# COTTON STRIPPER HARVESTER EVALUATION AND MODIFICATION FOR COTTON FIBER QUALITY PRESERVATION AND FOREIGN MATTER REMOVAL

By

WESLEY MARK PORTER

Bachelor of Science in Agricultural Mechanization and
Business
Clemson University
Clemson, SC
2007

Master of Science in Agricultural Engineering
Clemson University
Clemson, SC
2010

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Dissertation Approved:

Dr. Randal K. Taylor

Dissertation Adviser

Dr. Michael D. Buser

Dr. John D. Wanjura

Dr. Randal K. Boman

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Abstract: The goal of Phase I was to determine cotton fiber quality and foreign matter characteristics of bur cotton after it was processed through sequential selected cotton stripper conveyance/cleaning locations. Five sequential conveyance locations were selected for data collection along with hand picked cotton as a reference. The data analysis aided in targeting relevant locations for redesign to reduce foreign matter content while preserving fiber quality. Phase I identified points on the harvester located between the row units and field cleaner that could be modified or redesigned to aid in fiber quality preservation and foreign matter removal.

The objective of Phase II was to design and evaluate an alternative conveyance system. A wire belt conveyor was selected as a replacement for the cross auger. A wire belt conveyor was designed and built convey bur cotton from one half of a four row cotton stripper and was evaluated in a laboratory. The results were compared to a standard cross auger in terms of fiber quality and foreign matter impact. There were no significant differences identified between the current auger design and the wire belt conveyor in either foreign matter removal or fiber quality.

The objective of Phase III was to characterize and parameterize bur cotton flow on a wire belt conveyor. Two techniques were used: fiber quality and foreign matter data were collected along with use of a top view high speed camera. Three yields common to the Southern High Plains, a one m row width, and 5.6 km $h^{-1}$ ground speed were used to determine three material conveyance rates. Four wire belt conveyor widths (0.18, 0.36, 0.53, and 0.69 m), and four material depths (0.025, 0.05, 0.10, 0.18 m), were chosen. Fiber quality, percent foreign matter removal, and foreign matter data were collected from the extreme high and low depths for each belt width and material flow rate to determine the wire belt configuration effects. Results determined that wire belt configuration had insignificant impact on fiber quality, lower material depths produced higher foreign matter removal, and wider, greater material depths aided in a more uniform velocity profile development.

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# INTRODUCTION

### *Stripper Harvested Cotton*

Cotton fiber quality begins to degrade with the opening of the boll (ICAC 2001). Mechanical harvesting processes result in an increase in the amount of foreign matter contained in seed cotton at the gin and influence the quality of ginned lint. Stripper harvested bur cotton contained 27.8% total trash compared to 4.6% for spindle picked seed cotton (Kerby et al., 1986; Baker et al., 1994; Faulkner et al. 2011a), and the quality of stripper harvested fiber is often lower than that of picker harvested lint for example micronaire was 3.2 for stripper cotton and 3.5 for picker cotton. Stripper harvested cotton had a length of 2.77 cm and 2.82 for picker cotton; the uniformity was 79.4 and 80.4 for stripper and picker cotton respectively (Faulkner et al. 2011b). Kerby et al. (1986) reported averages across experiments from stripper harvested cotton that produced mean fiber length 4 mm shorter, 0.9% more short fibers, and a uniformity ratio that was 0.9 units less than spindle harvested cotton. Fiber strength was not affected by harvest method, while micronaire was slightly lower for brush stripped seed cotton than spindle picked but still in the premium quality range. Brush stripped cotton averaged 37% more neps than spindle picked cotton. The amount of neps and short fiber contained in ginned lint is influenced by many factors including: variety, fiber maturity, harvest-aid product and timing, harvest method, and ginning practice. Inclement weather, periods of excessive soil moisture from rainfall or irrigation, and limited heat unit accumulation (< 2500 DD60's) are production conditions experienced on the High Plains that tend to produce immature fiber with low micronaire (Wanjura et al. 2010).

Garner et al. (1970) reported that spindle picked cotton ginned an average of 24% faster than stripped cotton due to much lower content of foreign matter. Unlike picker harvesters, which use spindles to remove seed cotton from open bolls, stripper harvesters use brushes and bats to indiscriminately remove seed cotton, bolls, leaves, and other plant parts from the stem of the plant. The harvesting efficiency or the amount of crop material removed during harvest with a picker is lower than that with a stripper harvester. Field losses are lower than those from pickers and under ideal harvesting conditions; a stripper can harvest 99% of the cotton on the plant compared to 95-98% with a picker and in some instances the picker will have harvest losses approaching 20% (Hughs et al. 2008). A cotton stripper has advantages in certain growing conditions. For a particular cotton crop, a picker harvests a different subset of the total fiber population than a stripper harvester. The subset of fiber harvested by a picker is typically more mature longer staple fiber while a stripper indiscriminately harvests all of the fibers on a plant. The difference in fiber quality between picker and stripper harvested cotton is dependent upon fiber maturity (Faulkner et al. 2011b). Since cotton stripping is a once-over operation, unlike picking which if needed can be performed more than once, harvesting has to be delayed until all bolls are mature and any green material is desiccated (Hughs et al. 2008). Micronaire and fiber length parameter differences between harvest methods are greater when more fibers are immature and favor picker harvesting because the picker harvests a higher majority of the mature fibers. However, stripper harvesting removes most if not all of the fiber from the plant while picker harvesting only removes the more mature fibers from fully open bolls. When fibers are mature, the quality differences tend to be less between harvest methods.

Stripper harvesting is predominately confined to the Southern Plains of the US due to several factors including: low humidity levels during daily harvest intervals, tight boll conformations and compact plant structures adapted to withstand harsh weather during the harvest season, and reduced yield potential due to limited rainfall and irrigation capacity. Cotton strippers typically cost about one-third the price of cotton pickers and have harvesting efficiencies in the range of 95 – 99% making them ideal for lower yielding cotton conditions (Faulkner et al. 2009 and Williford et al. 1994). In 2010, approximately 50% of the total number of cotton bales produced in the U.S. came from Texas and Oklahoma (USDA, 2011). Approximately 70-75% of the cotton harvested in these two states was harvested with stripper harvesters. Over one quarter of the cotton harvested in the U.S. in 2010 was harvested with cotton strippers (USDA, 2011). Cotton produced in the Texas High Plains has exhibited substantial improvements in terms of yield and fiber quality over the last decade. These improvements are due primarily to new cultivars, improved irrigation practices, and utilization of harvest-aid chemical products. However, cotton produced in the region continues to receive larger price discounts from buyers compared to cotton of equal grade and classification produced in other area of the US (Wanjura et al. 2010). Cotton strippers continue to play a major role in the U.S. cotton industry. Research focused on improving cotton quality and reducing foreign matter from stripper harvest cotton is a critical need in the cotton industry.

Many studies have investigated the overall quality of stripper harvested cotton, quality of stripper harvested cotton versus picker harvested cotton, and cost comparison of the two harvest methods (Faulkner et al. 2011b, Faulkner et al. 2011c, Kerby et al. 1986, Nelson, et al. 2001. Wanjura et al. 2012.). Use of field cleaners on strippers and their effectiveness at removing foreign matter was the focus of several studies (Brashears 2005, Smith and Dumas 1982; Wanjura and Baker 1979; Wanjura and Brashears 1983; and Wanjura et al. 2011). Field cleaners were determined to be an effective system for removing foreign material from stripper harvested cotton; however these studies do not address any other components of the stripper harvester such as the row units, cross auger, or separation duct. Brashears (1994) observed that attaching pieces of square key stock to the outer edge of the conveyor auger flights on a cotton stripper increased the amount of foreign material removed from harvested bur cotton by up to 60% but the influence of these modifications on fiber quality was not reported.  To the author's knowledge, only the previous work by Porter et al. (2012 and 2013) addresses the influence of the individual harvesting and conveying systems of a stripper harvester on fiber quality.

### *Cotton Ginning, Cotton Fiber Quality, and Foreign Matter*

Higher levels of foreign material can have negative impacts throughout the harvesting and processing steps.  High foreign matter content results in increased harvesting and ginning costs while excessive bark results in grade and price reductions which may cost the producer $20 to $25 per bale (Brashears 1992).  Foreign matter levels in seed cotton before gin processing usually range from 1 to 5% for hand harvested, from 5 to 10% for spindle-harvested, and from 10 to 30% for stripper harvested cottons.  The foreign matter level dictates the amount of cleaning needed (International Cotton Advisory Committee 2001.).  Gin turnout is typically about ten percent lower with stripper harvested cotton than with picker harvested cotton.  Stripper harvested bur cotton contains 210 to 635 kg of trash per bale depending upon growing and harvesting conditions (Baker et al., 1977).  Approximately 80% of the foreign matter is composed of burs and sticks.  These large plant components, if not removed from the cotton, interfere with the operation of the gin stand and contribute to the fine trash and bark content of the ginned lint (Baker and Laird, 1982).  Thus, by weight 40% more of the material being transported from the field to the gins is foreign material, meaning an extra associated cost of transporting the foreign material.  The extra material must then be removed at the gin, incurring an added cost.  The added cost is directly incurred by the producer.  Any improvement in reducing foreign material will aid in reducing the added costs associated with stripper harvested bur cotton.

An extraneous amount of foreign matter not only has impacts at the field level but incurs extra costs all through the processing steps.  More foreign matter in bur cotton results in lowering lint turnout.  Lower lint turnouts mean the producer delivers less fiber per modules to the gin.  Thus, on a per bale basis, more transportation cost is incurred by the producer along with higher ginning costs. Typically, stripped cotton requires more levels of cleaning before it reaches the gin stand to ensure efficient ginning. Trash and moisture in mechanically harvested seed cotton are the most important factors that influence lint quality (Barker et al. 1973). It has been documented that an increase in mechanical actions typically increase the quantity of foreign matter by reducing larger pieces of foreign matter into multiple smaller pieces (Sui et al. 2010). Thus, the extra amounts of cleaning and mechanical action required for stripper harvested cotton can potentially increase the fiber damage. The typical ginning machinery sequence for processing spindle picked seed cotton is a module feeder, a dryer, cylinder cleaner, stick machine, dryer, cylinder cleaner, extractor-feeder and saw-type gin stand followed by two stages of saw-type lint cleaning. Machine stripped cotton requires the addition of at least one extractor prior to ginning (International Cotton Advisory Committee 2001.). Even though stripper harvested cotton typically requires multiple stages of pre-cleaning, a study by Holt et al. (2002) stated that bypassing the second stages of cleaning had no significant effects on turnout. However, the Holt et al. (2002) study reported an increase in foreign matter collected during the lint cleaning stage. Thus, stripper harvested cotton still requires higher levels of cleaning throughout the ginning process to properly prepare the fiber for spinning. Wanjura et al. (2012) recommended using one stick machine in seed-cotton cleaning systems processing picker-harvested cotton and two stick machines in systems processing stripper-harvested cotton. Wanjura et al. (2012) reported a higher total lint value, on a production area basis for stripper-harvested cotton after two stages of lint cleaning compared to picker-harvested cotton due to yield differences. The lint value was based on the USDA Agricultural Marketing System. The recommended lint moisture range at the gin stand feeder apron is 6-8%. At moistures less than 6%, cleaning machinery will remove more trash resulting in better leaf grades, but more fiber damage can result and the turn out will be reduced (Valco 2005). Extractors in the seed cotton systems are generally 80 to 85% efficient in removing sticks from seed cotton (Baker and Lalor 1990). In a stripper versus picker study performed in New Mexico by Hughs (1983), stripped cotton had initial trash levels that were five times higher than that of picked cotton and lint turnout that was just over half that of picked cotton.

The quality of ginned lint is directly related to the quality of the cotton before ginning. Lower grades and quality will result from cotton that comes from grassy, weedy fields in which poor defoliation or harvesting practices were used. When used in the recommended sequence, 75-85% of the foreign matter is usually removed from seed cotton during the ginning process. Cleaning seed cotton is a compromise between foreign matter level and fiber loss and damage (International Cotton Advisory Committee 2001). Fiber quality has been shown to vary by field location, boll location on the plant, and location on the seed (Ge et al., 2008; Johnson et al., 1998., Johnson et al., 2002., Bednarz et al, 2007; Bradow et al., 1997; Bradow and Davidonis, 2000).

Two primary fiber tests are used in cotton research; High Volume Instrument (HVI) and Advanced Fiber Information System (AFIS). The HVI system is comprised of nine parameters that can be used to classify the fiber. These nine parameters are micronaire, length, uniformity, strength, elongation, Rd (reflectance), +b (yellowness), Color Grade, and Leaf grade. AFIS is comprised of 20 parameters including Nep Size, Neps per gram, Length (by weight), Length (CV %), Upper Quartile Length, Short Fiber Content (by weight), Length (by number), Length (CV %), Short Fiber Content (by number), L5% (by number), Total (counts per gram), Trash Size, Dust (counts per gram), Trash (counts per gram), Visible Foreign Matter (%), SCN size, SCN (counts per gram), Fineness, IFC (%), Maturity Ratio.

Currently HVI is the only test used by the USDA-AMS to classify cotton in the US. HVI is used for because sample analysis is much faster and less labor intensive than AFIS. AFIS takes more handling and sample preparation than the HVI samples.  However AFIS gives much more information and more in depth information than HVI.

## Research Outline

The main objective of this study was to improve stripper harvester performance by reducing the foreign matter content, while preserving cotton fiber quality.  The specific objectives were divided into three phases:

1) Determine fiber quality properties from successive cotton stripper conveyance locations. The locations included:  1) hand-picked from the field, 2) after the row unit brush rolls, 3) after the row units, 4) from the separation duct after the cotton was conveyed by the cross auger, 5) from the basket with the field cleaner by-passed, and 6) from the basket after the cotton was processed through the field cleaner.
2) Use data from objective one to select a target conveyance location for modification.  A new design will be developed, built and evaluated in terms of foreign matter reduction, preservation of fiber quality and feasibility.
3) Determine the material flow characteristics and parameterization for conveying bur cotton on a wire belt conveyor.

### *Research Plan*

In Phase I, cotton fiber quality and foreign matter content were tracked and reported throughout the conveyance/cleaning components on a stripper harvester.  The results suggest that there were points throughout the machine that had limited foreign matter removal and could have enhanced the fiber quality degradation.  The conveyance/cleaning location after the row units but before the field cleaner was selected as the target for potential improvement.  In Phase II the cross auger was the specific target.  The cross auger was replaced with a wire belt conveyor.  The goal of Phase II was to test the efficacy of foreign matter removal and fiber quality preservation of a wire belt conveyor compared to the current cross auger design. The goal of Phase III was to characterize and parameterize bur cotton flow on a wire belt conveyor. This was accomplished using two techniques: data was collected using a high speed camera for conveyance velocity characterization and fiber quality and product quality characterization. The evaluation parameters included: wire belt conveyor widths (0.18, 0.36, 0.53, and 0.69 meters), depths of material (0.025, 0.05, 0.10, 0.18 meters), and belt speeds (calculated based on material flow rate required). The material flow rate obtained from these evaluation parameters were used to match three common bur cotton yields observed in the Southern High Plains 428.6, 642.9, and 857.1 kg ha$^{-1}$ (which are equivalent to1, 1.5 and 2 bale per acre yields). These wire belt configurations were used in conjunction with a top and side view high speed camera to determine flow characteristics of bur cotton. Fiber quality, trash removed, and foreign matter data were collected from the extreme high and low speeds and depths within each of the widths for a total of four runs each configuration to determine the effects on fiber quality.

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# CHAPTER II

## PHASE I: TRACKING COTTON FIBER QUALITY AND FOREIGN MATTER THROUGHOUT A STRIPPER HARVESTER

The goal of Phase I was to determine the cotton fiber quality and foreign matter characteristics of bur cotton after it had been processed through sequential selected cotton stripper conveyance/cleaning locations. Five sequential conveyance locations were selected for data collection along with hand picked cotton as a reference. The data analysis aided in targeting relevant locations that could be redesigned to reduce foreign matter content while preserving fiber quality. The overall purpose was to identify components and/or systems on the stripper that if redesigned, could help to improve the cleanliness and better preserve the quality of brush-roll stripper harvested cotton.

### Review of Literature

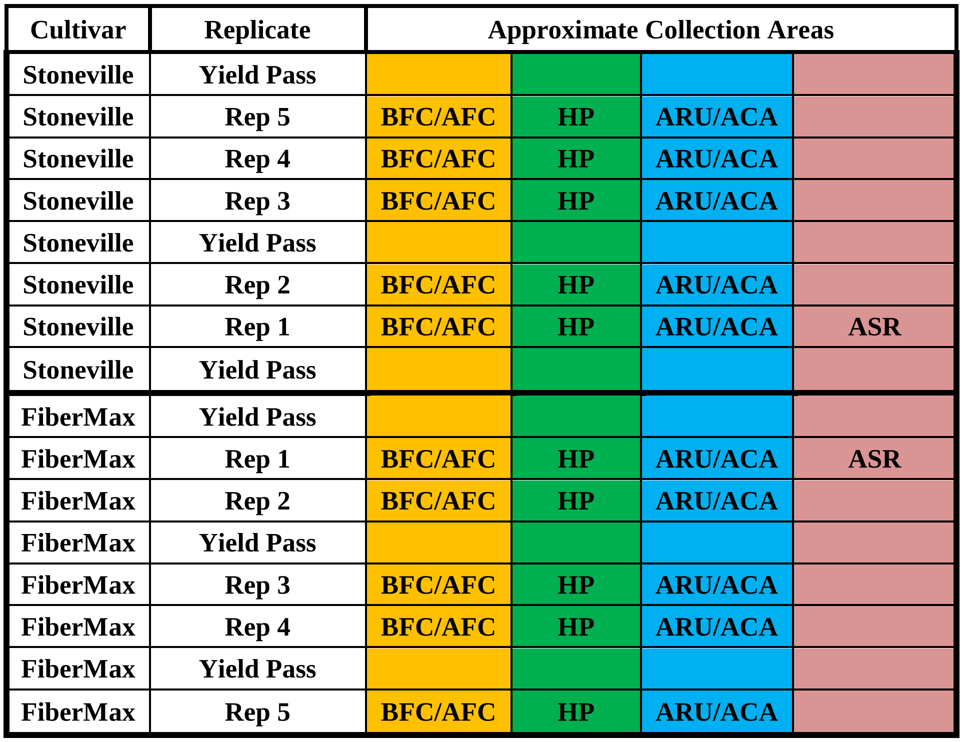
Stripper harvesters remove the cotton, bur, sticks, and any leaf that is left on the plant. This type of harvesting was first referred to as sledding. Horse drawn sleds were used in Texas as early as 1914 (Colwick, 1965). In the early 1920's early improvements were made by replacing fixed rods on a stripper harvester with a rotating pair of rods (Smith et al., 1935). These rolls had a fixed gap that allowed the plant but not the cotton bolls to pass through. In 1951, agricultural engineers in Oklahoma developed a stripping roll covered with brushes to reduce the amount of trash that accompanied the cotton. Improvements were made in the number of rows that could be harvested in one pass, ground speed, and conveyance of cotton to the hopper (Hughs et al. 2008). Many studies have investigated the overall quality of stripper harvested cotton, quality of stripper harvested cotton versus picker harvested cotton, and a cost comparison of the two harvest methods (Faulkner et al., 2011b; Faulkner et al., 2011c; Kerby et al., 1986; Nelson, et al., 2001; Wanjura et al., 2012). Several studies focused on the use of field cleaners on strippers and their effectiveness at removing foreign matter (Brashears, 2005; Smith and Dumas, 1982; Wanjura and Baker, 1979; Wanjura and Brashears, 1983; and Wanjura et al, 2011). All of these studies show that a field cleaner is an effective system for removing foreign material from stripper harvested cotton; however these studies do not address other components of the stripper harvester. Smith and Dumas (1982) reported on a field evaluation of a field cleaner that indicated overall cleaning efficiencies ranging from 65 to 80%, with an average of 71%. The initial trash content of the stripped material ranged from 29 to 38%, with an average of 34%. Conventional equipment currently used for cleaning seed cotton, either at the gin (Baker and Laird, 1973) or on harvesting machines (Kirk et al., 1972) incorporates one or more variations of four basic cleaning concepts which may be described as: 1) the scrubbing action of spiked cylinders moving the trashy seed cotton over grid bars; 2) the dislodging action of a stripping roller operating adjacent to a saw cylinder that is carrying trashy seed cotton; 3) the centrifugal action on trash entangled with seed cotton that is attached to a rotating saw cylinder; and 4) the combing action of a finger-type cylinder as the fingers mesh between adjacent blades of a saw cylinder that is carrying trashy seed cotton. The respective machines that incorporate these concepts are cylinder cleaners, bur machines, stick machines and the limb and stalk remover (Smith and Dumas 1981). Brashears (1994) observed that attaching pieces of square key stock to the outer edge of the conveyor auger flights on a cotton stripper increased the amount of foreign material removed from harvested bur cotton by 40% but the influence of these modifications on fiber quality was not reported. Brashears and Baker (1998) reported on modifications to a cotton stripper that included changing the combination of brushes and bats, use of a wider spacing between stripper rolls and between combing pans, and improved adjustment of grid bars in field cleaners. Brashears (1984) found that by reducing the width of the bats on the stripper roll, the stick content of the harvested cotton was reduced by 50% and the number of barky grades reduced by two-thirds.

## Materials and Methods

Cotton for this project was grown at the Texas A&M AgriLife Research and Extension Center north of Lubbock, TX. Two cultivars, FiberMax 9170 B2F and Stoneville 5458 B2RF, were evaluated. These cultivars were selected because they are currently common to the Southern Plains and typically stripper harvested. The cultivars were planted on May 6 in 2011 and on May 17 in 2012 on 1.0 m row spacing in a furrow irrigated field that was 236 m long. The focus of this project was only on the machine effects on the fiber quality and foreign matter content. The cotton was harvested using a John Deere 7460 with a four row stripper head. This was a two year project and the harvest dates were October 18 and 19, 2011 and on November 6 and 7, 2012. During both harvest years, bur cotton was harvested at approximately 4.8 km $h^{-1}$ with brush roll and cross auger speed of approximately 660 rpm, and a field cleaner saw speed of approximately 620 rpm. During 2011 five harvester locations and a hand-picked sample (HP) were identified as sample collection points. The five cotton stripper harvester locations of interest were after brush stripper rolls (ASR), after the row unit/before the cross auger (ARU), after the cross auger (ACA), before the field cleaner (BFC), and from the basket (after field cleaner) (AFC) of the stripper after the cotton has been field cleaned (Figure 1). The same locations minus the ASR location were collected during the 2012 season. This study did not explore the agronomic performance differences of these cultivars.

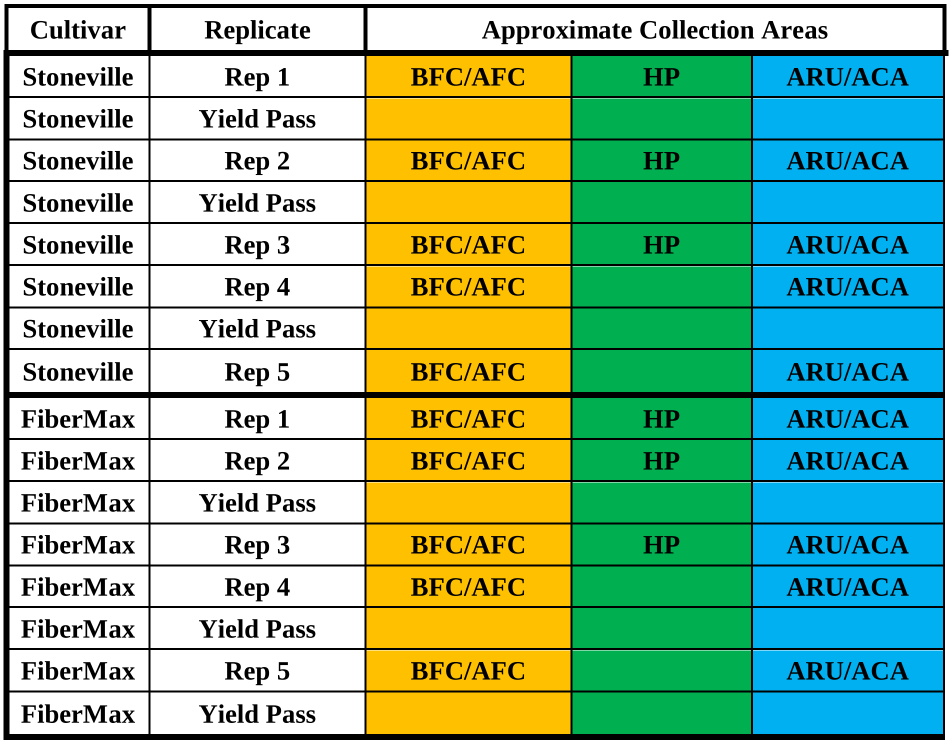
Figure 1. Collection locations for bur cotton samples represented on a John Deere 7460 cotton stripper similar to the one used.

The plots were 4-rows wide and 236 meter long. A total of eight plots were harvested from each cultivar in both 2011 and 2012. Five of the plots were used as harvester component evaluation replications and three of the plots were used to measure yield (Figures 2 and 3). The harvester component evaluation replications and yield plots were randomly assigned to the cultivar blocks. Yield was measured by weighing the bur cotton harvested from the plot and dividing the weight by the plot area. Weight was measured with an instrumented boll buggy with integral digital scales. Yield was only collected and measured as a reference for average field yield. Figures 2 and 3 are oriented in cardinal direction with North to the top, and represent the plots and approximate field layout for the sample collection areas.



| Cultivar | Replicate | Approximate Collection Areas | | | |
|---|---|---|---|---|---|
| Stoneville | Yield Pass | | | | |
| Stoneville | Rep 5 | BFC/AFC | HP | ARU/ACA | |
| Stoneville | Rep 4 | BFC/AFC | HP | ARU/ACA | |
| Stoneville | Rep 3 | BFC/AFC | HP | ARU/ACA | |
| Stoneville | Yield Pass | | | | |
| Stoneville | Rep 2 | BFC/AFC | HP | ARU/ACA | |
| Stoneville | Rep 1 | BFC/AFC | HP | ARU/ACA | ASR |
| Stoneville | Yield Pass | | | | |
| FiberMax | Yield Pass | | | | |
| FiberMax | Rep 1 | BFC/AFC | HP | ARU/ACA | ASR |
| FiberMax | Rep 2 | BFC/AFC | HP | ARU/ACA | |
| FiberMax | Yield Pass | | | | |
| FiberMax | Rep 3 | BFC/AFC | HP | ARU/ACA | |
| FiberMax | Rep 4 | BFC/AFC | HP | ARU/ACA | |
| FiberMax | Yield Pass | | | | |
| FiberMax | Rep 5 | BFC/AFC | HP | ARU/ACA | |

Figure 2. Field and cultivar layout for the collection strips 2011.



| Cultivar | Replicate | Approximate Collection Areas | | |
|---|---|---|---|---|
| Stoneville | Rep 1 | BFC/AFC | HP | ARU/ACA |
| Stoneville | Yield Pass | | | |
| Stoneville | Rep 2 | BFC/AFC | HP | ARU/ACA |
| Stoneville | Yield Pass | | | |
| Stoneville | Rep 3 | BFC/AFC | HP | ARU/ACA |
| Stoneville | Rep 4 | BFC/AFC | | ARU/ACA |
| Stoneville | Yield Pass | | | |
| Stoneville | Rep 5 | BFC/AFC | | ARU/ACA |
| FiberMax | Rep 1 | BFC/AFC | HP | ARU/ACA |
| FiberMax | Rep 2 | BFC/AFC | HP | ARU/ACA |
| FiberMax | Yield Pass | | | |
| FiberMax | Rep 3 | BFC/AFC | HP | ARU/ACA |
| FiberMax | Rep 4 | BFC/AFC | | ARU/ACA |
| FiberMax | Yield Pass | | | |
| FiberMax | Rep 5 | BFC/AFC | | ARU/ACA |
| FiberMax | Yield Pass | | | |

Figure 3. Field and cultivar layout for the collection strips 2012.

