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POWERED PADDLE ROLL GIN STAND

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Abstract

The USDA Agricultural Research Service ginning laboratory in Lubbock, Texas has an extensive research program underway to develop new saw gin stand technology that promises to substantially benefit cotton producers. Ginning test results show that the experimental gin stand can be configured and operated to produce more lint from seedcotton compared to a conventional high capacity saw gin stand. Results from fiber tests also has shown that the experimental gin will give better staple length and less short fiber. The changes to the gin stand that make up the powered paddle roll design must be done together or the performance and fiber quality results may be lower than with a conventional saw gin stand.

Introduction

The basic operating principle of saw gin stands has not varied greatly from the original pattern developed before 1900 (Bennett, 1962). The expected function of the gin stand embodied in the spike tooth gin stand invented by Eli Whitney in 1794 and the saw cylinder version created by H. Odgen Holmes in 1796 was to separate the lint from the seeds. A number of other functions have been integrated into saw gin stands since that time to increase ginning rate and handle cotton from rougher harvest methods. This resulted in development of what became known as huller front gin stand designs that have been universally used. Feeding seedcotton through the huller front for the saws to pull it into the bottom of the gin roll box between huller ribs has become the method of choice.

Ginning capacity has increased significantly by evolutionary changes during the past 50 years as the number of saws has increased from the 80 or 90 saw designs that were prevalent into the 1950's to the over 200 saw versions of today. There has also been some capacity gain by increasing saw diameter from the traditional 12 inches to 16 and 18 inches. Roll agitators and/or seed tubes were added to increase capacity, remove seeds quickly and help eliminate the stick and stem accumulation in the center of the seed roll that increases roll tightness and slows ginning rate. Recently developed super capacity saw gin stands have either opened up or eliminated the huller ribs for a further gain in ginning capacity. This became feasible when much better seedcotton pre-cleaning systems and cleaner-feeders were developed and installed in gins.

Background

The USDA Agricultural Research Service ginning laboratory in Lubbock, Texas has an extensive research program underway to develop new gin stand technology that promises to substantially benefit cotton producers. This is being done under a cooperative research and development agreement between USDA-ARS, Cotton Incorporated, American Industrial and Bearing Co., and J & F Saw and Gin Machinery Inc. Ginning test results with an experimental saw gin stand have shown that the experimental gin stand can be configured and operated to produce five to eight percent more lint from seed cotton compared to a conventional high capacity saw gin stand (Laird, et al. 2001). Results from fiber tests also have shown slight differences in fiber properties with a tendency for the experimental gin to give better staple length and less short fiber (Holt, et al. 2001). The test results show that there are a number of changes that make up the powered paddle roll design which need to be done together or performance and fiber quality results can be lower than with a conventional saw gin stand.

The powered paddle roll gin stand design concept was developed at the Lubbock, Texas USDA-ARS ginning laboratory in cooperative work with Cotton Incorporated to remove a small residue of lint from gin-run cottonseed that was a problem as a coating process was developed for making fuzzy cottonseed free flowing (Laird, et al. 1997). It became apparent during this project that modern high capacity saw gin stands usually leave long fiber on the seeds that is equal to 2 to 3 percent of the seed weight. Fiber quality tests showed that properties of lint obtained by reginning cottonseed was near that of the lint ginned into the bale (Laird et al. 1999). The amount of fiber removed from gin-run seeds would add 4 to 6 percent to bale weight, or 20 to 30 pounds. These results prompted us to open up a research program to go back and examine operating elements of saw type gin stands with the purpose of finding why lint was consistently left on the seeds and to find ways to correct this.

