UNIVERSITY OF

SOUTHERN QUEENSLAND

Improving Gin Stand Performance to Benefit Australian Cotton

A dissertation submitted by

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ABSTRACT

This investigation was into the processing of long, fine Australian cotton in high-mass throughput saw gins. The research was conducted at the Auscott Narrabri gin in New South Wales, Australia using Australian cotton with a UHML of 30.9 mm and 31.8 mm, with a micronaire value of 3.85. Mass production rates trials ranged between 3200 and 3800 kg/h of lint.

In particular, the feed and discharge of seed was investigated, and the results demonstrate that the gin stand motor load frequently fluctuates due to the varying mass input of seed cotton. Furthermore, the distribution of seed cotton presented to the gin stand is laterally non-uniform. It is thought that a non-uniform vertical feed results in elevated nep and seed-coat nep due to the changing seed-roll density. The source of the uneven lateral distribution of seed cotton to the gin stand lies within the design of distributor conveyor, which feeds seed cotton to the gin stand. Because of the high speed required to transport seed cotton in the conveyor distributor, the drop zone of seed cotton to each feed hopper is overshot. The trailing edge of the hopper is further seed cotton deficient. The auger blade together with the auger housing create a nip point allowing for the seed cotton to be pulled out of the feed hopper. Methods to overcome the problem were trialled,, including redirecting the seed cotton on the gin stand apron, modifying the conveyor distributor, and increasing the seed cotton mass in the affected areas to improve the uniformity of the seed roll density.

The uneven input of seed cotton creates an uneven output of fuzzy seed. The region of the gin stand most affected was the corresponding delivery side. This output region expelled up to four times more fuzzy seed than other expulsion areas of the gin stand. The uneven fuzzy seed expulsion is attributed to the seed roll density, as the roll box is unevenly loaded with incoming seed cotton. Uneven loading of seed cotton creates areas within the roll box that experience a reduction in density, and this creates a movement of fuzzy seed from high-density areas to the neighbouring lower-density areas. Therefore, high levels of fuzzy seed expulsion occur in areas of lesser density. The output distribution curve of fuzzy seed equates approximately to the inverse curve of the seed cotton input.

Elongation of the leading and trailing edge angle on the hopper of the gin stand was not finalised because of time constraints. This method is believed to enable the elimination of the uneven seed roll. The elongation length may be required up to 60 cm. Overcoming the uneven vertical flow can be achieved through electrical settings of the feed hopper motor. Eliminating the uneven lateral feed has the potential to increase production by approximately 12 per cent. It is envisaged that tight seed roll occurrence will reduce with an evenly loaded

seed roll, further increasing productivity. Saw blade wear should also reduce, together with the event of fires as a result of tight seed rolls.

Roll box geometry was also investigated, and this highlighted frictional properties, mechanical interaction of the saw teeth, and seed roll densities. Decreasing the time that the seed cotton is present in the roll box would reduce mechanical interaction. Further, the lint mass production rate was investigated, and results indicated that reducing mass production rates decreased nep and seed-coat nep because of a decrease in the seed roll density.

Research was conducted on Continental Eagle 161 gin stands.

CERTIFICATION OF DISSERTATION

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

CANDIDATE

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Kevin Michael Bagshaw Date

ENDORSEMENT

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Dr Joseph Foley Date

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GLOSSARY

Apron	A stainless steel slide on which the seed cotton passes prior to the delivery to the gin stand.
Bale	A mass of 227 kg of ginned cotton.
Roll box	Within the gin stand is the integral part of the machine where fibre is removed from the seed.
Boll	Cotton fruit.
Bundle strength	The bundle strength is the number of newtons force required to break an aligned bundle of fibres of one tex held between two clamps.
Colour grade	A grading system that typically uses values of 11, 21, 31, 41, 51, 61 & 71.
Cotton	Ginned lint.
Conveyor distributor	A "U" shaped trough that contains an auger. The system is used to convey seed cotton into hoppers above each gin stand.
DAVS	"Distribution Analyses Vision System". A system developed by CSIRO for the analyses of the gin stand input distribution.
Extractor feeder	A system after the hopper and prior to the gin stand apron that provides some final cleaning and opening of the lint prior to the gin stand.
Fuzzy seed	Upland seed cotton that has had the cotton fibre removed from the seed during the ginning practice. The seed is fuzzy in appearance.
Gin	The factory that contains the processing equipment necessary to gin the cotton.
Ginning	The entire process of drying, cleaning, fibre removal from the seed, further cleaning and eventual baling of the cotton fibre.
Gin stand	A single piece of equipment within the gin that is responsible for the removal of the cotton fibre from the cottonseed.
Hopper	A rectangular shaped box that contains a mass of seed cotton allowing for a constant feed of seed cotton to the extractor feeder.
Incremented mass output	The mass output of lint is adjusted from a known mass output to another mass output. An example of incremented mass output is 3000, 3400 and 3800 kg/h mass output.
Leaf grade	The USDA grading system of the leaf content from one to seven in increments of one, whereas one indicates low leaf and seven indicates high leaf.
Module (rectangular)	Seed cotton that has been picked, transported to the gin and contained within a free standing shape that is similar in size to a large shipping container.
Module (round)	Seed cotton that has been picked, transported to the gin and contained in a round shape by a plastic wrapper.
Nep	Small entanglements of fibre.
Rib	A machined steel multi curved support that is situated between saw blades supports the seed cotton during processing.

Saw blade	The saw blade contains teeth on its outer perimeter. The saw blade teeth remove the cotton fibre from the seed and transport the fibre out of the seed roll to and awaiting brush and air stream.
Seed coat nep	Small seed shell particles within the lint. The shell particle will usually have lint still attached to it.
Seed cotton	Cotton prior to the gin stand is referred to as seed cotton as the fibres have not yet been removed from the seed.
Seed roll	The seed roll is the accumulated mass of seed cotton in the roll box during the process of fibre removal from the seed.
Seed tube	The seed tube contains a quantity of holes within the shell of the tube. The tubes purpose is to remove fuzzy seed from the seed roll. The seed tube is situated within the central zone of the roll box. Only Continental Eagle Corporation gin stands contain seed tubes.
Seed tube auger	The seed tube auger is situated within the seed tube and its sole purpose is the continual removal of fuzzy seed from within the seed tube.
Tex	The mass in grams per 1000 meters of fibres
Trash	Any form of leaf or twigs of the plant that are present in the lint at any stage.
Upper half mean length (UHML)	Average length of the longer one half of the fibres.
Upper quartile length (UQL)	Average length of the longer one quarter of the fibres.

