HIGH SPEED ROLLER GINNING OF UPLAND COTTONS

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Abstract

It has long been known that saw ginning of Upland cottons results in less than optimum fiber lengths, increased short fiber in the sample and an increase in nep count. Roller ginning of Upland cottons, while producing a longer staple fiber with fewer short fibers and neps, has here to date been impractical, due to its limited throughput capability and subsequent high per-bale cost when compared to saw ginning. Recent developments utilizing high speed technology are leveling the field in favor of roller ginning. As markets change, and more of the US crop is exported, the benefits of roller ginning Upland cottons will merit further consideration.

Background

Evidence indicates cotton and cotton fabrics may have been used by the ancient societies of China, Egypt, India and Peru as long ago as 12,000 B.C., long before flax. The commercial spinning and weaving of cotton began in India and fabrics were produced as early as 1500 B.C. In the United States Pima Indians of the Southwest were raising cotton when the Spaniards were in the midst of discovering the region. The oldest mechanical method known for ginning or separating the cotton seed from the fiber utilized a smooth roller manipulated by hand against an opposing smooth surface, typically a flat rock. When rolled over the loose lock of cotton the action of the roller against the smooth surface would literally squeeze the seed from the lock, thus causing a separation of the two. Although it was a relatively efficient way of separating the seed from the lint, the work was painstakingly slow and tedious. By 1000 B.C. necessity bred a two-roller system and the "Churka" gin was born (Fig. 1). Two opposing rollers increased the production capability of one person by providing a mechanical advantage over previous methods of separation. Even though this type of ginning principle was available for several centuries it was not used extensively until the 1840's, when Fones McCarthy invented the reciprocating knife roller gin. Roller gins of the McCarthy type were used primarily to gin the extra-long staple, slick seed cottons of the species *"Gossypium barbadense."* The principle of the McCarthy roller gin (Fig. 2) is to rotate an approximately 8" diameter ginning roller covered in a packing material, having cohesive properties similar to cotton itself, against a stationary blade. The tip of the blade is approximately tangent to the surface of the roller, which is held under force against the blade while rotating. This point of tangency is known as the ginning point. A movable bar, often referred to as a "pick," is strategically located adjacent to the ginning point, where it is driven to reciprocate linearly in such a way as to dislodge ginned seeds from the ginning point. Seed cotton feeds to the ginning roller in such a fashion the ginning roller "grabs" the lint, pulling the seed lock towards the ginning point. The stationary blade is set so as to allow the lint to pass along with the surface of the ginning roll under the stationary blade, leaving the ginned seed at the ginning point. The reciprocating blade stroke length is dependent on fiber length, and its frequency is relative to the surface speed of the ginning roller. A correctly set reciprocating knife will dislodge only ginned seeds from the ginning point.

Most of the operating roller gins in the world today are of the McCarthy design and found exclusively in third world countries where labor is cheap and cash is scarce. Fuzzy seed cottons of the species *"Gossypium hirsutum,"* referred to as Upland cottons, had been hand ginned using the "Churka" type roller gin until the invention of the cotton "engine" by Eli Whitney in 1794. The cotton "engine," or "gin" for short, became the new high production method of separating the seed from the lint for Upland cottons and continues to be the preferred method employed to this day. For extra-long staple cottons, however, roller ginning was and is the preferred process by which seed can be separated from the lint, as the process preserves the desirable fiber characteristics of long staple with minimal mechanical degradation in the form of short fibers and neps. The focus of this report will be developments in roller ginning technology.