Simultaneous sampling of the harvested bur cotton at each harvester location of interest was problematic from a safety and feasibility standpoint. Therefore, each of the harvester component evaluation plots were divided into sub-plots for harvester sampling locations of interest, as shown in Figures 2 and 3. The ASR location only had one collection per variety due to excessive dirt and debris introduced into the machine. Only three collection areas of hand-picked cotton were harvested during 2012 due to the extremely low variability within the hand-picked samples collected during 2011.

Field moisture samples were collected in conjunction with each of the field samples taken. The following sequence of events was conducted to collect the bur cotton samples from each harvester location replicate:

1. Before field cleaner (BFC) sample collection: The machine was operated at full load into the un-harvested cotton with the field cleaner bypassed so that the harvested cotton flowed directly into the basket and not through the field cleaner. After the machine traveled approximately 45 m into the field, the harvester was stopped and at least a 9 kg sample of bur cotton was collected in the basket. The remaining bur cotton in the basket was moved to the back of the basket to keep the sample material collected in step one from mixing with the material collected during step 2.

2. After field cleaner (AFC) sample collection: The bypass lever on the field cleaner was switched to allow the cotton to pass through the field cleaner before entering the basket. The harvester was operated at full load into the un-harvested cotton in the same replicate as in step 1 for approximately 45 m. The harvester was stopped and a 9 kg sample of bur cotton was collected from the field cleaned cotton in the basket. The stripper basket was emptied. Steps 1 and 2 were completed for all replicates in both cultivars before samples were collected from other machine locations.

3. Hand-picked (HP) sample collection: a 9 kg sample of bur cotton was hand-picked from each replication in both cultivars after step 2 to ensure the hand-picked cotton was collected from the center of the plots to avoid any border affects. In this study hand picking cotton refers to the removal of seed cotton from the open bolls on the plant. Bolls, sticks, stems, leaf trash, or any other foreign matter was not removed, only the seed cotton was removed from the plant. Seed cotton was systematically removed from all open bolls along the plant. Each plant had all seed cotton removed from it before seed cotton was removed from the next plant.

4. After row unit (ARU) and after cross auger (ACA) sample collection: The right-hand section of the cross auger was removed from the header allowing the two right-hand

row units to empty directly into the open auger trough. A large sack was connected to the bottom of the main cotton conveying (separation duct) duct to collect the cotton moved to the center of the header by the remaining left-hand section of the cross auger. With the main conveying fan disengaged and the row units and cross auger running, the stripper proceeded into the un-harvested cotton located after the hand-picked collection area. The machine was operated until the cross auger trough behind the right hand row units was full at which time the cotton was removed from the open auger trough and placed in a collection bag. The large sack was removed from the bottom of the harvester and closed. Step 4 was conducted for all replications in both cultivars before step 5.

5. After stripper roll (ASR) sample collection: The drive gears used to operate the two row unit augers in each row unit were removed from the harvester. The stripper was operated at full engine speed into the un-harvested cotton and stopped when the row unit auger troughs were full of harvested material. The material was removed from the row units and placed in a collection bag. This process was repeated until a total of 9 kg of harvested material was collected. Step 5 was only conducted for one replication in each cultivar due to the excessive accumulation of soil and debris. As stated earlier this collection location was not sampled in 2012.

Figure 4. Pictures of the selected harvester sampling locations, pictures in the left column correspond to the harvester locations prior to collection, and pictures in the right column correspond to the harvester locations after the collection was completed.

After the harvesting samples were collected they were transported to the USDA-ARS Cotton Production and Processing Research Unit in Lubbock, TX for cotton ginning. Prior to ginning, two fractionation sub-samples were collected from each of the harvesting samples during 2011 and one sample was collected from the 2012 samples. The reduction of fractionation samples in 2012 was due to the low sample variability of 2011 samples. Each of the harvesting samples was processed through an extractor-feeder (Continental Gin Company-Moss Gordin, Birmingham, AL, Type C-95, Serial No.: 8866 (BM: 948428), top saw 0.36 m diameter @ 374 rpm, middle saw 0.36 m diameter @ 374 rpm, bottom saw 0.36 m diameter @ 77 rpm), 16-saw gin stand (Continental Gin Company, Birmingham, AL, Model: 610, Type: 16B79, Saw Cylinder 0.41 m diameter @ 720 rpm originally 21 saw original width reduced to 16 saws, and doffer brush speed 1830 rpm), and one stage of saw-type lint cleaning (Continental Gin Company Birmingham, AL, Model: 620, Type: G120B, upper roller speed 86 rpm, feed roller speed 91.5 rpm, main saw 0.41 m diameter @ 882 rpm, doffer brush speed 1472 rpm). A moisture sample was collected from the extractor-feeder apron above the gin stand during ginning. The moisture samples were processed using an Ohaus Corporation scale (Model: Scout Pro SP402, Capacity 400 g, resolution: 0.01 g). Fractionation and moisture content analysis were performed as outlined by the standard procedures developed by USDA (Shepherd 1972). These moisture samples were used to account for environmental conditions that could have an effect on ginning results. Fractionation samples were weighed on an A&D company scale (Model: HP 20K, Serial No.: 13013097, Capacity: 21 kg, resolution 0.1 g). After ginning all the cleaned lint from a harvesting sample was weighed on an Electroscale (Model LC2424, capacity: 99.8 kg, Display: Electroscale Weigh Master 551, capacity: 90.7 kg, resolution 0.005 kg) to obtain lint turnout. Lint turnout was calculated by dividing the clean lint weight by the total sample weight and multiplying by 100. The trash collected from the extractor-feeder and seeds from the gin stand were collected and weighed on the same Electroscale. The seed and trash weights were used to aid in ensuring that the total sample weight was accounted for in the final lint turnout analysis. Percent trash was calculated by dividing the trash weight collected from the extractor feeder by the total sample weight. Two samples of cotton lint after the lint cleaner, from each harvesting sample were collected and sent to the Texas Tech University, Fiber and Biopolymer Research Institute in Lubbock, TX for the HVI Breeder's Test (Uster Technologies HVI 1000) and the AFIS three replication test (Uster Technologies AFIS Pro 2) fiber analysis.

Analysis of Variance (ANOVA) was performed using the Statistical Analysis System 9.3 program (SAS Institute Inc. Cary, NC). Tukey's Studentized Range test was used to declare differences among treatment means ($\alpha = 0.10$). An alpha level of 0.10 was used since this was preliminary and exploratory work.

## Results and Discussion

The ASR location was removed in 2012 because the method of collecting this material introduced high amounts of dirt and debris introduced into the machine. The ASR location was not included in the 2011 statistical analysis since only one sample per cultivar was obtained. The data are not presented for the ASR location within the tables, but is mentioned in the text. The representation of two cultivars in a table indicates that there was a statistical difference in cultivars and the data were separated for analysis. Thus, if the cultivars are represented separately there was a between cultivar statistical difference for that particular fiber quality parameter and it should not be interpreted that the cultivars are similar. The statistical groupings indicate the value for a sample location within each cultivar is similar and there was statistical difference between cultivars for this fiber parameter.

The results of the fractionation analysis for each location were shown in Table 1. There were not significant differences between cultivars. The ASR location had mean values of 9.2, 3.3, 3.3, 2.6, and 21.7 percent of burs, sticks and stems, leaf trash, motes, and fine trash respectively. It was apparent that the row unit augers reduce fine trash in the cotton. The ARU location had 6.8% fine trash approximately one quarter that of the ASR location supporting the efficacy of the row unit augers at removing fine trash. There were no significant differences in the fractionation composition for the samples sequentially corresponding to ARU through BFC harvester locations in either 2011 or 2012. The sampling locations past the row units consistently had burs making up the highest percentage of trash except for the AFC sample location in 2011 where fine trash and burs were equivalent. The fine trash was the second highest contributing composition and followed a similar reduction pattern as the bur cotton progressed throughout the harvester. The data shown in Table 1 indicate that the field cleaner performs sufficiently by removing at least 50% of each of the fractionation compositions and more in some instances. The main difference between the data from 2011 and 2012 was in the shift from the secondary percentage or second highest contribution of foreign matter after the field cleaner being fine trash and burs in 2011 to being mainly burs in 2012. There was a large dust storm one day prior to harvest in 2011 which could have led to the fiber having an abnormally high amount of fine trash. This was not the case in 2012.

Table 1. Fractionation data from 2011 and 2012 that is grouped by harvester sampling location.

| Machine Location | Burs % | Sticks and Stems (%) | Leaf Trash (%) | Motes (%) | Fine Trash (%) |
|---|---|---|---|---|---|
| | | | **2011** | | |
| **HP** | $0.5^{D}$ | $0.3^{C}$ | $1.0^{C}$ | $1.1^{C}$ | $1.0^{C}$ |
| **ARU** | $12.5^{AB}$ | $2.8^{A}$ | $2.8^{AB}$ | $2.1^{AB}$ | $6.8^{A}$ |
| **ACA** | $12.9^{A}$ | $3.0^{A}$ | $3.1^{A}$ | $2.5^{A}$ | $7.3^{A}$ |
| **BFC** | $11.6^{B}$ | $3.0^{A}$ | $2.4^{B}$ | $2.3^{A}$ | $6.6^{A}$ |
| **AFC** | $4.0^{C}$ | $1.4^{B}$ | $1.5^{C}$ | $1.8^{B}$ | $4.3^{B}$ |
| **P-Value** | $P<0.0001$ | $P<0.0001$ | $P<0.0001$ | $P<0.0001$ | $P<0.0001$ |
| | | | **2012** | | |
| **HP** | $0.1^{D}$ | $0.1^{C}$ | $0.3^{D}$ | $0.5^{C}$ | $3.1^{C}$ |
| **ARU** | $21.3^{A}$ | $2.4^{B}$ | $2.6^{AB}$ | $1.0^{A}$ | $1.3^{BC}$ |
| **ACA** | $17.8^{B}$ | $4.1^{A}$ | $2.7^{A}$ | $1.0^{A}$ | $1.5^{AB}$ |
| **BFC** | $18.7^{AB}$ | $3.2^{AB}$ | $2.1^{BC}$ | $1.2^{A}$ | $2.4^{A}$ |
| **AFC** | $4.5^{C}$ | $2.6^{AB}$ | $1.7^{C}$ | $1.2^{A}$ | $1.7^{AB}$ |
| **P-Value** | $P<0.0001$ | $P<0.0001$ | $P<0.0001$ | $P<0.0001$ | 0.001 |

There were no statistical differences in moisture content at the feeder apron. Ginning moisture contents for 2011 ranged from 4.3% to 8.5% with a mean of 6.2% on a wet basis and 4.5% to 9.3% with a mean of 6.6% on a dry basis. The ginning moisture contents for 2012 ranged from 4.9% to 8.2% with of mean of 5.9% on a wet basis and 5.2% to 8.9% with a mean of 6.3% on a dry basis. The moisture contents are similar for each year and fall within ±2% of the values reported by Childers and Baker (1978). Childers and Baker (1978) reported that typical moisture contents of High Plains cotton range from 5 to 7% when the cotton arrives at the gin. They reported that it was disadvantageous to dry the cotton under these conditions because the dried cotton was generally worth less than the un-dried cotton.

Percent trash collected from the extractor feeder and lint turnout, based on total sample weight, are shown in Table 2. There were no significant differences in the lint turnout data between cultivars, thus the data for the two were combined. Lint turnout was highest for the hand-picked (HP) location (37% in 2011 and 38% in 2012). This was expected since only seed cotton was intentionally removed from the plants minimizing the trash present in the hand-picked (HP) seed cotton. In the cross auger (ACA) collection area, there was statistically no difference in lint turnout between locations ARU to ACA in either year. However, at the BFC location, even though the cotton was allowed to flow up the separation duct, by-pass the field cleaner and then was collected there was a small difference in lint turnout from the previous sampling locations in both years. The non-field cleaned, cross auger, and after brush roll cotton had statistically similar lint turnouts and trash contents in both years. The cotton collected from the ASR location even though not statistically analyzed or printed in the table had a lint turnout of 11.8% and a 45.6% of trash, was out of the range of the other locations with a high trash content and low lint turnout. Slight differences were observed between the 2012 and 2011 harvest seasons the data indicated that the overall trends were similar between years even though years were statistically different. An average 5% increase was observed in the lint turnout when the cotton was allowed to pass through the field cleaner. The field cleaner is the only point on the machine that substantially influences the turnout after the row unit augers. There is potential for machine redesign after the row units and before the field cleaner to increase lint turnout and reduce overall trash content. The field cleaner was effective in achieving a lint turnout level about 5% lower than that of hand-picked cotton. If the overall turnout could be increased earlier in the machine, the field cleaner could potentially provide an opportunity to increase the turnout level closer to that of hand-picked cotton. Consistent with the lint turnout, total trash collected from the extractor feeder had a trend of reduced trash content as the crop moved through the harvester. The ASR location had a mean total trash percentage of 45.6 which was much higher than any of the other locations. No appreciable change is in total trash occurred until the trash was allowed to pass through the field cleaner, at which it was reduced by over half.

Table 2. 2011 and 2012 lint turnout data as reported from lint turnout and trash weight collected from the extractor feeder.

| Machine Location | Turnout (%) | Trash (%) |
|---|---|---|
| | **2011** | |
| **HP** | $36.6^{A}$ | $2.3^{D}$ |
| **ARU** | $24.5^{CD}$ | $24.6^{A}$ |

| | | |
|---|---|---|
| **ACA** | $23.5^{D}$ | $22.7^{AB}$ |
| **BFC** | $26.5^{C}$ | $18.8^{B}$ |
| **AFC** | $32.2^{B}$ | $8.6^{C}$ |
| **P-Value** | $P<0.0001$ | $P<0.0001$ |
| | **2012** | |
| **HP** | $38.2^{A}$ | $1.2^{D}$ |
| **ARU** | $27.0^{D}$ | $20.5^{A}$ |
| **ACA** | $31.0^{C}$ | $18.7^{AB}$ |
| **BFC** | $27.0^{D}$ | $16.6^{B}$ |
| **AFC** | $33.0^{B}$ | $7.0^{C}$ |
| **P-Value** | $P<0.0001$ | $P<0.0001$ |

There were statistically significant differences between cultivars for Reflectance (Rd) and Yellowness (+b). The average Rd for FiberMax in 2011 was 81.53 as compared to 80.68 in 2012. The average Rd for Stoneville was 78.18 in 2011 as compared to 77.24 in 2012. The +b for FiberMax was 7.49 in 2011 as compared to 7.63 in 2012. The +b for Stoneville was 8.72 in 2011 as compared to 8.63 in 2012. There was no significant difference between harvester sampling locations for Rd or +b. The Rd and +b data by harvester sampling location were provided in the appendix.

The ASR location had an HVI trash of 24.25% which was lower than the sequential machine sampling locations. As shown in Table 3, HP was significantly lower than all harvester locations for both 2011 and 2012. The field cleaner removed a majority of the foreign matter contained in the bur cotton and helped reduce the percentage of trash in the sample in both years by approximately 6%. There were no significant differences in HVI percent trash for ARU through BFC harvester sampling locations in 2011 or 2012. AFC was not statistically similar to HP in 2011 but it was in 2012. However the final percent trash of the field cleaned bur cotton was at least double that of hand-picked cotton in both years. The fiber collected from the row units had not been mechanically conveyed through the rest of the machine, thus the trash was not mechanically incorporated into it and the gin was better able to remove more of the foreign matter than the sequential locations. HVI trash increased throughout sampling locations HP through

ACA because the mechanical action imparted on the cotton during harvesting and conveying causes leaf trash and other foreign matter to be broken-up and further mixed into the fiber (Table 3).

Table 3. Trash percentage of visual sample size reported by HVI from 2011 and 2012.

| **Machine Location** | **Trash Percent %** | |
|---|---|---|
| | **2011** | **2012** |
| **HP** | $15.2^{C}$ | $6.2^{C}$ |
| **ARU** | $33.3^{A}$ | $18.6^{AB}$ |
| **ACA** | $37.4^{A}$ | $24.2^{A}$ |
| **BFC** | $35.7^{A}$ | $22.4^{AB}$ |
| **AFC** | $27.0^{B}$ | $16.4^{C}$ |
| **P-Value** | <0.0001 | <0.0001 |

The Stoneville cultivar had an average micronaire of 5.2 while the FiberMax had an average micronaire of 4.3 in 2011. In 2012 the Stoneville cultivar had an average micronaire of 4.0 and the FiberMax had an average of 3.7. Independent of year effect and the cultivar differences there was no significant difference in fiber micronaire between machine locations. Micronaire is an estimate of maturity and fineness thus should not be significantly affected by mechanical handling. Therefore the micronaire results were consistent with what was expected.

As shown in Table 4, HVI fiber length was not statistically different in 2011 for FiberMax and in 2012 for Stoneville with respect to sample location. Fiber lengths were similar across each of the sample locations with cultivar and year differences. The Stoneville in 2011 and FiberMax in 2012 had statistical differences between harvester sampling locations. The ASR location was lower than the other sampling locations with 2.72 and 2.90 cm for the Stoneville and FiberMax cultivars respectively. There were insignificant year effects observed in the fiber length data, but the data were still separated by year for consistency with the other fiber quality parameters. Even though length appears to increase at certain sampling locations, this is just a sampling anomaly potentially caused by field variation, within sample variability, or even within plant variability. In general the fiber length differences were 0.04 cm or less. Similar trends were observed in many other studies (Ge et al., 2008; Johnson et al., 1998; Johnson et al., 2002; Bednarz et al., 2007; Bradow et al., 1997; Bradow and Davidonis, 2000; Wanjura et al., 2010.).

Table 4. Fiber Length as reported by HVI from 2011 and 2012. Values without letters were not statistically different.

| Machine Location | Length (cm) | | | |
|---|---|---|---|---|
| | 2011: | | 2012: | |
| | Stoneville | FiberMax | Stoneville | FiberMax |
| **HP** | $2.74^{B}$ | 2.90 | 2.74 | $2.98^{A}$ |
| **ARU** | $2.78^{AB}$ | 2.89 | 2.77 | $2.86^{C}$ |
| **ACA** | $2.80^{A}$ | 2.87 | 2.79 | $2.90^{BC}$ |
| **BFC** | $2.78^{AB}$ | 2.88 | 2.76 | $2.89^{BC}$ |
| **AFC** | $2.78^{AB}$ | 2.90 | 2.79 | $2.94^{AB}$ |
| **P-Value** | 0.078 | 0.445 | 0.084 | 0.003 |

No statistical differences among cultivars or sample locations were observed for HVI length uniformity (Table 5). The uniformity was significantly lower in 2012. ASR samples had lower length uniformity than the other sample locations in 2011. The length uniformity for the ASR sample location was 80.7. The other sample locations had minimal variation observed in uniformity between sampling locations, and the slight differences can likely be attributed to potential variation as referenced above in the strength discussion.

Table 5. Fiber Uniformity as reported by HVI from 2011 and 2012.

| Machine Location | Uniformity (%) | |
|---|---|---|
| | 2011 | 2012 |
| **HP** | 81.2 | 80.4 |
| **ARU** | 81.7 | 79.6 |
| **ACA** | 81.7 | 80.0 |
| **BFC** | 81.9 | 79.8 |
| **AFC** | 81.5 | 80.3 |
| **P-Value** | 0.140 | 0.069 |

HVI fiber strength data are shown in Table 6. There were not statistical differences between cultivars. Again the ASR had lower strength values than the other sampling locations with a measured HVI strength of 29.33 grams per tex. Variations were observed in HVI fiber strength as the fiber was conveyed throughout the harvester. These variations could be attributed to natural causes or due to the method in which HVI measures strength. Strength is measured as a bundle thus extraneous amounts of foreign matter could cause the fiber bundle to appear weaker. Fiber strength would be expected to decrease as the fiber was exposed to more mechanical handling. The use of the field cleaner seems to reduce the fiber strength but not back to that observed in the hand-picked samples.

Table 6. Fiber Strength as reported by HVI from 2011 and 2012.

| **Machine Location** | **Strength (g/Tex)** | |
|---|---|---|
| | **2011** | **2012** |
| **HP** | 29.3$^{C}$ | 32.3 |
| **ARU** | 30.1$^{AB}$ | 32.0 |
| **ACA** | 30.4$^{A}$ | 32.3 |
| **BFC** | 29.9$^{ABC}$ | 32.0 |
| **AFC** | 29.7$^{BC}$ | 31.9 |
| **P-Value** | <0.0001 | 0.567 |

The AFIS trash and dust content data are provided in Table 7. The ASR location had approximately double counts per gram of trash (53.5) and dust (224.5) over the hand-picked sample collection locations. The levels generally increase through the machine until the cotton is pneumatically conveyed and then passed through the field cleaner. The pneumatic conveyance of the cotton through the separation duct allows dust and larger/heavier trash to separate from the bur cotton. However, the field cleaner AFIS trash and dust levels were higher than the hand-picked cotton. Similar to Tables 1 and 2, there were only minor differences occurred between the ARU to the BFC locations. These data indicated that an appropriate location for redesign is located between the ARU to BFC machine locations.

Table 7. Trash and Dust Content reported by AFIS from 2011 and 2012.

| **Machine Location** | **Trash (Cnt/g)** | **Dust (Cnt/g)** |
|---|---|---|
| | **2011** | |
| **HP** | $26.0^{D}$ | $119.4^{D}$ |
| **ARU** | $80.6^{B}$ | $338.3^{B}$ |
| **ACA** | $99.7^{A}$ | $393.0^{A}$ |
| **BFC** | $90.9^{AB}$ | $359.9^{AB}$ |
| **AFC** | $62.7^{C}$ | $246.8^{C}$ |
| **P-Value** | P<0.0001 | P<0.0001 |
| | **2012** | |
| **HP** | $19.7^{D}$ | $91.5^{D}$ |
| **ARU** | $78.7^{B}$ | $336.3^{B}$ |
| **ACA** | $93.2^{A}$ | $422.6^{A}$ |
| **BFC** | $93.8^{A}$ | $419.4^{A}$ |
| **AFC** | $53.8^{C}$ | $236.7^{C}$ |
| **P-Value** | P<0.0001 | P<0.0001 |

Two cotton fiber parameters that were expected to be affected by mechanical handling were nep size and nep content. Differences were present between years and cultivars for both nep size and nep content. No statistical differences in the data were observed in nep size in 2011, with respect to sampling location (Table 8) and both years for nep content data (Table 9). The ASR location had nep sizes of 717.5 and 662.5 um and nep contents of 195.5 and 276.0 counts per gram for the Stoneville and FiberMax cultivars respectively. The data show that mechanical processes do not have significant effects on either nep size or nep content. There were neither consistent increases nor decreases in either nep size or nep content as the bur cotton was allowed to pass through the sampling locations on the harvester.

Table 8. Nep Size as reported by AFIS from 2011 and 2012.

| **Machine Location** | **Nep Size (um)** | | | |
|---|---|---|---|---|
| | **2011:** | | **2012:** | |
| | **Stoneville** | **FiberMax** | **Stoneville** | **FiberMax** |
| **HP** | 705.8 | 682.2 | 715.7$^{AB}$ | 699.5$^{B}$ |
| **ARU** | 723.0 | 691.9 | 719.7$^{A}$ | 729.6$^{A}$ |
| **ACA** | 714.8 | 699.2 | 710.1$^{AB}$ | 717.6$^{AB}$ |
| **BFC** | 710.1 | 693.4 | 713.20$^{AB}$ | 710.1$^{B}$ |
| **AFC** | 697.8 | 689.3 | 701.5$^{B}$ | 709.2$^{B}$ |
| **P-Value** | 0.306 | 0.443 | 0.133 | 0.007 |

Table 9. Nep Content as reported by AFIS from 2011 and 2012.

| **Machine Location** | **Neps (Cnt/g)** | | | |
|---|---|---|---|---|
| | **2011:** | | **2012:** | |
| | **Stoneville** | **FiberMax** | **Stoneville** | **FiberMax** |
| **HP** | 153.2$^{AB}$ | 254.1$^{AB}$ | 296.0$^{C}$ | 344.7$^{C}$ |
| **ARU** | 170.4$^{A}$ | 272.6$^{AB}$ | 399.1$^{A}$ | 546.9$^{A}$ |
| **ACA** | 145.0$^{B}$ | 278.0$^{A}$ | 348.0$^{BC}$ | 461.2$^{B}$ |
| **BFC** | 160.7$^{AB}$ | 231.0$^{B}$ | 377.0$^{AB}$ | 438.1$^{BC}$ |
| **AFC** | 169.5$^{A}$ | 251.2$^{AB}$ | 345.6$^{ABC}$ | 433.8$^{BC}$ |
| **P-Value** | 0.028 | 0.097 | 0.004 | <0.0001 |

Differences were observed among sampling locations for AFIS short fiber content (SFC) by weight (Table 10). The ASR sampling location had the highest level of SFC at 10.9 percent based on weight. It was noted that SFC was higher during the 2012 harvest season. The variances observed in SFC were attributed to natural variations in cotton fiber length and field variability because the variations were not consistent with machine sampling locations. It was expected that short fiber content would increase throughout the harvest process as the fibers are handled and exposed to additional mechanical action; however, this trend was not observed. The sampling methods could have aided in incorporating levels of field variation that caused the unexpected trends. Since machine location samples were harvested from similar areas of the field it is possible that SFC was similar at the sampling locations for each of the five collection repetitions.

Table 10. Short Fiber Content as reported by AFIS from 2011 and 2012.

| **Machine Location** | **Short Fiber Content (w %)** | | |
|---|---|---|---|
| | **2011** | **2012:** | |
| | | **Stoneville** | **FiberMax** |
| **HP** | $10.1^{AB}$ | $13.8^{AB}$ | $9.8^{D}$ |
| **ARU** | $10.0^{AB}$ | $15.4^{A}$ | $14.1^{A}$ |
| **ACA** | $10.1^{A}$ | $14.1^{AB}$ | $13.3^{AB}$ |
| **BFC** | $9.4^{B}$ | $15.1^{A}$ | $12.1^{BC}$ |
| **AFC** | $9.9^{AB}$ | $13.5^{B}$ | $10.9^{CD}$ |
| **P-Value** | 0.083 | 0.009 | <0.0001 |

## Conclusions for Tracking Cotton Fiber Quality

The ASR harvester location was eliminated from four reps in 2011 and entirely in 2012 due to potential damage from excessive dirt and debris introduced into the machine by disabling the row unit augers. Bur cotton total foreign matter content was highest after the stripper rolls and before the cotton was conveyed out of the row units by the row unit augers. Based on the small amount of data collected at the ASR machine location the row unit augers decreased total foreign matter content in the bur cotton by removing a substantial amount of fine trash comprised mostly of soil and small plant parts. Total foreign matter content remained at a statistically consistent level during conveyance in the cross auger until the harvested bur cotton was processed through the field cleaner. The field cleaner decreased total foreign matter content by removing primarily burs and fine trash. Leaf grade and AFIS trash and dust content measurements follow similar trends where parameter levels increase on the stripper from the stripper rolls until the inlet to the field cleaner. Leaf grade, AFIS trash, and AFIS dust content were decreased by the field cleaner back to levels observed just after the stripper rolls. HVI and AFIS fiber analysis results indicated that the harvesting and conveying systems on the cotton stripper did not have a detrimental impact on fiber length, strength, and uniformity characteristics or on the formation or size of neps. Year effects were observed between the 2011 and 2012 harvest seasons. It is important to note that independent of the year effect the results presented in this paper show analogous trends between two harvest seasons. The results of this work indicate that the cross auger and pneumatic conveying systems on stripper harvesters could potentially be redesigned to help improve bur cotton cleanliness. The data indicate no appreciable change from the ARU to BFC locations this indicates potential for improvement within these systems on a cotton stripper harvester.

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# CHAPTER III

# PHASE II: COMPARISON OF A BELT CONVEYOR TO CURRENT AUGER CONVEYANCE IN COTTON STRIPPERS

The objective of Phase II was to expand on the work from Phase I, by designing and evaluating an alternative conveyance system. It was decided to replace the cross auger with a wire belt conveyor. A belt conveyor is less aggressive at conveying material than an auger. Also, a wire belt provides the opportunity for foreign matter to be removed from the bur cotton as it passes along the belt. A wire belt conveyor was designed and built to convey bur cotton from one half of a four row cotton stripper. This wire belt conveyor was evaluated in a laboratory and the results were compared to a standard cross auger in terms of fiber quality and foreign matter impact. No significant differences were discovered between the current cross auger design and the wire belt conveyor from the standpoint of foreign matter removal and bur cotton fiber quality.

