliver is insufficient to provide the required quantity of second pass sliver. On the other hand, if the ISS is accidently set to 520 on the second pass, then a heavier sliver than required is delivered (4.61 ktex or 65.0 gr/yd), increasing the likelihood that the length of sliver delivered to the final can will be short of the target. This means that draft and length settings have to be altered at the roving or spinning frame in order to deliver the required number of packages of material of the desired length and linear density.

Table 1: Regression Equations for Output Sliver Weight (gr/yd)

Dependent Variable	Intercept	Slope for Main Draft	Slope for ISS	Multiple Coefficient of Determination	Standard Error
Linear Density, First Passage	**46.28**	**-7.264**	**0.107**	**0.995**	**0.824**
Linear Density, Second Passage	**51.76**	**-8.071**	**0.118**	**0.994**	**0.848**

Autolevelling at the first passage of drawing also has the benefit of accommodating variations in the mean linear density of the card sliver between lots that may result from differences in fiber properties and storage conditions. With a guaranteed product linear density, a specified length of sliver produces a can of known weight. If no autolevelling were to be used on the first pass, then greater care has to be taken to ensure that sufficient sliver is delivered to each can. In such instances, it is likely that the amount of sliver wasted will increase, and the process needs more attention to minimize losses. While this is not of much concern when the sample lot is plentiful, it is of increasing importance when quantities are limited (as can occur with breeders' samples) and it is necessary to provide a stipulated amount of yarn or other product.

The results have shown that it is possible to perform first and second passes of drawing on one machine using the autoleveller at fixed settings, and no gear changes other than a simple change of a timing belt pulley. For a given cotton the output from both passes of drawing will be within quite close limits, irrespective of the variation of input material of about +/- 20%. This has benefits in reducing waste, i.e., maximizing the yield of product from a limited quantity of material. Provided that it can be shown that there are no detrimental effects in yarn quality, the advantages of the reduced number of changes between drawframe passages are justification for the use of the method in the small-scale protocol.

If such a simplified procedure is implemented, then there should be no need for such extensive experimental work to re-check relationships. Records of sliver linear density involving the use of control charts should be sufficient to note and correct any deviations. Furthermore, extensive experience with a wide range of cottons may lead to the establishment of relationships that will include fiber properties such as Micronaire value to fine tune the ISS, thereby permitting the production of sliver with less variation in mean linear density between lots of cotton.

CONCLUSIONS

Small-scale sample processing has been a formal means of cotton quality evaluation in the US for over 60 years. As different organizations began to process small-scale samples, contemporary machines were used, which were faster and more advanced technologically. Advances in fiber testing instruments, particularly their speed and versatility, permit a much better characterization of the fiber and its behavior in processing. One particular linear density of yarn (27 tex, Ne22) has been used consistently in small scale sampling procedures, which is useful for comparative studies. The new protocol at the USDA-ARS-SRRC for small-scale sample processing includes the knitting and/or weaving of a homogenous fabric. The new protocol requires that one drawframe is used to perform the required two passes of drawing. The need to make five changes in converting the machine specification from one processing stage to another can be reduced to one, essentially by keeping the autoleveller active for both passes, reducing the likelihood of errors and reducing machine downtime.

DISCLAIMER

Mention of a trademark, warranty, propriety product or vendor does not constitute a guarantee by the U.S. Department of Agriculture and does not imply approval or recommendation of the product to the exclusion of others that may be suitable.

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