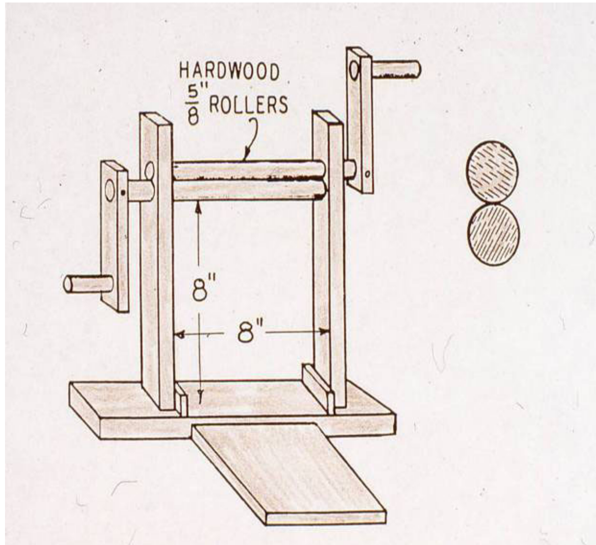

FIG 1

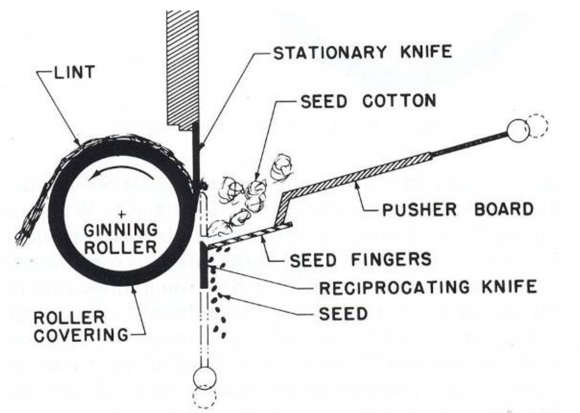

FIG 2

In the late 1950's, research conducted by the USDA-ARS Southwestern Ginning Laboratory in Las Cruces, New Mexico, led to the next major contribution in roller ginning technology. The new technology developed by the USDA took the principle behind the linearly-reciprocating blade and gave it a rotational relationship relative to the ginning point, thus developing the first rotary knife roller gin, referred to today as the "high-capacity" roller gin. This is not a misnomer. The reciprocating knife roller gin of the McCarthy design is capable of producing 150 to 200 pounds (68 to 91 kg) of extra-long staple ginned lint per hour. The new rotary knife design is capable of capacities from 500 to 750 pounds (227 to 341 kg) of extra-long staple ginned lint per hour. The principle behind the high-capacity roller gin (Fig. 3) is to rotate an approximately 15"diameter ginning roller, covered in a packing material, having cohesive properties similar to that of the McCarthy design, against a stationary blade. In this case the packing material is composed of 13 plies of cotton cord, bonded with a thin layer of rubber between each ply. The arrangement of the cotton cords in the final material is such that the ends of each cord are exposed at the surface of the packing. It is to the ends of these exposed cords that the cotton fibers attach themselves during the ginning process. As the ginning roller turns, it is forced against a stationary knife blade, much as the ginning roller in the McCarthy design. The tip of the stationary blade is relatively tangent to the surface of the ginning roller. A rotary knife, approximately 2¾" in diameter, is strategically located a short distance from and tangent to the ginning point. The rotary knife, with a plurality of substantially radial blades, performs the same function as the reciprocating knife in the McCarthy design with one major difference. In the McCarthy design, the stroke and frequency of the reciprocating knife has to be such that the seed is completely ginned prior to the reciprocating bar passing the ginning point. The amount of seed cotton on the ginning roll at any one time is dictated by the amount of free surface on the ginning roller. In this way, the amount of un-ginned cotton at the ginning point is limited. In the case of the high-capacity roller gin, the conditions at the ginning point are dictated by the chaotic and random introduction of seed cotton from the feeder to the ginning point of the roller gin. For the ginning roller to accept the flow of cotton from the feeder, while maintaining the ability to properly remove lint from the seed, multiple opportunities for the rotary knife to engage un-ginned and partially-ginned seed are necessary. The rotary knife design is such that partially ginned seeds are given the opportunity to be completely ginned before the blades on the rotary knife dislodge the seed from the ginning point. This subsequent opportunity is due to the angular displacement of the blade relative to the angular velocity of the rotary knife and the blade's proximity to the ginning point. The angular displacement of the blade on the small-diameter rotary knife allows the seed to return to the stationary knife tip for further removal of lint as each blade distances itself obliquely from the ginning point. The relationships between 1) the angular displacement of the blade as it passes the ginning point, 2) the diameter and surface speed of the rotary knife, 3) the ginning roller to the stationary knife, and 4) the surface speed of the ginning roller are all interdependent, and, when optimized, provide the best results.

