MODIFYING RIB RAIL PLACEMENT FOR THE POWERED ROLL GIN STAND: RESULTS FROM STUDIES CONDUCTED ON A RETROFITTED LUMMUS GIN STAND

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Abstract

The powered roll gin stand (PRGS) is a technology that has shown evidence of improving ginning rate, turnout, and fiber quality. However, results from the numerous studies comparing the technology against the conventional gin stand has given rise to speculation that the technology is only fitting for a certain make of gin stand, the one that was used to develop the initial prototype (Continental Eagle). Further investigation as to the differences between the models of gin stands that were working and those that had less than desirable results revealed the primary difference was the rib rail angle and location of the ginning point. Two studies were conducted on a retrofitted Lummus-116 gin stand to evaluate the hypothesis that the rib rail angle and ginning point location were the reasons why the PRGS technology was not working as hoped on other makes of gin stands than the initial prototype. Results validated the hypothesis and indicated that the optimal rib rail angle and gin point needed to be reduced by four degrees and increased by half an inch, respectively, from the initial settings on the Lummus-116. Findings demonstrate that the initial concept that all that was needed to implement the PRGS technology on an existing gin stand is just to replace the front, was in error. The dynamics of the components of the powered roll technology in regards to the rib rail angle and ginning point location need to be considered when retrofitting any existing gin stand with PRGS technology.

Introduction

The powered roll gin stand is USDA-ARS patented technology (Laird, 2000) initially developed to remove the residual fibers from cottonseed for the EASI*flo*™ process (Laird et al., 1997). Numerous studies have been conducted over the past eight to nine years demonstrating the potential of this technology to improve the efficiency of ginning seed cotton without adversely affecting fiber properties (Laird et al., 2000; Laird et al. 2001; Holt et al. 2001; Laird et al. 2002; Holt et al., 2002; Laird and Holt, 2003; Holt, 2004). In addition to ginning capacity and fiber quality evaluations, optimization studies were conducted (Holt, 2007(a); Holt, 2007(b); Holt and Laird, 2007) to determine the operational settings for the three primary components of the powered roll gin stand: 1) the saw, 2) the paddle roll, and 3) the seed finger roll (Figure 1).

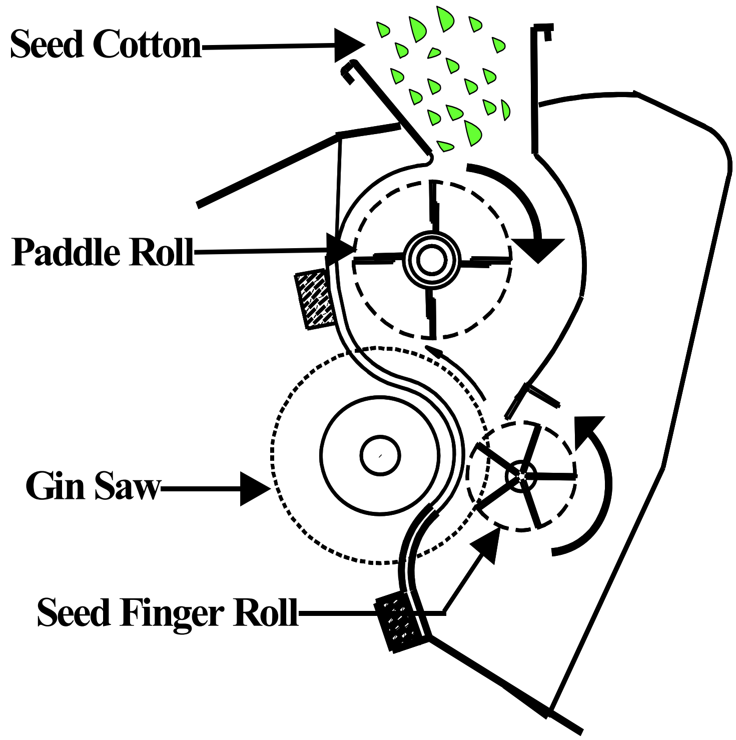


Figure 1. Schematic of the powered roll gin stand showing the paddle roll, gin saw, and seed finger roll components.

Even though the powered roll gin stand (PRGS) technology can be utilized by fabricating a new gin stand, the prototype and initial field test models were obtained by taking existing gin stands and retrofitting them with new fronts that contained the powered paddle and seed finger rolls as depicted in Fig 1. The initial prototype model, located at the United States Department of Agriculture–Agricultural Research Service's (USDA-ARS), gin lab in Lubbock, Texas, showed promising results that prompted the conversion of the first commercial unit, a Continental Double Eagle 141, installed at Servico, Incorporated's gin in Courtland, Alabama. The initial testing and evaluation performed in 2002, resulted in all three of Servico's gin stands being converted. Askew et al. (2004), documented Servico's experience with evaluation and operating the PRGS in a commercial cotton gin. The information and results obtained during the installation and evaluation at Servico prompted other gin stand conversions at other cotton gins. In spite the success and experience gained at Servico, other conversions had their own unique installation and operational challenges. One of the main challenges was the operation of this technology on makes of gin stands that differed from the original Continental Eagle models that were used to develop the prototype and were operated at Servico, Inc.