## Review of Literature

It is widely reported that stripper harvested cotton has lower fiber quality and higher foreign matter content than picker harvested cotton. Stripper harvesting is predominately confined the Southern Plains of the United Stated due to several factors including: low humidity levels during daily harvest intervals, tight boll conformations and compact plant structures adapted to withstand harsh weather during the harvest season, and sometimes reduced yield potential due to limited rainfall and irrigation capacity( Faulkner et al. 2009.). Based on USDA (2011) approximately 50% of the total number of cotton bales produced in the US came from Texas and Oklahoma. A majority of the cotton harvested in these two states was harvested with stripper harvesters.

Previous research has investigated the overall quality of stripper harvested cotton, quality of stripper harvested cotton versus picker harvest cotton, and cost comparison of the two harvest methods (Faulkner et al. 2011b, Faulkner et al. 2011c, Kerby et al. 1986, Nelson, et al. 2001.). Other research focused on the use of field cleaners on strippers and their effectiveness at removing foreign matter, and has proved they are an effective system for removing foreign matter from stripper harvest cotton (Brashears 2005, Smith and Dumas 1982; Wanjura and Baker 1979; Wanjura and Brashears 1983; and Wanjura et al. 2011). However, few studies have investigated individual conveyance/cleaning components on stripper harvesters. Brashears (1994) investigated the attachment of square key stock to the outer edge of the cross auger flights. Brashears (1994) found that the key stock attachments aided in increasing the amount of foreign matter removed by up to 60%. However, only the work by Porter et al. (2012 and 2013) addresses the influence of the individual harvesting and conveying systems of a stripper harvester on fiber quality. Porter et al. (2012 and 2013) reported that the conveying/cleaning components of a stripper harvester located between the row units and field cleaner including the cross auger, the green boll separator and the separation duct, did not significantly improve foreign matter removal and preserve fiber quality. Porter et al. (2012 and 2013) verified the selection of one of these conveyance locations for potential of foreign matter reduction and fiber quality preservation.

Very few studies have investigated the use of a wire belt for conveying bur cotton. A study conducted by Laird and Baker (1985) investigated using a wire belt to convey machine-stripped cotton on an inclined plane into a feeder house at a cotton gin. In this study, the belt was set at different inclines to determine the optimal incline seed cotton could be effectively conveyed without rolling back down the incline. Bur cotton density from this study was reported to range from 27.2 kg $m^{-3}$ to 35.2 kg $m^{-3}$ (1.7 lb $ft^{-3}$ to 2.2 lb $ft^{-3}$). Laird and Baker (1985) reported an angle of repose range of 65°-85° based on the moisture and foreign matter content. The Laird and Baker (1985) study did an excellent job outlining the foundation for the design of a wire belt conveyor for conveying bur cotton that would be feasible by reporting parameters about bur cotton including density and angle of repose.

### Materials and Methods

Cotton for this project was grown at the Texas A&M AgriLife Research and Extension Center north of Lubbock, TX. Two cultivars, FiberMax 9170 B2F and Stoneville 5458 B2RF, were evaluated. Both cultivars are common in the Southern High Plains and have inherently different leaf pubescence properties (FM 9170 B2F - smooth leaf, STV 5458 B2F – hairy leaf). The cultivars were planted on May 17 in 2012 on 1.0 m row spacing in a furrow irrigated field that was 236 m long. The cotton was harvested using a John Deere 7460 with a four row stripper head. The harvest dates were November 6 and 7, 2012. Bur cotton was harvested at approximately 4.8 km $h^{-1}$ brush roll and cross auger speed of approximately 660 rpm, and a field cleaner saw speed of approximately 620 rpm. Before harvest, the cross auger was removed from the right-hand side of the stripper header so that the cotton harvested by the rightmost row units could be dropped into the empty auger trough for collection without being exposed to the action of the auger. Cotton harvested by the two leftmost row units on the stripper header was conveyed to the center of the machine by the cross auger and collected in a bag attached to the outlet of the auger. The harvester moved through the field at approximately 4.8 km $h^{-1}$ (3.0 mi $h^{-1}$) until the right side of the auger trough was full of cotton. Once the harvester was stopped, the cotton in the right side auger trough was removed by hand and placed in a bag. This collection process was conducted ten times for each cultivar such that a total of 40 samples (twenty per cultivar) of approximately 9.0 kg were obtained; half of which had not been exposed to the conveying action of the cross auger. Of the ten samples collected from the auger trough and the separation duct five were only exposed to the cross auger or the belt conveyor and the other five were processed through a laboratory field cleaner after treatment. Five baseline samples per cultivar were collected for comparison. These samples were collected just after the row unit on the machine from the right hand side of the open auger trough.

A wire-belt conveyor was designed and built to convey bur cotton at a target rate of 136 kg $\text{min}^{-1}$ (300 lbs $\text{min}^{-1}$). This is the same material conveyance rate for a cotton stripper cross auger conveying cotton from two row units (1.0 m row spacing) harvesting a lint yield of 1558 kg $\text{ha}^{-1}$ (1390 lbs $\text{ac}^{-1}$) (25% turnout) at 6.4 km $\text{h}^{-1}$ (4 mi $\text{h}^{-1}$) (Personal correspondence with Jeff Widghal, engineer at John Deere). The trough was built 0.33 meters (13 inches) wide to match the cross section width of the cross auger trough on a John Deere 7460 stripper. The equation used to calculate material conveyance on a belt is:

$$Q = \rho * A * V \qquad (1)$$

Q is the material conveyance rate in kg $\text{s}^{-1}$ (lb $\text{s}^{-1}$), ρ is the density of the material in kg $\text{m}^{-3}$ (lb $\text{ft}^{-3}$), A is the cross-sectional area of bulk solid material on the belt in $\text{m}^2$ ($\text{ft}^2$), and V is the belt velocity in m $\text{s}^{-1}$ (ft $\text{s}^{-1}$). The density of the material was assumed to be 32.0 kg $\text{m}^{-3}$ (2.0 lb $\text{ft}^{-3}$) based on Laird and Baker (1985). The density of bur cotton is variable and dependent on moisture and foreign matter content, thus the estimated density should be relevant and fall within an acceptable range based on the reported data from the Laird and Baker (1985). Calculation of the cross-sectional area of the cotton being conveyed used the angle of repose of bur cotton and the width of the auger trough. An angle of repose equivalent to 75° was chosen for the cross-sectional area calculation to fall within the middle of the range of the reported angles of repose as reported by Laird and Baker (1985). The only user controlled factor during this conveyance process is the speed of the belt. Thus, using equation 1, the estimated belt velocity needed to achieve the target material conveyance rate is approximately 4.0 m $s^{-1}$ (13 ft $sec^{-1}$).

After harvest, the samples were transported to the USDA ARS Cotton Production and Processing Research Unit (CPPRU) in Lubbock, TX and weighed on an Electroscale (Model LC2424, capacity: 99.8 kg, Display: Electroscale Weigh Master 551, capacity: 90.7 kg, resolution 0.005 kg). The four treatment combinations evaluated were: standard cross auger without field cleaning (CA), 2) the standard cross auger with field cleaning (CA+FC), 3) the wire belt conveyor without field cleaning (BC), and 3) the wire belt conveyor with field cleaning (BC+FC). A total of five replications per treatment were collected and processed. The twenty samples collected from the right side auger trough (not exposed to the cross auger) were divided in half and loaded onto two belt conveyors one at a time (Figure 5) that fed the cotton onto the experimental wire belt conveyor (Figure 6). The belt conveyors were used to simulate the feeding action of two row units depositing cotton onto the wire belt conveyor at the same rate that the cotton was harvested in the field. Bur cotton weights were recorded before and after the wire belt conveyor and all material separated by the wire belt was weighed and recorded using the Electroscale.

Half of the samples (five replications) collected in the field that were exposed to the cross auger and half of the samples that were processed on the wire belt conveyor in the laboratory were passed through a field cleaner in the laboratory (Figure 7.) Samples were fed into the field cleaner by a belt conveyor at a rate equal to the loading rate (i.e. mass per time per unit width of cleaner) of the field cleaner on the stripper when harvesting at the rate observed in the field. The width was reduced to one half of the full width in the laboratory field cleaner to ensure a more equivalent loading to that of a field scale field cleaner under full load. Bur cotton weights before and after the field cleaner were recorded along with the weight of trash removed by the cleaner obtained from the Electroscale.

After the samples were processed through the appropriate treatments they were transported to the USDA-ARS Cotton Production and Processing Research Unit in Lubbock, TX for cotton ginning. Prior to ginning, one fractionation sub-sample was collected from each of the samples. Each of the samples was processed through an extractor-feeder (Continental Gin Company-Moss Gordin, Birmingham, AL, Type C-95, Serial No.: 8866 (BM: 948428), top saw 0.36 m diameter @ 374 rpm, middle saw 0.36 m diameter @ 374 rpm, bottom saw 0.36 m diameter @ 77 rpm), 16-saw gin stand (Continental Gin Company, Birmingham, AL, Model: 610, Type: 16B79, Saw Cylinder 0.41 m diameter @ 720 rpm originally 21 saw original width reduced to 16 saws, and doffer brush speed 1830 rpm), and one stage of saw-type lint cleaning (Continental Gin Company Birmingham, AL, Model: 620, Type: G120B, upper roller speed 86 rpm, feed roller speed 91.5 rpm, main saw 0.41 m diameter @ 882 rpm, doffer brush speed 1472 rpm). A moisture sample was collected from the extractor-feeder apron above the gin stand during ginning. The moisture samples were processed using an Ohaus Corporation scale (Model: Scout Pro SP402, Capacity 400 g, resolution: 0.01 g). Fractionation and moisture content analysis were performed as outlined by the standard procedures developed by USDA (Shepherd 1972). These moisture samples were used to account for environmental conditions that could have an effect on ginning results. Fractionation samples were weighed on an A&D company scale (Model: HP 20K, Serial No.: 13013097, Capacity: 21 kg, resolution 0.1 g). After ginning all the cleaned lint from a harvesting sample was weighed on an Electroscale (Model LC2424, capacity: 99.8 kg, Display: Electroscale Weigh Master 551, capacity: 90.7 kg, resolution 0.005 kg) to obtain lint turnout. Lint turnout was calculated by dividing the clean lint weight by the total sample weight and multiplying by 100. The trash collected from the extractor-feeder and seeds from the gin stand were collected and weighed on the same Electroscale. The seed and trash weights were used to aid in ensuring that the total sample weight was accounted for in the final lint turnout analysis. Percent trash was calculated by dividing the trash weight collected from the extractor feeder by the total sample weight. Two samples of cotton lint after the lint cleaner, from each harvesting sample were collected and sent to the Texas Tech University, Fiber and Biopolymer Research Institute in Lubbock, TX for the HVI Breeder's Test (Uster Technologies HVI 1000) and the AFIS three replication test (Uster Technologies AFIS Pro 2) fiber analysis.

Analysis of Variance (ANOVA) was performed using the Statistical Analysis System 9.3 program (SAS Institute Inc. Cary, NC). Tukey's Studentized Range test was used to declare differences among treatment means ($\alpha = 0.10$). An alpha level of 0.10 was used since this was preliminary and exploratory work.

Figure 5. The two flow rate simulators used to control the material being conveyed onto the wire belt conveyor.

Figure 6.  The wire belt conveyor used as a comparison to the cross auger.

Figure 7. The flow rate simulator used to control the material being conveyed into the laboratory field cleaner.

## Results and Discussion

The results for the baseline samples were presented for each of the parameters represented in the tables below. Statistical analysis was not performed on the baseline samples, as they were included as a reference only because their primary reason for collection was not initially for this study. Standard deviation of the baseline sample measurements are shown in parenthesis. The baseline gives a value for the fiber parameters before it was introduced to either the CA or the BC.

Lint turnout and percent trash, based on total sample bur cotton weight, are presented in Table 11 for treatments. Tables 11-14 include a baseline value which is the mean of the parameters for cotton that was collected from the right side auger trough but was not processed by the cross auger, wire belt conveyor, or field cleaner. Analysis of the lint turnout data shows that the field cleaner removed a substantial amount of foreign material from the bur cotton. There were no significant differences in the lint turnout data between cultivars, thus the data for the two were pooled. The BC increased lint turnout slightly over the baseline while the CA significantly increased turnout to a higher level than that of the BC. Even though the BC turnout was statistically lower initially, the field cleaner was able to remove the same amount of trash from both the BC and CA treatments so that each treatment had statistically similar turnouts.

Table 11. Ginning and Fractionation data as reported from lint turnout, trash weight and standard fractionation procedures by percentage of total sample weight.

| **Treatment** | **Turnout (%)** | **Trash (%)** | **Burs (%)** | **Sticks and Stems (%)** | **Leaf Trash (%)** | **Motes (%)** | **Fine Trash (%)** |
|---|---|---|---|---|---|---|---|
| **Baseline** | **27.04<br>(±1.38)** | **20.49<br>(±1.54)** | **21.3<br>(±1.9)** | **2.4<br>(±0.9)** | **2.6<br>(±0.4)** | **1.0<br>(±0.2)** | **1.3<br>(±0.6)** |
| **BC** | $28.23^{C}$ | $20.34^{C}$ | $23.2^{A}$ | $3.2^{AB}$ | $2.2^{B}$ | $1.1^{A}$ | $1.6^{A}$ |
| **BC+FC** | $37.03^{A}$ | $6.38^{A}$ | $5.7^{C}$ | $2.0^{B}$ | $1.7^{B}$ | $1.1^{A}$ | $1.2^{A}$ |
| **CA** | $30.95^{B}$ | $18.73^{B}$ | $17.8^{B}$ | $3.9^{A}$ | $2.7^{A}$ | $1.0^{A}$ | $1.5^{A}$ |
| **CA+FC** | $37.95^{A}$ | $6.26^{A}$ | $5.1^{C}$ | $2.5^{B}$ | $1.8^{B}$ | $1.0^{A}$ | $0.9^{A}$ |
| **P-Value** | <0.0001 | <0.0001 | <0.0001 | 0.002 | <0.0001 | 0.143 | 0.161 |

The fractionation results are in presented in Table 11. In all instances the BC and CA results were within the baseline sample ranges. Thus it can be inferred that the CA and BC treatments are not doing any better than the previous sampling location at removing foreign matter. The BC+FC resulted in better removal of all types of foreign matter except for motes than the BC, and the CA treatments. Even though the BC treatment seemed to have a high percentage of burs, the field cleaner was still able to remove these to the same level as the CA+FC treatment. Even though the wire belt did not remove as many burs as the cross auger, it did not appear it was entangling the burs to the point they became difficult to remove.

As seen in Table 12, there was no apparent difference in the results based on yellowness (+b) and reflectance. It appears that both the treatments did slightly improve both of these values. The level of improvement was slightly increased once the cotton was allowed to pass through the field cleaner.

Table 12. HVI fiber parameters in which the cultivars were statistically significant different.

| **Treatment** | **+b (Yellowness)** | **Rd (Reflectance)** | **Micronaire** | **Length (cm)** | **HVI Trash (%)** |
|---|---|---|---|---|---|
| | | | **FiberMax** | | |
| **Baseline** | **8.1 (±0.72)** | **80.1 (±0.67)** | **3.5 (±0.09)** | **1.12 (±0.04)** | **15.3 (±4.1)** |
| **BC** | $8.4^{A}$ | $79.2^{B}$ | $3.47^{B}$ | $2.87^{AB}$ | $16.3^{B}$ |
| **BC+FC** | $8.1^{AB}$ | $80.0^{AB}$ | $3.59^{AB}$ | $2.84^{B}$ | $13.3^{B}$ |
| **CA** | $7.9^{B}$ | $80.2^{AB}$ | $3.58^{A}$ | $2.90^{A}$ | $22.5^{A}$ |
| **CA+FC** | $7.8^{B}$ | $80.8^{A}$ | $3.62^{A}$ | $2.90^{AB}$ | $13.1^{B}$ |
| **P-Value** | 0.051 | 0.031 | 0.039 | 0.053 | 0.001 |
| | | | **Stoneville** | | |
| **Baseline** | **9.0 (±0.55)** | **76.3 (±1.18)** | **3.9 (±0.11)** | **1.09 (±0.02)** | **22.6 (±2.6)** |
| **BC** | $8.5^{A}$ | $77.2^{BC}$ | $3.88^{A}$ | $2.80^{A}$ | $26.3^{A}$ |
| **BC+FC** | $8.5^{A}$ | $78.0^{AB}$ | $3.93^{A}$ | $2.80^{A}$ | $23.5^{A}$ |
| **CA** | $8.6^{A}$ | $76.8^{C}$ | $3.96^{A}$ | $2.80^{A}$ | $27.1^{A}$ |
| **CA+FC** | $8.3^{A}$ | $78.3^{A}$ | $3.88^{A}$ | $2.80^{A}$ | $24.8^{A}$ |
| **P-Value** | 0.299 | <0.0001 | 0.253 | 0.847 | 0.639 |

No differences in micronaire were observed among treatments for the Stoneville cultivar and only slight natural variations of no importance were observed for FiberMax (Table 12). Average Micronaire was 3.6 for the FiberMax and 3.9 for the Stoneville. This observation was expected since mechanical conveyance has no influence on the maturity level of cotton fibers unless a significant portion of fibers were being lost or removed. The same statistical similarities can be observed in the fiber length as reported by HVI in Table 12. Only natural variations are present in fiber length, and no statistically significant differences.

HVI trash (Table 12) was reported higher than the mean of the baseline values for both cultivars over the baseline sample values by both conveyance methods especially the CA and then was reduced once the bur cotton passed through the field cleaner. The data supports a higher trash removal by the BC in only the FiberMax variety. The field cleaner was able to reduce the HVI trash to the same level for all treatments in both varieties.

Fiber uniformity and HVI strength are presented in Table 13. The uniformity was not statistically different due to mechanical handling in either case. The decreases were not statistically different within each conveyor type but were different among treatments. In this case the statistical difference is insignificant from a practical standpoint. Thus, it can be inferred the neither the cross auger nor the wire belt conveyor result in significant effects on fiber uniformity.

HVI strength data is presented in Table 13. The fiber strength was reduced slightly as the fibers passed through the mechanical conveyance locations within the harvester. The field cleaner caused a lower strength than did either the wire belt conveyor or the auger conveyor. Thus, these two methods do not have a significant effect on the HVI strength of the fiber.

Table 13. HVI parameters in which there were no statistically significant differences between cultivars.

| **Treatment** | **Uniformity (%)** | **Strength (g/Tex)** |
|---|---|---|
| **Baseline** | **79.5 (±1.03)** | **32.0 (±0.97)** |
| **BC** | $79.49^{B}$ | $31.84^{AB}$ |
| **BC+FC** | $79.41^{B}$ | $30.96^{C}$ |
| **CA** | $79.98^{A}$ | $32.33^{A}$ |
| **CA+FC** | $79.80^{AB}$ | $31.35^{BC}$ |
| **P-Value** | 0.011 | <0.0001 |

Fiber quality data reported from AFIS tests are shown in Table 14. Nep Size and Nep Count as determined by the AFIS are both unaffected by mechanical conveyor type or field cleaning. There seemed to be a higher Nep Count from the FiberMax BC treatment, even though this same trend was not observed in the Stoneville cultivar. Thus, this could possibly be attributed to sample or field variation. The field cleaner did seem to reduce the Nep Count in this case back to the same statistical level as the CA treatments.

Table 14. Cotton fiber quality parameters as reported by AFIS from each sample treatment.

| Treatment | Trash (Cnt/g) | Dust (Cnt/g) | Nep Size (um) | Nep Count (Cnt/g) | SFC (w%) | VFM (%) |
|---|---|---|---|---|---|---|
| | | | **FiberMax** | | | |
| **Baseline** | **67.7 (±17.0)** | **313.2 (±86.6)** | **729.6 (±21.8)** | **546.9 (±107.9)** | **14.1 (±1.5)** | **1.44 (±0.31)** |
| **BC** | $74.3^{A}$ | $354.4^{A}$ | $722.9^{A}$ | $555.4^{A}$ | $14.0^{A}$ | $1.47^{A}$ |
| **BC+FC** | $40.2^{B}$ | $224.3^{B}$ | $721.4^{A}$ | $496.6^{AB}$ | $13.7^{AB}$ | $0.90^{B}$ |
| **CA** | $88.5^{A}$ | $427.3^{A}$ | $717.6^{A}$ | $461.2^{B}$ | $13.28^{AB}$ | $1.80^{A}$ |
| **CA+FC** | $46.8^{B}$ | $235.8^{B}$ | $718.3^{A}$ | $461.8^{B}$ | $12.4^{B}$ | $0.94^{B}$ |
| **P-Values** | <0.0001 | <0.0001 | 0.754 | 0.006 | 0.092 | <0.0001 |
| | | | **Stoneville** | | | |
| **Baseline** | **89.6 (±13.9)** | **359.3 (±44.4)** | **719.7 (±18.4)** | **399.1 (±49.6)** | **15.4 (±0.86)** | **1.71 (±0.27)** |
| **BC** | $88.6^{AB}$ | $359.6^{AB}$ | $713.1^{A}$ | $380.8^{A}$ | $15.3^{A}$ | $1.68^{AB}$ |
| **BC+FC** | $74.2^{B}$ | $353.4^{AB}$ | $706.5^{A}$ | $390.3^{A}$ | $14.9^{A}$ | $1.45^{B}$ |
| **CA** | $98.0^{A}$ | $417.9^{A}$ | $710.1^{A}$ | $348.0^{A}$ | $14.1^{A}$ | $1.94^{A}$ |
| **CA+FC** | $75.4^{B}$ | $327.8^{B}$ | $708.2^{A}$ | $378.1^{A}$ | $14.0^{A}$ | $1.34^{B}$ |
| **P-Values** | 0.001 | 0.048 | 0.633 | 0.191 | 0.174 | <0.0001 |

Trash content was relatively unchanged in both cultivars by the BC treatment, while it seemed that the CA treatment appeared to have a higher trash level over the original baseline. However, due to sampling methods the CA treatment may have had higher trash levels than the baseline before the samples were processed, but the higher trash levels in both the BC and CA treatments could be due to the conveyance of the bur cotton. Table 4 from Phase I follows the same trend of higher trash levels as the bur cotton is allowed to pass across the cross auger and up to before the field cleaner. Similar to Phase I the data in Table 14 has reduced trash levels once the cotton is allowed to pass through the field cleaner. It is possible that the conveyance of the bur cotton through the cross auger and across the belt conveyor is causing slight entanglements in the fibers not allowing as much trash and dust to be separated. A significant amount of trash was removed by the field cleaner from both the BC and CA treatments. However, it appears that less trash was removed from the Stoneville cultivar than the FiberMax cultivar by the field cleaner. The higher amount of leaf still present in the Stoneville cultivar could be explained by this cultivar having higher leaf pubescence. Both treatments were ineffective at removing dust from the samples over the baseline.  In both cultivars, the CA treatment had significantly higher amounts of dust present in the sample over the baseline, which is important to note was collected from the same area as the BC samples.  Neither conveyance method was effective at removing dust.  The field cleaner still removed a significant amount of dust, when compared to the previous treatments especially in the FiberMax cultivar.

Trivial reductions were observed in short fiber content as the fiber was allowed to pass through the machine.  Since it is obvious that the fibers cannot be repaired, these anomalies can be attributed to field and sample variation, or cotton loss and fiber population change throughout the machine.  When the standard deviation for the baseline is accounted for within the samples it can be inferred that there is no change except for individual sample variation.

Visible foreign matter (VFM) was reduced by the mechanical actions of the field cleaner in all instances.  The BC had no effect and the CA slightly increased the amount of VFM.  Even though the CA treatment increased the amount of VFM in both cultivars the field cleaner was able to remove the foreign matter to statistically the same level after treatment.  Thus, the increased of VFM caused by the CA treatment was not significant.

## Summary and Conclusions

A wire belt conveyor was compared to the standard auger conveyor on a stripper harvester.  Fiber quality and foreign matter content data were collected and analyzed.  Minimal differences in terms of foreign matter content and fiber quality parameters were observed between the two conveyor systems.  Foreign matter content of cotton conveyed by either system was substantially reduced by the use of a field cleaner with no apparent damage to fiber quality.  Future optimization work performed on wire belt conveyors could aid in increasing their cleaning ability to higher levels than currently possible with the cross auger.  Thus, research focused on increasing the cleaning and fiber quality preservation abilities of a wire belt conveyor could make it a viable replacement for the current cross auger used on a cotton stripper harvester.

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# CHAPTER IV

# PHASE III: BUR COTTON MATERIAL FLOW CHARACTERIZATION AND PARAMETERIZATION ON A BELT CONVEYOR

The goal of Phase III was to characterize and parameterize bur cotton flow on a wire belt conveyor. This was accomplished using two techniques: data were collected using a high speed camera to aid in velocity characterization and fiber quality and foreign matter data were collected to aid in the parameterization process of the fiber. Three typical yields common to the Southern High Plains (428.6, 642.9, and 857.1 kg $ha^{-1}$ which are equivalent to1, 1.5 and 2 bale per acre yields), a one meter row width, and 5.6 km $h^{-1}$ ground speed were used to determine three material follow rates. Four wire belt conveyor widths (0.18, 0.36, 0.53, and 0.69 m), and four material depths (0.025, 0.05, 0.10, 0.18 m), were chosen. Belt speed was determined for each of the16 width/depth combinations to achieve the three flow rates. These material flow rates were used in conjunction with a top and side view high speed camera to determine flow characteristics of bur cotton. Fiber quality, percent foreign matter removal, and foreign matter data were collected from the extreme high and low velocities as determined by each belt width and material flow rate and shallowest and deepest material depths (0.025 and 0.18 m) within each of the wire belt widths to determine the wire belt configuration effects on fiber quality and foreign matter content.

## Review of Literature

Material conveyance can produce many unique challenges especially when it comes to agricultural products. Harvesters are expected to perform at an utmost level of harvesting and field efficiency during the harvest season. Baumgarten et al. (2009) investigated an assistance system for optimization of the grain combine harvest process and many of the principles can be transferred to cotton harvesters. Proper parameterization and characterization of harvesting equipment should start with individual component investigation. Studies by Porter et al. (2012 and 2013) investigated consecutive conveying/cleaning components on a cotton stripper harvester and identified and tested a redesign of the cross auger for bur cotton conveyance. Rademacher (2009) explored the harvesting and processing efficiency of a combine as related to the optimization of the machine settings. Benefits such as an increased quality of canola and wheat were observed during harvest by Rademacher (2009) from using the Claas electronic machine optimization service (CEMOS), the same system used by the Baumgarten et al. (2009) study. There are two other main parameters, independent of conveyance ability, that are the central focus for stripper harvested cotton, foreign matter content and fiber quality. Brashears and Ulich (1986) investigated pneumatic removal of fine material from bur cotton. Exhaust hoods were mounted over the stripper rolls and succeeded in removing up to 70 kg ha$^{-1}$ but the fine material was not significantly reduced over a standard stripper harvester. Laird and Baker (1985) investigated conveying cotton on an inclined wire belt. They reported that the physical forces that control conveying of a material such as cotton on an inclined belt are frictional forces between the material and the conveying surface, flow characteristics of the conveyed material, and inertial and other forces resulting from the non-uniform flow situation. Laird and Baker (1985) reported that the rigorous mathematical theory describing the interactions of all these forces in a belt conveyor has not been developed and was beyond the scope of their study. They reported that the angle of slide, or the angle at which the cotton began to slide back down the surface was 60°, however with a compressible material such as cotton, the angle of slide may vary considerably with depth, density, trash, and moisture content, and other properties of the cotton. Also the angle of slide under non-uniform flow conditions may be less than the angle determined under static conditions (Laird and Baker 1985). The angle of slide is directly related to static and dynamic friction. Similar to the Laird and Baker (1985) the bur cotton in this study has non-uniform material composition structure and the flow characteristics can change based on material properties. The non-uniform characteristics of the bur cotton composition make it hard to predict the actual velocity and flow characteristics since the frictional forces are so variable. The principles investigated during the Brashears and Ulich (1986) study could be applied to a wire belt conveyor to employ an aided method of cleaning. Thus, this portion of the study not only investigates bur cotton conveyance on a wire belt but works towards characterizing foreign matter content and fiber quality associated with various belt widths, speeds and depths.