Chapter 1
Project background

Australian cotton breeders are progressing towards the production of new Upland cotton varieties that have long, fine fibre and high yield potential. Lint yield is determined by two factors: the number of seeds per unit area, and the number of fibres per seed. Yields in Australian varieties generally increase as seed numbers increase, and seed size decreases. Maintaining both quality and yield in the field means the Australian cotton industry preserves the premium it currently receives for its fibre, and the benefits productivity. However, high yielding long, fine cotton is subject to more damage in the ginning system by virtue of the increased density of fibres.

The objective of this study is to investigate and improve the efficiency with which long, fine fibre is separated by the saw whilst improving fibre and seed quality. Spinners look poorly upon the nep and short-fibre content of Australian (Van der Sluijs, 2006). Research by Gordon et.al (2006) involved surveying 31 spinning companies and collecting information on the spinner's impression on Australian Cotton. Results indicated that nep and short fibre in Australian cotton rated poorly and were judged as low as two out of a possible five. Neps affect the appearance fabrics and yarns. Neps reduce spinning ability and produce a yarn having more irregularities. Protests about neps from the ginning process were first raised shortly after the invention of the gin. An article appeared in the Chronicle, an American newspaper, and told of the damage that was being done to the cotton by the gin (Lakwete, 2003).

Gin stand operation extracts both fuzzy seed and lint. Current gin stand configurations produce fuzzy seed output that is expelled non-uniformly. That is, the mass of fuzzy seed exiting the gin stand is not uniform across its width. The non-lateral uniformity is a new discovery and attempts were made to solve the source of the non-linearity. The gin stand is capable of operating over a wide range of mass production rates. The mass production rate of the gin stand is adjustable by the gin operator and is based on quality of the incoming and outgoing lint.

1.1 Cotton in Australia – a perspective

The ginning industry within Australia has 37 gins comprising of approximately160 gin stands in total (Gordon & Bagshaw, 2006). The gin stands within Australia range in age from 10 years to approximately 50 years of age. The oldest gin stands in Australia have as few as 98 saw blades across their width, while the later models have as many as 198 saw blades.

Production per gin stand over a 24-hour period ranges from 30 tonnes to in excess of 70 tonnes. The average yearly throughput of Australian gins between 2001 and 2005 was 75,000 bales/gin or 17,025 tonnes/gin (Gordon and Bagshaw, 2006).

Australia produces between three million and five million bales of cotton a year during non-drought circumstances. In comparison, China produces around 28 million bales of cotton each year while the US produces around 22 million. Cotton Australia, Narabri, Victoria, viewed February 2012 <www.cottonaustralia.com.au>. The modern cotton industry (2011) was pioneered by Californian growers who introduced cotton to land near Wee Waa, New South Wales in the early 1960s, although cotton production had been known in Queensland since the American Civil War. In the late 1960s the first high throughput gin of the time was imported from the USA and built in Wee Waa, Australia by the Namoi Cotton Cooperative and by the early 1970s the industry was producing over 22,700 tonnes per year. In 2010/11 a record production of 3.7 million bales was forecast after five years of reduced production as a result of drought.

Characteristics of Australian cotton fibre quality have changed dramatically since the 1960s largely as a result of the Commonwealth Scientific Industrial Research Organisation (CSIRO) Plant Industry breeding program. Figure 1-1 illustrates the increase in staple length during the last 35 years of the CSIRO breeding program. The average fibre length of Australian cotton has increased by around 2.5 mm during this time (Constable, 2011). The extra length equates to stronger yarn and allows for finer yarn production.

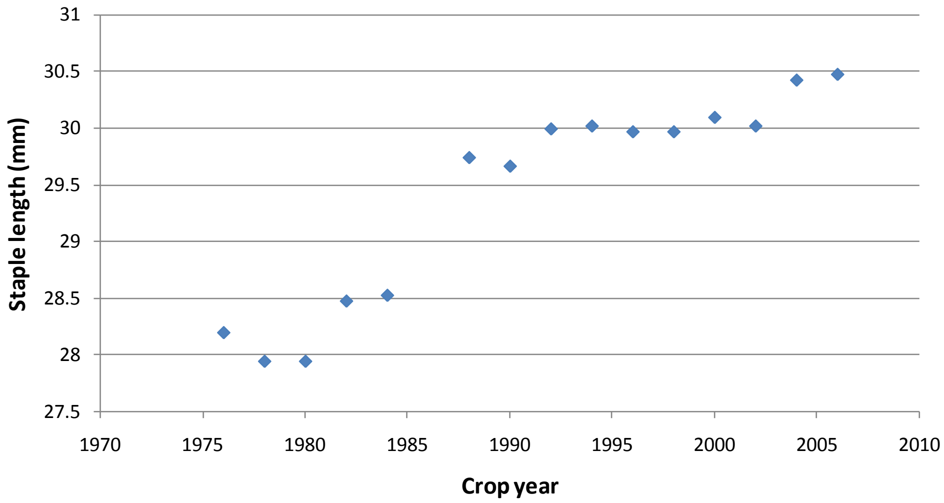


Figure 1-1: Staple length of Australian cotton.

Cotton fibre staple length has increased greater than 2.5 mm during the last 35 years.

1.2 Cotton ginning

Cotton ginning involves the separation of the fibre from the cottonseed and further cleaning and packaging of the fibre. Cotton prior to being ginned is referred to as seed cotton. Once the fibre is removed from the seed, two products are referred to; lint and fuzzy seed. The gin stand within the ginning process is responsible for the removal of the fibre from the seed. The gin stand process can be likened to the peeling of an apple, with the rotating apple being the seed roll and the constant output of peel being the seed. Without the engagement of the sides of the saw, and saw teeth, the rotation of the seed roll stops. Fibre is used in textile and paper manufacture, while the seed can be used for replanting, crushed for oil or used for stock feed.