One make of gin stand, Lummus, which was retrofitted with the PRGS technology, was evaluated at several locations: Minturn Coop in Chowchilla, CA; Roscoe Coop in Roscoe, TX; and Coastal Plains Gin in Mathis, TX. The production rate, fiber properties, and turnout results from these initial retrofitted Lummus gin stand studies showed promise but revealed an inconsistency in performance that was puzzling. Separate from any mechanical issues resulting from manufacturing problems, the retrofitted gin stands would outperform the conventional (i.e. non-retrofitted) gin stand in one test and then perform identically in the next test. This inconsistency in performance, compared to the existing gin stands, coupled with manufacturing problems that were occurring with some of the earlier units, resulted in some of the initial cotton gins evaluating the PRGS technology to stay with their existing gin stands since there did not appear to be a definitive advantage to implementing the technology. The inconsistency in performance from the initial studies to the results obtained at Minturn, Roscoe, and Coastal Plains led some to believe that the technology would only work on one make of gin stand.

When investigating why the PRGS technology appeared to perform better on one make of gin stand than others, it became evident that the primary difference between the gin stands that were working consistently and those that were not was the angle of the ribs and the location of the ginning point. Thus two studies were conducted to address the objectives: 1) Evaluate if there are other gin rib configurations (i.e. rib angle and placement) in a retrofitted Lummus

PRGS that display better performance characteristics (i.e. gin rate, turnout, and fiber quality) than the "initial" retrofitted Lummus PRGS; and 2) If the initial evaluation reveals other configurations that show promise, determine the optimal configuration to be used when retrofitting a Lummus gin stand with the PRGS technology.

Materials and Methods

To accomplish the objectives, two tests were performed. The first test evaluated whether alternative rib angles and placements might improve the performance characteristics of a Lummus gin stand retrofitted with PRGS technology. The second test focused on optimizing rib angle and the ginning point. Tests were performed on the second generation prototype PRGS at the USDA-ARS Cotton Production and Processing Research Unit (CPPRU) in Lubbock, Texas. The second generation prototype involved retrofitting a Lummus 116-saw gin stand with the PRGS technology. Specific details of the modifications made in retrofit are found in Holt, 2007(b). The operational settings of the PRGS components in both tests were: 1) paddle roll speed = 208 rpm, 2) paddle roll load = 17.5 amps, 3) saw speed = 830 rpm, and 4) seed finger speed = 26.4 rpm. Both tests were performed using a single variety (Paymaster 2326) that had been stripper harvested without a field cleaner. Moisture samples for both tests were obtained by collecting seed cotton from the feeder apron. Moisture was determined by the procedure developed by Shepard (1972). Lint samples were collected before and after lint cleaning and analyzed using High Volume Instrumentation (HVI) and Advanced Fiber Information System (AFIS) at Cotton Incorporated's facility in Cary, North Carolina. For both the moisture and lint samples, a total of three samples were taken for each run. Two lint cleaners were used during the tests. The setup of the precleaning equipment (i.e. prior to the gin stand) was identical for both tests.

Study 1: Setup of Treatments

For this study, modifications were accomplished by inserting a combination of spacers behind the rib rail and changing out the guide rollers with rollers of varying diameters (Figure 2). Figure 3 shows how the six combinations of spacers and guide rollers, used in this study, influenced rib angle and gin point.