## Materials and Methods

### *Common Methods of High Speed Image Capture of Bur Cotton Conveyance and Wire Belt Conveyance for Determining Foreign Matter Content and Cotton Fiber Quality*

Expanding from Phase II, this section explores various speeds, depths, and widths on a wire belt conveyor. Data from Phase II supported the idea that a wire belt conveyor can be used as a viable replacement for a cross auger on a cotton stripper. The FiberMax 9170 B2F cultivar was used for Phase III.

To properly design and optimize a wire belt for conveying bur cotton, multiple material conveyance parameters needed to be tested and quantified. A standard field harvest speed of 5.6 km $h^{-1}$ (3.5 m $h^{-1}$) was used in combination with three estimated common bur cotton yields observed in the Southern High Plains: 429, 643, and 857 kg lint $ha^{-1}$ (1, 1.5 and 2 bale $ac^{-1}$ yields). The speed and yields in combination with a one row (1 m) harvest width equate to 0.30, 0.45, and 0.60 kg $s^{-1}$ of material flow respectively. A wire belt conveyor was built with 0.69 m in width. The wire belt had rectangular slots that were 1.27 cm by 2.54 cm (Figure 8). The belt conveyor was driven by a single v-belt using a 110 volt electric motor with a variable frequency drive (Figure 9).

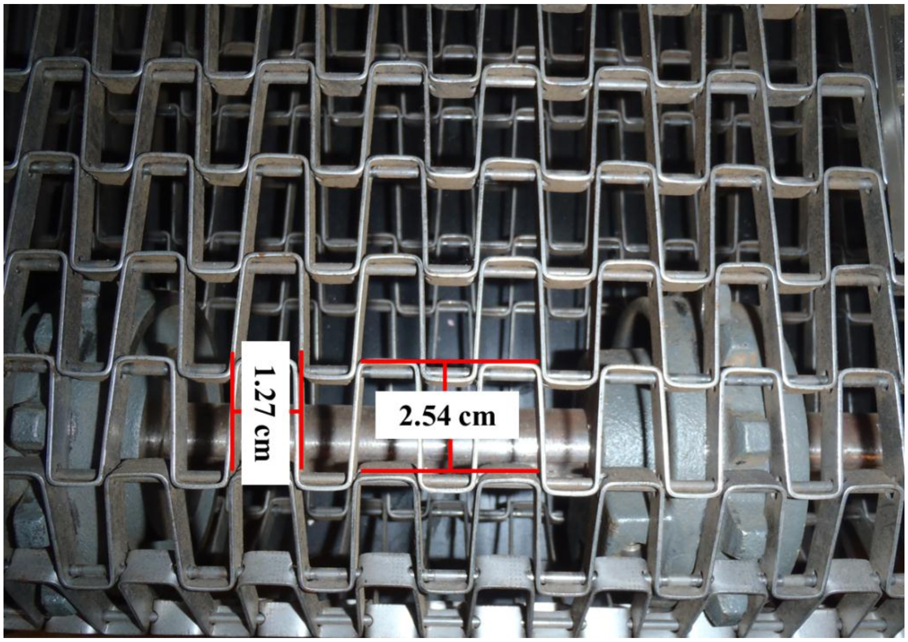


Figure 8. The dimensions of the wire belt that was used for the wire belt conveyance of bur cotton.

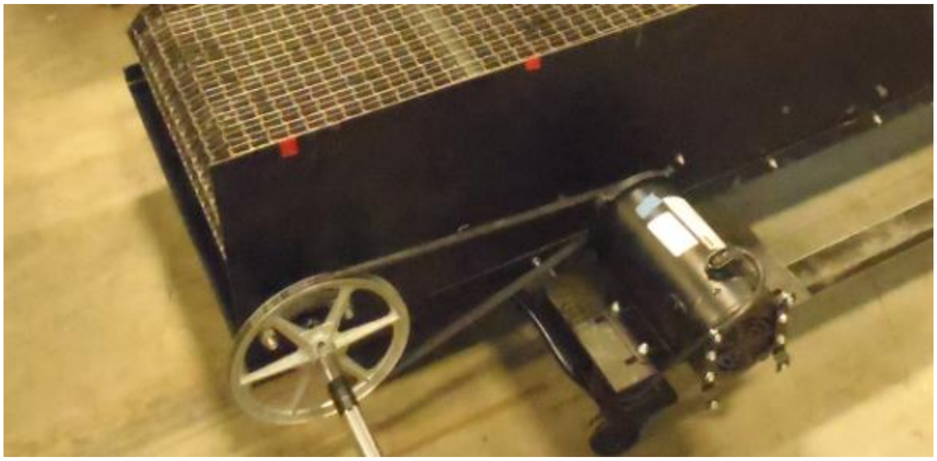


Figure 9. The motor and drive belt that operated the wire belt conveyor.

Four belt widths were tested: 0.18 m, 0.36 m, 0.53 m and 0.69 m. The minimum and maximum widths were determined based on the width of the current auger trough on a cotton stripper. The minimum width was half and the maximum width was double that of the current width of the auger trough on a John Deere 7460 cotton stripper. The width of the belt conveyor was made adjustable by a divider (Figure 10) that was designed to fit over the top of the wire belt conveyor. The divider had slotted rails so it could be set to any width. Four depths were chosen, 0.03 m, 0.05 m, 0.10 m, and 0.18 m. Belt speeds were calculated based on these depths. As with any material conveyance there is a minimum and maximum speed that would be feasible for field operation. Thus the calculated belt speed was set throughout the tests based on the width and depth settings. Belt speed was controlled by a variable frequency drive on the drive motor and an optical tachometer was used to measure the speed of the belt head-shaft. The test matrix represents the test combinations that were used for both high speed camera work and fiber quality data collection (Table 15). The red highlighted fields represent velocities deemed non practical because they were either too slow or too fast for the electrical motor. The eliminated speeds are not practical from a field harvesting standpoint as these extreme velocities would be either much slower or faster than bur cotton would be introduced into the machine. Slower velocities could lead to greater material depths and potential clogging within the wire belt conveyance trough slowing and even disrupting harvest in certain cases. Extremely fast velocities would never allow the wire belt to be fully loaded and perform under full load. The fast velocities could also introduce other issues such as high power requirements and potential for increased wear to moving parts on the wire belt conveyor.

Table 15. Test matrix that was used for testing the wire belt conveyor for high speed camera and fiber quality work (velocities highlighted in red were not performed due to being non practical.

| **Width (Meters)** | **0.03 m Material Depth** | **0.05 m Material Depth** | **0.10 m Material Depth** | **0.18 m Material Depth** |
|---|---|---|---|---|
| **Velocities (m/s) for 0.30 kg $s^{-1}$ of Material Flow** | | | | |
| **0.18** | 2.05 | 1.03 | 0.51 | 0.29 |
| **0.36** | 1.03 | 0.51 | 0.26 | 0.15 |
| **0.53** | 0.68 | 0.34 | 0.17 | 0.10 |
| **0.69** | 0.53 | 0.27 | 0.13 | 0.08 |
| **Velocities (m/s) for 0.45 kg $s^{-1}$ of Material Flow** | | | | |
| **0.18** | 3.08 | 1.54 | 0.77 | 0.44 |
| **0.36** | 1.54 | 0.77 | 0.38 | 0.22 |
| **0.53** | 1.03 | 0.51 | 0.26 | 0.15 |
| **0.69** | 0.80 | 0.40 | 0.20 | 0.11 |
| **Velocities (m/s) for 0.60 kg $s^{-1}$ of Material Flow** | | | | |
| **0.18** | 4.11 | 2.05 | 1.03 | 0.59 |
| **0.36** | 2.05 | 1.03 | 0.51 | 0.29 |
| **0.53** | 1.37 | 0.68 | 0.34 | 0.20 |
| **0.69** | 1.06 | 0.53 | 0.27 | 0.15 |

The wire belt speeds were calculated using equation 1, and followed the material flow rates as they relate to the estimated common selected yields. Table 15 contains 48 tests, but due to the impractical speeds, only 43 tests were actually completed. The wire belt velocities ranged from 0.08 m $s^{-1}$ to 4.10 m $s^{-1}$ or 14 rpm to 770 rpm on the shaft attached to the drive pulleys on the wire belt conveyor. The current auger design on the cotton stripper moves material laterally at approximately 2.0 m $s^{-1}$. The current auger design is rated much faster than required for the material flow rates selected for this test. Thus the velocity ranges selected for this test covered a full range of speeds to adequately evaluate a wire belt conveyor.

A bur cotton bat (Figure 10) was placed on the wire belt conveyor equivalent to one row in width or 1.0 m. The bur cotton bat was placed at the appropriate depth on the wire belt conveyor. Guide marks (Figure 10) were placed on the divider to ensure the appropriate depth was matched. Once the camera began recording a switch was flipped on the motor to begin the wire belt conveyor moving.

Figure 10. The guide marks on the divider were used to ensure the bur cotton bat was placed at the appropriate depth and can be seen on the right to the far end of the wire belt conveyor.

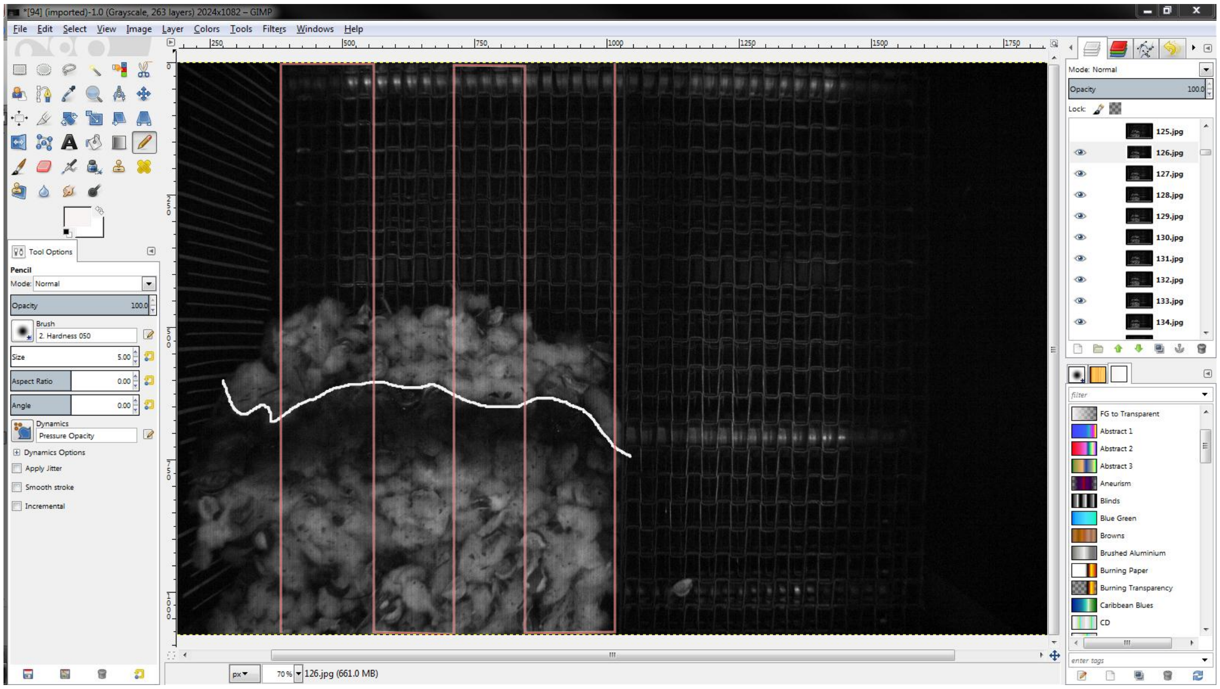
### *High Speed Image Capture*

A Basler high speed camera (model acA2000-340km, Basler Electric Company, Highland, IL) was mounted vertically over the wire belt conveyor. The camera was set to capture jpeg file type images at a frame rate of 60 hertz. Due to limited computational speed of the computer used during data collection the images were only recorded at approximately 8 hertz (or approximately 125 milliseconds per frame). In a number of instances individual frames were skipped, but this was accounted for during data analysis. The 8 Hz rate was more than sufficient to develop flow-velocity profile estimation equations. Since four widths, four depths, and three material flow rates were used a total of 48 runs were initially proposed. Five of these were omitted because the speeds were deemed impractical. Once half of the runs were completed using a top view camera, one side of the belt conveyor was removed and replaced with a piece of plexi-glass so that the camera could be used to capture a side view (Figure 11) of the same widths, depths, and material flow rates that were filmed vertically. The images captured horizontally were not used for analysis in this project. Image processing on bur cotton was challenging due to extraneous amounts of foreign matter in many instances which made it impossible to track individual pieces of foreign matter. It was not possible to analyze the video data collected from the side view due to inconsistent collection environments including lighting and the lack of track-able velocity identification points or markers such as leaf trash or cotton burs within the bur cotton.

Figure 11. The high speed camera and the belt conveyor with the plexi-glass side installed.

### *Image Analysis*

The bur cotton that was conveyed across the belt using the camera mounted vertically had four lines painted on it at 0.254 m intervals using bale marking paint. The first line was painted on the leading edge of the cotton before the belt conveyor was operated and the following lines were evenly spaced to the trailing edge. The painted lines were used as reference marks for analysis and are referred to as the reference line throughout the Methods and Results sections. The bale marking paint was water soluble and did not affect any of the fiber quality results as reported by either HVI or AFIS. Five equally spaced points from each of the lines were selected from the images that were used for analysis and were used as reference points for equation development. As can be viewed in Figure 12, the same horizontal distances (X positions) for analysis were used throughout the entire process to ensure velocity path consistency. GIMP, an open-source image manipulation program (GIMP Development Team, 2013), was used to collect reference points on a reference grid for each of the images. Points were selected along the five red lines to represent a consistent X position line and were used throughout an entire belt width analysis. These lines were called velocity sampling points (VSPs). The white line is the approximation of the black reference line that was painted on the bur cotton. The width of the cotton on the wire belt conveyor can be easily distinguished in Figure 12, from the rest of the background. The left the side of the photo in Figure 12 has equally spaced vertical white lines on the edge of the trough. These were used as distance reference marks. The divider, which made the width adjustments possible, is visible to the right of the bur cotton.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Opacity 100.0
Brush 2. Hardness 050
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Angle 0.00
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Dynamics Options
☐ Apply Jitter
☐ Smooth stroke
☐ Incremental

Mode: Normal
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Figure 12. GIMP software with imported pictures that was used to obtain reference points.

Six sample frames were selected throughout the time the reference line was visible within the frames to collect velocity points. Each frame looked similar to Figure 12 except the reference line was located at different vertical (Y) positions. Figure 13 represents the same leading reference line as it travels through 24 frames, at 4 frame increments traveling clockwise from top left to bottom left. Each one of these pictures was imported into GIMP and the process outlined above from Figure 12 was repeated for each frame. Thus, the vertical lines denoting a constant X position were present and reference lines denoting the leading edge of the cotton reference line were traced across the black reference line. The X, Y locations of the intersections of the vertical and horizontal reference lines were recorded for each of the frames.

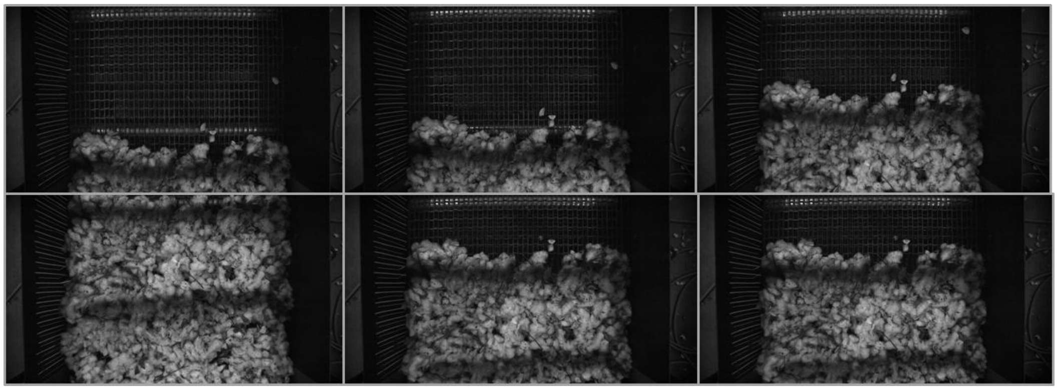

Figure 13. The visual representation of a leading edge reference line as it travels through 24 frames at 4 frame increments (clockwise from top left to bottom left).

Since each of the collection runs were completed at different velocities, the reference line did not appear in a consistent number of frames among belt configurations. To ensure the analysis was completed on the reference line, the entire time it was within the camera's field of view, the total number of frames (N) the line was in the camera's view was determined by counting the frames with each reference line present and then divided by five, since five velocity profiles were being developed for each reference line. The first frame in which the entire reference line was visible was used to begin the analysis process and designated as frame one. Then N was added back to the first frame a total of five times to evenly distribute the analyzed frames throughout the time the reference line was visible. This was a standardization procedure used for all frames analyzed to ensure that each of the reference lines had a full evaluation of its time on the belt conveyor.

The GIMP software displays the current X, Y pixel location when a mouse cursor is hovered over a particular point. At each intersection of the vertical lines and the horizontal reference line, the coordinates were recorded into an Excel (Microsoft Office 2010) program. Based on known dimensions within the camera frame the pixels were converted into local coordinates in mm. With the location, frame number, and time between frames known, the velocity profile between consecutive frames was calculated. Five velocity profiles were plotted for each reference line for a total of twenty velocity profiles per wire belt conveyor configuration.

Minitab was used to perform Response Surface Analysis on the first fully developed velocity profile line from each of wire belt conveyor run grouped by material flow rate to determine the optimum flow velocity profile based on wire belt width and material depth. The velocity of the VSPs was averaged for the last frame in which the first reference line was visible within the collected images to determine where the straight velocity profile would be located and what its average velocity was. Then, the absolute value of the deviation from this line was calculated for each of the VSPs.

### *Wire Belt Conveyance, Foreign Matter Content and Cotton Fiber Quality*

To aid with the characterization and parameterization process, fiber quality samples were collected from the lowest and highest material flow rate and minimum and maximum depths of the belt conveyance tests for all four belt widths for a total of four replications. The data from Phase II has shown that a belt conveyor does not have a significant impact on foreign matter content or fiber quality when compared to the standard auger conveyance method. Thus, potential optimization work could be performed on a belt conveyance system to aid in foreign matter removal and further preservation of fiber quality. Due the low impact on evaluated fiber quality parameters from Phase II, only select tests were used to collect foreign matter content and fiber quality samples. It was decided to select extreme testing parameters to aid in discovering differences between wire belt configurations. Thus the 0.45 kg $s^{-1}$ material flow rate was eliminated from this test, leaving only the remaining 0.30 and 0.60 kg $s^{-1}$ material flow rates. Table 16 represents the test matrix that was used to determine the testing parameters for the fiber quality portion of Phase III. The use of the extreme wire belt parameters should show relationships, if they exist, without the testing of every belt configuration necessary.

Table 16. Test matrix that was used for testing the wire belt conveyor for fiber quality work.

| **Width (Meters)** | **0.03 m Material Depth** | **0.18 m Material Depth** |
|---|---|---|
| **Velocities (m/s) for 0.30 kg $s^{-1}$ of Material Flow** | | |
| **0.18** | 2.5 | 0.29 |
| **0.36** | 1.03 | 0.15 |
| **0.53** | 0.68 | 0.10 |
| **0.69** | 0.53 | 0.08 |
| **Velocities (m/s) for 0.60 kg $s^{-1}$ of Material Flow** | | |
| **0.18** | 4.11 | 0.59 |
| **0.36** | 2.05 | 0.29 |
| **0.53** | 1.37 | 0.20 |
| **0.69** | 1.06 | 0.15 |

Since the full range of widths, depths, and speeds was tested for all material flow rates for the high speed camera work both vertically and horizontally, two of the necessary four replications were already collected. This combined for a total of 52 samples plus ten untreated samples collected directly from the row units and not exposed to either the wire belt conveyor or the cross auger.

Separated foreign matter was collected and weighed after each run from the bottom of the conveyance trough for all samples including those performed during the high speed camera analysis. The bur cotton samples were collected at the end of the conveyor belt into a container, weighed on an Electroscale (Model LC2424, capacity: 99.8 kg, Display: Electroscale Weigh Master 551, capacity: 90.7 kg, resolution 0.005 kg), and then transferred to be prepared for ginning. Since this was bur cotton, all samples were processed through the same extractor feeder used during phases I and II prior to ginning to ensure the ginning process was consistent. A fractionation sample was collected from each bur cotton sample prior to passing through the extractor feeder and was processed as outlined by USDA (Shepherd 1972). An A&D Company Ltd. (Model: HP 20K, Serial No.: 13013097, Capacity: 21 kg, resolution 0.1 g) scale was used for weight collection of the fractionation data. Due to the small sample size (usually <4.5 kg), the samples were ginned on a 10 saw gin. Due to the differences in sample sizes and potential time requirements for ginning large samples on a small gin, sub-sample sizes were limited to 1.5 kg. If the sample was smaller than 1.5 kg then the entire sample was ginned, if larger than 1.5 kg then only 1.5 kg was ginned. The clean lint was collected and weighed along with the trash and seeds to obtain lint turnout and a lint sample was taken and sent to the Texas Tech University, Fiber and Biopolymer Research Institute in Lubbock, TX for HVI (Uster Technologies HVI 1000) and AFIS (Uster Technologies AFIS Pro 2) fiber analysis. Analysis of Variance (ANOVA) was performed using the Minitab Statistical Software version 16 (Minitab Inc. State College, PA). Tukey’s Studentized Range test was used to declare differences among treatment means ($\alpha = 0.10$). An alpha level of 0.10 was used since this was preliminary and exploratory work.

## Results and Discussion

### *High Speed Camera Work*

Trends were observed between material depth, belt width and sidewall friction. There appeared to be an increase in the amount of rotation and turbulence in the cotton flow when the material depth was increased and the belt width increased. This could be explained because a narrower belt did not allow the cotton much free movement, the analysis of the video combined with visual observations supported a theory that the bur cotton seemed more compacted when it was conveyed across the 0.18 m wide belt. While a wider belt allowed for much less apparent compaction and allowed for an appearance of more movement between the bur cotton and foreign material. One issue that occurred in a few instances was bur cotton from the material bat at the greatest depth sloughed off the top of the material bat from the trailing edge and onto the wire belt conveyor. This material fell from the top of the material bat because the velocity difference between the bottom and top of the material was high. However, in a field situation this should not occur because there would be an almost continuous flow of cotton moving onto the belt from the stripper row units.

Another challenge that occurred during this part of Phase III was with the record rate of the data collected from the high speed camera. As stated in the Materials and Methods section, the camera was set to collect and write at a 60 Hz frame rate. This typically would not be a major issue; however, in the instances in which frames were skipped they were not successive and actually caused the collection rate to be different than 8 Hz. It was discovered that even though the average frame rate for each of the tests was 8 Hz the individual frame rate was not equivalent to 8 Hz due to the write speed of the hard drive being used for data collection. Using an 8 Hz frame rate to calculate bur cotton velocity produced values that were dissimilar to the original calculated testing velocities in Table 15. To determine the source of the velocity error, an electric motor and wire belt start-up delay test was performed. The delay test consisted of measuring the velocities of selected points on the wire belt from start up until it exited the visible frame of the high speed camera. It was determined from this test that the start-up time on the motor was insignificant and had no effect on the calculated velocities from the image analysis. Thus the dissimilar velocity problem was found to be with the frame recording rate. To calculate the velocities of the bur cotton calculated using the frame rate actual belt velocities were used to solve for the average frame sampling rate that occurred during velocity profile analysis process. Excel solver was used to determine the sampling rate per image by minimizing the error between the tested and calculated velocities. The error minimization solving method produced the most consistent calculated velocities based on frame rate for each of the tests. However, skipped frames were still an issue. The skipped frames artificially increased the velocity between frames as calculated by the analysis process used. Figure 14 is a representation of the five velocity profiles collected from the 0.18 m width. In instances frames were skipped it appears that the velocity has at least doubled (Figure 14). This data could be eliminated from the analysis process, but even though the velocity appears to have tripled in this case the overall velocity profile is still relevant and useful and describes what the bur cotton is doing at this point.

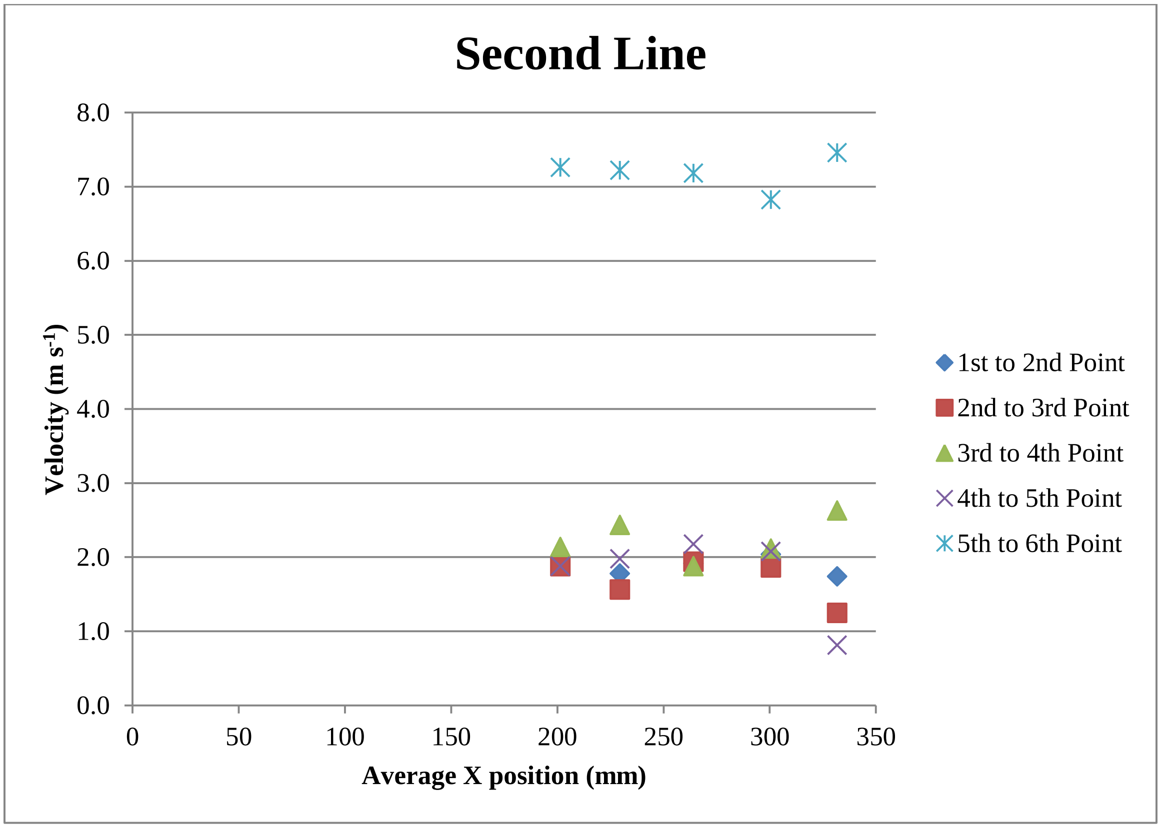

Figure 14. The second reference line on the 0.30 kg/s material flow rate 0.18 m width at the fastest velocity and 0.03 m depth represents visual skipped frames in the data collection process.