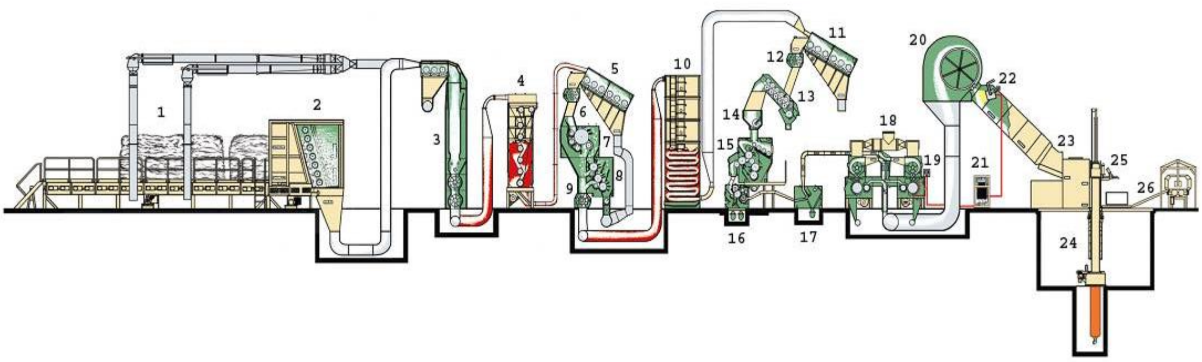
Cotton ginning, in a form, has occurred since man has utilised the cotton fibre for textiles. The use of cotton fibre for textiles dates back more than 5,500 years (Yafa, 2005). Aside from separating the fibre from the seed by hand, the first gin apparatus consisted of a flat rock together with a tapered roller (Lakwete, 2003). A tapered roller would be rolled along a flat surface with seed-cotton positioned at the leading edge of the roller. This action would remove the fibre from the seed. This action of ginning later led to the development of the mechanised roller gin. However, the original mechanism itself dates back some 2000 years ago to ancient times (Lakwete, 2003). Sometime between the 12th and 16th centuries, roller gins were starting to be produced with two rollers, removing the flat surface that was used prior. In 1746 Pratt produced a roller gin of a more modern engineering focus. Web site viewed February 2012, <http://www.pratthistory.com/>. However, roller gins were more useful in separating fibre from cotton species with naked seed, i.e. seed that leaves no fuzz after the longer fibre is pulled from it. Upland cotton (*G. hirsutum*) requires greater force to detach it from the seed.

In 1794 Eli Whitney patented a new form of de-linting Upland seed (Bennett, 1960). His invention occurred at the time when African slaves were used to hand gin cotton that was produced in the southern states of the USA. Two years after Whitney's invention, Holmes developed a gin that was of superior workings. Holmes's gin consisted of a stand that contained saw blades as used today (as per Figure 1-4), while Whitney's gin consisted of spikes on a roller. Whitney soon followed Holmes's idea of using saw blades. Further, while Whitney's gin had to be manually emptied of seed and then refilled, Holmes's gin stand was self emptying and could be filled and discharged continuously. Web site viewed February 2012, <http://www.pratthistory.com/>. Whitney's gin in 1793 could produce 50 kg of lint in 24 hours, however by 1860 a gin was capable of producing up to 1600 kg in 24 hours.

Since Whitney's invention, gin production rates have increased many times over. From initially around 50 kg/day, single stands in a modern gin now produce in excess of 70 tonnes of lint/day. Significant increases in production rates occurred particularly after the Second World War with widespread introduction of mechanical harvesting. Mechanical harvesting required the introduction of continuous cleaning systems before and after the gin stand. These changes ushered in the era of automation for the ginning process where seed-cotton was processed continuously from harvest baskets and later modules through to baled lint. The desire for increased ginning rates led to gins becoming wider with the addition of more saw blades and more powerful motors to drive the saws. The gin stand saw quantity has risen from approximately 80 saw blades per gin stand in 1858 to the latest 201 saw blade gin stand by Continental Eagle in 2010. To house the increasing numbers of saws on the shaft, the centre to centre spacing of the saws has also decreased. Gin saw motor sizes have increased significantly in the last 50 years from a mere 18 kilowatt motor to over 150 kilowatts for the most modern gins of today. Whilst throughput and automation have improved the productivity of the modern saw gin, the mechanism for separating the fibre from the seed, and the effects of this mechanism on fibre quality, have not changed. Indeed, the increased mass production rates have led to compromises in fibre quality (e.g. seed coat neps and neps). Gin stand motors consume different power levels depending on the processing rate of the cotton. The turnout of lint varies depending on how free the modules are of waste materials such as leaf. Turnout is a measure of the lint yield from a module of seed-cotton. Turnout values typically range between 33 per cent for trashy cotton to > 40 per cent for clean cotton. Further research has been conducted in Australia by Bel (2004) regarding the prediction of white speck neps at the bale stage. Since the emphasis was not on the gin stand, no processing data on the gin stand was available.

1.3 Continental Eagle gin characterisation

The layout of a gin can take on a number of forms depending on the customers' requirements and the type of cotton to be processed (i.e. clean spindle picked or stripper picked cotton). The gin configuration as set out by Continental Eagle Corporation is set out in Figure 1-2



1 – Suction telescope
2 – Module feeder
3 – Big J feed control
4 – Vertical flow dryer
5 – Inclined cleaner
6 – Vacuum feeder
7 – Striper cleaner
8 – Stick machine
9 – Vacuum feeder
10 – Tower dryer
11 – Inclined cleaner
12 – Vacuum feeder
13 – Impact cleaner
14 – Conveyor distributor
15 – Extractor feeder
16 – Gin stand
17 – Centrifugal cleaner
18 – Lint cleaners
19 – Lint cleaner louvers
20 – Battery condenser
21 – Eagle eye imaging
22 – Moisture max
23 – Belt feeder
24 – Press system
25 – Jenglo wire tying
26 – Bale bagging system

Figure 1-2: Gin layout schematic – Image by Continental Eagle

1.3.1 Continental Eagle gin schematic description

The module opening bay unit is a system that is used for the feeding of modules for further processing. The feeder opens the module into loosened, more individualised seed cotton proportions. The drying tower is the first stage of drying and aides in the removal of foreign matter. The seed cotton may now also begin to be dried to acceptable moisture levels for processing. The inclined cleaner further removes particles of trash that are present in the seed cotton. The trash removal is achieved by beating the seed cotton against grid bars. The vacuum feeders are a means of transporting the seed cotton. The inclined cleaner is designed to remove sticks, leaf and other impurities found in the seed cotton.