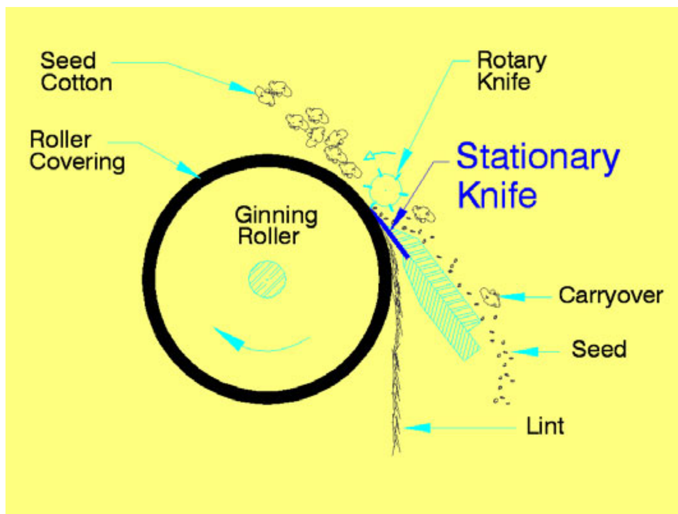

FIG 3

One characteristic of high-capacity roller ginning is carry-over of partially-ginned and un-ginned seed cotton (Fig. 3), necessitating an intermediate process by which un-ginned and partially-ginned seed cotton can be separated from the ginned seed and re-introduced to the ginning process. This intermediate process is known as reclaiming. Two factors contribute to carry-over. One is trash (in the form of sticks, hulls and other vegetable materials), intermingled with seed cotton as a result of mechanical harvesting. Trash intermixed with the normal flow of seed cotton from the feeder will pass between the rotary knife and the stationary blade, discharging along with the ginned seed, pulling one or more locks of seed cotton with it. The other is the non-uniform feed of the seed cotton from the feeder. An ideal feed is a continuous, uniform sheet of single-locked seed cotton, fed to the ginning point with no interruptions or agglomerations. The fact that the high-capacity roller gin feeder does not produce an ideal feed forces one to accept a certain amount of carry-over as normal. What is normal? This varies from gin stand to gin stand and operation to operation. Normal is whatever the reclaiming system can reasonably handle while the ginning plant maintains an "acceptable" level of throughput.

High-speed roller ginning development got its start in the mid-1980's when research at the USDA-ARS Southwestern Ginning Laboratory in Las Cruces, New Mexico, investigated the relationship between ginning rate and feed rate. Results from Gillum's research showed that higher ginning rates of Pima cotton were achieved without damaging the fiber, although the level of feed was limited by the amount of carry-over at the rotary knife. Also, ginning roller temperature increased proportionally with surface speed (rpm) and/or roller-to-stationary knife force (RSK). The ginning roller temperature decreased, however, as feed rate was increased, provided ginning roller speed and RSK force remained constant. Further testing indicated the decrease in ginning roller temperature occurred as a result of heat transfer from the roller surface to the lint cotton, as well as to the gin flue and ambient air masses. Subsequent years of research at the Southwestern Gin Lab led to further improvements, such as an automatic feed control using the rotary knife power as the process variable, application of a gin-roll cooler to mitigate the impact of temperature increases and roll wear, and modifications to commercial roller gin feeders to improve conditioning of seed cotton prior to introduction at the ginning point. The end result of the years of research directed at high-speed roller ginning was the first commercial trials in the fall of 2005. The success of the field trials led to the conversions of fifteen high-capacity roller gins to high-speed in 2006. Of the fifteen, one was added to the field trial gin; the remaining fourteen were installed at four gin sites in California.

Equipment and Procedure

During the spring of 2006, an engineering and sales team established criteria for a development program geared towards the practical application of a high-speed roller gin conversion to existing commercial roller gins. Those criteria were:

- Significant capacity increase for both ELS and Upland cottons
- No degradation in key quality factors of fiber length, short fiber content, and neps
- No increase in seed damage as a result of higher speeds
- Carry-over comparable to that of high-capacity gins

The high-speed roller gin conversion kit includes new mechanical components, one group of which optimizes the flow of seed cotton through the roller gin feeder. One key to successful high-speed roller ginning is the degree to which seed cotton is single-locked as it is introduced to the ginning point. Leonard stated, “The ideal seed cotton feed to a rotary-knife, high-capacity roller gin would be a continuous, uniform sheet of cotton one unit thick, the speed of which could be automatically controlled to give the optimum ginning rate . . .” The mechanical modifications to the feeder do just that: facilitate an “ideal feed.” The flow of seed cotton through the feeder is streamlined by eliminating queues and other areas of potential agglomeration (Figs. 4 & 5). The modifications include both geometric changes and speed changes to facilitate flow.