As we considered the basic operating functions of modern saw gin stands, hand trials showed that gin saws are capable of far higher ginning rates than they presently operate at. The main limiting factors are failure to load many of the saw teeth with lint, and very poor capacity to sort out and remove fully ginned seeds from the gin stand. The function of all the elements of a saw gin needs to be aimed at getting the lint quickly attached to the saw teeth and pulled off the seed at the base. This should be done with as little contact as possible between the saw and seeds containing lint to maintain lint quality. Otherwise continued rotation of the seed containing unginned lint within the seed roll may produce tangling, fiber damage and friction which generates neps that are a characteristic of saw ginned lint contrasted to roller ginned lint. Lint needs to be caught by the saw in large clumps that can be quickly removed from the seed. This will help reduce fiber breakage because of more fibers in the tuft to endure the ginning forces in the seed roll and at the gin point against the ribs.

Research with an old model 90 saw Continental gin stand that was converted to a 110 saw paddle roll design showed it was capable of ginning rates exceeding 10 bales per hour. In comparison tests the experimental gin stand gave higher lint turnout than a modern high capacity gin stand with less fiber and seed damage (Laird, et al. 2000) (Laird, et al. 2001). The development includes modification of both size and shape factors and incorporation of new moving parts. Tests have also been conducted with a partial conversion of a Lummus 88 saw gin converted to 116 saws and with a 6 inch paddle roll in place of the off-center agitator, but without a new front and seed finger roll. This gin stand gins fast for a short while but quickly develops a packed seed roll and quit dropping ginned seeds. The smaller off-center paddle roll caused considerable scalped and damaged seed and the gin stand would not gin at the high rate that is possible in the other gin stand with a larger and centered paddle roll, a seed finger roll, a new front and reshaped roll box.

Objective

The objective of this paper is to describe the new gin stand design that has been developed and to lay out the reasons and configuration of the various parts that have been found necessary for successful implementation of the technology. Research results have shown that success in using this technology requires the complete package. Unfortunately, labeling it as the powered paddle roll gin stand implies that it only consists of adding a paddle roll in the roll box, but it is much more than that. Research with various stages of modifications to experimental gin stands has shown that several complementary modifications are required or severe operating problems and/or lint and seed quality problems can occur. The essential changes are:

- Create a large round roll box shape.
- Install a properly sized and centered powered paddle roll in the roll box.
- Provide an induction slot for seedcotton in the upper front of the roll box.
- Provide increased area in the lower front of the roll box.
- Install a seed finger roll at the lower front of the roll box for more effective charging of cotton onto the saw and to remove ginned seeds quickly.

The research effort has resulted in a set of design features that can be used to create conversion kits for satisfactorily modifying most existing saw gin stands, though it is more desirable to build a new gin stand that is not limited by an existing machine configuration. Simply replacing the roll agitator or seed tube in an existing gin stand with a paddle roll does not work well. An extensive program of research tests has shown the essential design and operating parameters that give good results. There is still a broad research effort underway to fully explore areas for optimization of the technology, but it is now at the point that it has potential for significant benefits for cotton producers if adopted by cotton ginners. The research results have shown there are critical design configurations required for most efficient operation and maximizing fiber quality, and the primary objective of this paper is to provide this information.

Design Features

Roll Box

Test results with the range of roll box modifications that is possible using the modified 12-inch saw gin stand show that a large round shape for the roll box from the ginning ribs around to the gap at the top above the paddle roll worked best. The paddle roll needs to be centered within the arc formed by the back half of the roll box and the upper end of the ginning ribs. The largest roll box diameter possible within the existing frame of the 90 saw gin stand was 10 3/4 inches. The proper paddle roll size was related to the roll box dimension. An 8 ½ inch tip diameter paddle roll centered in the 10 3/4-inch roll box gave the good results. A 9 ½ inch diameter paddle roll was too big as indicated by visible seed damage, slower ginning, and a seed roll that was too tight causing difficulty turning the paddle roll at high ginning rates. The clearance between the paddle roll and roll box is also important. Too little clearance caused slower ginning and more seed damage. Too small a paddle roll (too much clearance) does not turn the roll as well. The clearance with the 8 ½ inch paddle roll was 1-1/8 inch from the paddle tips to roll box wall and 5/8 inch from the saw teeth.