The conveyor distributor is a means of conveying the seed cotton to the next zone of cleaning, being the Extractor Feeder. The conveying of the seed cotton is performed mechanically by means of an "auger". The extractor feeder is the last stage of cleaning prior to the fibre removal from the seed. The Extractor Feeder removes fine trash particles that are still present in the seed cotton.

Fibre is removed from the seed at the gin stand. The fibre removal results from the lint being grabbed by saw blade teeth that then pull the fibre through small gaps between each rib. Once fibre passes through this gap it is then "doffed" off the saw blades for further processing. The seed cannot pass through the gaps present between each rib. The seed roll within the roll box "bursts" at its lowest point allowing the fuzzy seed to drop out of the seed roll and be conveyed away.

The centrifugal cleaner is a cleaning system for the lint. Lint and trash particles that are still present are subjected to a sudden change in direction while being transported in the airflow. This sudden change in direction forces heavy trash particles to continue forward at this point and leave the air stream and, ultimately, the lint. The research conducted utilized equipment as shown in Figure 1-2 in the following order: 2, 3, 4, 5, 5, 14 & 15 prior to the gin stand.

1.3.2 Saw teeth productivity

The lint cleaner is a mechanical method of further removing trash particles. Lint cleaning is the last opportunity to remove any trash still present within the lint while at the gin. The lint cleaner subjects the lint to a combing action and secondly an action that impacts the lint and trash against steel bars to expel any trash still present. Processing taking place beyond the lint cleaner is simply required to encapsulate the lint into a 227 kg bale.

Modern day gin stands are capable of producing as much as 3800 kg of lint in one hour; however the quantity of lint produced per saw blade is minimal. An image of the saw teeth required to remove enough lint for one end of a cotton bud is depicted in Figure 1-3.

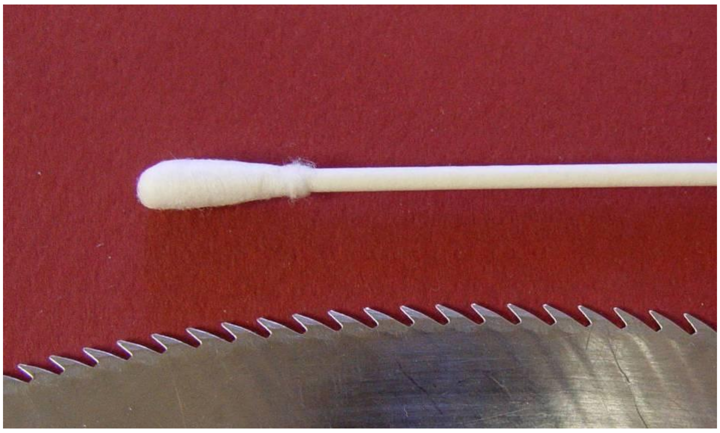


Figure 1-3: Mass process rate indicator

Although the modern gin stand is capable of processing approximately 3800 kg of lint per hour, twenty saw teeth are required to remove the required mass of lint for one end of a cotton bud. The gin stand utilises approximately 32,000,000 saw teeth per 60 seconds.

1.3.3 Gin stand description

A gin stand (see Figure 1-4) is essentially a roll box. The roll box within the gin stand contains the seed roll. Within the roll box, the working elements of the gin stand are contained. The working elements are discussed individually herein. The roll box skin that houses the seed roll is stainless steel with a circular like shape. The roll box contains approximately 30 to 35 kg of fuzzy seed and seed cotton. Centrally located within the seed roll on Continental Eagle gin stands is a perforated seed tube encasing two augers travelling in a lateral direction while removing fuzzy seed which has passed through the perforations. Within the roll box, there are 161 metal ribs. The rib profile is such to allow for a smooth ginning process including both introduction of seed cotton and expulsion of fuzzy seed. Positioned between each rib on a Continental Eagle gin stand is a saw blade of 406.4 mm diameter consisting of 330 teeth. Saw blade teeth are responsible for the removal of the fibre from the seed and transportation of fibre from the seed roll.

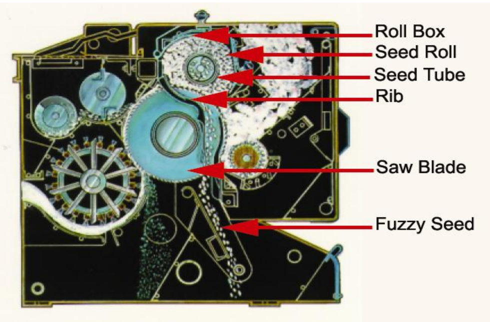


Figure 1-4: Gin stand diagram – adapted from Continental Eagle, (2012)

The saw blade rotates at approximately 615 rpm, and the wear affects the ginning process and production (Towns 2010, pers. comm.). Saw blade attributes are poorly understood and require further research. The teeth of each saw blade separate the cottonseed from the fibre and pull the cotton fibre between the ribs. While rotating, the sides of the protruding saw and its teeth have a clutch like effect as it interacts with the fibre. Friction created engages a mixture of newly ginned seeds and un-ginned seed cotton mass creating rotation. This mass of turning material is known as the seed roll, and rotates in a clockwise direction and contained within a tube like structure called the roll box. This is the fundamental part of the ginning process. Hypotheses regarding the slowing of the seed roll by the stationary roll box end plates have been put forward (Towns & Noble 2010, pers. comm.; Lummus 2009, pers. comm.). Knowledge of the acute behaviour of cottonseed, fuzzy seed and cotton fibres within the roll box is limited in the ginning industry and requires enhancement.

The mass production of an individual gin stand is related to the current draw of the motor driving the gin stand. The exact throughput of an individual gin stand mass (kg of ginned lint per hour) is not known, but is estimated by the ginner based on total output of the gin per hour. Gin stand motors differ in current draw depending on the processing rate of the cotton. Motor current analysis was required for seed cotton mass production rate conversion. Fibre qualities at production rates within the standard operating window together with production rates outside the current industry standard range are reported herein. Ginning production rates are determined and set by gin operators based on plant trash content of the incoming seed cotton and the subsequent requirement to produce ginned lint that falls within an acceptable classing leaf grade. There is less emphasis on other quality parameters such as length, short fibre content and neps, and usually with little attention being paid to the amount of fibre left on the ginned seeds. Typical production rates fall between 2900 and 3800 kg/h. The work herein was conducted to more closely assess the effects of these production rates and in addition to production rates outside the current industry standard range. The gin stand is illustrated in Figure 1-4. The diagram shows the location of the roll box, seed roll, seed tube, saw blade and fuzzy seed expulsion from the gin stand breast.