As a result of the speed changes, modifications had to be made to the deflector directly above the rotary knife to rapidly disperse air generated by the feeder doffing brush cylinder (Fig. 6). The deflector has a secondary function; that is to assist directing the single-locked seed cotton from the feeder to the optimum point of ginning.

The feed rate through the feeder is determined by the operator via an auto/semi-automatic process controller located at the front right-hand side of the feeder (Fig. 7). The process controller provides the input to a PLC, which, in turn, communicates information to the rotary knife VFD and gin roller VFD. Once entered, the feed rate setting will maintain a set feed rate determined by the actual operator-entered set point in manual or by the difference between the set point and the actual power used by the rotary knife drive in automatic. In manual, the feed rate setting determines both the speed of the rotary knife and the main gin roller. A minimum speed threshold is preset for all three drives (feed roller, rotary knife, and gin roller), to avoid low-frequency overload of the VFD’s. As the feed rate is increased, the other drives increase in speed proportionally. The relative surface speed ratio between the gin roller and the rotary knife remains constant throughout. In automatic mode, the relationships between the three drives are the same as in manual mode, although the feed rate will vary, depending on the actual power demand of the rotary knife drive (in kilowatts). The automatic control is based on pre-configured PID loop parameters.

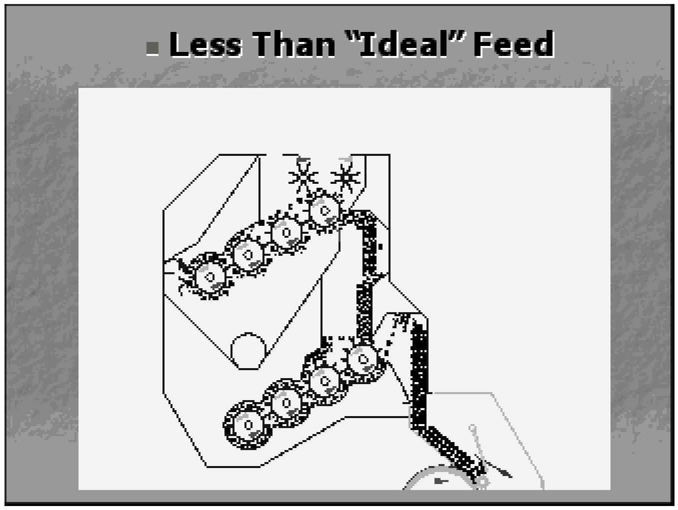

FIG 4

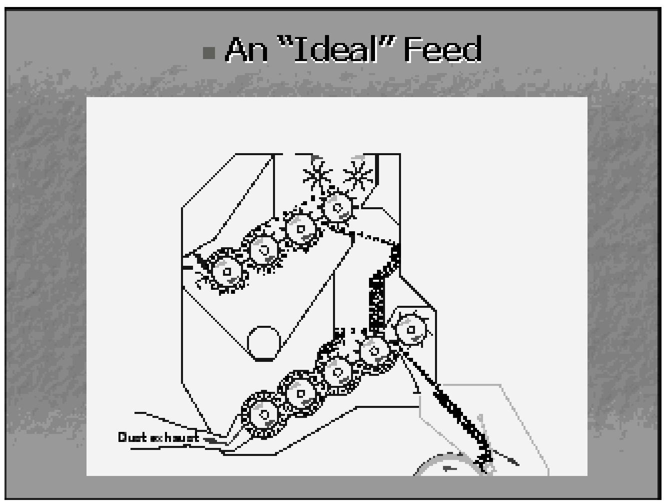

FIG 5

FIG 6

FIG 7

The ginning roll and rotary knife are of standard construction, identical to those utilized in conventional high-capacity roller gin stands. The ginning roll is 15" diameter by 40½" long (nominal), wrapped with 13-ply cotton duct packing. The rotary knife is 2¾" diameter with 6 blades, each at 120° right-hand spiral. The conventional rotary knife bearing restraining springs have been replaced with pneumatic cylinders, which function as dash pots via a self-relieving pressure regulator. The air cylinders provide better control and a much faster reaction time than do the springs. The speed of the ginning roller varies from a low of 225 rpm to a maximum 450 rpm. A 50 HP VFD is used to drive the 50 HP motor and vary the frequency (rpm). The rotary knife speed, as mentioned, varies directly with the speed of the ginning roller, from a low of 720 rpm to a maximum of 1450 rpm.