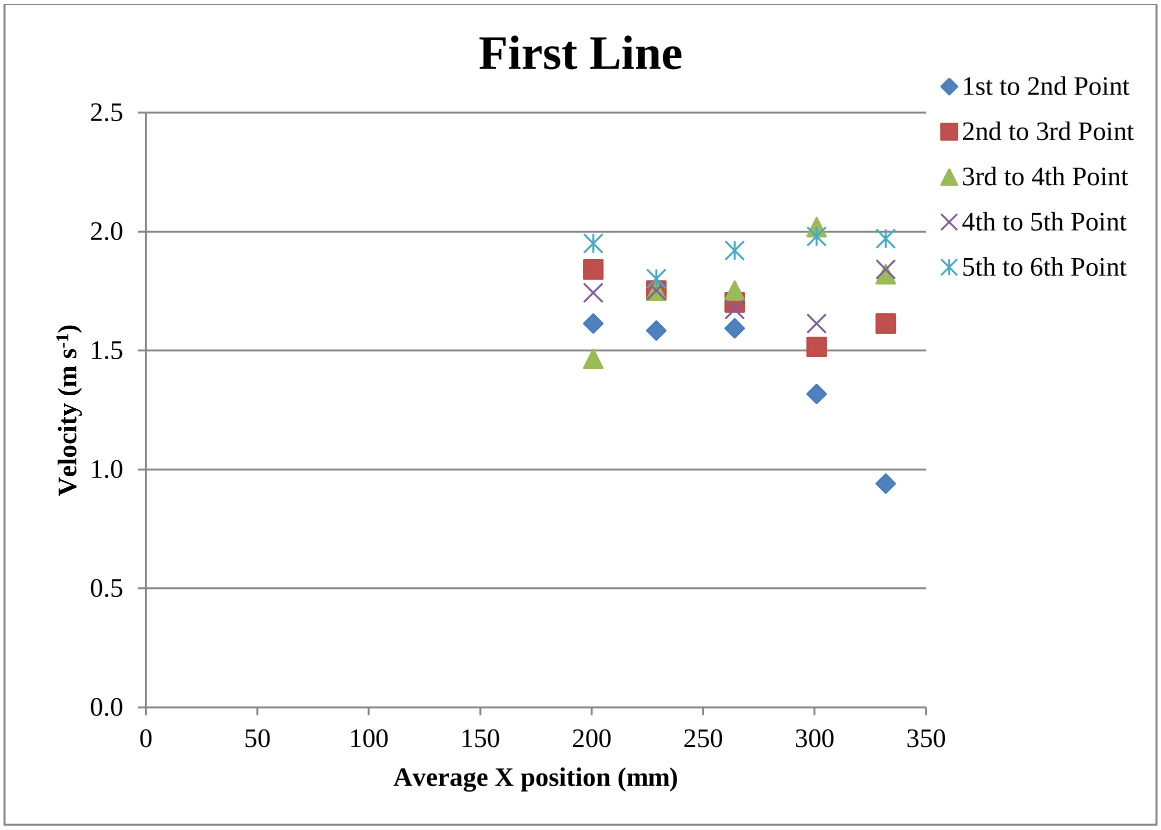

Figure 15. The first reference line on the 0.30 kg/s material flow rate, 0.18 m width at the fastest velocity and shallowest depth represents a visual of initial profile development.

Sidewall drag and friction effects can be viewed as the VSPs travel across the conveyor. A good representation of friction occurring between the bur cotton on the conveyor and the sidewall of the wire belt conveyor is present in Figure 15. The initial line ($1^{st}$ to $2^{nd}$ point) shows a much lower velocity occurring from the 300 mm position to the right of the belt conveyor due to sidewall friction. This graph is similar and representative to many of the other general trends. Initially a trend is observed as the lower velocity between the first and second points in this case. However, it does not appear that the sidewall drag is causing major problems once the bur cotton passes further along on the wire belt conveyor. This would suggest that once the initial resistances or static friction is overcome then there is little effect on the bur cotton as it flows with the wire belt. In most cases a general trend is present, it appears that as the belt widens and the velocity is slower, there is less erratic velocity profiles occurring throughout the four reference lines and even between each of the velocity sampling points on a single reference line.

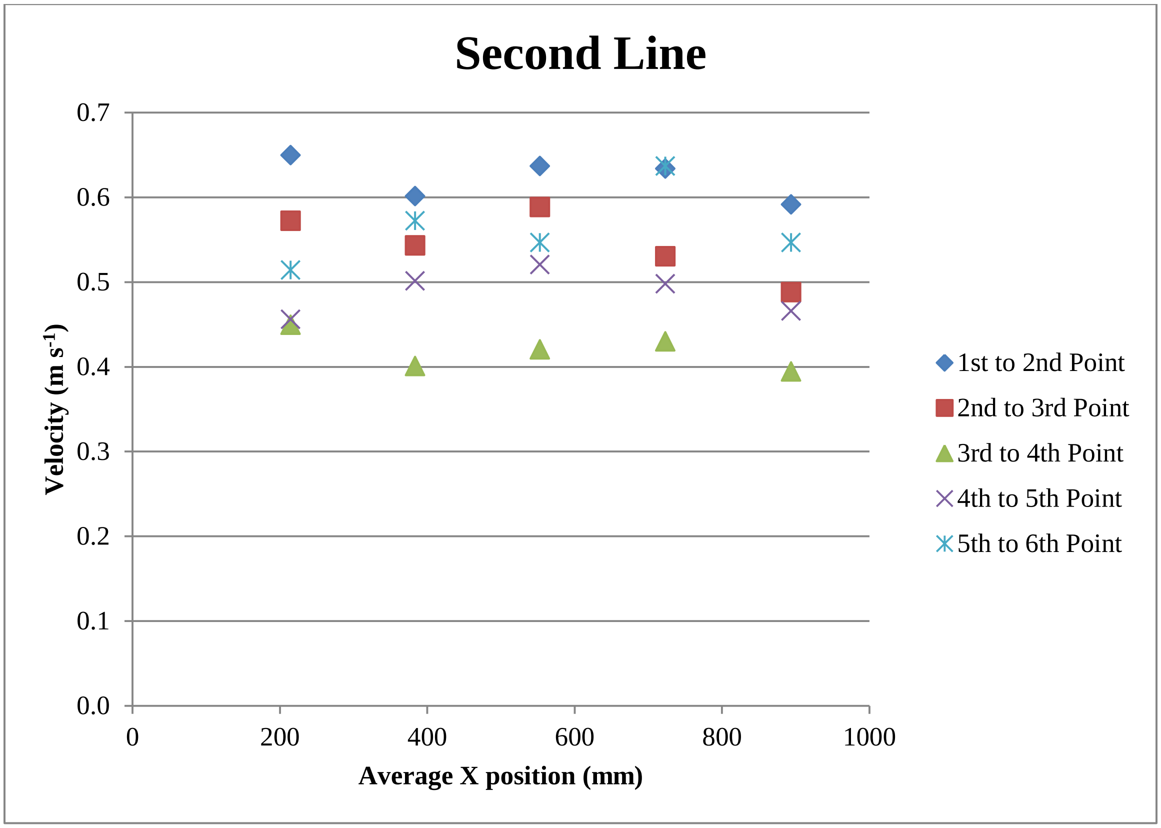

Figure 16. The second reference line on the 0.30 kg/s material flow rate 0.69 m width at the fastest velocity and shallowest depth represents a visual of initial profile development.

The second reference line collected from the 0.30 kg/s material flow rate and 0.69 m width is represented in Figure 16. There are slight variations between the VSPs as this line travels along the belt conveyor. In this case there also appears to be little to no sidewall friction causing lower velocities at the edges of the belt conveyor.

In most cases a second order polynomial equation is the best fit to describe the velocity profiles of the bur cotton as it travels across the wire belt conveyor. A few of the lines are linear and have a slope almost equivalent to zero. However, a clear trend as to when zero slopes will be present is not obvious in the profiles collected. The non-uniformity of the composition of bur cotton seems to prevent its velocity profile or particular shape from being predictable. In many instances the bur cotton rolled under and tumbled as it passed along the wire belt conveyor. The concentrations of foreign matter make the flow paths non-uniform in nature because the foreign matter changes the density of the material at points throughout the cotton bat and causes rolling and tumbling. Figures 17 and 18 are the graphed representations of the 0.18 and 0.03 m depths respectively. Figure 17 had slower velocities since more material was being conveyed with the greater material depth. The two figures provide the quadratic equations from the first reference line in each of the widths plotted. In most instances a quadratic equation was very effective at explaining the velocity profile of the bur cotton; however, a few of the non-uniform velocity profiles do not result in a quadratic equation fit. The non-quadratic relationships can be attributed to one of two issues: either the flow profile is linear with little influence from sidewall friction, or there are other interactions such as tumbling and rolling occurring due to the non-uniform characteristics of the bur cotton as described by Laird and Baker (1985). Due to the high levels of foreign matter in the cotton samples it was difficult to form fully stable velocity profiles across all wire belt conveyor widths and depths tested.

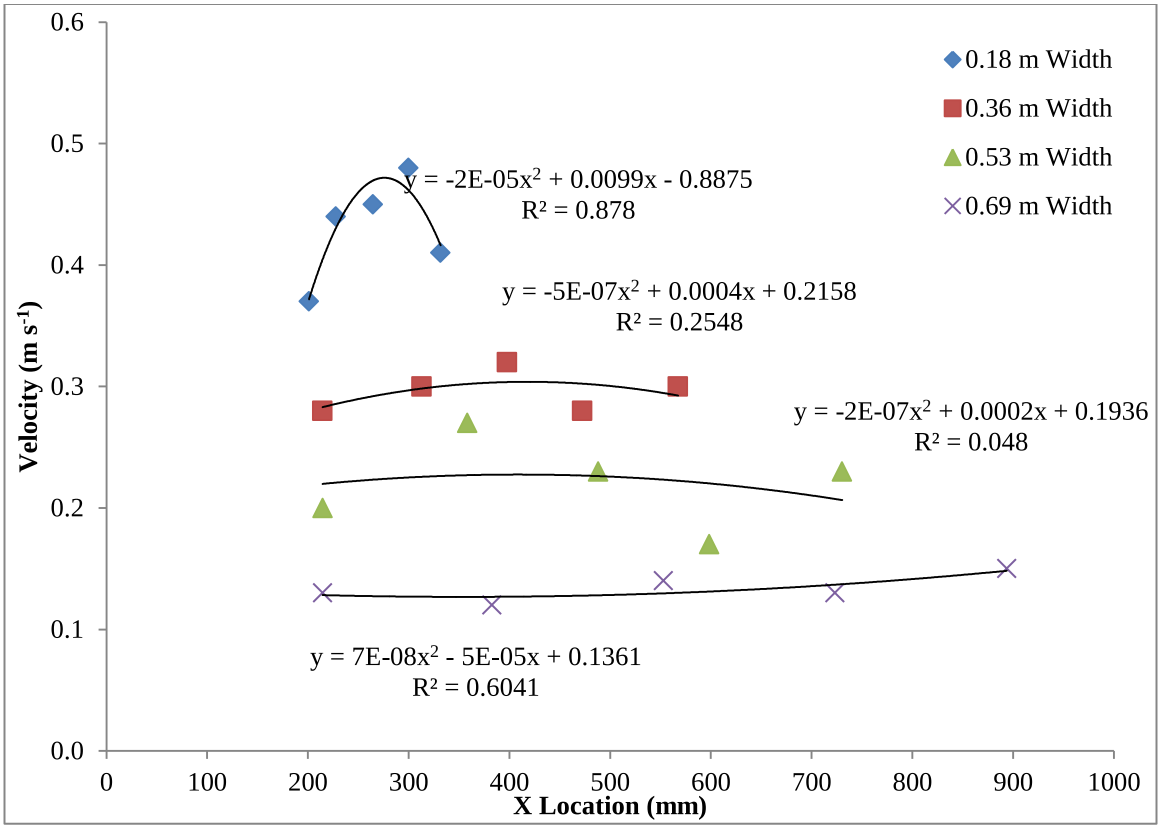

Figure 17. The first reference lines from the 0.60 kg $s^{-1}$ material flow rates and the 0.18 m depth.

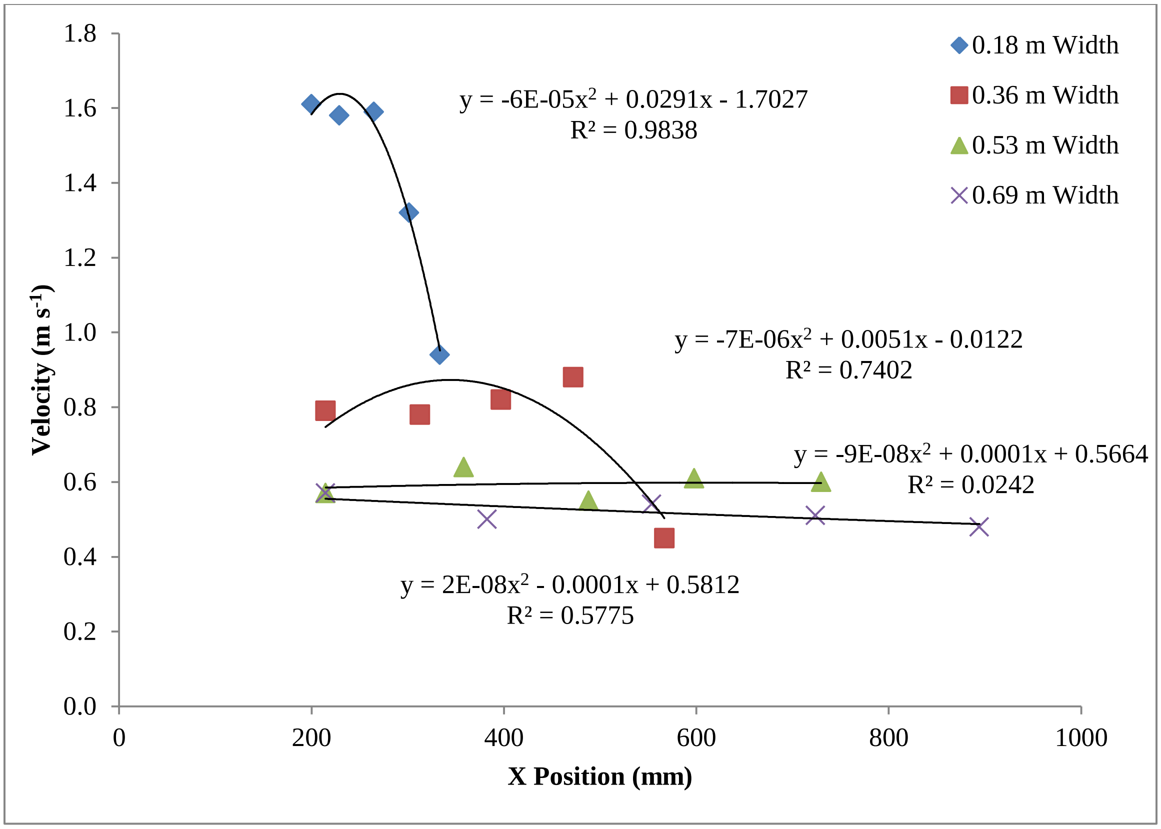

Figure 18. The first reference lines from the 0.30 kg $s^{-1}$ material flow rates and the 0.03 m depth.

In observing the trends from Figures 17 and 18, it is obvious that wider belts incur less sidewall friction in both deeper material depths and shallower material depths. These figures support the use of a wider belt for conveying bur cotton on to ensure that sidewall drag does not affect the bur cotton that is flowing behind the leading edge of the material flow path. With the exception of two extreme cases of sidewall drag in Figure 18 the shallower material depth tends to have less drastic changes across the velocity profile compared to the narrower widths from the greater depths. The faster velocity does tend to cause an initial high static friction in the narrow widths, thus the slow velocities observed in the 0.18 and 0.36 m belt widths from Figure 18. However, this increased static sidewall friction does not appear in the wider widths. The lack of a prevalent sidewall friction from the greater widths suggests that an optimal wire belt width should be designed at a 0.36 m width or wider.

The data collection methods in this section did not lend itself to using automated methods of data analysis and processing. The reported data was obtained through a manual and time intensive process making the equations a close approximation to the actual velocity profiles but not exact representations of the flow lines. Issues such as low lighting, non-uniform movement of the reference lines, skipped frames, and non-uniform material mixture of the bur cotton made automation difficult.

The absolute value of the deviation of the VSPs was used because it determines how uniform or straight the velocity profile was at that current location. Low deviation values represented a straight line and high deviations represented a non-uniform velocity profile. This data was used to determine what the optimum depth and width were for each material flow rate to produce a uniform velocity profile. Figure 19 presents a response surface analysis of the 0.30 kg $s^{-1}$ material flow rate. This analysis supports a wider belt and deeper material depth to produce a more uniform velocity profile with less mixing and agitation within bur cotton flow. The response surface and contours presented in Figures 19 and 20 interpolated outside of the data set and presented a negative deviation. Figure 20, the contour plot of the same data represented a decrease in deviation from a straight velocity profile as both the wire belt width and material depth increased.

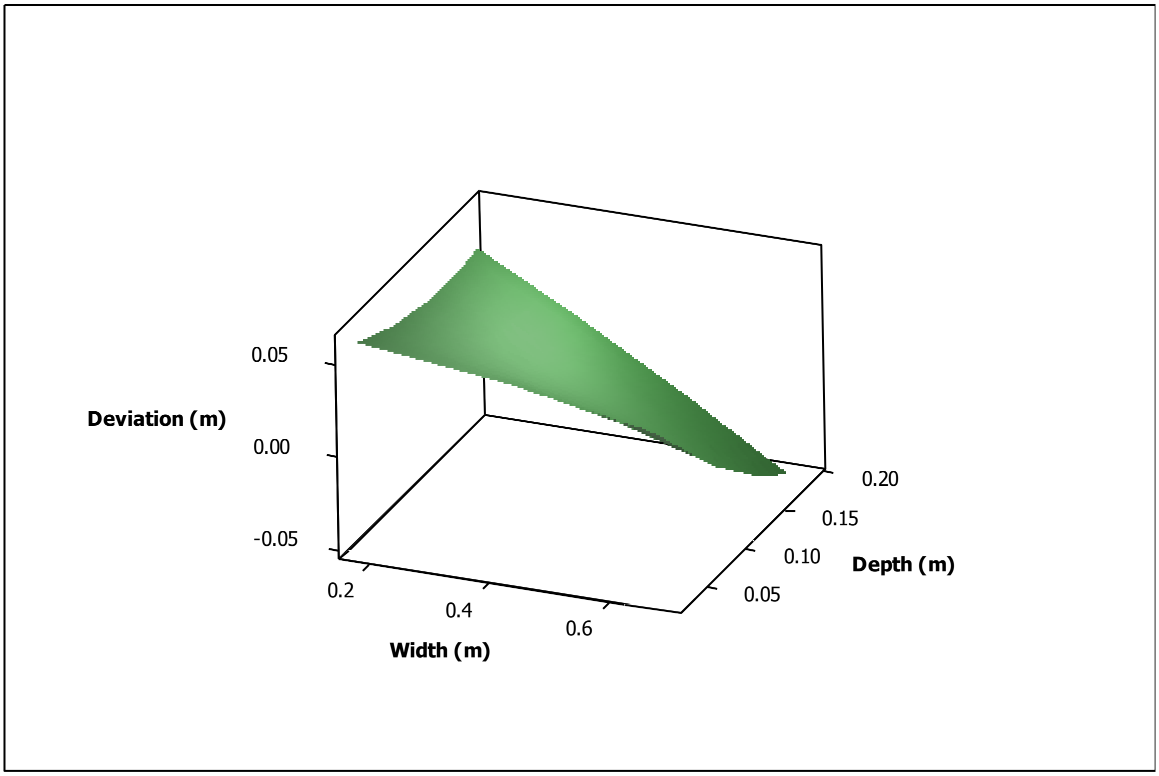

Figure 19. Response surface analysis of the deviation from the developed velocity profile collected from the 0.30 kg $s^{-1}$ material flow rate.

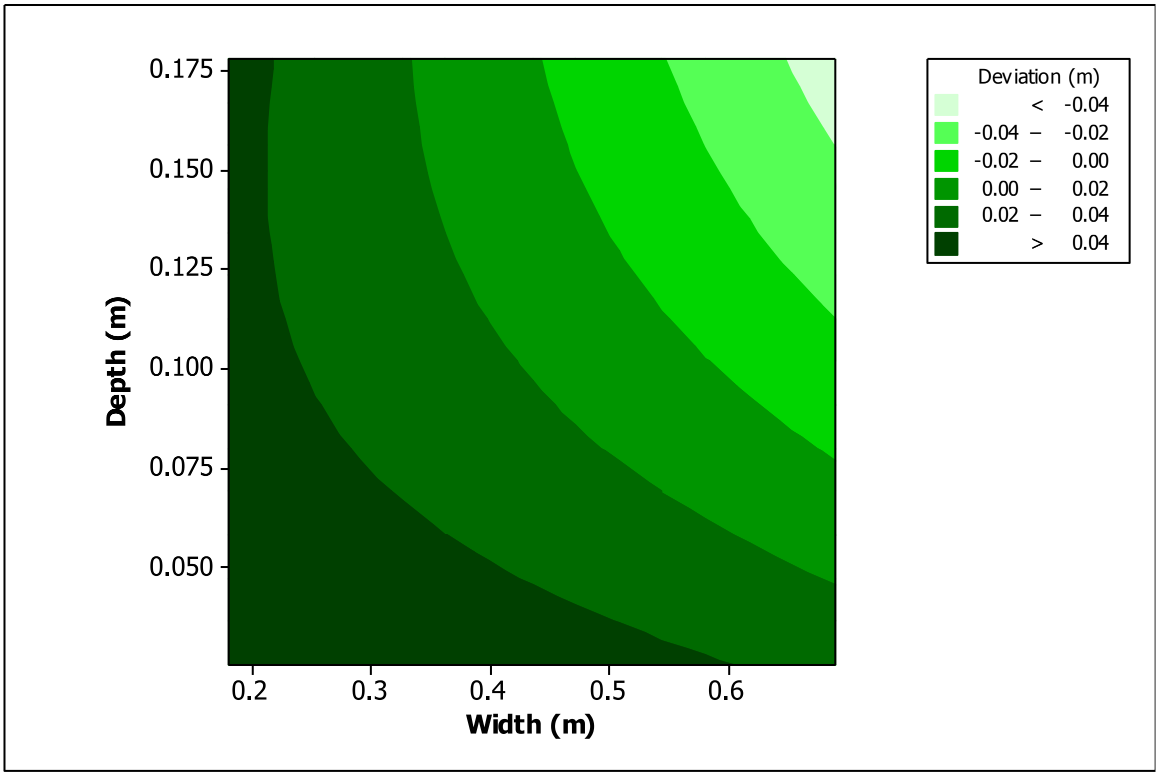

Figure 20. Contour plot of the deviation from the developed velocity profile collected from the 0.30 kg $s^{-1}$ material flow rate.

A higher material flow such as the 0.45 kg $s^{-1}$, supported the same result as the lower material flow rate as presented in Figure 21, a greater width and deeper depth reduced variation. The lowest deviation was achieved during the 0.45 kg $s^{-1}$ material flow rate with the widest belt and greatest material depth. Similar to the lower material flow rates (Figures 19 and 20) a deeper material depth could be used in combination with this flow rate to achieve a more uniform velocity profile (Figures 21 and 22).

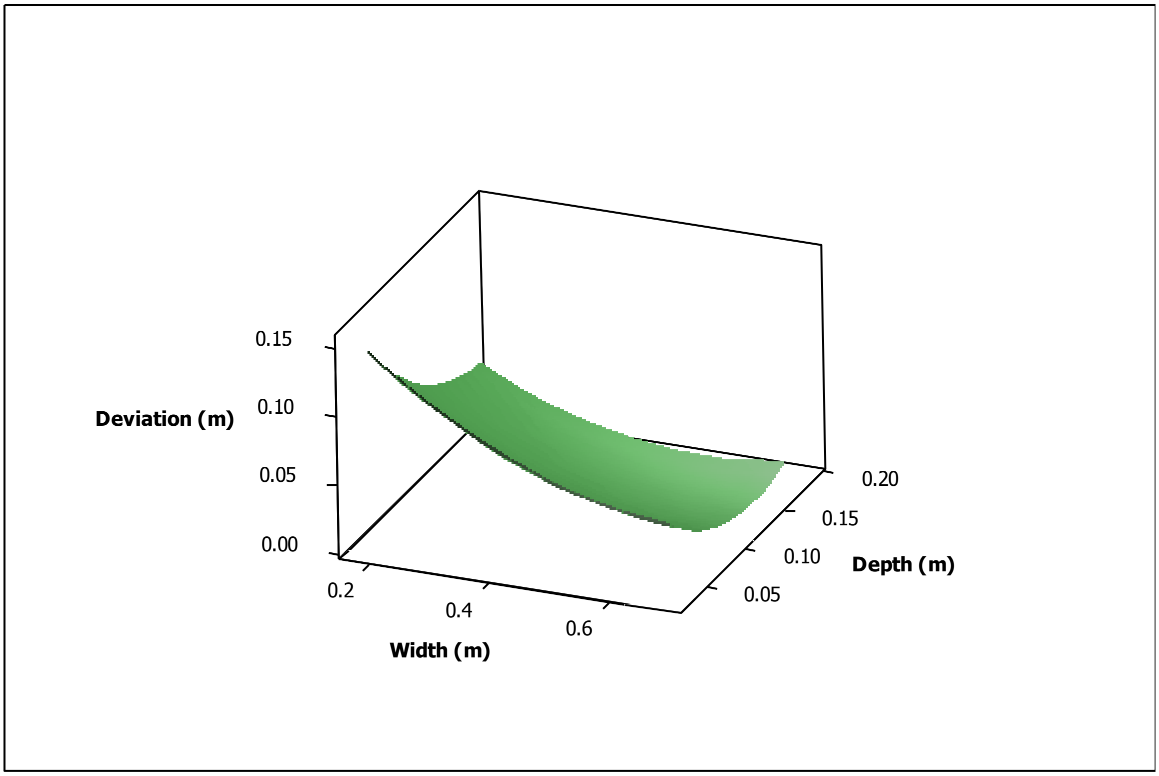

Figure 21. Response surface analysis of the deviation from the developed velocity profile collected from the 0.45 kg $s^{-1}$ material flow rate.

Figure 22 shows that the wider wire belt and deeper material aided in reducing deviation of the velocity profile. However, the deepest depth is not necessary because a low deviation can be achieved within the range of material depths ranging from 0.075 to 0.175 m if a wire belt of 0.5 m or greater in width is used.

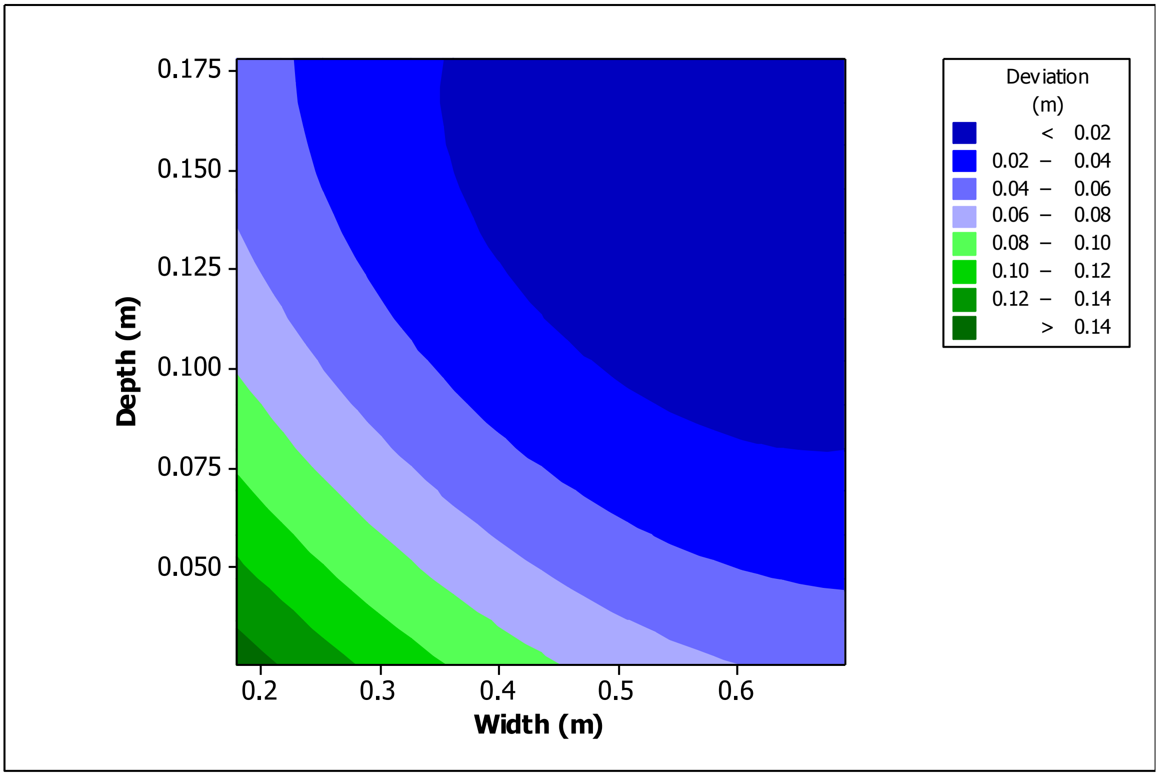

Figure 22. Contour plot of the deviation from the developed velocity profile collected from the 0.45 kg $s^{-1}$ material flow rate.