1.4 Roll box elements

1.4.1 Ginning point and zone

Fibre removal from the seed roll occurs at the point at which the saw teeth and the rib insert intersect. This intersection is referred to as the ginning point and is the hypothetical ginning point of the fibre. The removal of the fibre from the seed within the seed roll takes place during the entire ginning zone. The saw blade and rib configuration is shown in Figure 1-5.

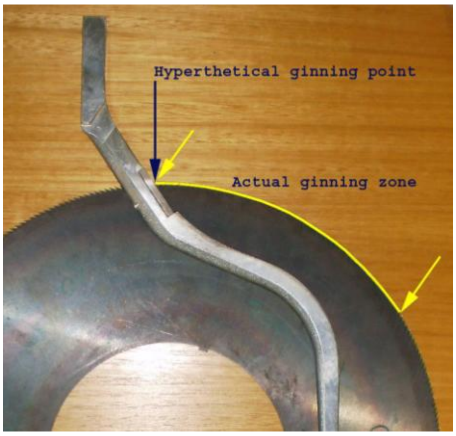


Figure 1-5: Ginning point and ginning zone

1.4.2 Working area of saw blade

The working area of the saw blade is defined by the portion of the blade that enters the seed roll. The area of the saw blade that is in use during the ginning cycle is approximately 9 per cent. The working depth of the saw blade is : Continental Eagle gin stand fuzzy seed output lateral distribution approximately 40 mm. This profile of the working area of the saw blade is illustrated in Figure 1-6.

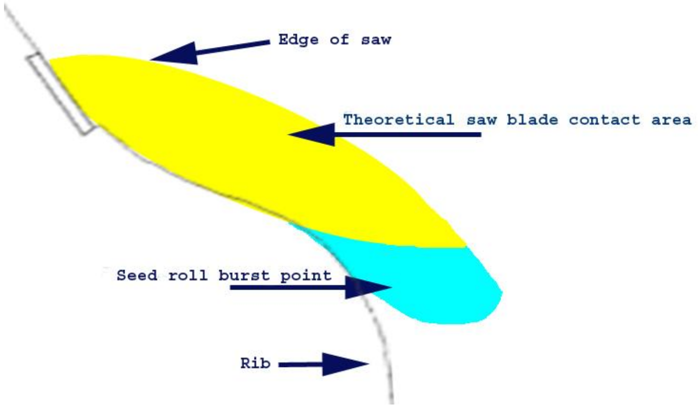


Figure 1-6: Saw blade working area

The profile of the saw blade contact area was achieved through the use of an overlay of a gin rib and saw blade. The burst point profile in blue has been approximated by means of visual inspection on a Continental Eagle 161 gin stand.

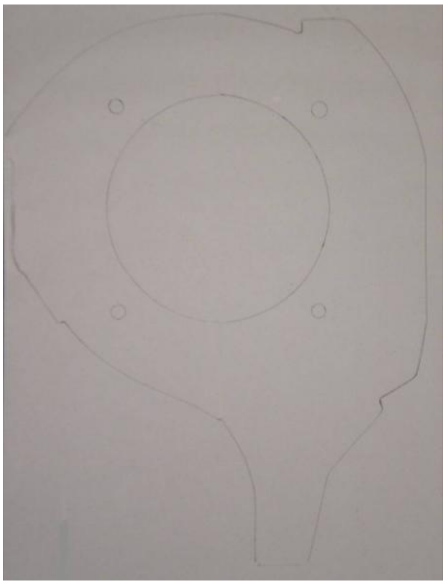


Figure 1-7: Roll box profile

1.4.3 Roll box geometry

The gin stand working element is the roll box and includes the saw blades and ribs. The roll box of the Continental Eagle 161 gin stand is fabricated out of stainless steel and the profile is shown in Figure 1-7.

The roll box profile was achieved through the placement and tracing of steel shim inserts into the roll box together with the removal and profiling of the roll box end plates.

1.4.4 Seed roll fuzzy seed expulsion

The continuous ginning process requires the roll box to expel ginned seed in a continuous manner. Gin stands release seed from the ginning process within the roll box through two methods. Method one employs the traditional exit zone of fuzzy, the breast section of the gin stand. To enable fuzzy seed expulsion at this point, seed must exit past the saw blade sides. Once past this point the seed is free of any mechanical and vacates the gin stand. Method two of fuzzy seed expulsion from the seed roll, which is specific to Continental Eagle gins, occurs at the intersecting area of the fuzzy seed and of the perforated seed tube within the seed roll. The seed tube contains two augers that are positioned end to end. These augers are adjacent at the mid point of the seed tube and draw the seed in a longitudinal direction where the seed is expelled. The proportional output discharge of the seed equates to approximately 42 per cent for the seed tube and approximately 58 per cent for the breast.

1.5 Process performance measurement – value structure

The value of the Australian cotton is determined largely by its USDA classing grade, which describes the cotton's colour, leaf content and preparation. If the lint has been under ginned, then the lint will appear to be not opened enough. Value is also attached to the staple length, bundle strength and micronaire of the fibre. All these properties can be assessed using a standardised high volume instrument (HVI) although in Australia classing grade is still largely determined by manual classers using the USDA physical standard grade boxes. The Uster HVI system is shown in Figure 1-8.

Figure 1-8: Uster HVI – *Uster, (2012)*

The Uster HVI system is used throughout Australia for the classing of ginned cotton. The measurements used within this research through the HVI system include the upper half mean length (UHML), leaf grade, short fibre content (SFC), micronaire (Mic), uniformity (Uni), nep and seed coat nep (SCN). Ideally fibre should be low in nep, SCN and SFC, and high in uniformity. Each of the above properties was measured to check the effect and performance of gin stand treatments (trials).

1.5.1 Colour grade

The base grade for Australian cotton is 31-3, although the average grade of Australian cotton regularly has a colour grade of 21 and a leaf grade of one or two. Should the base grade not be achieved then the value of the cotton will be discounted. The colour grades for Upland cotton is shown in Figure 1-9.