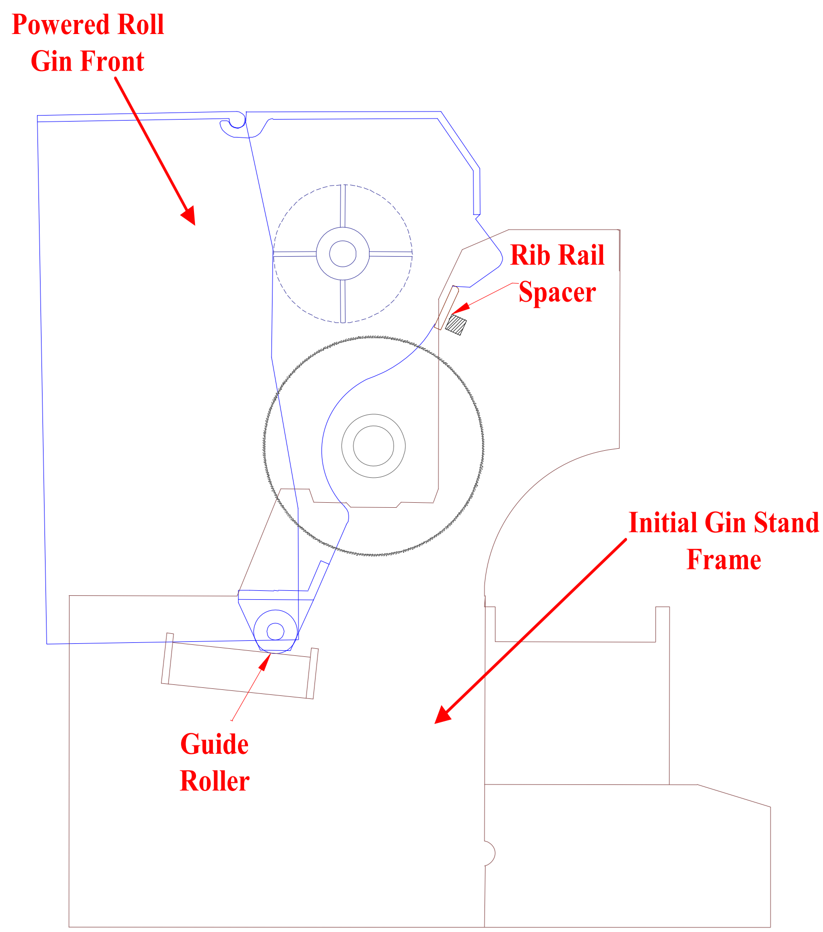
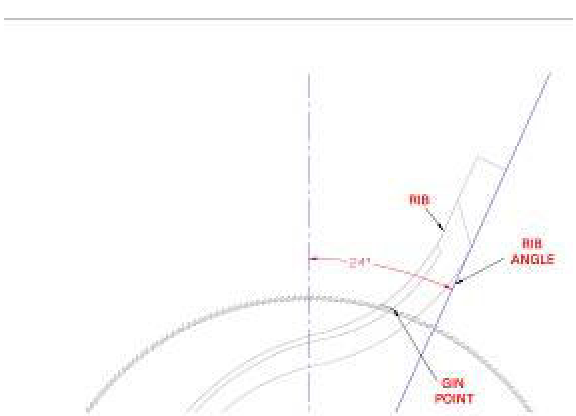
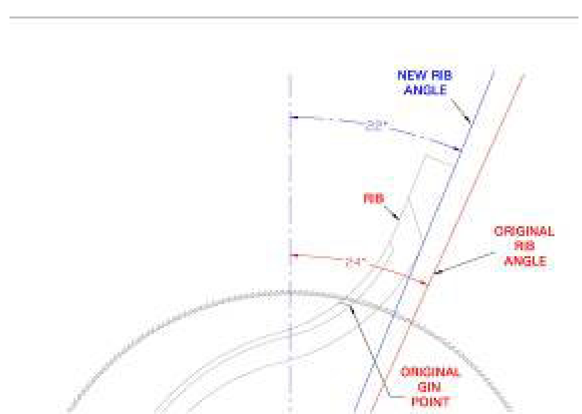


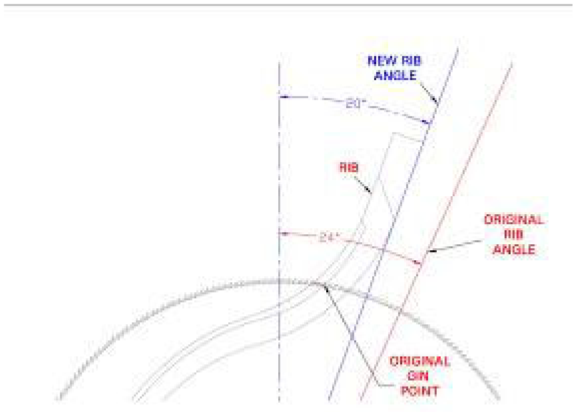
Figure 2. Schematic side-view showing the locations where modifications (rib rail spacers and guide rollers) were made on the second generation powered roll gin stand for study 1.



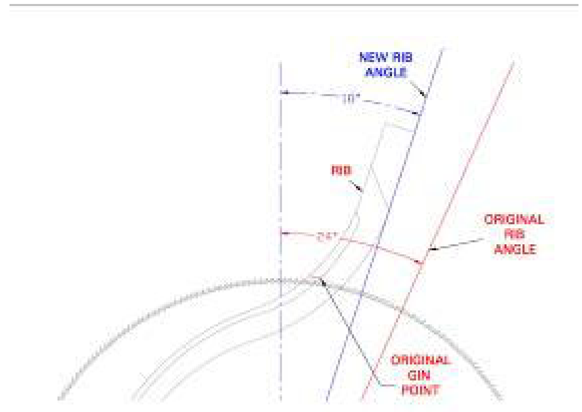
Setup 1(Original)



Setup 2



Setup 3



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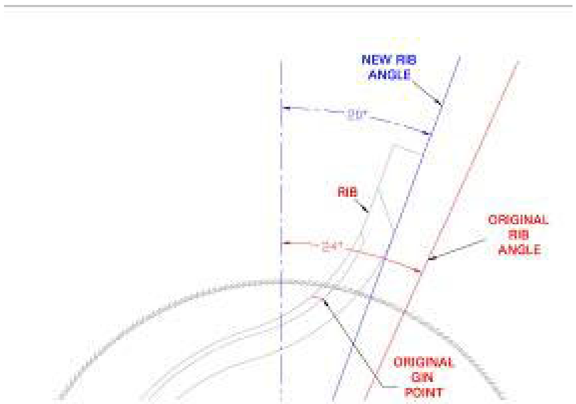