The 0.60 kg $s^{-1}$ material flow rate produced results similar to both the 0.30 kg $s^{-1}$ and 0.45 kg $s^{-1}$ material flow rates. Figure 24 confirms that a greater material depth aids in producing lower velocity profile deviations. The data support using a wider belt in this case as it does in the other response surface analysis. However, at a higher material flow rate a belt the wire belt width is less important than a greater material depth.

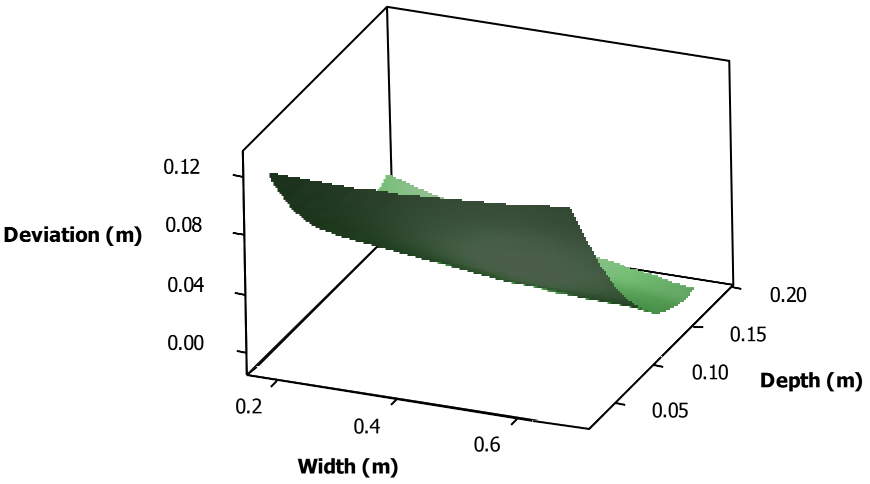

Figure 23. Response surface analysis of the deviation from the developed velocity profile collected from the 0.60 kg $s^{-1}$ material flow rate.

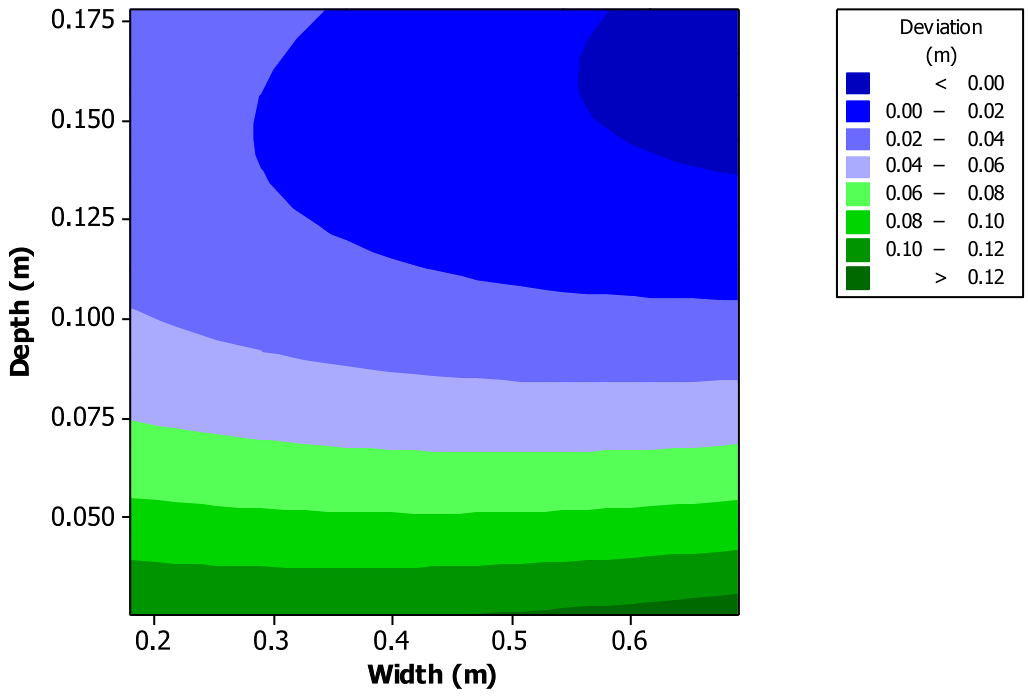

Figure 24. Contour plot of the deviation from the developed velocity profile collected from the 0.60 kg $s^{-1}$ material flow rate.

The lowest deviation or most uniform velocity profile was developed within the 0.60 kg $s^{-1}$ material flow rate by using the maximum wire belt width tested in combination with the maximum material depth. A greater material depth in combination with a wider belt seemed to prevent mixing and tumbling of the bur cotton as it was conveyed by the wire belt conveyor. Figure 23 developed a slight trough which supported an increase in material depth as the belt width increased to maintain a uniform velocity profile.

The response surface analysis data support that a minimum material depth in combination with a greater belt width produced greater velocity profile deviations, while a greater material depth seemed to produce lower deviations. The extra material depth could act as support for the leading edge of the bur cotton bat and prevent high levels of static friction and mixing from occurring, thus incurring lower velocity profile deviations.

*Wire Belt Conveyance, Foreign Matter Content and Cotton Fiber Quality*

Results from the foreign matter content and cotton fiber quality analysis provided insight into speed, width, depth, and material flow rate effects on foreign matter content and fiber quality. Figure 25 shows the amount of foreign matter removed from each sample as it passed across the wire belt conveyor. As the material depths increased in Figure 25 the velocities were reduced. A lower material depth required a higher velocity to transport the same amount of material than a greater depth. The data show that a lower material depth promotes an increase in foreign matter removal. There is not a statistical relationship but there appears to be an optimal speed in each of the material depths that also promotes an increase in foreign matter removal (Figure 25). The highest levels of foreign matter removal occurred at the 0.03 and 0.05 m material depths. It appears that an optimal velocity for the 0.03 m depth ranges from approximately 0.5 to 1.5 m $s^{-1}$ and an optimal velocity for the 0.05 m depth ranges from approximately 0.35 to 1.00 m $s^{-1}$. There do appear to be a few points that had much higher than average foreign matter removal percentages, but since this particular test was not replicated because the data were collected from the high speed camera tests, firm conclusions cannot be drawn. On a percent removal basis greater material depths remove less material than the lower material depths.

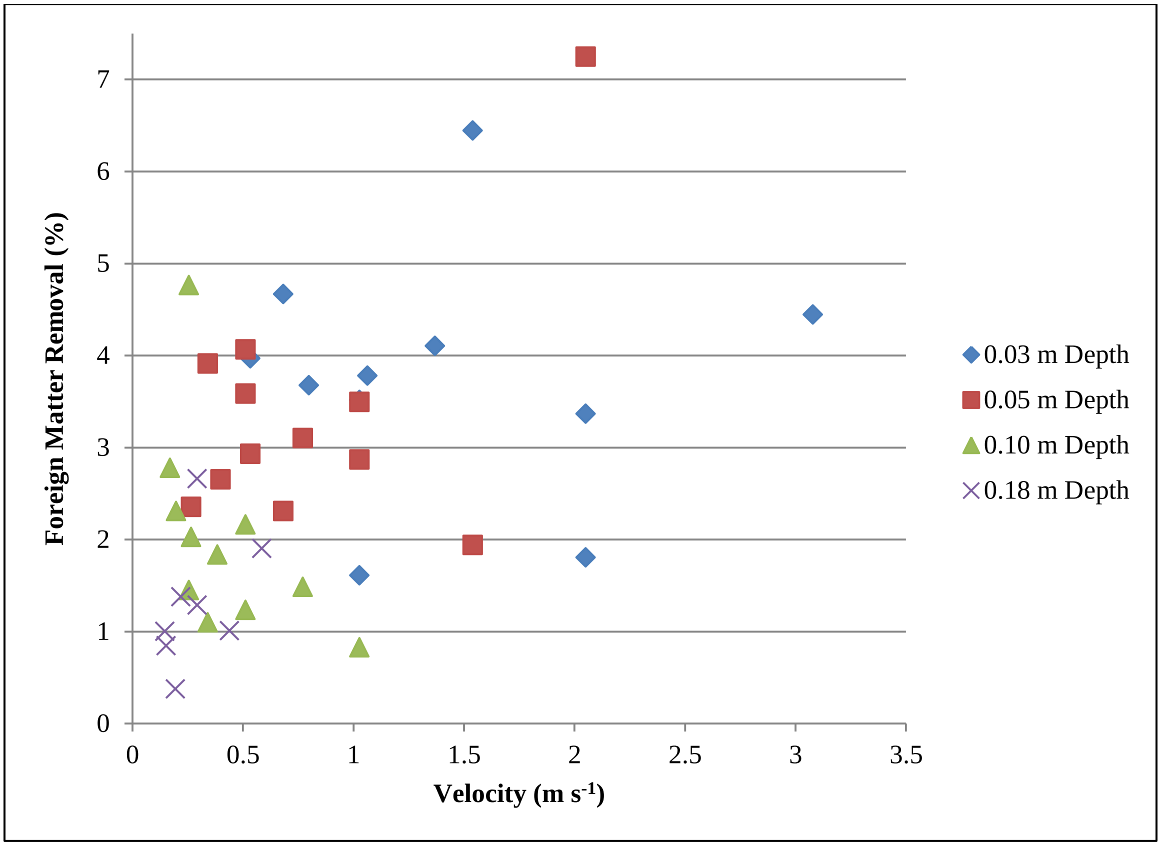

Figure 25. Percentage of foreign matter removed from the bur cotton by the wire belt conveyor based on bur cotton material depth.

The data represented in Figure 25 was collected from material pneumatically removed from the bottom of the wire belt conveyor and collected from the floor. The faster velocity could introduce a higher rate of vibration that accounts for a higher amount of material removal. As would be expected, a deeper depth did not incur a higher amount of foreign material removal. The same surface area of material was allowed to touch the wire belt independent of the material depth, verifying that foreign matter is only being removed from the portion of the bur cotton that is allowed to touch the belt. Approximately the same amount of foreign matter was collected from each sample, thus the data is presented as percent removal of foreign matter from each sample to aid normalizing this data collection. The sample size varied with each wire belt conveyor configuration such that smaller samples had the same amount of foreign matter collected as did the larger samples; however, in terms of percent removal the smaller samples had higher values since the weight of the foreign matter comprised a higher amount of the total sample weight. Thus, typically a shallower depth had a higher percent removal per sample size than did the deeper material depths. The mixing action of a cross auger aids in inverting and mixing the bur cotton allowing for foreign material to not only be removed from the bottom of the material flow, but from the entire material flow stream. However, the mixing action of a cross auger could also intermix foreign material making it more difficult to remove during later processes. The non-mixing flow action of a wire belt conveyor should make it easier to remove foreign material within the field cleaner and perhaps at the gin level because it prevents foreign matter from being further incorporated into the bur cotton.

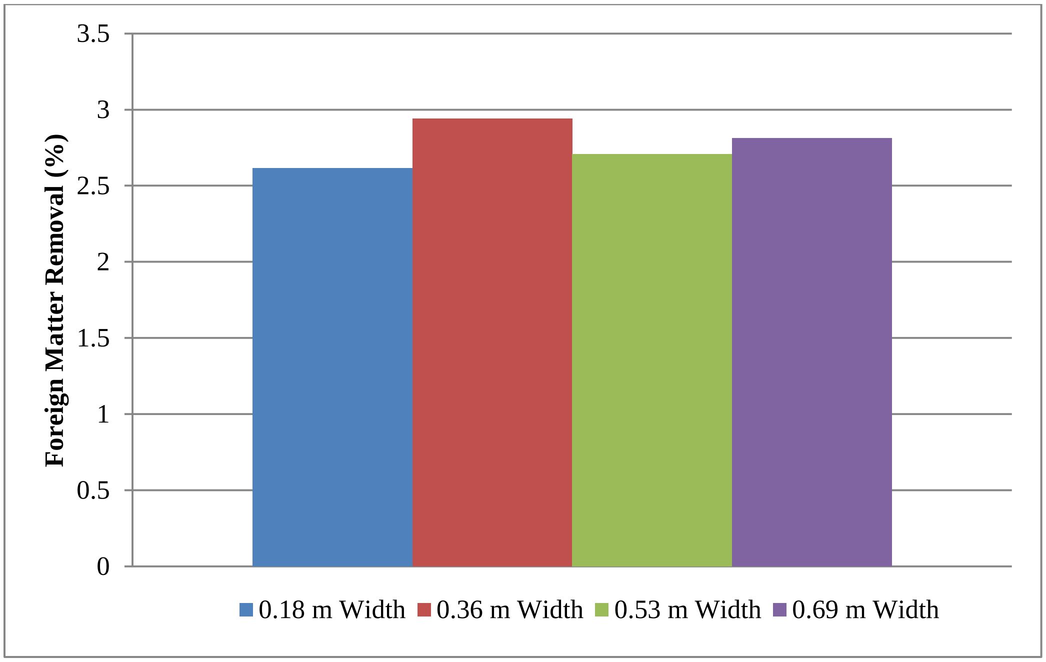

Figure 26. Percentage of foreign matter removed from the bur cotton by the wire belt conveyor based on wire belt width.

Figure 26 shows the percent removal of foreign matter based on the width of the wire belt conveyor. According to this data the 0.36 m wide belt performed best at removing foreign matter, with the 0.69 m wide belt removing approximately 0.1% less. However, it is important to note that there is only about a 0.3% difference between the highest and lowest foreign matter removals. After pairing this data with the depth and speed data, optimal ranges and widths can be determined and appear to range from 0.36 to 0.69 m in width, 0.5 to 1.5 m $s^{-1}$ in velocities and the material depth should stay at or below 0.05 m.

There were no statistical differences among the widths for lint turnout. Table 17 represents the mean groupings of the lint turnout data grouped by width.

Table 17. Lint turnout grouped by width of the wire belt conveyor.

| **Width (m)** | **Lint turnout % Lint** |
|---|---|
| **Untreated** | 37 |
| **0.18** | 38 |
| **0.36** | 38 |
| **0.53** | 36 |
| **0.69** | 36 |
| **P-Value** | 0.066 |

Greater belt widths had slightly lower lint turnouts than did the narrower belt widths. This could potentially be attributed to sample size, because typically the narrower widths were comprised of smaller samples, or it could just be because of natural variations in the cotton samples. All of the lint turnout numbers are high based on typical turnouts from stripper harvested bur cotton. However, the use of a small scale gin can sometimes increase the lint turnout and have other adverse effects on fiber quality parameters due to a few reasons such as differences in gin stand design and environmental conditions during ginning (Boykin et. al 2008). Since less sample flow is travelling through the gin, it may perform better at retaining more lint, or the smaller gin does not perform well at removing foreign material thus increasing the lint weight and consequently lint turnout.

Slight variations were observed in lint turnout when velocity was used as a factor. Table 18 presents the lint turnout divided by both width and material conveyance. Turnout tended to be slightly higher at low flow rates and minimum material depths. This could be attributed to more removal of foreign material occurring during the conveyance process of the bur cotton. However, the differences are slight and may not mean there is much difference between the material conveyance rates and depths.

Table 18. Percentage of foreign material removed from the bur cotton ginning based on material flow rate.

| Width (m) | Lint turnout % | |
|---|---|---|
| | 0.30 kg $s^{-1}$ of Material Flow | 0.60 kg $s^{-1}$ of Material Flow |
| **P-Value** | <0.0001 | |
| **Untreated** | $37.1^{BC}$ | |
| **0.18** | $41.0^{A}$ | $36.2^{C}$ |
| **0.36** | $38.5^{B}$ | $36.2^{C}$ |
| **0.53** | $36.2^{C}$ | $36.5^{C}$ |
| **0.69** | $36.6^{C}$ | $35.6^{C}$ |

To determine if the different combinations of speed, depth, and material flow rate had any effects on the type of foreign material being removed, the fractionation samples were collected and analyzed by all of the wire belt configurations. Differences were only significant for a few of the wire belt configurations tested. Leaf trash did have a significant relationship with width (Table 19).

Table 19. Leaf trash grouped by width for the wire belt conveyor reported from fractionation results.

| Width (m) | Leaf Trash % of Sample |
|---|---|
| **Untreated** | $3.0^{A}$ |
| **0.18** | $2.9^{AB}$ |
| **0.36** | $2.5^{AB}$ |
| **0.53** | $2.7^{AB}$ |
| **0.69** | $2.4^{B}$ |
| **P-Value** | 0.042 |

An increase in belt width seemed to reduce the total amount of leaf trash present in the samples. However there was not a statistical difference between the samples. This is potentially due to more surface area of the bur cotton being allowed to touch the wire belt conveyor. The area touching the belt allowed more of the leaf trash to be removed from the sample as it passed along the conveyor than did the reduced areas of the narrower widths. The only other significant interaction occurred between leaf trash as analyzed by depth and material flow rate (Table 20).

Table 20. Percentage of leaf trash present measured by fractionation procedures.

| **Width (m)** | **0.03 m Depth % Leaf Trash** | **0.18 m Depth % Leaf Trash** |
|---|---|---|
| **P-Value** | 0.012 | |
| **Untreated** | $3.02^{A}$ | |
| | **0.30 kg/s Material Flow** | |
| **0.18** | $2.6^{AB}$ | $3.2^{A}$ |
| **0.36** | $2.2^{AB}$ | $2.8^{AB}$ |
| **0.53** | $2.7^{AB}$ | Not Collected |
| **0.69** | $2.3^{AB}$ | Not Collected |
| | **0.60 kg/s of Material Flow** | |
| **0.18** | Not Collected | $2.8^{AB}$ |
| **0.36** | $2.3^{AB}$ | $3.0^{AB}$ |
| **0.53** | $2.8^{AB}$ | $2.6^{AB}$ |
| **0.69** | $2.1^{B}$ | $2.9^{AB}$ |

Again, the differences are minor, but the lower percentages of leaf trash tend to occur at the lowest depths and the greatest widths. This again supports that a faster velocity could introduce higher vibration levels that could aid in shaking out more foreign material, especially in these cases the leaf trash. The greater widths are allowing for more surface area of the conveyed bur cotton to be exposed to the open wire belt. The increase in exposure to the belt provides both an open area for the leaf trash to fall out and introduces more vibration to the material touching the wire belt. The increases in vibration at this point aid in removing foreign material from the bur cotton.

Larger trash such as burs, sticks, and stems may not be able to fall through the belt since typically they are larger than the openings of the belt. More research into belt design could aid in increasing the amount of larger sized trash that is removed from the bur cotton. However, this process must be taken with care to ensure that the burr cotton is not allowed to fall out of the material stream, effectively reducing yield and decreasing harvest efficiency.

Both HVI and AFIS results, similar to the turnout and fractionation results did not have significant differences in the treatments for many of the HVI parameters including micronaire, strength, reflectiveness, and yellowness. Minor significant differences were present for HVI length, uniformity, elongation, and leaf. The HVI parameters with differences are presented in Table 21 below. The letters only correspond to the statistical differences located within each column data and do not correspond to any other HVI parameter in the table. To simplify the chart the following code was used: 1B or 2B denotes one or two bale material flow rate based on ground speed, the width is next, and either V1 or V4 denotes velocity one or four for the particular run from the appropriate material flow rate and depth. An example code is 1B0.18V1, this denotes one bale, 0.18 m belt width, at velocity one.

Table 21. HVI parameters containing statistically significant differences based on treatment.

| **Treatment: Material flow rate, width, depth** | **Length (cm)** | **Uniformity %** | **Elongation** | **Trash (%)** |
|---|---|---|---|---|
| **Untreated** | $3.0^{AB}$ | $81.9^{AB}$ | $7.6^{A}$ | $67.0^{AB}$ |
| **0.30, 0.18, 0.03** | $3.0^{AB}$ | $82.0^{AB}$ | $7.2^{B}$ | $34.5^{B}$ |
| **0.30, 0.18, 0.18** | $3.0^{B}$ | $81.0^{B}$ | $7.6^{A}$ | $57.0^{AB}$ |
| **0.60, 0.18, 0.03** | Not Collected | Not Collected | Not Collected | Not Collected |
| **0.60, 0.18, 0.18** | $3.0^{AB}$ | $82.4^{AB}$ | $7.6^{A}$ | $61.8^{AB}$ |
| **0.30, 0.36, 0.03** | $3.1^{AB}$ | $82.5^{AB}$ | $7.7^{A}$ | $50.5^{AB}$ |
| **0.30, 0.36, 0.18** | $3.1^{AB}$ | $83.3^{A}$ | $7.6^{A}$ | $84.3^{A}$ |
| **0.60, 0.36, 0.03** | $3.0^{B}$ | $81.8^{AB}$ | $7.9^{A}$ | $53.5^{AB}$ |
| **0.60, 0.36, 0.18** | $3.0^{AB}$ | $82.3^{AB}$ | $7.6^{A}$ | $72.3^{AB}$ |
| **0.30, 0.53, 0.03** | $3.1^{A}$ | $83.2^{A}$ | $7.6^{A}$ | $64.0^{AB}$ |
| **0.30, 0.53, 0.18** | Not Collected | Not Collected | Not Collected | Not Collected |
| **0.60, 0.53, 0.03** | $3.0^{AB}$ | $82.8^{AB}$ | $7.6^{A}$ | $75.5^{A}$ |
| **0.60, 0.53, 0.18** | $3.1^{AB}$ | $82.5^{AB}$ | $7.6^{A}$ | $67.8^{AB}$ |
| **0.30, 0.69, 0.03** | $3.1^{AB}$ | $83.1^{A}$ | $7.7^{A}$ | $56.3^{AB}$ |
| **0.30, 0.69, 0.18** | Not Collected | Not Collected | Not Collected | Not Collected |
| **0.60, 0.69, 0.03** | $3.1^{AB}$ | $82.4^{AB}$ | $7.7^{A}$ | $53.3^{AB}$ |
| **0.60, 0.69, 0.18** | $3.1^{A}$ | $83.0^{A}$ | $7.6^{A}$ | $83.8^{A}$ |
| **P-Values** | 0.008 | 0.009 | <0.0001 | 0.012 |

As presented in Table 21, most of the differences present are slight and even though they are statistically different at $\alpha$=0.10 levels, the difference in actual fiber quality is not necessarily practical. There do not appear to be any trends present that correlate the fiber quality variation to the depth, width, and speed of material conveyance on the wire belt. AFIS results presented no statistical differences in fiber quality parameters tested, and variability was noted just as in the HVI data. As discussed in Phase I, the slight variations observed in the fiber quality data can be attributed to natural field variation on sampling and ginning methods. The set-up and evaluation of machinery projects often leave no feasible opportunities for treatment randomization. Even when considering the nature of this particular project, the foreign matter and fiber quality data do not seem to follow a trend that would suggest the issues could have been resolved by adjusting the testing procedures. As is often the case when working with natural environments, the variation present shows up in the data as slight differences with little to no pattern. Thus, it appears that various configurations of a wire belt conveyor do not seem to have a significant effect on cotton fiber quality parameters.

## Summary and Conclusions

### *High Speed Camera Work*

Images were collected using a high speed camera from all of the configurations listed above. Issues with the write speed of the computer hard drive prevented the images from being collected at the desired 60 Hz rate; instead the images were collected at various rates. The actual capture rates were calculated based on actual wire belt set velocity. Calculation of the capture rates allowed the velocity profiles to be accurately calculated. The rates were sufficient for performing manual analysis even though in instances frames were still skipped and erroneously increased the velocity. In the instances of skipped frames, the velocity was incorrect but the overall profile was still representative of what the reference line and the bur cotton was doing at that particular point in time.  Despite issues with data collection and processing, velocity profile equations were developed for combinations of wire belt conveyor parameters.  The velocity profile equations represent combinations of belt velocities, belt widths, material depths, which all relate to a material flow rate.  The equations were not directly correlated to any of the wire belt parameters tested, but represent combinations of wire belt configurations.  Based on response surface analysis greater material depths generally aided in reducing deviation from a straight velocity profile.  However, narrower belt configurations integrated more mixing of the bur cotton bat.  Mixing and rolling was more evident in deep and narrow situations.  The data suggest that wider belts with shallower material depths tend to have lower and less drastic sidewall friction.  Based on the velocity profiles developed, data would suggest that a belt at least 0.4 m wide would be a better option at conveying bur cotton than narrower belt widths to reduce the amount of sidewall friction on the bur cotton.  To obtain the necessary velocities required to convey high material flow rates at any depth from a narrow belt, too much non-uniform flow and frictional forces are introduced.  Even though the wire belt conveyor was capable of transporting material with a narrow belt there are potential problems associated with the non-uniform flows and increases in sidewall friction.  Clogging of the belt could easily occur when continuous flows of material are loaded onto the belt.  Visually it appeared that the shallow depths in combination with the greater widths tended to have reduced sidewall friction suggesting that a material depth in the range of 0.03 to 0.05 would be optimal.  Material depths greater than 0.10 m can cause an increase in the non-uniform flow patterns observed based on visual observations of the high speed camera data.  However, statistical data support a deeper material depth in combination with a wider wire belt conveyor.  All material flow rates supported a wire belt width of at least 0.4 m to maintain the most uniform fully developed velocity profile of the leading edge of the material bat.  Greater material depths prevented the leading edge of the material from becoming unstable during conveyance by the wire belt.  Material depths greater than 0.10 m produced the greatest reduction in velocity profile deviation based on the response surface analysis.  Low deviation in the leading edge velocity profile should prevent mixing and tumbling throughout the rest of the bur cotton bat travelling along the wire belt conveyor.

### *Wire Belt Conveyance, Foreign Matter Content and Cotton Fiber Quality*

Cotton fiber quality and foreign matter content samples were processed across four widths combined with two depths on a wire belt conveyor to produce two material conveyance rates. The combination of width, depth, and material conveyance rate was used to determine the speed at which the wire belt conveyor should be operated at.  The minimum and maximum conditions were tested for this part of the study.  It was decided to use two material flow rates that would be considered high and low in the Southern High Plains.  The fastest and slowest possible velocities were selected.  Fractionation, ginning, HVI, and AFIS data were collected from these testing parameters.  There were slight differences present from these processes and fiber quality tests. The various wire belt conveyor configurations did not have significant impacts on lint turnout, HVI and AFIS results.  However, percent removal data collected from the wire belt conveyor suggest an optimal belt configuration to ensure higher levels of foreign matter removal.  The optimal belt configurations based on the percent foreign matter removal data are velocities ranging from 0.5 to 1.5 m $s^{-1}$, widths ranging from 0.36 to 0.69 m and material flow depths less than 0.10 m.  Since the percent removal data was the only data that show significant differences between wire belt conveyor configurations it was used to determine optimum settings.  Designing a belt conveyor to meet these specifications would optimally increase the amount of foreign matter removed from bur cotton as it passes along a wire belt to higher levels than other belt configurations.  Most of the differences present in the foreign matter and fiber quality parameters that were statistically different were not of practical significance.  The results of these tests have aided in developing a foundation for wire belt conveyance and fiber quality parameters and foreign matter removal.  This foundation can be used to further optimize a wire belt conveyor for conveying bur cotton.