Upland Colour Grades
11, 21, 31, 41, 51, 61, 71, 81
12, 22, 32, 42, 52, 62, 82
13, 23, 33, 43, 53, 63, 83
24, 34, 44, 54, 84
25, 35, 85

Figure 1-9: USDA colour grades for Upland cotton

Web site accessed February 2012,<www.cottoncrc.org.au>

1.5.2 Leaf grade

Leaf grade refers to the amount of leaf particles that are contained within the lint mass after the ginning process has been completed. The classer determines leaf grades. A leaf grade scale ranging from one through to seven characterises the amount of plant trash particles present within the cotton and is represented by physical samples. High levels of leaf content require greater levels of cleaning by the spinner and may produce a product of inferior quality. A leaf grade of three represents base grade cotton. Higher numbers represent increased levels of plant trash. Leaf grades in excess of four incur discounts. It is important that leaf grade does not increase beyond grade three during different ginning configurations.

1.5.3 Fibre length

Fibre length is the result of genetics, agronomy and environmental factors. Mechanical processing can further reduce the fibre length. Fibre length is measured optically using a tapered fibre beard that is prepared, carded and brushed automatically by the HVI. The fibre length or staple length of Australian cotton is measured as the upper half mean length (UHML) or the average length of the upper half of the fibres. It is expressed in the trade as $^{1}/_{32}$ of an inch. This equates to 0.794 mm. A greater upper half mean length of cotton is desirable and can increase the value of the cotton and make it more desirable to spinners. The greater the length of the fibres, the stronger the yarn is as a result of the entwining of the fibre over a greater length. Longer fibre lengths further allow for increased production rates during the spinning process. The base grade length, determined as the UHML, of Australian cotton is now 28.58 mm ($1^1/_8$ inches or $^{36}/_{32}$). The classification instrument measures the length in hundredths of an inch. The length is reported on the classification record in both 32nds and 100ths of an inch. Length measurement conversion from 32nds to 100ths is as shown in Figure 1-10.

Upland Length Conversion Chart			
Length (32nds)	**Length (Inches)**	**Length (32nds)**	**Length (Inches)**
24	0.79 & shorter	36	1.11 kg–1.13
26	0.80 kg–0.85	37	1.14 kg–1.17
28	0.86 kg–0.89	38	1.18 kg–1.20
29	0.90 kg–0.92	39	1.21 kg–1.23
30	0.93 kg–0.95	40	1.24 kg–1.26
31	0.96 kg–0.98	41	1.27 kg–1.29
32	0.99 kg–1.01	42	1.30 kg–1.32
33	1.02 kg–1.04	43	1.33 kg–1.35
34	1.05 kg–1.07	44 & +	1.36 & +
35	1.08 kg–1.10		

Figure 1-10: USDA colour grades for Upland cotton

Web site accessed February 2012,<www.cottoncrc.org.au>

1.5.4 Micronaire

Micronaire is a measure of the cotton's fineness, the specific surface area of the fibre. This is measured by relating airflow resistance to the specific surface of fibres. The micronaire of Australian cotton has a base grade that falls between 3.5 and 4.9. Should the micronaire value fall on either side of the base value then the cotton produced with the outlying micronaire will be subjected to a discount in the sale.

1.5.5 Neps

Neps are small entanglements of fibre tightly knotted. Neps rarely appear in cotton prior to picking. Neps are generally made up of fibres that are immature. Neps have an increased presence when the fibre is long and fine and further when the fibre is immature. The ideal value of neps is less than 200 neps per gram. Neps can attract a discount on lint. Neps are undesirable to spinners and can play a role in the spinner's decision making when buying cotton. The nep becomes a waste product during the spinning process. Neps usually absorb less dye and appear as light coloured flecks on fabric. Australian cotton can be looked upon poorly if neps rise significantly. Therefore, the nep count of the ginned cotton is a performance indicator.

1.5.6 Seed coat neps

Seed coat neps (SCN) consist of a particle of the cottonseed shell with some fibres still attached to it. Seed coat neps can be more prevalent during dry seasons. These neps are difficult to remove once they are present in the lint. The neps will not absorb dye and are visible on fabrics. Seed coat neps attract a discount on the lint. They are undesirable to spinners and a reduction in seed coat nep would be beneficial to spinners and the Australian cotton industry. Therefore, a performance measure is the number of seed coat neps present in the sample.

1.5.7 Short fibre content

Short fibre content (SFC), refers to the proportion by weight of fibres shorter than 12.7 mm in length. Ideally the short fibre content should be lower than eight per cent. The short fibre content of Australian cotton is currently an issue with spinning companies. The short fibre content can increase if the fibre is not processed correctly. High levels of short fibre content do not attract a discount. However, short fibre content is undesirable to spinners as it reduces the strength and evenness of the yarn considerable. Short fibre content increases the amount of waste in the spinning process. The reduction in the short fibre content is desirable and is therefore a performance measure.

1.5.8 Uniformity

The uniformity of the fibre is based on the ratio between the mean length of fibres (ML) and the UHML and is expressed as a percentage. The greater the uniformity the more desirable it is to spinners. The ideal value is greater than 80 per cent. There are discounts associated with values less than 78 per cent, however they are small. Variation in the uniformity can lead to yarn quality of lesser quality.

1.6 Aim

The broad aim of this research is to improve the performance of Australian gin stands to preserve the inherent quality of long staple, fine Australian cotton. With this broad aim in mind, the hypothesis of this research is: Temporal and spatial variation in cottonseed supply to gin stands results in the production of lint with variable quality. Australian gin stand performance in terms of quality can be improved by altering the machine configuration. This can be altered by the mass production rate and the adjustment of the seed fingers.

Research encompassed studies of the seed roll and roll box within five subject zones. The areas of study were as follows:

1. Perform gin stand research at varied mass production rates to determine the effect on fibre qualities of long staple Australian cotton.
2. Observe the flow and discharge pathways of seed cotton and fuzzy seed.
3. Measure seed cotton flow on the gin stand apron by means of film.
4. Design and produce equipment allowing for the continuous electronic monitoring and data storage of the flow of seed cotton on the gin stand apron.
5. Investigate methods to overcome the non linearity of the fuzzy seed Discharge by means of:
   a) Produce a saw shaft extension and support housing to increase the rigidness
   b) Through the use of apron deflectors, modify the effectiveness to potentially change the distribution output of fuzzy seed and potentially improve fibre qualities.
   c) Manufacture an air-blowing device to manipulate the distribution of seed cotton allowing potential change to the distribution of fuzzy seed output and potentially improve fibre qualities.
   d) Modify the conveyor distributor to potentially allow for an improvement in the fuzzy seed output distribution and potentially improve fibre qualities.