A gin roller cooling system is an integral part of the high speed roller ginning scheme (Fig. 8). The cooling system is based on the USDA design, consisting of a commercial radial blower with motor, connecting duct work, and a cooling plenum. One down-side to the cooling system is with the blower constantly running, the ginning roller can actually be too cool to gin properly. Experience has shown that a ginning roller will not gin properly if it has not had ample opportunity to warm up. As a consequence of the blower constantly running, there is an extended time interval between the initiation of the ginning process and the point where the roller is actually warm enough to gin. The only way to limit the amount of cooling to be done is to manually turn the blower off. A solution to the problem has come about as a result of the systems installed in the 2007 season, which are equipped with temperature-monitoring devices to indicate hot spots on the ginning roller. The inputs from the devices are being integrated into a new cooling control scheme that will not only monitor the temperature of the ginning roller and graphically display hot spot locations on the touch screen display, but will also determine, based on operator presets, at what temperature to turn on (and off) the cooling fan.

FIG 8

One characteristic of a rotary knife roller gin is the accumulation and wrapping of fiber at either end of the rotary knife. The accumulation is the result of loose fibers, trash, and lint fly agglomerating at the proximity of the either end of the ginning plane and the gin flue connection. Sub-atmospheric free air at the ends contributes to the agglomeration. The accumulation in high-capacity roller gins is merely a nuisance and a housekeeping issue. In the case of the high-speed roller gin, it is more than a mere nuisance. The combination of high speed and volume can lead to massive accumulations and, in extreme instances, fires.

Attempts were made in the field during 2006, to mitigate the accumulation of lint with little success. For the 2007 season, shields were designed for both the conversions and production gins to deflect the flow of material in yet another attempt to mitigate the accumulation (Fig. 9). This latest solution failed as the accumulation continued. New success was achieved by deflecting the seed cotton away from the ends prior to the ginning plane. Further development along this same line has shown success.

FIG 9

In 2007, commercial applications expanded to include the first production version of a high-speed roller gin and feeder, as well as enhancements to the field conversions. The 2007 harvest season saw the installation of five gin and feeder conversions and fifteen new production gins and feeders. In addition, ten new production models were sold and delivered for the 2008 season.

Results and Conclusions

The 2006 harvest season proved commercial high-speed ginning technology was sound as it applied to ELS cottons. But the bulk of the seed cotton processed was ELS, not Upland. What Upland had been processed by the end of the 2006 season on high-speed gins showed similar quality characteristics with regard to length, short fiber, and nep content to that ginned to date at the USDA Mesilla Park Gin Lab. But questions remained. How would a gin season run of Upland impact the performance of the high-speed roller gin and feeder? Would the ginning roller life be comparable to that of a high-capacity roller gin? Would the reclaimers handle the higher volumes? What other "unknowns" were going to rear their ugly heads?

We were not long into the 2007 season before the bulk of the "unknowns" became apparent. Some minor mechanical deficiencies were dealt with at the beginning of the season and, for the most part, have been resolved. That leaves the following engineering issues to be addressed:

1) Fiber accumulation at either end of the rotary knife.
2) Ginning roller wear.
3) Reclaiming.

A retrofit is currently in production to address the accumulation of lint at either end of the rotary knife. Preliminary results indicate the problem is solvable, given some minor mechanical changes are implemented.

The jury remains out on ginning roller wear although preliminary reports (see comments on roll life on next page) are encouraging. Excessive ginning roller temperature at low feed rates has proven to be one of the leading contributors to premature ginning roller wear. One school of thought was that varying the speed of the ginning roller and rotary knife with the feed rate would result in longer roller life. The 2007 control scheme includes the ability to vary speed based on throughput as well as temperature. Data presently being accumulated will be compiled and analyzed after the 2007 harvest season to validate the effects of existing roll cooling technology and the 2007 temperature control scheme. In the meantime, research is under way for alternative ginning roll materials and methods.