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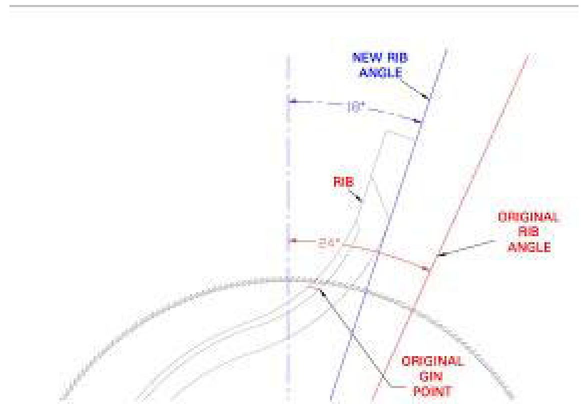
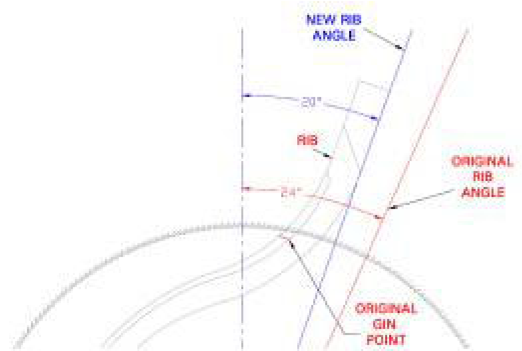


Setup 6

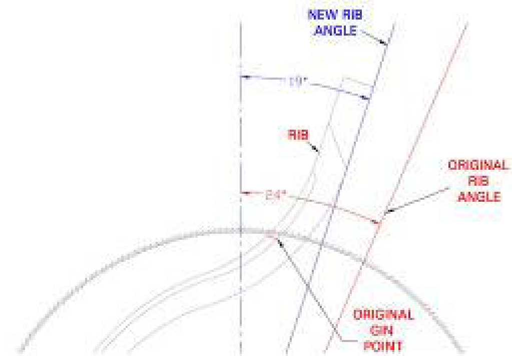
Figure 3. Schematics showing the gin saw passing through the ribs and how the combinations (setups) of rib rail spacers and guide rollers influenced rib angle and gin point for the six treatments evaluated in study 1.

<u>Study 2: Setup of Treatments</u>

Modifications were made using the same procedure as Study 1 but with different combinations of spacers and guide rollers. Figure 4 shows how the nine combinations of spacers and guide rollers, used in the second study, influenced rib angle and gin point.



Setup 1



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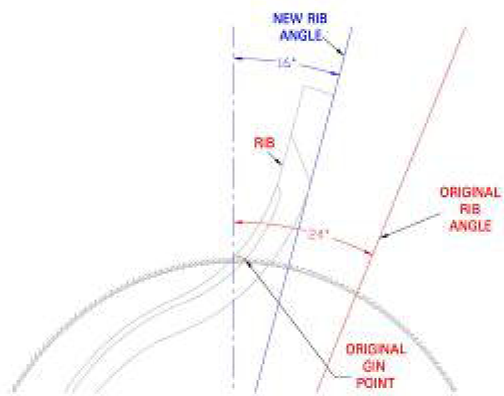

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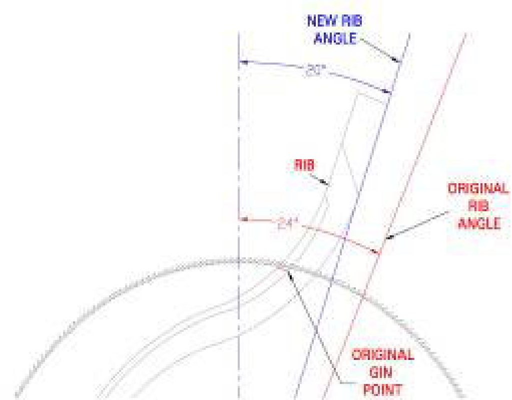

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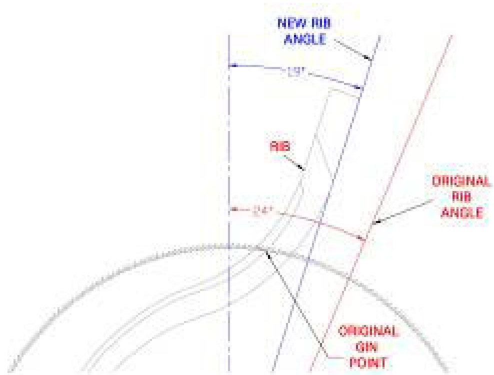

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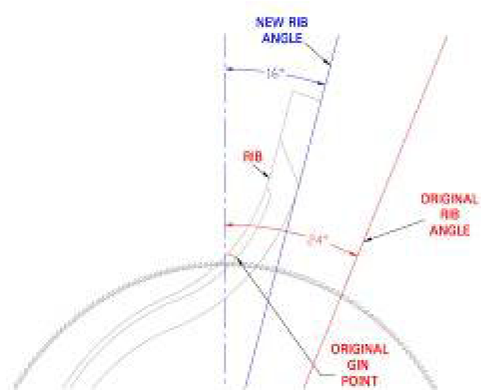