1.7 Structure of dissertation

Chapter 1: Background. The project background enters into discussion as to why the research was conducted, the aims of the project together with an introduction to the Australian industry. Process performance measures used in this Thesis are further described.

Chapter: Literature review of the gin stand. The literature review enters into discussion regarding research that has been conducted on the gin stand. The review includes Lummus, Consolidated and Continental Eagle gin stands.

Chapter 3: Seed roll and roll box analyses – methodology and research. Methodology, research, results and conclusions regarding the seed roll and roll box are contained within this chapter. Research includes mass production rate trials, mass production rate conversion, seed roll surface speeds as a result of mass throughput and the lateral distribution of seed cotton and fuzzy seed. The saw blade analyses included friction and wear.

Chapter 4: Input distribution mapping of seed cotton into the gin stand – methodology and research. Methodology, research, results and conclusions regarding the input distribution of seed cotton are contained in this chapter. Methods of analyses of the flow of seed cotton into the gin stand are explored. The cause of the uneven seed roll together with methods of modifying the distribution of seed cotton into the gin stand and the effect is discussed.

Chapter 5: Conclusion of research results and future research direction. The conclusions from the research achieved in chapters three and four are discussed together with direction for future research on the gin stand regarding the saw blade dynamics and the seed cotton distribution.

Chapter 2
Literature review

2.1 Introduction

A review of research previously achieved on the gin stand is discussed within chapter two. The literature review primarily encapsulates research discussion regarding methods of saw ginning, roll box internal components, mass production rate effects and methods of seed roll drive.

Much of the research undertaken dates back more than 40 years and was primarily conducted on US grown cotton, most of which was considerably shorter than that produced today in the USA and Australia. Ginning productivity has grown from gin stands capable of 1.3 tonne mass output of lint per hour not more than 30 years ago to almost 3 tonne mass output of lint per hour on modern gins. Production rate increases have occurred due to increased saw blade numbers, greater horse power motors and improved fuzzy seed release. A gin stand review is required to investigate new methods of ginning with existing equipment to en-capture the length of long fine Australian cotton. The rate at which gin stand mass production rates have increased during the period 1793 to 2010 is shown in Figure 2-1.

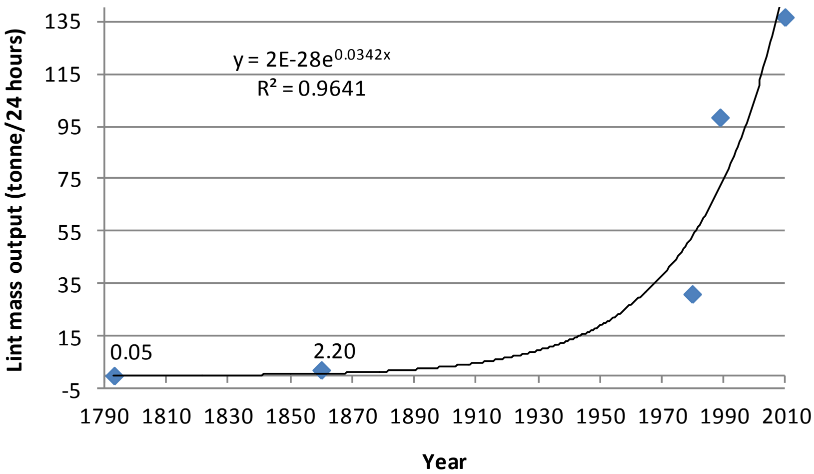


Figure 2-1: Gin stand mass production rate time line

Figure 2-1 adapted from Lakwette (2003) & <www.pratthistory.com>.

The mass production rate of a gin stand has increased from 50 kg/day up to present mass production rates of 135 tonne/day on the very latest equipment.

Little research on the gin-stand has been undertaken in Australia, i.e. research undertaken to examine the interaction between the saw-gin mechanism and fibre quality. Nearly all of the ginning technology in Australia is imported from the USA, although Australian gin set-ups process more bales/gin than USA gins. The Australian ginning industry is the most modern and productive in the world. Knowledge in the Australian industry is chiefly focused on increasing gin stand productivity and overcoming production issues, including issues around processing various cotton types, different moisture levels and trash contents. Subsequently, the industry is well equipped with a know-how discipline. In the past the US ginning sector has relied upon the USDA Agricultural Research Service Ginning Laboratories and until 15-20 years ago a reasonably vibrant gin-manufacturing sector, which commercialised USDA outputs and generated their own intellectual property. With contraction in the US ginning sector, this model is no longer producing the same advances.

Gin brands in Australia are shared between the US manufacturers, Continental Eagle and Lummus. Figure 2-2 illustrates the share of gins per US manufacturer in Australia.

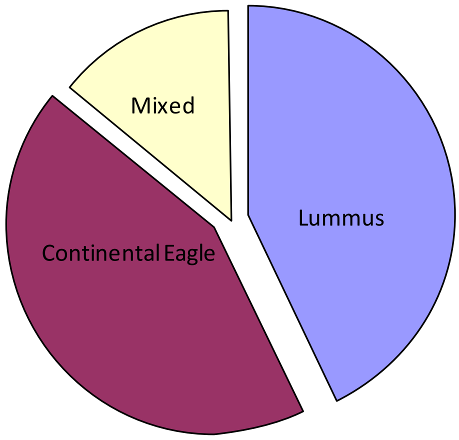


Figure 2-2: Gins within Australia by manufacturer

Figure 2-2 adapted from "Australian gin survey, (2006)". Where a gin uses a variety of ginning equipment brands, the outcome is stated as mixed

As at 2006, gins within Australia were of variable age. The average age of the gins together with the newest and oldest are shown in Figure 2-3.