Reclaiming is an area of opportunity where we will focus development work for the upcoming season. With respect to high-speed roller ginning, current reclaiming technology is adequate only for cottons ideally suited for ginning. That is, cottons with little or no trash, cottons that are dry and warm, single-locked, and have a robust, substantial seed. It has not been uncommon during the 2007 season for plant capacity to be reduced as a result of excessive carry-over overloading the reclaiming system. As stated earlier, normal carry-over is "whatever the reclaiming system can reasonably handle while the ginning plant maintains an 'acceptable' level of throughput." The inability to maintain an acceptable level of throughput is counter to the application of high-speed roller ginning, thus providing an opportunity for improvement through new development.

To date, one gin in California has processed 12,200 bales, 7,000 of which were variety 725 Acala, and the rest Pima. The gin can average 5 bales per hour per stand although they try to keep it around 4 so as not to tax the lint cleaning system. The manager of the gin feels he could average 2000 bales per gin roll provided there is no damage to the roll from fire or mechanical intrusion. One of the gins is running on the original ginning roll which works out to be 2,444 bales so far during the 2007 season.

Fiber tests are presently under way, the results of which will be forthcoming. Samples of both ELS and Upland cotton ginned lint from the 2007 season have been gathered from sites in California. In addition, fiber samples were collected of Upland cotton ginned in Brazil on the high-speed roller gin and of Pima and the hybrid Hazera from a high-speed roller gin in Arkansas. The following three graphs represent HVI data from upland samples ginned on the high speed roller gin in Brazil during the 2007 season. Included with each graph is simultaneous sample data taken from a saw gin located next to the high speed roller gin. The first graph (Fig. 10) is the upper-half-mean-length for 10 samples. The average length is 30.6 and 29.8 mm for roller ginned versus saw ginned respectively. The second graph (Fig. 11) is short fiber content for the 10 samples. The average SFC is 6.3 and 7.3% for roller ginned versus saw ginned respectively. The third graph (Fig. 12) is the uniformity index for 10 samples. The average UI is 86.8 versus 85.2 for roller ginned versus saw ginned respectively.

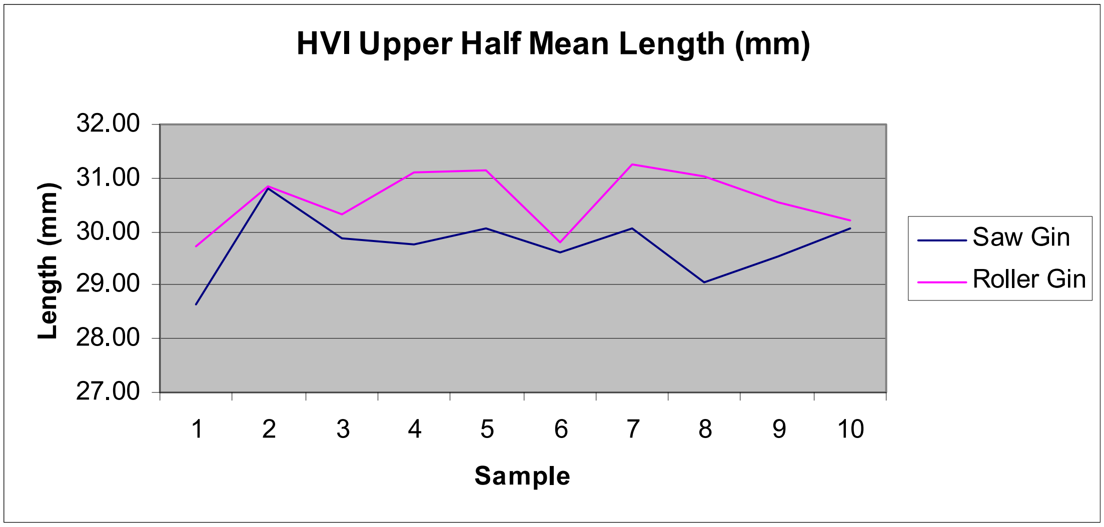
HVI Upper Half Mean Length (mm)
Length (mm)
32.00
31.00
30.00
29.00
28.00
27.00
1
2
3
4
5
6
7
8
9
10
Sample
Saw Gin
Roller Gin