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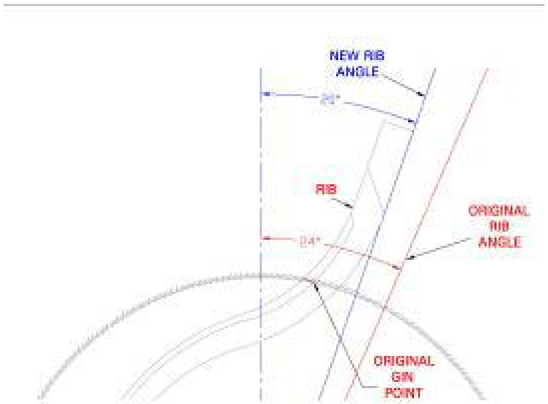

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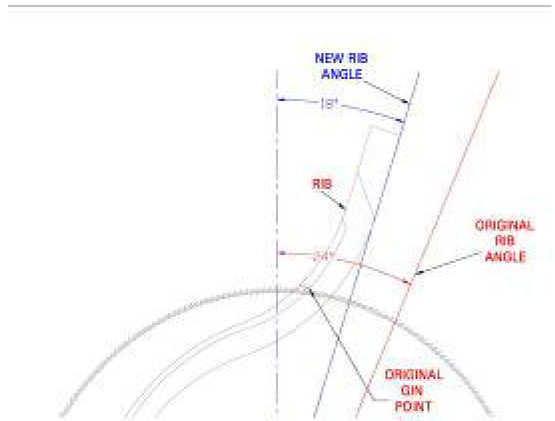

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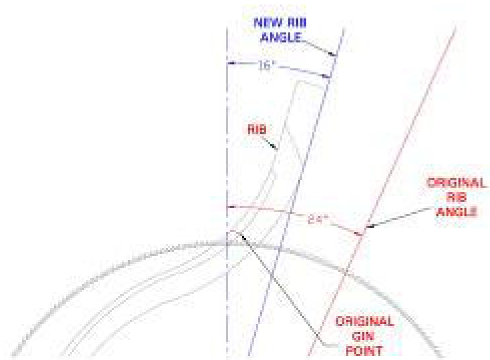

Setup 9

Figure 4. Schematics showing the gin saw passing through the ribs and how the combinations (setups) of rib rail spacers and guide rollers influenced rib angle and gin point for the nine treatments evaluated in study 2.

Experimental Design and Data Collection

Study 1: Six treatments were evaluated in this study, as depicted in Figure 3 above. There were three replications of each treatment for a total of 18 runs. For each run, one moisture and three lint samples were collected. The experiment was arranged as a complete randomized design. Standard analysis of variance techniques were used to analyze the data using the Ryan-Einot-Gabriel-Welsch multiple range test to determine statistically significant differences between the treatments at the 90% confidence interval (SAS, 2005).

Study 2: Based on the finding from Study 1, response surface methodology was used to determine the optimal location of the Lummus rib rail on the prototype PRGS. Nine treatments were evaluated, as per Figure 4, using a face-centered central-composite design (FCD), blocked by day, to perform 22 runs (eleven each day). The FCD contained two independent variables (spacer thickness [in] and guide wheel diameter [in]) and 20 response variables. The response variables included fiber properties obtained from HVI and AFIS analyses, seed analysis data, and production data. Model coefficients for the individual response variables were determined using the backward elimination procedure and hierarchy principle. The level of significance was set at 10% ($\alpha = 0.1$) with the optimization analysis performed using desirability functions (Derringer and Suich, 1980).

Results & Discussion

Study 1: The average moisture content of the seed cotton was 8.07% with a standard deviation of 0.57%. Table 1 shows select production and fiber property data from the statistical analysis. The factors which had treatments with significant differences at the 95% confidence limit were gin rate, nep size, and leaf grade. Table 1 shows some of the other more commonly evaluated variables that were measured but were not significant for the treatments evaluated. While Nep Size and Leaf Grade showed significance between the treatments, the most notable statistically significant response was that of ginning rate. The data revealed the highest ginning rate to be with Setup 5 (7.4 bales/h) and the lowest was with the original setup (6.06 bales/h). The importance of ginning rate being significant was highly important because in field trials with retrofitted Lummus gin stands, mixed results were encountered giving way to the idea that the technology worked better on one make of gin stand more than others. However, the findings of this study imply that some of the less than desirable ginning rates encountered in the retrofitted Lummus field models were more a result of the improper alignment of the rib rail and gin point than the PRGS technology. Results from this test prompted a second test where the objective was to determine the optimal setup for the rib rail and gin point using the prototype Lummus-116 PRGS.

Table 1. Production and fiber property data, based on samples taken after lint cleaning, from the initial test evaluating six combinations of rib rail angle and gin point on a retrofitted Lummus-116 powered roll gin stand .