The front sheet of the roll box was positioned with about 3 inches of space between it and the tips of the paddle roll. This is more than the clearance from the back sheet. The lower part of the front sheet was positioned further out and down than in a conventional gin stand which provided a larger space in the lower section that acts as a secondary seed roll space. We found that the top edge of the existing roll box back scroll sheet needed an extension so that it wrapped around about 35 to 40 degrees beyond the vertical centerline of the paddle roll, figure 1-A. The extended lip and extra space between the front sheet and paddle roll at the top create action that gives a strong force to draw incoming seedcotton into the seed roll. The shape and position of the front and back roll box sheets has to be carefully designed but it is possible to configure it to develop a very good action to pull the cotton into the gin stand. A less desirable alternative considered was to install a smooth roller across the top of the outer front sheet of the roll box to pull the cotton in but this requires additional moving mechanical parts that could be more trouble.

A significant change was reshaping the lower part of the front sheet of the gin stand roll box to be farther out and lower down, providing more space for a secondary rolling and sorting action to develop in the area between the point where the cotton comes over the paddle roll and where it contacts the seed finger roll and the saw, figure 1-B. The design objective for this was to create a sorting area to help the seed finger roll separate fully ginned seeds from the incoming cotton before it attaches to the saw and blocks access for ginned seed to get out of the gin stand. The seed finger roll was positioned lower down with respect to the saw than the conventional fixed seed fingers or plate. The new front sheet also was positioned further out and down to expose a larger area of the saw periphery to the cotton to create more opportunity for lint to become attached to the saw.

Loading/Unloading Roll

To improve attachment of lint to the saw and provide for more positive removal of fully ginned seeds the conventional seed finger or plate was replaced with a rotating seed finger roll installed at the bottom of the gin front. This roll was designed to function as a loading/unloading unit that pushes seeds with lint against the saw for more positive contact of lint with the saw teeth and also serves in sorting out fully ginned seeds and raking them through between the saws and out of the gin stand. One of the major limitations of saw gin stand performance seems to be the ability to sort out and discharge fully ginned seeds. The traditional saw gin stand design relies primarily on gravity to sift the ginned seeds out through the channel between the ginning and huller ribs and has no positive mechanism for removal of ginned seeds. Seeds trying to escape are interfered with by a cross flow of seedcotton being pulled through the same area. The perforated seed tube installed in some of the later model gin stands was the first effort to provide a mechanism to help remove ginned seeds from the seed roll.

Operating Results

The current research results seem to indicate that even higher ginning rates are possible with a larger seed roll box and matching paddle roll. The saws can handle a higher ginning volume but there has to be enough space within the roll box to keep a loose seed roll. Making modifications to existing equipment imposes limits on the extent of changes that can be studied. Indications from the research conducted under these conditions are that roll box size and shape factors beyond what can be built into the existing frames needs to be studied. Larger roll box size was associated with increased ginning capacity and better preservation of fiber quality and less seed damage. An experimental test frame has been designed that will allow exploration of the full range of design elements. A research program is under way to evaluate each of the different elements in a logical sequence of experiments.

Fiber data from a range of tests with the modified Continental gin stand shows upper quartile length was maintained with less scatter about the trend line as ginning rate was increased, figure 2. This data covers a number of tests that used different cotton sources and different combinations of saw, paddle roll, and seed finger roll speeds and gin stand loading rates. Less optimum combinations of operating factors accounts for the wide variation of the data around the trend lines at low to medium ginning rates. Short fiber content had a wide variation around the trend but had a strong tendency to go down with increasing ginning rate, figure 3. Maintaining upper quartile length coupled with reduction of short fibers means that with the optimum combinations of gin operating settings, which gives the higher ginning rates, the median fiber length will be preserved better. This is probably the most important result for end use or spinning performance of the lint.