*Combined Conclusions*

The data from both sections of Phase III supported use of a wider wire belt conveyor with a shallower material depth from the standpoint of cotton fiber quality.  The high speed camera work suggests that deviation from the developed velocity profile is lessened when a wider belt is used in combination material depths greater than 0.10 m.  Reductions in deviation from the developed velocity profile aid in preventing high levels of non-uniform flow from occurring.  Non-uniform flow can cause conveyance issues and fiber quality issues.  The data from the fiber quality and foreign matter section suggest that a shallower material depth aids the wire belt conveyor in having a higher percent foreign matter removal than greater depths.  The data from the foreign matter section also suggest that wider belts typically had higher percent removals of foreign matter than narrower belts.  Thus, Phase III would suggest that a wider belt would be more of a viable option from the perspectives of both material conveyance and foreign matter removal.  However, a further study could suggest an optimal depth at which both fiber quality and uniform velocity profile development occur.  A compromise must be reached to ensure high velocity profile uniformity in combination with high levels of fiber quality preservation and foreign matter removal.  Since there were no practical differences between the fiber quality data, perhaps the main focus should be on the velocity profile development data.  Based on the velocity profile deviation data, a greater wire belt and greater material depth should be used.

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# CHAPTER V

# SUMMARY AND CONCLUSION

This work has met the outlined objectives by determining the fiber quality and foreign matter content of successive cleaning/conveying components on a cotton stripper harvester. The data from Phase I of this project aids greatly in developing the premise of succeeding Phases II and III. An appropriate location was targeted based on the data from Phase I and a wire belt conveyor was designed and built to match the material handling capacity of the current cross auger design. The wire belt conveyor was tested against the current cross auger design for fiber quality and foreign matter removal properties. Work was performed to aid in the optimization process of a wire belt conveyor. This work targeted velocity profile relationships to belt conveyor configurations including material depth, material flow rate, belt velocity, and belt width. Work was also documented relating the same belt conveyor configurations to ginning, fractionation, HVI, and AFIS fiber quality and foreign matter parameters.

## Key Discoveries and Results in Light of the Specific Objectives

The main objective of this study was to determine a viable way to lower the foreign matter content, while preserving cotton fiber quality as close to field level as possible in stripper harvested cotton.

The main objective in this study was met by testing, characterizing, and parameterizing a modified version of the cross auger on a cotton stripper harvester, a wire belt conveyor. The wire belt conveyor has the material capacity and capabilities to replace a cross auger on a stripper harvester. The data collected for this objective have provided a good foundation for outlining the effects of a wire belt conveyor and wire belt configurations on fiber quality parameters of bur cotton. The wire belt conveyor had similar foreign matter and fiber quality results as the current cross auger. The wider the belt and shallower the depth of material, the higher percent removal was observed from the bur cotton sample based on the foreign material collected from the wire belt conveyor.

The secondary objectives are divided into three phases within this paper and were:

*Specific Objective 1:*

Determine ginning and fiber quality parameters from successive machine conveyance locations on a cotton stripper harvester, with the locations including: 1) hand-picked from the field, 2) just after the brush rolls in the row unit, 3) just after the row units, 4) from the separation duct after the cotton was conveyed by the cross auger, 5) from the basket with the field cleaner by-passed, and 6) from the basket after the cotton was processed through the field cleaner. Use the ginning and fiber quality parameters to select an appropriate conveyance location for modification to meet the primary objective.

This objective was met by Phase I of this study. Foreign matter and fiber quality parameters were documented based on the successive machine conveyance locations outlined from above. These data give a foundation for the fiber quality and foreign matter parameters throughout successive locations on a stripper harvester. Based on these data it was determined that the cross auger was an ideal location to select for redesign. It was found from a machine standpoint that the row units were very hard to sample. By disabling the row unit augers too much dirt and debris was introduced into the machine causing possible damage. A better method of sampling this location should be determined so that it can be fully explored.

*Specific Objective 2:*

Design, build, and test a "modified" version of the selected conveyance location. Collect ginning and fiber quality parameters from the modified conveyance device. Compare the ginning and fiber quality parameters of the modified conveyance device to that of the standard conveyance method.

A wire belt conveyor was designed and built to replace one half of a standard cross auger on a four row John Deere 7460. The conveyor was tested against the standard cross auger on the machine in a laboratory. To obtain bur cotton that had been harvested and conveyed by a row unit the right half of the cross auger was removed. Bur cotton was collected from the open auger trough to be tested on the wire belt conveyor. The bur cotton was removed from the open auger trough and placed in sample bags of approximate 9.0 kg mass. The impact on the bur cotton of being packed into the auger trough could lead to influences on both fiber quality and foreign matter content. However, there are currently few ways to sample these locations any better. Overall, the belt conveyor did not perform any better or worse than the standard cross auger. In a few instances such as removing leaf trash and HVI trash the wire belt conveyor performed better than the cross auger and in the other instances the wire belt conveyor performed the same as the cross auger. The lack of difference between the two conveyance methods could be a result of the sampling methods used; the compaction and extra handling of the bur cotton could make it harder to remove the foreign matter. Even with issues the belt, conveyor still performed at an adequate level, indicating there is potential for use and improvement of a wire belt conveyor on a cotton stripper.

*Specific Objective 3:*

Determine the flow characterization and parameterization of bur cotton on a wire belt conveyor.

A high speed camera was used in conjunction with the earlier described wire belt configurations to aid in the determination of a velocity profile and the characterization of foreign matter and fiber quality. Four different belt widths in combination with four material depths and three typical yields from the Southern High Plains were used to create a total of 48 configurations minus four configurations that were deemed too fast or slow to be practical. Each one of the 42 configurations was filmed using a high speed camera. The lowest and highest speeds for the lowest and highest material conveyance rates were repeated a total of four times for ginning, fractionation, HVI, and AFIS analysis. The results from the fiber quality and foreign matter tests did not provide many correlations among the wire belt conveyor configurations. In several instances the greater belt widths in combination with shallower material depths aided in increasing percent removal of foreign matter as the sample traveled along the wire belt conveyor. Certain wire belt design parameters were discovered to aid in a design optimization process for a wire belt to transport bur cotton. If the suggested design parameters are followed then the wire belt conveyor has the potential to remove more foreign matter than other non-optimal wire belt configurations. The increase in surface area of the sample touching the belt tended to allow more foreign matter to be removed. However, the highest foreign matter removal from belt width was observed from a 0.36 m wide belt. A faster velocity did not necessarily mean a higher percent removal either, an optimal range was found to be between 0.5 to 1.5 m $s^{-1}$. Response surface analysis of velocity profile development determined that an optimal material depth is possible to aid in maintaining the most uniform velocity profile to lessen the amount of mixing and tumbling occurring to the bur cotton bat as it is conveyed by a wire belt conveyor.

### Future Work

It is important to note this is an initial study that has focused on developing and adding new information and knowledge. The end results of this study will not necessarily have immediate impacts on cotton stripper design or practices. There is much work that was considered during this particular project that can be performed in the future to ensure the technology developed during this study follows the correct path and is incorporated into production practices:

1. The collection methods used during Phase I could use improvement. The process of disabling machine components and having bur cotton stopping throughout the machine could add bias to the fiber quality and foreign matter results. Bur cotton was packed into the empty auger trough, then removed using a metal rake and placed into large bags. There were many opportunities to increase the amount of foreign matter, Nep Size, Nep Count and other potential issues with fiber quality parameters. A better way to sample these locations could be to do it without stopping the machine or compacting the bur cotton into an auger trough or other containers. However, this is the first time samples from all of these sampling locations have been collected and this data is new and novel and has never been documented before. Thus, it has great value.
2. A wire belt conveyor should be retrofitted into an operating cotton stripper and used under field conditions. The wire belt conveyor could be integrated into a stripper harvester in a few different capacities. One such way would be to leave a two-piece auger in the auger trough and retrofit the right hand side of the auger trough with a wire belt conveyor. The use of a wire belt conveyor under field conditions would allow for true comparisons between an auger conveyor and the wire belt conveyor. The wire belt could be set where it could run in reverse so that bur cotton could be removed from the

cross auger trough without compaction of the bur cotton in the auger trough. Another method would be to replace an entire auger trough with a wire belt conveyance trough. This would allow full use of a wire belt conveyor under field and harvest conditions. The data collected from the full wire belt could be compared to that of a standard machine with a cross auger.

3. Other means of foreign matter separation should be explored. In this study the wire belt conveyor was only tested under laboratory conditions. Slight vibrations were added due to the belt and the electric drive motor but nothing significant enough to simulate vibratory shaking. Just by attaching a wire belt conveyor to a harvester and operating under typical harvest conditions added vibrations will be incurred. These vibrations will come both from the operation of the machine itself and from driving the machine through the field at harvest speeds. If there still seems to be issues with removing foreign matter then a vibratory shaker could be added to the header or wire belt conveyor on the machine to aid in removing more foreign matter. Another alternative to using a vibratory shaker is to use a pneumatic bath to aid in removing foreign matter. Air could be passed up through suitable points throughout the belt conveyor to allow the bur cotton to “float” and heavier foreign matter to fall out or vice versa for smaller foreign matter such as dust. This method could potentially work for larger foreign matter including sticks, stems, burs, motes, and leaf trash. Of course adding either a vibratory shaker or a pneumatic bath could drastically increase the power requirements of the machine or lead to higher maintenance costs.
4. This study explored using one chain belt material, sizing, and arrangement. There are many different designs of wire belt conveyors that could be used. It is important to keep the size of the holes in the belt small enough that bur cotton does not easily fall through the belt and/or become lost or entangled in the belt. Differing belt configurations could

lend to the ability of removing types of foreign matter such as burs in the case of more rounded holes or sticks and stems in the case of longer more narrow slits in the belt.

5. Again this study only explored using one type of belt material. A steel belt was the easiest to be custom designed and built for a reasonable cost. However, other belt material such as aluminum or rubber could work just as effectively or potentially better. Both of those materials would be lighter than steel, and rubber would be easier to handle and manipulate. Draper headers on grain combines currently use a type of rubber belt; a similar style could be adapted to a cotton stripper with holes incorporated to ensure foreign matter is still allowed to pass through the belt and out of the machine instead of up into the machine.
6. More in-depth research could be completed moving towards making the belt velocity adjustable. The benefit of an adjustable velocity would be to ensure the velocity is matched to the varying material flow rates that are coming into the machine during harvest. This parameter may be a little premature since to be able to adjust speed real time based on material flow an accurate yield monitor would be needed.
7. One important benefit of using a wire belt conveyor instead of a solid auger is the ability to incorporate wider headers on a machine. Currently the widest stripper header available is an eight-row header. Width restrictions and certain field conditions prevent the headers from being any wider. An auger is typically a solid piece of tubing with flights that runs at least one half of the width of the header, however, a wire belt conveyor could be dedicated to one or two individual row units. This could first create a header that could be folded up much like a larger planter can for ease during road transport. Individual rows could be added or removed increasing or decreasing the width of the header when necessary. The dedication of individual wire belt conveyors to single or double row units would also add the ability for the auger to become a flexible header.

Instances where a wider rigid header would not typically be able to harvest near a slope or terrace in a field a flexible header could potentially have the flex necessary to still touch the ground and harvest the crop. This could be one of the biggest advantages to adding a belt conveyor system to a header on a cotton stripper harvester.

8. If it is deemed necessary to continue bur cotton characterization and parameterization on a wire belt the data collection methods need to be refined. First, better and even lighting is needed to ensure that all of the conveyance runs are producing the best available images. Issues were detected with automated image processing that did not allow an automated process to detect the reference lines in all of the collected images. Either a color camera or a better reference marking system or the combination of both needs to be implemented to make automated image processing more reliable. The reference method used in this study only allowed for limited analysis. A better tracer method would aid in more readily determining flow characteristics. High speed images were collected from a side view of the wire belt conveyor, however due to the non-uniform flow paths of the foreign matter in the bur cotton reference points could not be identified and tracked throughout the conveyance process. The more simplified method of profile tracking used for this study had no valid way to account for rotational flow paths in the bur cotton flow. There were also instances that prevented flow differences from being detected by the method used. It may have been obvious that a few areas of the bur cotton were flowing faster, slower, rotating, or being affected by sidewall friction but since these areas were not captured by the reference line they were not reported. However, this method even though simple, did aid in developing equations that explain the velocity profiles of bur cotton as it relates to the wire belt parameters tested in this study.

# APPENDICES:

## Appendix A: Mean Gin Data from Phase I and Phase II

| **Cultivar: FM: FiberMax STV: Stoneville** | **Sample Location Code** | **Ginning Date** | **Temp °C** | **Humidity %** | **Bur cotton Weight (kg)** | **Trash Weight (kg)** | **Lint turnout (%)** |
|---|---|---|---|---|---|---|---|
| | | | **2011** | | | | |
| **FM** | HP | 10/21/2011 | 16.8 | 34 | 11.0 | 0.28 | 35.90 |
| **FM** | ASR | 10/21/2011 | 16 | 34 | 15.25 | 6.68 | 11.62 |
| **FM** | ARU | 10/21/2011 | 17 | 33.8 | 12.84 | 3.64 | 22.62 |
| **FM** | ACA | 10/21/2011 | 17.2 | 33.8 | 15.03 | 4.02 | 21.62 |
| **FM** | BFC | 10/21/2011 | 17.2 | 33.8 | 8.87 | 1.76 | 26.14 |
| **FM** | AFC | 10/21/2011 | 17.4 | 33.4 | 7.52 | 0.74 | 31.85 |
| **STV** | HP | 10/21/2011 | 23.4 | 22.6 | 10.33 | 0.22 | 37.35 |
| **STV** | ASR | 10/21/2011 | 22 | 25 | 23.51 | 11.14 | 11.87 |
| **STV** | ARU | 10/21/2011 | 23.6 | 22.4 | 13.62 | 2.92 | 26.46 |
| **STV** | ACA | 10/21/2011 | 23.6 | 22.2 | 13.94 | 2.75 | 25.47 |
| **STV** | BFC | 10/21/2011 | 23.6 | 22 | 10.03 | 1.81 | 26.87 |
| **STV** | AFC | 10/21/2011 | 23.6 | 21.8 | 7.58 | 0.57 | 32.48 |
| | | | **2012** | | | | |
| **FM** | HP | 11/26/2012 | 12 | 35.3 | 10.09 | 0.12 | 36.65 |
| **FM** | ARU | 11/26/2012 | 12.2 | 38.8 | 9.25 | 1.89 | 27.70 |
| **FM** | BC | 11/26/2012 | 13 | 39.0 | 10.72 | 2.13 | 28.77 |
| **FM** | BC + FC | 11/26/2012 | 14.2 | 35.8 | 8.92 | 0.56 | 38.92 |
| **FM** | ACA | 11/26/2012 | 15.7 | 33.1 | 11.39 | 2.14 | 31.43 |
| **FM** | ACA+FC | 11/26/2012 | 16 | 32.0 | 10.22 | 0.65 | 39.01 |
| **FM** | BFC | 11/26/2012 | 16 | 31.4 | 12.03 | 2.18 | 27.36 |
| **FM** | AFC | 11/26/2012 | 16 | 30.0 | 11.00 | 0.78 | 32.70 |
| **STV** | HP | 11/27/2012 | 6.3 | 38.0 | 9.87 | 0.12 | 39.75 |
| **STV** | ARU | 11/27/2012 | 5.0 | 40.8 | 9.71 | 2.00 | 26.39 |
| **STV** | BC | 11/27/2012 | 5.0 | 42.0 | 9.86 | 2.04 | 27.68 |
| **STV** | BC + FC | 11/27/2012 | 6.0 | 42.0 | 8.79 | 0.57 | 35.14 |
| **STV** | ACA | 11/27/2012 | 6.2 | 41.2 | 10.92 | 2.04 | 30.47 |
| **STV** | ACA+FC | 11/27/2012 | 7.0 | 39.0 | 10.26 | 0.65 | 36.88 |
| **STV** | BFC | 11/27/2012 | 7.6 | 38.0 | 11.64 | 1.80 | 26.73 |
| **STV** | AFC | 11/27/2012 | 8.0 | 37.2 | 10.39 | 0.71 | 33.30 |

## Appendix B: Mean Gin Data from Phase III

| Material Flow Rate (kg/s): 0.30, 0.60, or UT: Untreated | Wire Belt Conveyor Width (m) | Velocity m/s | Ginning Date | Bur cotton Weight (kg) | Trash/Seed Weight (kg) | Lint turnout (%) |
|---|---|---|---|---|---|---|
| **UT** | | | 5/06/2013 | 1.5 | 0.93 | 37.08 |
| **0.30** | 0.18 | 2.50 | 5/06/2013 | 0.2 | 0.13 | 41.05 |
| **0.30** | 0.18 | 0.29 | 5/06/2013 | 1.0 | 0.64 | 35.87 |
| **0.60** | 0.18 | 0.59 | 5/06/2013 | 1.0 | 0.59 | 36.56 |
| **0.30** | 0.36 | 1.03 | 5/06/2013 | 0.4 | 0.26 | 39.17 |
| **0.30** | 0.36 | 0.15 | 5/06/2013 | 1.5 | 0.93 | 36.62 |
| **0.60** | 0.36 | 2.05 | 5/06/2013 | 0.4 | 0.26 | 38.22 |
| **0.60** | 0.36 | 0.29 | 5/06/2013 | 1.5 | 0.93 | 36.04 |
| **0.30** | 0.53 | 0.68 | 5/06/2013 | 0.7 | 0.41 | 36.12 |
| **0.60** | 0.53 | 1.37 | 5/06/2013 | 0.7 | 0.43 | 36.34 |
| **0.60** | 0.53 | 0.20 | 5/06/2013 | 1.5 | 0.93 | 36.46 |
| **0.30** | 0.69 | 0.53 | 5/06/2013 | 0.7 | 0.46 | 36.96 |
| **0.60** | 0.69 | 1.06 | 5/06/2013 | 0.8 | 0.52 | 36.28 |
| **0.60** | 0.69 | 0.15 | 5/06/2013 | 1.5 | 0.95 | 35.59 |

## Appendix C: Mean Cotton Fiber Field Moisture Content Data

| Cultivar: FM: FiberMax STV: Stoneville | Sample Location Code | Temperature $^{o}$C | Relative Humidity (%) | Wet Basis Moisture Content (%) | Dry Basis Moisture Content (%) |
|---|---|---|---|---|---|
| | | **2011** | | | |
| **FM** | B/AFC/HP | 20 | 17.9 | 4.34 | 4.54 |
| **FM** | B/AFC/HP | 20 | 17.8 | 2.58 | 2.65 |
| **FM** | B/AFC/HP | 20 | 17.7 | 4.18 | 4.36 |
| **FM** | B/AFC/HP | 20 | 17.2 | 4.43 | 4.64 |
| **FM** | B/AFC/HP | 20 | 17.5 | 4.40 | 4.60 |
| **FM** | Header | 26 | 13 | 4.33 | 4.52 |
| **FM** | Header | 26 | 13 | 3.97 | 4.13 |
| **FM** | Header | 28 | 10.7 | 4.22 | 4.41 |
| **FM** | Header | 28 | 9.5 | 4.42 | 4.63 |
| **FM** | Header | 28 | 10.2 | 5.64 | 5.98 |
| **STV** | B/AFC/HP | 19 | 18.5 | 4.73 | 4.97 |
| **STV** | B/AFC/HP | 18 | 20.1 | 4.99 | 5.25 |
| **STV** | B/AFC/HP | 20 | 17.9 | 4.76 | 5.00 |
| **STV** | B/AFC/HP | 20 | 17.9 | 4.17 | 4.35 |
| **STV** | B/AFC/HP | 19 | 19.1 | 4.34 | 4.53 |
| **STV** | Header | 17 | 24.6 | 5.30 | 5.59 |
| **STV** | Header | 18 | 23.9 | 5.28 | 5.58 |
| **STV** | Header | 19 | 23.2 | 4.74 | 4.97 |
| **STV** | Header | 20 | 20.4 | 4.79 | 5.03 |
| **STV** | Header | 21 | 19.3 | 3.85 | 4.00 |
| | | **2012** | | | |
| **FM** | HP | N/A | N/A | 4.87 | 5.12 |
| **FM** | ACA | N/A | N/A | 4.76 | 5.00 |
| **FM** | BFC | N/A | N/A | 4.92 | 5.18 |
| **FM** | AFC | N/A | N/A | 4.92 | 5.18 |
| **STV** | HP | N/A | N/A | 4.87 | 5.12 |
| **STV** | ACA | N/A | N/A | 5.12 | 5.40 |
| **STV** | BFC | N/A | N/A | 4.92 | 5.17 |
| **STV** | AFC | N/A | N/A | 4.87 | 5.12 |

## Appendix D: Cotton Fiber Ginning Moisture Content Data

| Cultivar: FM: FiberMax STV: Stoneville | Sample Location Code | Temperature °C | Relative Humidity (%) | Wet Basis Moisture Content (%) | Dry Basis Moisture Content (%) |
|---|---|---|---|---|---|
| | | **2011** | | | |
| **FM** | HP | 16.8 | 34.0 | 4.70 | 4.93 |
| **FM** | ASR | 16 | 34 | 5.35 | 5.65 |
| **FM** | ARU | 17.0 | 33.8 | 6.00 | 6.38 |
| **FM** | ACA | 17.2 | 33.8 | 5.96 | 6.34 |
| **FM** | BFC | 17.2 | 33.8 | 6.78 | 7.27 |
| **FM** | AFC | 17.4 | 33.4 | 6.12 | 6.52 |
| **STV** | HP | 23.4 | 22.6 | 4.90 | 5.15 |
| **STV** | ASR | 22 | 25 | 5.53 | 5.86 |
| **STV** | ARU | 23.6 | 22.4 | 7.55 | 8.17 |
| **STV** | ACA | 23.6 | 22.2 | 7.26 | 7.84 |
| **STV** | BFC | 23.6 | 22.0 | 6.98 | 7.50 |
| **STV** | AFC | 23.6 | 21.8 | 6.25 | 6.67 |
| | | **2012** | | | |
| **FM** | HP | 12.0 | 35.3 | 6.27 | 6.69 |
| **FM** | ARU | 12.2 | 38.8 | 5.64 | 5.98 |
| **FM** | BC | 13.0 | 39.0 | 5.53 | 5.85 |
| **FM** | BC + FC | 14.2 | 35.8 | 5.62 | 5.95 |
| **FM** | ACA | 15.7 | 33.1 | 5.63 | 5.97 |
| **FM** | ACA+FC | 16.0 | 32.0 | 5.66 | 6.00 |
| **FM** | BFC | 16.0 | 31.4 | 5.88 | 6.25 |
| **FM** | AFC | 16.0 | 30.0 | 5.59 | 5.93 |
| **STV** | HP | 6.3 | 38.0 | 6.08 | 6.49 |
| **STV** | ARU | 5.0 | 40.8 | 6.49 | 6.95 |
| **STV** | BC | 5.0 | 42.0 | 6.30 | 6.73 |
| **STV** | BC + FC | 6.0 | 42.0 | 5.83 | 6.19 |
| **STV** | ACA | 6.2 | 41.2 | 6.15 | 6.55 |
| **STV** | ACA+FC | 7.0 | 39.0 | 5.75 | 6.10 |
| **STV** | BFC | 7.6 | 38.0 | 6.14 | 6.55 |
| **STV** | AFC | 8.0 | 37.2 | 5.80 | 6.16 |

## Appendix E: Mean Fractionation Results from Phase I and Phase II

| Cultivar: FM: FiberMax STV: Stoneville | Sample Location Code | Total Sample Weight (g) | Burs (g) | Sticks and Stems (g) | Leaf Trash (g) | Motes (g) | Fine Trash (g) | Seed Cotton (g) |
|---|---|---|---|---|---|---|---|---|
| | | | | **2011** | | | | |
| **FM** | HP | 231.7 | 1.3 | 0.47 | 1.81 | 2.25 | 1.58 | 218.87 |
| **FM** | ASR | 240.5 | 21.0 | 4.75 | 5.50 | 5.45 | 61.85 | 99.85 |
| **FM** | ARU | 233.1 | 28.1 | 6.11 | 5.73 | 4.78 | 16.28 | 155.80 |
| **FM** | ACA | 219.0 | 26.2 | 6.22 | 5.61 | 5.41 | 16.21 | 143.45 |
| **FM** | BFC | 224.0 | 26.8 | 5.67 | 4.03 | 5.13 | 15.11 | 152.05 |
| **FM** | AFC | 219.9 | 8.9 | 2.77 | 2.60 | 3.99 | 10.46 | 179.69 |
| **STV** | HP | 235.5 | 1.1 | 0.76 | 2.71 | 2.58 | 2.96 | 220.38 |
| **STV** | ASR | 222.9 | 15.9 | 8.60 | 7.85 | 4.95 | 24.60 | 140.40 |
| **STV** | ARU | 223.1 | 25.7 | 5.79 | 6.44 | 4.30 | 12.41 | 156.93 |
| **STV** | ACA | 222.0 | 27.4 | 6.32 | 7.21 | 5.07 | 13.70 | 152.68 |
| **STV** | BFC | 231.6 | 23.1 | 6.90 | 6.24 | 4.47 | 12.98 | 165.99 |
| **STV** | AFC | 221.3 | 7.9 | 3.26 | 3.70 | 3.61 | 7.88 | 186.53 |
| | | | | **2012** | | | | |
| **FM** | HP | 282.6 | 0.1 | 0.30 | 0.73 | 0.87 | 0.27 | 279.30 |
| **FM** | ARU | 269.0 | 54.8 | 4.68 | 7.06 | 2.44 | 2.84 | 193.70 |
| **FM** | BC | 269.8 | 63.4 | 7.20 | 5.60 | 2.58 | 2.88 | 184.26 |
| **FM** | BC + FC | 233.3 | 11.6 | 4.44 | 3.56 | 2.30 | 2.10 | 206.98 |
| **FM** | ACA | 263.0 | 51.4 | 7.00 | 7.05 | 2.24 | 2.60 | 190.79 |
| **FM** | ACA+FC | 244.5 | 11.8 | 5.18 | 3.88 | 2.04 | 1.86 | 217.74 |
| **FM** | BFC | 257.0 | 48.3 | 5.04 | 5.46 | 3.02 | 5.56 | 184.48 |
| **FM** | AFC | 258.0 | 12.0 | 5.34 | 4.22 | 2.56 | 3.86 | 224.82 |
| **STV** | HP | 228.3 | 0.3 | 0.33 | 1.03 | 1.20 | 0.87 | 223.53 |
| **STV** | ARU | 332.7 | 71.8 | 9.36 | 8.60 | 3.16 | 4.98 | 231.12 |
| **STV** | BC | 269.8 | 59.7 | 10.16 | 5.86 | 3.22 | 5.50 | 180.82 |
| **STV** | BC + FC | 264.2 | 16.3 | 5.70 | 4.96 | 3.26 | 3.74 | 227.74 |
| **STV** | ACA | 302.5 | 47.3 | 15.07 | 7.90 | 3.11 | 6.06 | 218.77 |
| **STV** | ACA+FC | 238.5 | 12.7 | 6.80 | 4.78 | 2.52 | 2.60 | 206.56 |
| **STV** | BFC | 316.1 | 55.7 | 13.66 | 6.52 | 3.84 | 8.32 | 221.12 |
| **STV** | AFC | 245.1 | 10.3 | 7.28 | 4.20 | 3.08 | 4.60 | 211.28 |