Treatments [a]	Production[b]		AFIS Fiber Data				HVI Fiber Data & Loan Value			
	Gin Rate (bale/h)	Turnout (%)	Nep Size (um)	Neps (cnt/g)	Length by wt. (in)	Short Fiber Content (%)	Length (in)	Unif (%)	Leaf Grade	Loan Value[c] ($)
Setup 1 (original)	6.06d	32.9	698 ab	380	0.920	11.5	1.07	80.2	3.0ab	0.525
Setup 2	6.83b	32.6	703ab	379	0.927	10.7	1.08	80.4	3.0ab	0.533
Setup 3	6.63bc	33.2	698 ab	381	0.917	11.3	1.07	80.3	3.0ab	0.530
Setup 4	6.21cd	33.0	685 b	350	0.927	10.7	1.06	79.6	2.3b	0.511
Setup 5	7.40a	33.1	693 ab	369	0.930	10.7	1.06	80.4	3.3a	0.512
Setup 6	6.68bc	33.6a	713 a	360a	0.920a	11.1a	1.07	80.6	3.0ab	0.528

(a) Setups obtained by inserting spacers behind the rib rail and by replacing the guide rollers with rollers of different diameters. Setups 2 through 5 resulted in different rib angles and gin points compared to Setup 1 (original).
(b) Means within the same column followed by different letters are significant at the 95% confidence limit.
(c) Loan value calculated from the 07-08 CCC loan chart for Lubbock, Texas.

Study 2: The average moisture content of the seed cotton was 6.88% with a standard deviation of 0.60%. The data presented in this report is based on fiber data from lint samples collected after lint cleaning. The before lint cleaning fiber quality data did not yield any significant models for optimization analysis. Regression analysis produced fitted models to seven response variables: 1) ginning rate, 2) reginned lint (residual lint), 3) HVI Length, 4) Short Fiber Content by weight (SFCw), 5) AFIS Length by number (Ln), 6) Short Fiber Content by number (SFCn), and 7) Seed Coat Nep Size. Table 2 shows the mean, standard deviation, R-Squared, significant model terms, and signal-to-noise ratio for the seven response variables yielding models. The signal-to noise ratio is a metric that indicates whether or not there is adequate model discrimination of the response variable to noise. A ratio value greater than 4 is desirable (Whitcomb et al., 2003). Normally in a ginning test, ginning rate would be held relatively constant. In this test, the operation of the gin stand was held at a constant paddle roll loading of 17.5 amps thus, variations in ginning rate were due to the “ease of ginning” experienced by the gin stand. The reginned lint response variable is an indication of the cleanliness of the seed (i.e. less lint means better cleaning of the seed). The other five response variables producing fitted models are associated with fiber quality measurements.

Table 2. Model analysis data for the ginning rate, reginned lint, HVI length, short fiber content by weight, AFIS length by number, short fiber content by number and seed coat nep size response variables for the retrofitted Lummus-116 gin stand based on lint samples collected after lint cleaning.

Response Variable[a]	Units	Model Data[b]				
		Mean	RMSE	R^2	Model Terms[c]	S/N Ratio
Ginning rate	bales/h	7.52	0.21	0.667	S^2, RS^2	7.3
Reginned lint	%	0.329	0.13	0.848	S, S^2	13.9
HVI Length	in	1.05	0.0059	0.383	RS, R^2	9.2
Short Fiber Content (w)	%	8.10	0.47	0.409	R, R^2	8.0
AFIS Length(n)	in	1.15	0.0082	0.371	R, R^2	7.3
Short Fiber Content (n)	%	24.6	1.10	0.456	R, R^2	6.9
Seed Coat Nep Size	um	1074	45.2	0.377	R, R^2	5.8

(a) Reginned lint = the percent of lint recovered off of the seed after ginning, a lower percentage is desirable and indicates cleaner seed. (w) = by weight. (n) = by number (i.e. by count).
(b) RMSE = root mean square error, S/N = signal-to-noise.
(c) Only statistically significant terms ($p \leq 0.1$) in the models are shown. S = Spacer thickness, R = guide Roller diameter

The only response variables that were deemed acceptable for use in the optimization analysis, based on R^2 values, were ginning rate and reginned lint. With the exclusion of the all the response variables except ginning rate and reginned lint, the optimization was based on variables that are not dependent on lint cleaning since these response variables are production parameters of the system and not fiber properties which are influenced by lint cleaning. The significant model terms for ginning rate were spacer thickness squared (S^2) and the interaction of guide roller diameter and spacer thickness squared (RS^2). The regined lint response variable had two significant model terms, S and S^2. Figures 5 through 7 show the graphs for ginning rate, reginned lint, and desirability, respectively.