From another perspective upper quartile length was maintained as gin saw rpm (which is directly related to ginning rate), increased, figure 4. At the very slow saw speed there were some high upper quartile lengths. This may have been caused by a greater relative paddle roll speed in relation to saw speed. It also could have been a result of less complete ginning leaving some shorter fibers on the seed. Relative turnout increased with gin saw speed, more so for field cleaned cotton than for machine-stripped, figure 5. The results indicate that we need quite a bit more study of the relationships between the various operating elements of the gin stand. However there is evidence that improved ginning results from a number of standpoints should be possible. Some tradeoffs may be required but we do not know enough at this point to decide that.

Ginning rate is very high for the powered paddle roll gin stand and seems to be limited mainly by available volume or size of the roll box and/or horsepower of the gin saw motor. The powered paddle roll gin stand does not keep a seed roll as in a conventional saw gin stand but operates with a seed roll density that is directly related to the ginning rate and gin stand settings. It typically required 15 to 20 seconds to reach a full seed roll density and about 20 seconds for the roll box to empty after stopping seed cotton feed. Consequently a seed does not make many circuits through the seed roll box before being completely ginned and discharged. Because the gin stand operates in such a fast, critical mode, a standard feeder control would not properly operate the gin stand feeder based on gin saw amp load. It either got behind and the gin stand lost the seed roll causing it to fail to properly clean the seeds or it would get ahead and overload the saw motor before it had time to cut back the feed. An automatic PC based modulating feed control and data system was developed for operating the gin stand, capable of controlling feed rate based on amps or kW signals from the paddle roll and gin saw motor. Additionally, overload limit signals are used from each of the motors to halt feed for short intermittent surge loadings.

Summary and Conclusions

A series of tests of the new gin stand technology on seed cotton was carried out to measure ginning performance and lint properties and to identify objectives for further development of the gin stand. The primary goal was to develop a gin stand that would remove all of the long lint from the seed. It was also considered necessary for the gin stand to be capable of processing rates comparable to modern high capacity gin stands, without adversely affecting lint properties. The research is currently being expanded in two directions. The basic program is being aimed at examining each of the different parts of the gin stand in detail and also using multivariate response surface methods to look for optimum combinations among the many factors. Also a test stand is being developed to allow basic studies of different design patterns for several parts of the gin stand. The other effort is using what has been learned from the first modified gin stand to develop similar modifications to provide design data for conversion kits to apply the new technology to other models of existing gin stands.

The experimental paddle roll gin stand has consistently given higher lint turnout and better fiber properties than a modern conventional high capacity saw gin stand when it is properly set up. It will produce about five to eight percent more lint from the seedcotton compared to the conventional high capacity gin stand, which is a substantial benefit for producers. It is likely that better fiber length results from the very loose seed roll with which the experimental gin operates. An automatic feed control system sensing both paddle roll and saw loading allows the gin stand to operate at the proper rate. There are a number of gin stand design factors that require more research but the results from the current machine show that a significant benefit from the new technology is possible. A patent was obtained through the USDA-ARS patent division for the paddle roll gin stand (U. S. Patent number 6,061,875) and is available for licensing by contacting the USDA-ARS Technology Transfer Coordinators, Dr. Tommy Valco at 662-686-5255 or Dr. Bryan Kaphammer at 970-229-5528 or e-mail at kaphammer@npa.ars.usda.gov.

Note: Specific company or product names are used in this paper for exact information and is not a recommendation or endorsement over other similar products by USDA-ARS.