FIG 10

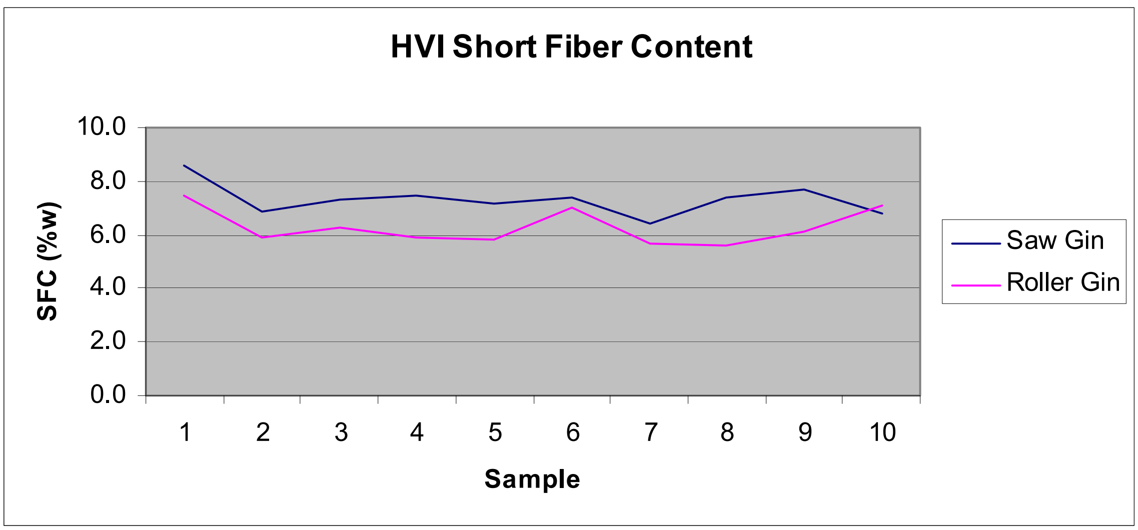
HVI Short Fiber Content
SFC (%w)
10.0
8.0
6.0
4.0
2.0
0.0
1
2
3
4
5
6
7
8
9
10
Sample
Saw Gin
Roller Gin

FIG 11

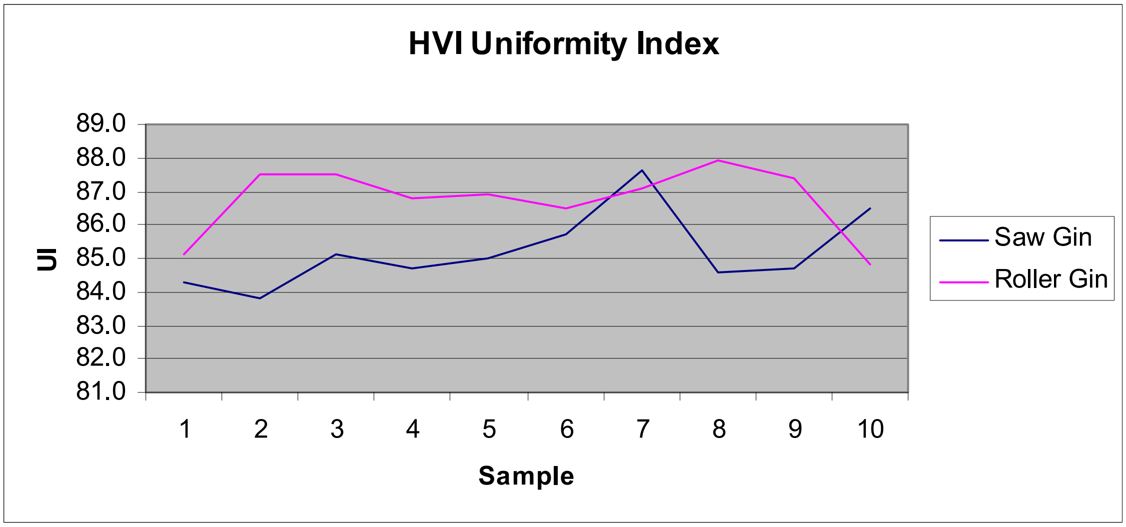

FIG 12

Acknowledgements

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