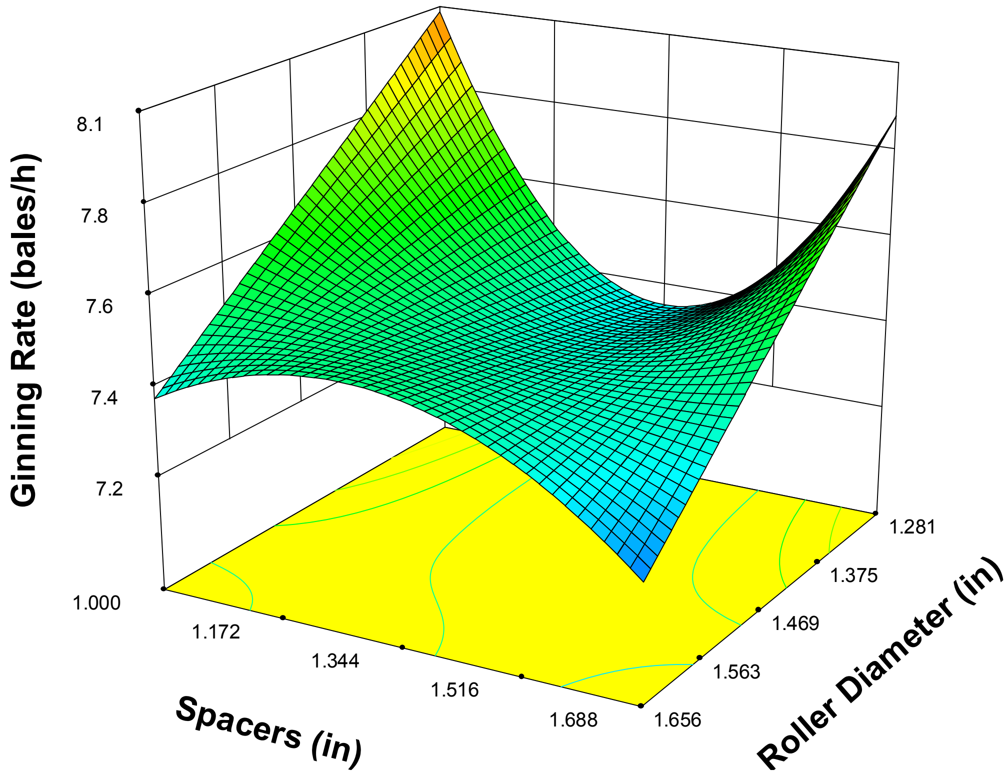

Figure 5. Three-dimensional graph for ginning rate over the range of spacers and guide roller diameters evaluated.

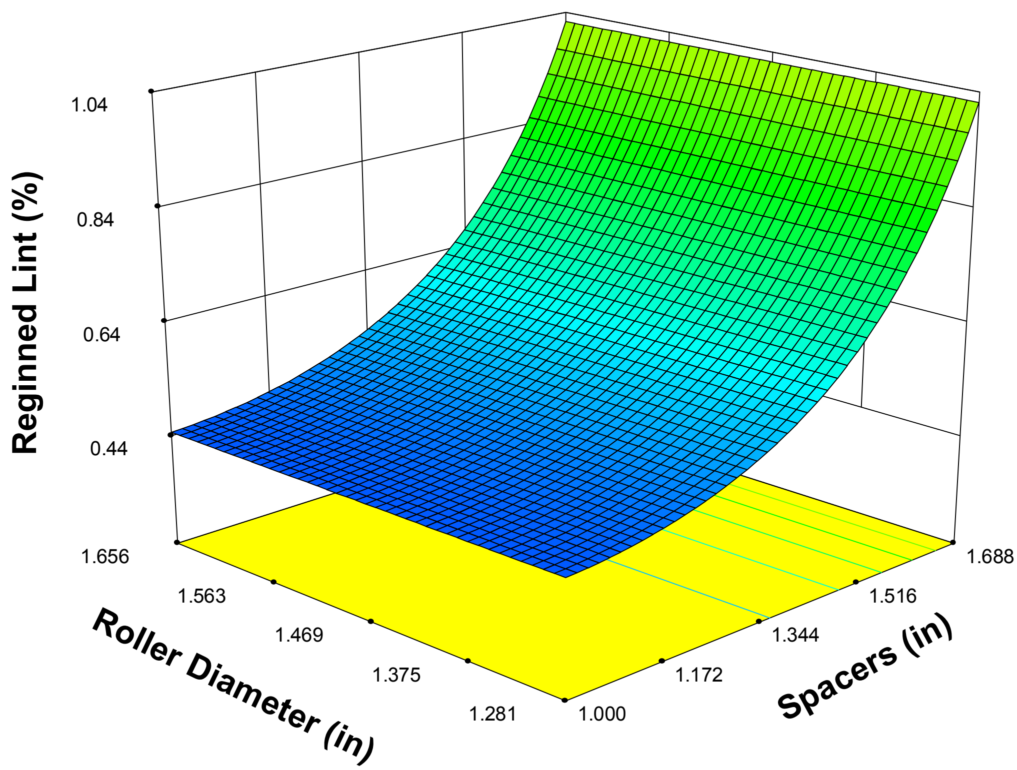

Figure 6. Three-dimensional graph for reginned lint (residual lint) over the range of spacers and guide roller diameters evaluated.