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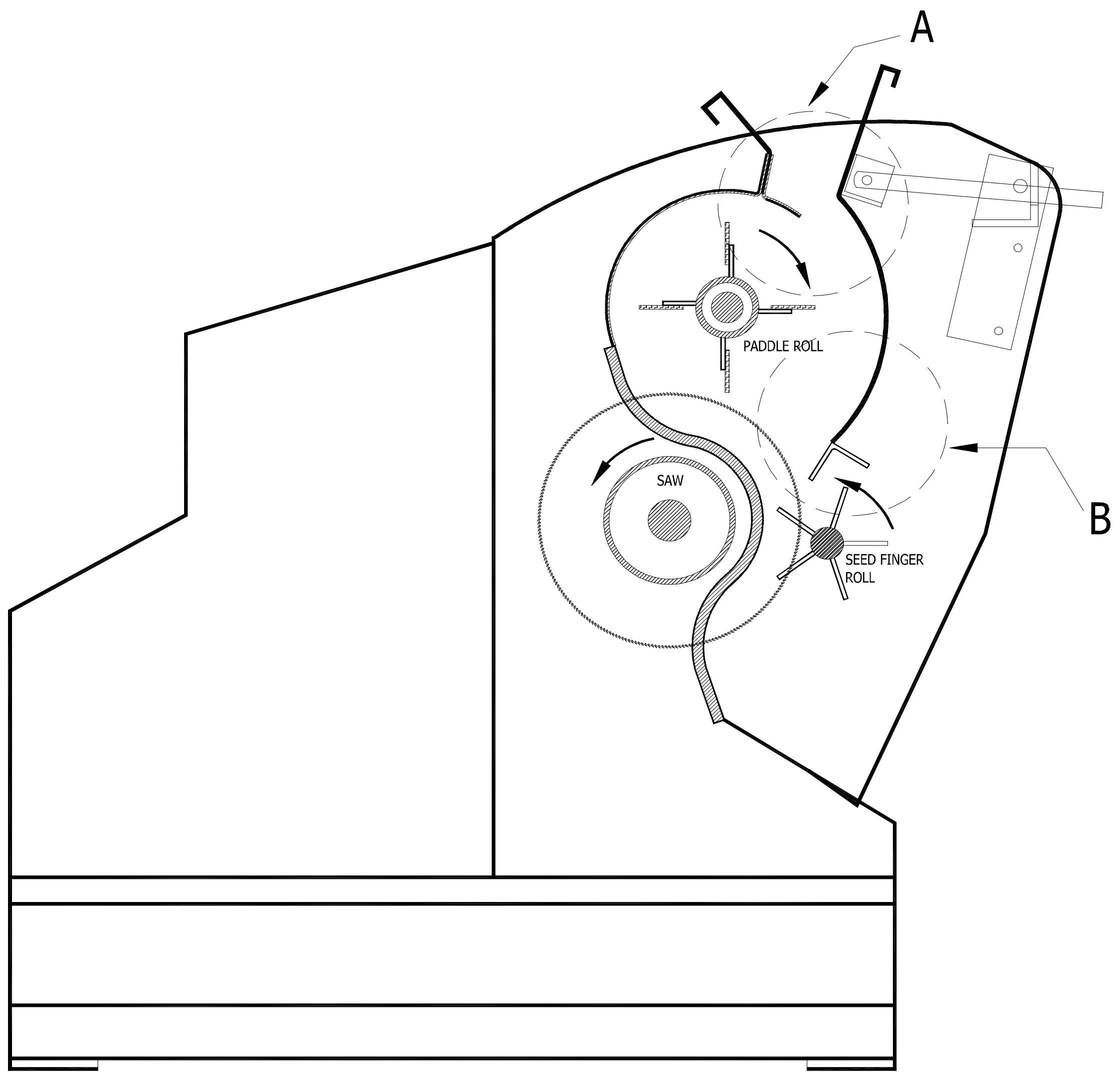

Figure 1. Schematic cross section of the powered paddleroll gin stand with two areas circled where we made major changes from the conventional layout. **A** is the new inlet slot arrangement and **B** is the expanded lower roll box section with rotating seed finger roll.