## Appendix F: Mean Fractionation Results from Phase III

| Material Flow Rate (kg/s): 0.30, 0.60, or UT: Untreated | Wire Belt Conveyor Width (m) | Rep | Velocity (m/s) | Total Sample Weight (g) | Burs (g) | Sticks and Stems (g) | Leaf Trash (g) | Motes (g) | Fine Trash (g) | Seed Cotton (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| **UT** | | 1 | | 252.0 | 40.33 | 13.57 | 7.48 | 3.71 | 4.23 | 177.89 |
| **0.30** | 0.18 | 1 | 2.50 | 251.5 | 38.18 | 13.20 | 6.28 | 4.18 | 4.38 | 178.50 |
| **0.30** | 0.18 | 1 | 0.29 | 250.9 | 38.45 | 13.03 | 7.78 | 3.80 | 5.85 | 175.90 |
| **0.60** | 0.18 | 1 | 0.59 | 250.5 | 37.63 | 11.98 | 6.80 | 4.20 | 7.18 | 173.93 |
| **0.30** | 0.36 | 1 | 1.03 | 252.3 | 40.38 | 14.53 | 5.28 | 4.28 | 4.65 | 176.43 |
| **0.30** | 0.36 | 1 | 0.15 | 251.4 | 39.48 | 14.43 | 6.78 | 4.73 | 5.98 | 173.60 |
| **0.60** | 0.36 | 1 | 2.05 | 251.8 | 38.83 | 11.60 | 5.60 | 3.90 | 5.55 | 178.33 |
| **0.60** | 0.36 | 1 | 0.29 | 251.9 | 35.60 | 12.95 | 7.28 | 4.08 | 7.20 | 177.10 |
| **0.30** | 0.53 | 1 | 0.68 | 251.7 | 36.53 | 15.80 | 6.55 | 3.73 | 3.63 | 180.03 |
| **0.60** | 0.53 | 1 | 1.37 | 250.4 | 39.00 | 13.90 | 6.83 | 3.70 | 5.73 | 174.73 |
| **0.60** | 0.53 | 1 | 0.20 | 251.9 | 39.70 | 12.98 | 6.45 | 3.68 | 4.33 | 178.35 |
| **0.30** | 0.69 | 1 | 0.53 | 251.0 | 37.80 | 12.25 | 5.60 | 3.45 | 3.23 | 185.95 |
| **0.60** | 0.69 | 1 | 1.06 | 251.7 | 39.63 | 12.43 | 5.10 | 3.53 | 3.13 | 184.75 |
| **0.60** | 0.69 | 1 | 0.15 | 252.3 | 43.13 | 17.10 | 7.23 | 4.75 | 4.18 | 172.78 |

## Appendix G: HVI Data from Phases I and II

| **Cultivar: FM: FiberMax STV: Stoneville** | **Sample Location Code** | **MIC** | **Length** | **Unif.** | **Strength** | **Elon.** | **Rd** | **+b** | **CGRD** | **Leaf** | **HVI Trash (%)** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **2011** | | | | | | |
| **FM** | HP | 4.4 | 1.1 | 81.10 | 29.44 | 7.39 | 83.52 | 7.02 | 21-1 | 1.00 | 12.40 |
| **FM** | ASR | 4.4 | 1.1 | 80.97 | 29.55 | 7.38 | 82.64 | 7.21 | 31-1 | 1.10 | 15.10 |
| **FM** | ARU | 4.2 | 1.1 | 81.11 | 29.91 | 7.26 | 80.90 | 7.60 | 21-1 | 1.30 | 26.80 |
| **FM** | ACA | 4.3 | 1.1 | 80.98 | 30.02 | 7.27 | 80.31 | 7.72 | 21-1 | 2.40 | 30.90 |
| **FM** | BFC | 4.4 | 1.1 | 81.82 | 30.05 | 7.20 | 81.35 | 7.60 | 31-1 | 2.60 | 29.50 |
| **FM** | AFC | 4.4 | 1.1 | 81.37 | 29.62 | 7.35 | 81.92 | 7.47 | 21-2 | 1.90 | 24.90 |
| **STV** | HP | 5.3 | 1.1 | 81.39 | 29.25 | 8.22 | 79.78 | 8.47 | 21-1 | 2.70 | 18.00 |
| **STV** | ASR | 5.3 | 1.1 | 81.00 | 29.20 | 8.15 | 75.10 | 8.95 | 31-3 | 2.00 | 26.00 |
| **STV** | ARU | 5.2 | 1.1 | 82.23 | 30.37 | 8.01 | 77.57 | 8.82 | 31-3 | 2.89 | 39.22 |
| **STV** | ACA | 5.3 | 1.1 | 82.50 | 30.72 | 7.81 | 77.46 | 8.83 | 31-3 | 2.30 | 43.90 |
| **STV** | BFC | 5.2 | 1.1 | 81.88 | 29.73 | 8.09 | 77.89 | 8.75 | 31-1 | 2.50 | 41.90 |
| **STV** | AFC | 5.2 | 1.1 | 81.71 | 29.71 | 8.10 | 78.79 | 8.68 | 21-2 | 3.20 | 29.00 |
| | | | | | **2012** | | | | | | |
| **FM** | HP | 3.8 | 1.2 | 81.58 | 33.63 | 8.57 | 83.25 | 7.10 | 21-2 | 1.00 | 7.50 |
| **FM** | ARU | 3.5 | 1.1 | 79.57 | 32.30 | 8.78 | 80.14 | 8.09 | 31-1 | 1.00 | 16.10 |
| **FM** | BC | 3.5 | 1.1 | 79.33 | 31.64 | 8.91 | 79.19 | 8.37 | 31-1 | 1.30 | 17.00 |
| **FM** | BC + FC | 3.6 | 1.1 | 79.33 | 30.51 | 9.09 | 80.03 | 8.11 | 31-1 | 1.00 | 12.80 |
| **FM** | ACA | 3.6 | 1.1 | 80.01 | 32.41 | 8.77 | 80.21 | 7.86 | 31-1 | 1.55 | 21.10 |
| **FM** | ACA+FC | 3.6 | 1.1 | 79.85 | 31.17 | 8.84 | 80.81 | 7.79 | 31-1 | 1.00 | 14.30 |
| **FM** | BFC | 3.7 | 1.1 | 80.21 | 32.61 | 9.01 | 79.62 | 7.79 | 31-1 | 1.40 | 17.60 |
| **FM** | AFC | 3.7 | 1.2 | 80.72 | 32.04 | 8.96 | 79.98 | 7.63 | 31-1 | 1.10 | 12.40 |
| **STV** | HP | 4.3 | 1.1 | 79.18 | 30.95 | 9.42 | 79.27 | 8.43 | 21-2 | 1.00 | 7.33 |
| **STV** | ARU | 3.9 | 1.1 | 79.57 | 31.61 | 9.61 | 76.84 | 8.72 | 21-4 | 1.90 | 22.60 |
| **STV** | BC | 3.9 | 1.1 | 79.65 | 32.03 | 9.48 | 77.21 | 8.52 | 31-1 | 2.50 | 27.40 |
| **STV** | BC + FC | 3.9 | 1.1 | 79.48 | 31.40 | 9.56 | 78.01 | 8.54 | 31-1 | 1.70 | 21.80 |
| **STV** | ACA | 4.0 | 1.1 | 79.95 | 32.25 | 9.49 | 76.84 | 8.63 | 31-1 | 2.20 | 26.20 |
| **STV** | ACA+FC | 3.9 | 1.1 | 79.75 | 31.52 | 9.58 | 78.31 | 8.29 | 31-1 | 1.90 | 24.80 |
| **STV** | BFC | 3.9 | 1.1 | 79.37 | 31.42 | 9.63 | 76.11 | 8.79 | 31-4 | 2.10 | 26.40 |
| **STV** | AFC | 4.1 | 1.1 | 79.83 | 31.69 | 9.54 | 77.22 | 8.57 | 31-2 | 1.90 | 25.80 |

## Appendix H: Mean HVI Data from Phase III

| Material Flow Rate (kg/s): 0.30, 0.60, or UT: Untreated | Wire Belt Conveyor Width (m) | Rep | MIC | Length | Unif. | Strength | Elon. | Rd | +b | CGRD | Leaf | HVI Trash (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **UT** | | 1 | 3.7 | 1.2 | 81.89 | 31.11 | 7.60 | 77.05 | 7.63 | 31-2 | 6.30 | 67.00 |
| **0.30** | 0.18 | 1 | 3.7 | 1.2 | 81.98 | 31.95 | 7.18 | 79.00 | 7.08 | 31-2 | 4.00 | 34.50 |
| **0.30** | 0.18 | 1 | 3.8 | 1.2 | 80.98 | 30.33 | 7.63 | 77.95 | 7.38 | 31-2 | 5.50 | 57.00 |
| **0.60** | 0.18 | 1 | 3.8 | 1.2 | 82.43 | 30.85 | 7.60 | 77.33 | 7.28 | 41-1 | 6.25 | 61.75 |
| **0.30** | 0.36 | 1 | 3.6 | 1.2 | 82.50 | 30.90 | 7.70 | 78.68 | 7.03 | 31-1 | 6.00 | 50.50 |
| **0.30** | 0.36 | 1 | 3.8 | 1.2 | 83.13 | 31.63 | 7.58 | 75.60 | 6.83 | 41-1 | 6.50 | 84.25 |
| **0.60** | 0.36 | 1 | 3.7 | 1.2 | 81.63 | 31.10 | 7.80 | 77.95 | 7.00 | 41-1 | 7.25 | 53.50 |
| **0.60** | 0.36 | 1 | 3.8 | 1.2 | 82.60 | 31.10 | 7.58 | 77.75 | 7.30 | 31-2 | 6.25 | 72.25 |
| **0.30** | 0.53 | 1 | 3.8 | 1.2 | 83.15 | 30.85 | 7.60 | 77.55 | 7.00 | 31-1 | 6.25 | 64.00 |
| **0.60** | 0.53 | 1 | 3.8 | 1.2 | 82.78 | 31.20 | 7.55 | 75.98 | 7.05 | 41-1 | 7.25 | 75.50 |
| **0.60** | 0.53 | 1 | 3.7 | 1.2 | 82.48 | 31.08 | 7.58 | 77.35 | 7.23 | 41-1 | 7.00 | 67.75 |
| **0.30** | 0.69 | 1 | 3.6 | 1.2 | 83.13 | 31.03 | 7.73 | 77.55 | 7.05 | 41-1 | 6.00 | 56.25 |
| **0.60** | 0.69 | 1 | 3.7 | 1.2 | 82.40 | 31.23 | 7.65 | 78.58 | 7.78 | 31-2 | 5.25 | 53.25 |
| **0.60** | 0.69 | 1 | 3.7 | 1.2 | 82.95 | 31.48 | 7.58 | 76.68 | 6.88 | 41-2 | 6.75 | 83.75 |

## Appendix I: Mean AFIS Data from Phases I and II: Nep Size through L5%

| Cultivar: FM: FiberMax STV: Stoneville | Sample Location Code | Nep Size (um) | Neps per GM | L (w) [in] | L (w) CV [%] | UQL (w) [in] | SFC (w) [%] | L (n) [in] | L (n) CV [%] | SFC (n) [%] | L5% (n) [%] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2011** | | | | | | | | | | | |
| **FM** | HP | 682.2 | 254.1 | 0.95 | 36.13 | 1.17 | 10.12 | 0.75 | 50.86 | 27.91 | 1.34 |
| **FM** | ASR | 662.5 | 276.0 | 0.94 | 35.20 | 1.17 | 9.90 | 0.75 | 50.20 | 27.45 | 1.33 |
| **FM** | ARU | 691.9 | 272.6 | 0.94 | 36.27 | 1.17 | 10.28 | 0.75 | 51.31 | 28.32 | 1.34 |
| **FM** | ACA | 699.2 | 278.0 | 0.94 | 36.53 | 1.16 | 10.81 | 0.74 | 52.02 | 29.44 | 1.33 |
| **FM** | BFC | 694.6 | 243.6 | 0.97 | 35.09 | 1.19 | 9.10 | 0.77 | 50.04 | 26.20 | 1.35 |
| **FM** | AFC | 688.1 | 238.6 | 0.96 | 35.31 | 1.18 | 9.50 | 0.77 | 50.26 | 26.85 | 1.34 |
| **STV** | HP | 705.8 | 153.2 | 0.92 | 33.75 | 1.13 | 10.00 | 0.74 | 48.99 | 27.50 | 1.27 |
| **STV** | ASR | 717.5 | 195.5 | 0.89 | 35.50 | 1.10 | 11.90 | 0.70 | 51.25 | 30.95 | 1.25 |
| **STV** | ARU | 723.0 | 170.4 | 0.93 | 33.55 | 1.14 | 9.75 | 0.75 | 48.98 | 27.21 | 1.29 |
| **STV** | ACA | 714.8 | 145.0 | 0.94 | 33.57 | 1.15 | 9.44 | 0.76 | 48.93 | 26.70 | 1.29 |
| **STV** | BFC | 710.1 | 160.7 | 0.93 | 33.89 | 1.14 | 9.85 | 0.75 | 49.12 | 27.30 | 1.29 |
| **STV** | AFC | 697.8 | 169.5 | 0.93 | 34.05 | 1.14 | 9.96 | 0.75 | 49.27 | 27.50 | 1.28 |
| **2012** | | | | | | | | | | | |
| **FM** | HP | 699.5 | 344.7 | 0.98 | 36.57 | 1.21 | 9.75 | 0.77 | 52.37 | 27.97 | 1.40 |
| **FM** | ARU | 729.6 | 546.9 | 0.91 | 40.01 | 1.15 | 14.09 | 0.67 | 59.25 | 37.20 | 1.33 |
| **FM** | BC | 722.9 | 555.4 | 0.91 | 40.12 | 1.16 | 13.98 | 0.68 | 59.11 | 36.90 | 1.34 |
| **FM** | BC + FC | 721.4 | 496.6 | 0.90 | 39.66 | 1.14 | 13.67 | 0.68 | 57.16 | 35.44 | 1.32 |
| **FM** | ACA | 717.6 | 461.2 | 0.92 | 39.65 | 1.16 | 13.28 | 0.69 | 58.03 | 35.47 | 1.35 |
| **FM** | ACA+FC | 718.3 | 461.8 | 0.93 | 38.86 | 1.17 | 12.42 | 0.71 | 55.98 | 33.24 | 1.36 |
| **FM** | BFC | 710.1 | 438.1 | 0.94 | 38.44 | 1.18 | 12.10 | 0.71 | 56.93 | 33.66 | 1.35 |
| **FM** | AFC | 709.2 | 433.8 | 0.95 | 37.35 | 1.19 | 10.94 | 0.74 | 54.25 | 30.65 | 1.37 |
| **STV** | HP | 715.7 | 296.0 | 0.89 | 38.37 | 1.12 | 13.77 | 0.68 | 55.10 | 34.73 | 1.29 |
| **STV** | ARU | 719.7 | 399.1 | 0.88 | 39.98 | 1.12 | 15.43 | 0.65 | 58.80 | 38.67 | 1.28 |
| **STV** | BC | 713.1 | 380.8 | 0.88 | 39.86 | 1.12 | 15.29 | 0.66 | 58.45 | 38.29 | 1.29 |
| **STV** | BC + FC | 706.5 | 390.3 | 0.88 | 39.38 | 1.12 | 14.90 | 0.66 | 57.50 | 37.31 | 1.29 |
| **STV** | ACA | 710.1 | 348.0 | 0.89 | 38.88 | 1.13 | 14.15 | 0.67 | 57.23 | 36.39 | 1.29 |
| **STV** | ACA+FC | 708.2 | 378.1 | 0.89 | 38.91 | 1.13 | 14.00 | 0.67 | 56.96 | 36.02 | 1.29 |
| **STV** | BFC | 713.2 | 377.0 | 0.87 | 39.45 | 1.11 | 15.09 | 0.65 | 58.16 | 38.04 | 1.27 |
| **STV** | AFC | 702.6 | 348.5 | 0.89 | 38.30 | 1.13 | 13.65 | 0.68 | 56.21 | 35.29 | 1.29 |

## Appendix J: Mean AFIS Data from Phases I and II: Total through Maturity Ratio

| Cultivar: FM: FiberMax STV: Stoneville | Sample Location Code | Total Cnt/g | Trash Size [um] | Dust Cnt/g | Trash Cnt/g | VFM [%] | SCN Size (um) | SCN (Cnt/g) | Fine [mTex] | IFC [%] | Mat Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **2011** | | | | | | |
| **FM** | HP | 134.2 | 327.6 | 112.40 | 21.70 | 0.48 | 1258.30 | 14.60 | 163.60 | 6.70 | 0.91 |
| **FM** | ASR | 228.0 | 338.0 | 189.50 | 38.50 | 0.71 | 1264.50 | 14.50 | 163.00 | 6.45 | 0.91 |
| **FM** | ARU | 382.3 | 353.6 | 315.50 | 66.90 | 1.44 | 1274.70 | 16.60 | 162.50 | 6.78 | 0.91 |
| **FM** | ACA | 400.9 | 362.8 | 324.20 | 76.40 | 1.50 | 1263.90 | 19.40 | 164.10 | 6.62 | 0.91 |
| **FM** | BFC | 383.5 | 362.1 | 310.20 | 73.20 | 1.45 | 1223.50 | 18.00 | 164.50 | 6.45 | 0.92 |
| **FM** | AFC | 332.4 | 359.8 | 268.10 | 64.40 | 1.25 | 1230.80 | 16.20 | 166.00 | 6.46 | 0.92 |
| **STV** | HP | 156.6 | 346.6 | 126.30 | 30.30 | 0.56 | 1274.60 | 18.60 | 190.90 | 5.45 | 0.95 |
| **STV** | ASR | 327.5 | 343.5 | 259.50 | 68.50 | 1.12 | 1213.00 | 25.50 | 189.00 | 6.20 | 0.93 |
| **STV** | ARU | 455.0 | 379.2 | 361.00 | 94.20 | 1.88 | 1252.20 | 22.50 | 189.70 | 5.74 | 0.95 |
| **STV** | ACA | 584.9 | 379.3 | 461.80 | 123.00 | 2.36 | 1180.40 | 21.10 | 190.10 | 5.63 | 0.95 |
| **STV** | BFC | 478.8 | 378.0 | 377.30 | 101.50 | 1.87 | 1187.90 | 20.40 | 187.50 | 5.74 | 0.94 |
| **STV** | AFC | 325.9 | 370.6 | 257.70 | 68.10 | 1.21 | 1207.70 | 19.40 | 185.90 | 5.98 | 0.93 |
| | | | | | **2012** | | | | | | |
| **FM** | HP | 95.5 | 341.3 | 79.33 | 16.17 | 0.41 | 1158.83 | 17.17 | 153.33 | 7.60 | 0.88 |
| **FM** | ARU | 380.9 | 364.4 | 313.20 | 67.70 | 1.44 | 1250.80 | 26.00 | 149.90 | 9.48 | 0.85 |
| **FM** | BC | 428.5 | 351.6 | 354.40 | 74.30 | 1.47 | 1170.60 | 25.80 | 149.20 | 9.44 | 0.84 |
| **FM** | BC + FC | 264.3 | 339.6 | 224.30 | 40.20 | 0.90 | 1249.70 | 22.00 | 152.80 | 8.88 | 0.85 |
| **FM** | ACA | 515.6 | 354.5 | 427.30 | 88.45 | 1.80 | 1226.85 | 22.70 | 150.75 | 8.79 | 0.86 |
| **FM** | ACA+FC | 282.5 | 350.3 | 235.80 | 46.80 | 0.94 | 1254.90 | 20.90 | 152.10 | 8.60 | 0.86 |
| **FM** | BFC | 504.6 | 356.4 | 415.40 | 89.50 | 1.80 | 1184.80 | 22.60 | 150.10 | 8.90 | 0.86 |
| **FM** | AFC | 257.7 | 355.3 | 213.20 | 44.30 | 0.95 | 1262.40 | 21.20 | 152.30 | 8.00 | 0.87 |
| **STV** | HP | 126.5 | 372.0 | 103.67 | 23.17 | 0.57 | 1292.33 | 20.17 | 168.33 | 7.97 | 0.87 |
| **STV** | ARU | 448.7 | 376.6 | 359.30 | 89.60 | 1.71 | 1231.40 | 24.00 | 164.40 | 8.89 | 0.86 |
| **STV** | BC | 448.2 | 376.0 | 359.60 | 88.60 | 1.68 | 1244.30 | 20.30 | 163.90 | 8.67 | 0.86 |
| **STV** | BC + FC | 427.6 | 348.1 | 353.40 | 74.20 | 1.45 | 1196.40 | 21.10 | 164.10 | 8.84 | 0.86 |
| **STV** | ACA | 515.7 | 370.2 | 417.85 | 97.95 | 1.94 | 1194.90 | 20.15 | 165.90 | 8.63 | 0.86 |
| **STV** | ACA+FC | 403.4 | 356.5 | 327.80 | 75.40 | 1.35 | 1232.60 | 21.10 | 162.20 | 9.08 | 0.85 |
| **STV** | BFC | 521.4 | 366.3 | 423.30 | 98.00 | 1.81 | 1263.10 | 23.00 | 164.10 | 8.90 | 0.86 |
| **STV** | AFC | 323.4 | 358.4 | 260.10 | 63.20 | 1.12 | 1204.40 | 22.10 | 167.40 | 8.42 | 0.87 |

## Appendix K: Mean AFIS Data From Phase III: Nep Size through L5%

| **Material Flow Rate (kg/s): 0.30, 0.60, or UT: Untreated** | **Wire Belt Conveyor Width (m)** | **Nep Size (um)** | **Neps per GM** | **L (w) [in]** | **L (w) CV [%]** | **UQL (w) [in]** | **SFC (w) [%]** | **L (n) [in]** | **L (n) CV [%]** | **SFC (n) [%]** | **L5% (n) [%]** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **UT** | | 682.2 | 325.4 | 1.00 | 36.86 | 1.24 | 9.40 | 0.80 | 50.82 | 26.53 | 1.42 |
| **0.30** | 0.18 | 689.5 | 347.0 | 1.02 | 36.43 | 1.25 | 8.80 | 0.81 | 50.10 | 25.25 | 1.44 |
| **0.30** | 0.18 | 683.3 | 300.8 | 1.00 | 37.25 | 1.24 | 10.05 | 0.78 | 52.00 | 28.13 | 1.42 |
| **0.60** | 0.18 | 677.5 | 265.3 | 1.03 | 36.33 | 1.26 | 8.45 | 0.83 | 49.40 | 24.30 | 1.46 |
| **0.30** | 0.36 | 720.5 | 373.5 | 1.04 | 35.58 | 1.27 | 8.15 | 0.83 | 48.93 | 23.73 | 1.45 |
| **0.30** | 0.36 | 682.3 | 299.8 | 1.02 | 36.25 | 1.25 | 8.65 | 0.82 | 50.05 | 25.03 | 1.44 |
| **0.60** | 0.36 | 681.0 | 324.5 | 1.03 | 35.45 | 1.25 | 8.20 | 0.83 | 48.73 | 23.88 | 1.43 |
| **0.60** | 0.36 | 686.0 | 368.8 | 1.02 | 36.40 | 1.25 | 8.90 | 0.82 | 50.00 | 25.35 | 1.44 |
| **0.30** | 0.53 | 675.0 | 290.3 | 1.04 | 36.35 | 1.28 | 8.43 | 0.83 | 50.28 | 24.70 | 1.48 |
| **0.60** | 0.53 | 678.0 | 272.3 | 1.01 | 37.18 | 1.25 | 9.43 | 0.80 | 51.43 | 26.73 | 1.45 |
| **0.60** | 0.53 | 667.5 | 305.3 | 1.02 | 36.63 | 1.26 | 9.08 | 0.81 | 50.75 | 25.93 | 1.45 |
| **0.30** | 0.69 | 680.3 | 320.8 | 1.02 | 35.60 | 1.25 | 8.20 | 0.84 | 48.03 | 23.23 | 1.45 |
| **0.60** | 0.69 | 688.5 | 373.5 | 0.99 | 37.75 | 1.23 | 10.20 | 0.78 | 51.90 | 27.98 | 1.42 |
| **0.60** | 0.69 | 675.5 | 255.3 | 1.05 | 35.95 | 1.28 | 8.00 | 0.84 | 49.30 | 23.68 | 1.48 |

# Appendix L: Mean AFIS Data From Phase III: Total-Maturity Ratio

| **Material Flow Rate (kg/s): 0.30, 0.60, or UT: Untreated** | **Wire Belt Conveyor Width (m)** | **Total Cnt/g** | **Trash Size [um]** | **Dust Cnt/g** | **Trash Cnt/g** | **VFM [%]** | **SCN Size (um)** | **SCN (Cnt/g)** | **Fine [mTex]** | **IFC [%]** | **Mat Ratio** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **UT** | | 1321.1 | 332.2 | 1082.70 | 238.10 | 4.56 | 1129.10 | 8.00 | 155.80 | 6.37 | 0.91 |
| **0.30** | 0.18 | 962.8 | 327.5 | 785.00 | 177.50 | 3.46 | 1113.25 | 6.50 | 157.50 | 6.00 | 0.91 |
| **0.30** | 0.18 | 1558.3 | 324.3 | 1284.50 | 273.25 | 5.11 | 1030.75 | 10.50 | 153.50 | 6.55 | 0.90 |
| **0.60** | 0.18 | 1325.8 | 325.5 | 1084.25 | 241.25 | 4.52 | 885.50 | 9.50 | 157.00 | 5.98 | 0.91 |
| **0.30** | 0.36 | 1215.0 | 308.0 | 1010.25 | 204.25 | 3.75 | 1062.50 | 6.50 | 155.50 | 6.33 | 0.91 |
| **0.30** | 0.36 | 1466.8 | 319.5 | 1208.00 | 258.50 | 4.79 | 1078.25 | 10.00 | 156.00 | 6.38 | 0.91 |
| **0.60** | 0.36 | 966.5 | 324.8 | 799.50 | 166.50 | 3.35 | 927.00 | 9.75 | 157.00 | 6.05 | 0.92 |
| **0.60** | 0.36 | 895.3 | 331.8 | 730.00 | 165.00 | 3.16 | 953.50 | 7.25 | 156.50 | 6.23 | 0.91 |
| **0.30** | 0.53 | 1207.5 | 311.5 | 1011.75 | 195.25 | 3.90 | 1024.50 | 9.50 | 154.75 | 6.33 | 0.91 |
| **0.60** | 0.53 | 1303.5 | 313.5 | 1085.75 | 217.25 | 4.10 | 1031.50 | 10.25 | 156.00 | 6.40 | 0.90 |
| **0.60** | 0.53 | 1247.5 | 343.8 | 1015.50 | 231.75 | 4.65 | 975.00 | 10.25 | 154.00 | 6.25 | 0.91 |
| **0.30** | 0.69 | 984.0 | 326.5 | 811.75 | 172.25 | 3.25 | 1100.00 | 7.75 | 157.75 | 5.85 | 0.92 |
| **0.60** | 0.69 | 1185.3 | 317.5 | 994.50 | 190.75 | 3.77 | 1013.25 | 6.25 | 154.50 | 6.58 | 0.90 |
| **0.60** | 0.69 | 1395.5 | 336.0 | 1124.00 | 271.25 | 5.07 | 957.00 | 10.50 | 157.50 | 5.83 | 0.92 |

# VITA

Wesley M. Porter

Candidate for the Degree of

Doctor of Philosophy

Thesis: COTTON STRIPPER HARVESTER EVALUATION AND MODIFICATION FOR COTTON FIBER QUALITY PRESERVATION AND FOREIGN MATTER REMOVAL

Major Field: Biosystems Engineering

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy/Education in Biosystems Engineering at Oklahoma State University, Stillwater, Oklahoma in 2013.

Completed the requirements for the Master of Science in Biosystems Engineering at Clemson University, Clemson, South Carolina, in August 2010.

Completed the requirements for the Bachelor of Science in Agricultural Mechanization and Business at Clemson University Clemson, South Carolina, in December 2007.

Experience:

Cotton Incorporated Fellow at Oklahoma State University, Stillwater, OK from 2012 through 2013 worked on Stripper harvested cotton fiber quality preservation and foreign matter content.

Extension Associate Engineer at Oklahoma State University, Stillwater, OK from 2010 through 2013 worked on many extension and research projects focusing around power, machinery, and precision agriculture.

Professional Memberships:

American Society of Agricultural and Biological Engineers