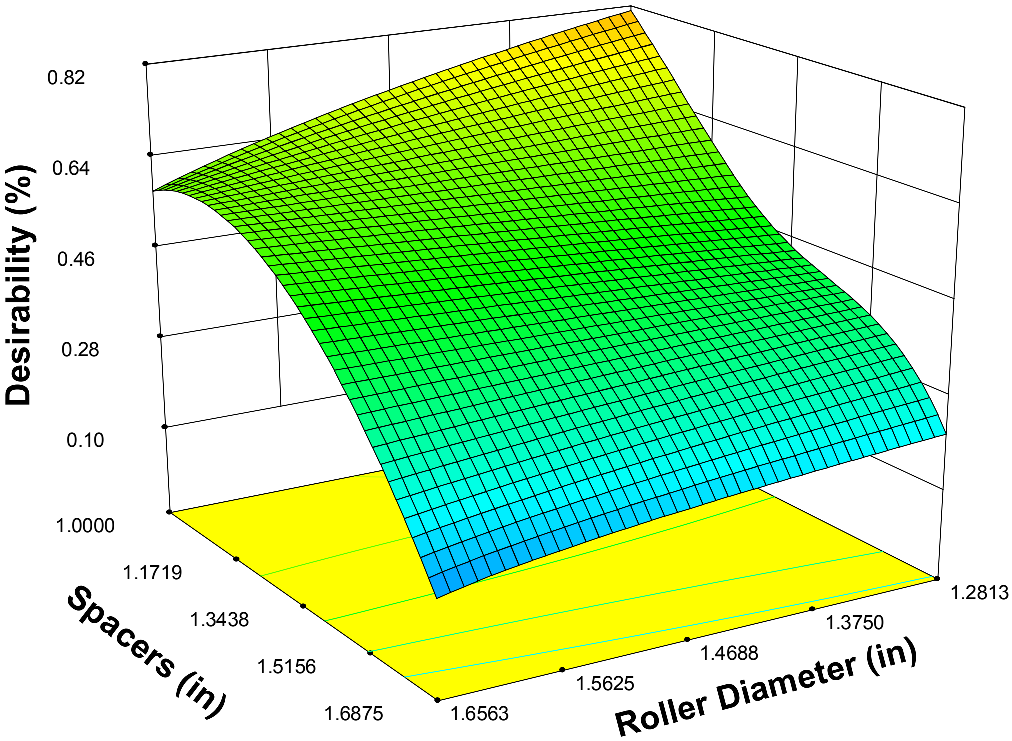

Figure 7. Three-dimensional graph for desirability over the range of spacers and guide roller diameters evaluated.

Figure 5 shows that at the smaller roller diameter the ginning rate increased as the spacer thickness either increased or decreased from 1.34 in. However, the opposite was true at the higher roller diameter. Figure 6 shows the influence of spacer thickness on residual lint. The smaller the spacer, the lower the amount of residual lint left on the seed regardless of the roller diameter. Figure 7 shows the most desirable configuration, based on the ginning rate and reginned lint response variables, would be Setup 1 in Figure 4 (a roller diameter of 1.28 in and a spacer thickness of 1in).

The results of the second study verify the findings of the first study. The ideal setup in the first study was with a spacer thickness of 1 in and a roller diameter of 1.18 in. The optimization analysis revealed the optimal roller diameter and spacer diameter to be at the edge of the design space. Additional studies should be conducted to narrow the design space as much as possible around the optimal setup found in this study to validate the findings. One of the main limitations that need to be considered for any additional study is making sure that a design space centered on a roller diameter of 1.28 in and a spacer thickness of 1 in can be obtained without the ribs rubbing against the saw mandrel. Rubbing against the saw mandrel was one of the problems encountered in the first study which is why the amount of combinations was limited to those reported. Lastly, items such as rib curvature, roll box dimensions and configuration, and paddle and seed finger roll placement are items that warrant further investigation. These items have been evaluated through mostly trial and error with optimization studies conducted with these items being "as was" however, a rigorous analysis of these items is needed to help understand the overall influence they could have on improving the performance and optimization of the PRGS technology.

Summary and Conclusions

Problems encountered in retrofitting the powered roll gin stand technology on makes and models of gin stands other than Continental Eagle gin stands led some to speculate that the technology only worked on those models and that it could not be successfully implemented on other makes and models. Further investigations into what differences might exist between the retrofitted models that were working and those that were not revealed the angle of the rib rail and the ginning point. One of the main assumptions in the initial installations of the technology was that the only component of the existing gin stands that needed to be changed was the gin front; the rib rail and the angle of the ribs could be left as they were originally designed. Findings from two studies conducted on a Lummus-116 that had been retrofitted with the PRGS technology, revealed that the initial assumption of leaving the rib rail and ginning point the same for all models to be in error. Results indicate the rib rail angle needs to be decreased by 4 degrees and the gin point moved up on the rib a half-inch for the Lummus-116 gin stand evaluated. The power roll gin stand technology has great potential to improve the operation of a gin stand however, a better understanding of how the PRGS components influence production and fiber quality parameters needs to be gained especially when retrofitting the technology onto existing gin stands.

Acknowledgement

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