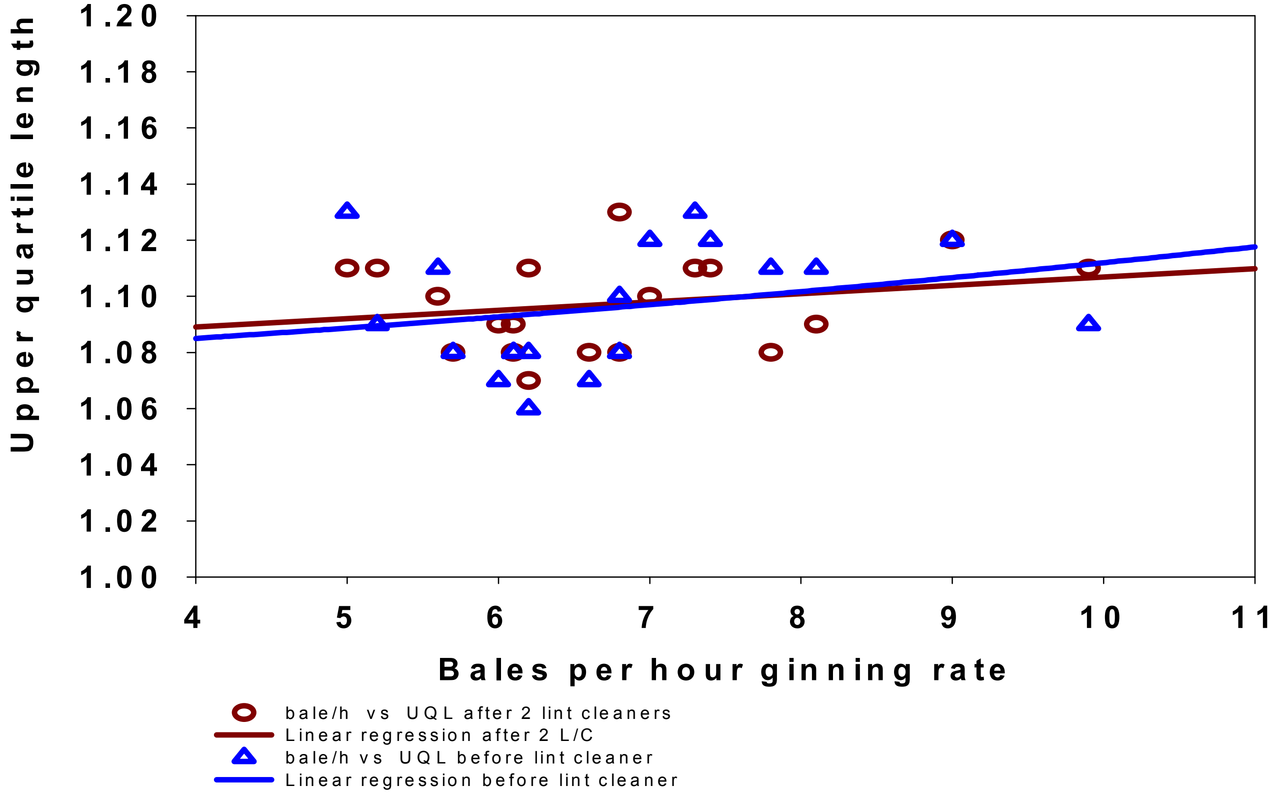

Figure 2. Mean Upper Quartile length vs. ginning rate for the experimental 110 saw powered paddle roll gin stand.

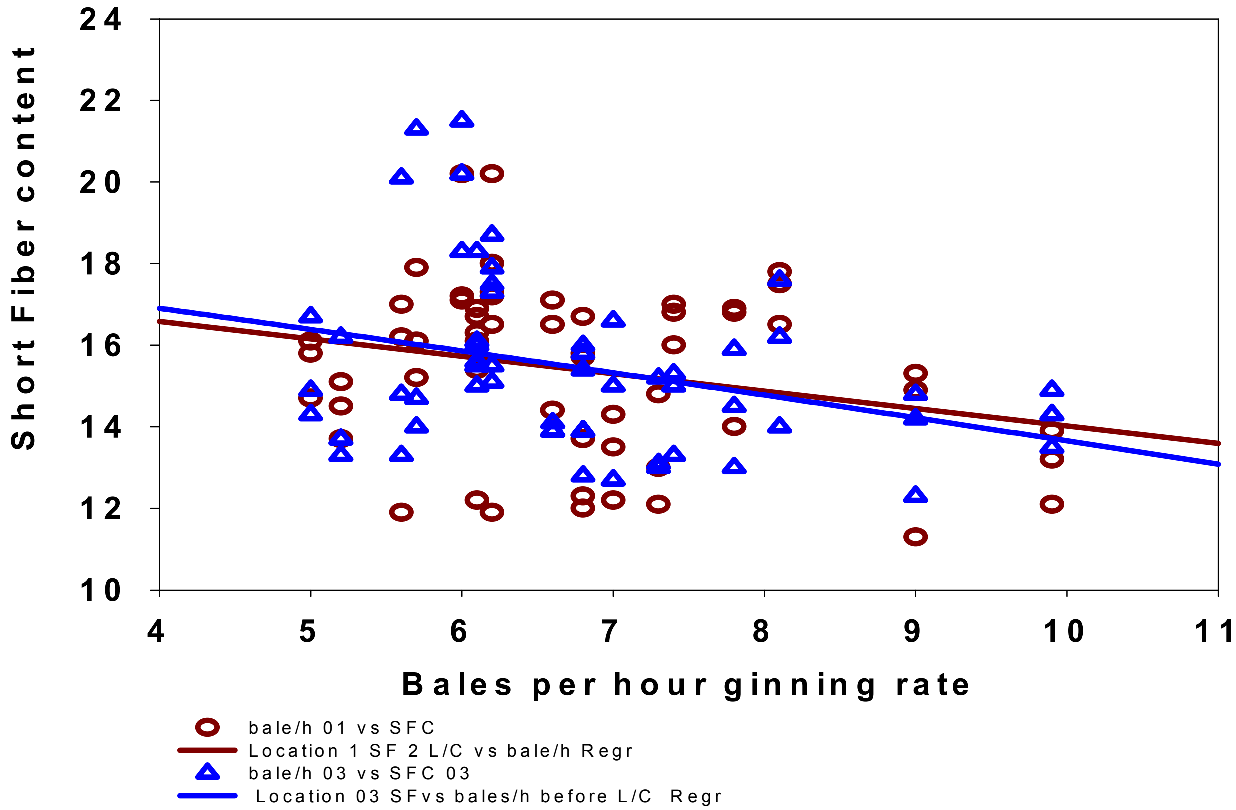

Figure 3. Short Fiber content vs. ginning rate for the experimental 110 saw powered paddle roll gin stand.

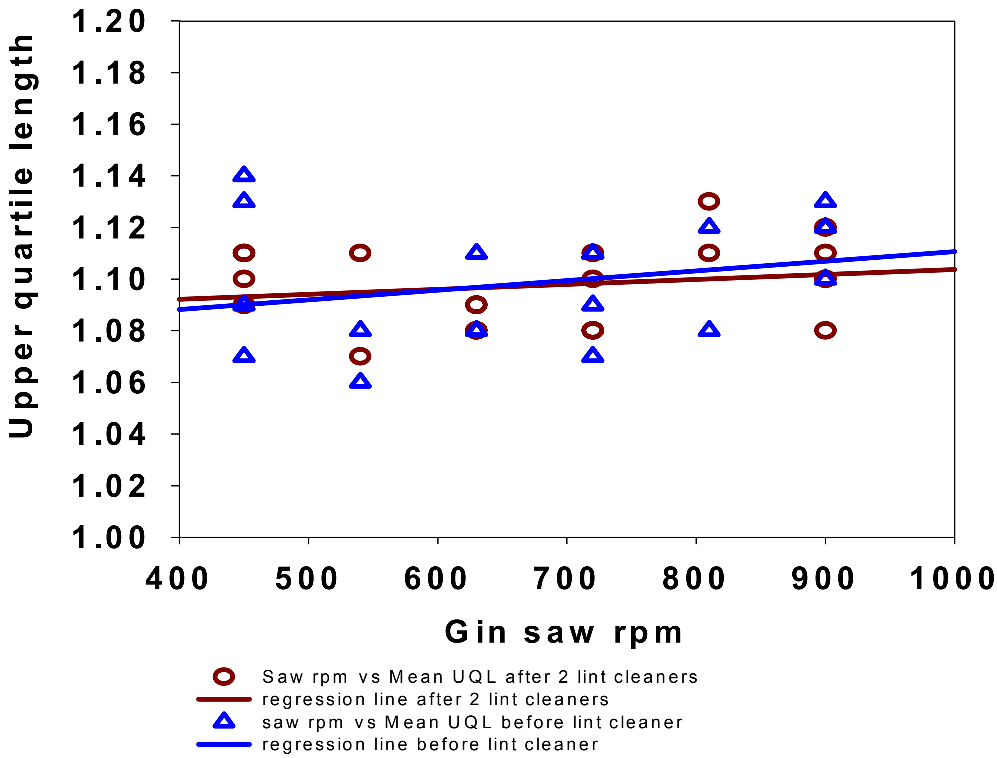

Figure 4. Upper quartile length versus gin saw operating speed, rpm, for the experimental 110 saw powered paddle roll gin stand.

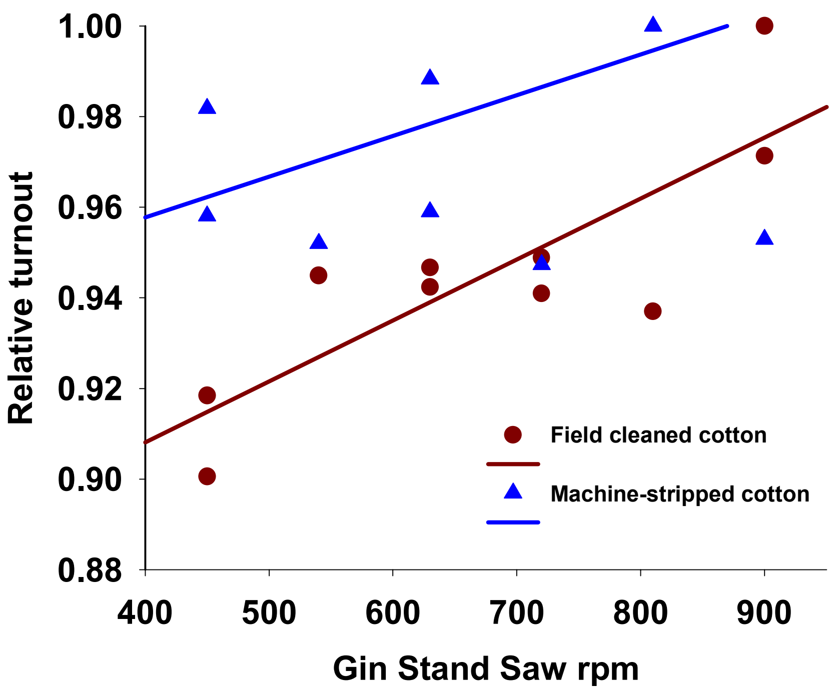

Figure 5. Relative turnout (% of highest) versus gin saw speed, rpm, for the experimental 110 saw powered paddle roll gin stand for seedcotton from two harvest methods.