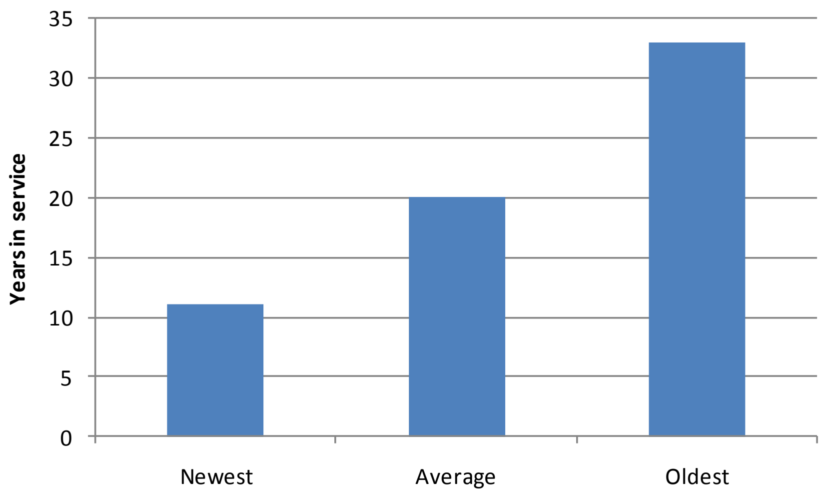


Figure 2-3: Australian gin plant age

Figure 2-3 adapted from "Australian gin survey, (2006)". Results shown are updated to 2011.

2.2 Literature review parameters.

The literature review herein includes research and discussion that has taken place with the gin stand dating back to the 1930s.

2.2.1 Inclusions

The literature review enters into discussion concerning fibre properties through:

- Forces within the seed roll as a result of throughput.
- Rotational speeds of the seed roll as a result of throughput.
- Friction occurrence within the roll box.
- Saw blade analyses.
- Differential ginning.

2.2.2 Exclusions

The literature review excludes parameters regarding:

- Farming procedures.
- Module configuration.
- Gin layout.
- Geographical position.
- Ginning equipment other than gin stand.

2.3 Gin stand feed rates

Gin stand mass production rate affects lint and residual lint properties. Mangialardi (1988) carried out research to determine the seed roll density at various ginning rates and on the ginned lint quality. The research indicated that as the mass production rate increases, physical damage to the seed coat also increases and that most of the damage occurs when fibres are separated from the seed at the gin stand. Trials were conducted at mass production rates of 340, 544, 749, 1098, 1339 and 1589 kg/h. The gin stand was rated at a mass output of 1089 kg/h. The seed roll density was measured for each ginning rate; density increased from 80 kg/m3 for the mass production rate of 340 kg/h, up to 272 kg/m3 for a mass production rate of 1589 kg/h. A seed roll pressure indicator was used to illustrate that pressure was increasing within the roll box.

2.4 Gin stand fibre moisture

Lint is subjected to moisture gain and loss. The ideal moisture content for the gin stand is between six and seven per cent. Should the moisture content be greater than seven per cent then lint will not be ginned properly. If the moisture content is below five per cent then lint will be damaged during the ginning process.

Research performed by Byler (2005) to determine the effects of moisture addition on fibre properties, demonstrated higher moisture contents produced ginned lint of greater trash content and better fibre length. Byler (2005) demonstrated that fibre length increased by 0.76 mm per 1 per cent increase in fibre moisture content. Dry fibre length prior to the lint cleaner was 29.3 mm while the moisture restored fibre length prior to the lint cleaner was 29.6 mm. Trash counts increased from 700 counts per gram for the dry lint to 780 counts per gram for the moisture restored lint before the lint cleaner. Moore (1967) stated that lower moisture content within the seed of seed cotton allows for increased mechanical damage. Moore (1967) states that as the ginning rate per saw blade increases, so does the seed coat fragments percentage. Moore has not concluded whether the seed coat fragment increase was a result of the ginning rate per saw blade or whether it was the density increase within the seed roll. Seed coat fragments have been shown to increase as the ginning mass rate increases. Seed coat fragment values together with the mass-ginning rate (kg/h per blade) are illustrated in Figure 2-4.

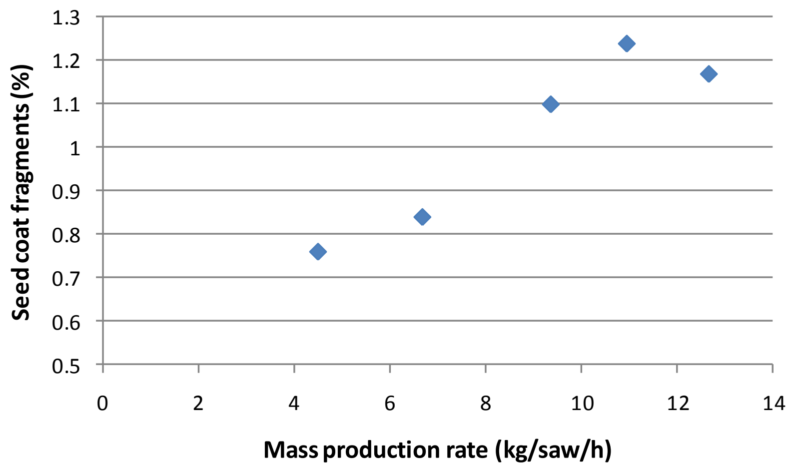


Figure 2-4: Seed coat fragments and ginning rate

Moore (1967) indicates that as the ginning rate increases, as does the seed coat fragments within the lint.

Further research by Columbus (1992) indicated that the moisture level of the lint increases, as does the visible foreign matter as shown in Table (2-1).

Table 2-1: Moisture effect on visible trash and seed damage

SCM%	LM %	SM %	VT %	SD %
7.5	4.1	7.7	1.48	6.1
11.8	5.5	11.6	1.93	11.1
14.4	7	14.5	2.19	23.1
15.9	8.3	16.9	2.72	25
15.9	7.7	17.3	2.38	26.6

SCM per cent - Seed cotton moisture, LM per cent - Lint moisture, SM per cent - Seed moisture, VT – Visible trash, SD – Seed damage.

Adapted from Mangialardi (1988) indicates that the trash levels together with the seed damage increase as the moisture levels increase.

Observations by Mangialardi (1988) observed a significant relationship between moisture level, mass production rate and seed damage. This indicated that damper seeds are softer and more susceptible to damage at higher mass production rates. Visible non-lint matter increased with the increase of lint moisture. Boykin (2008) observed twice as many damaged seeds in the seed roll than there are in the gin stand feeder as a result of mechanical damage. Boykin (2008) states that seed damage within the gin stand was seven per cent. Boykin (2008) further mentions that ginning research focused on reducing seed coat neps should primarily be focused at the gin stand and that seeds with more mature stronger seed coats should form fewer seed coat neps. As a result of this, production practices could be changed depending on seed properties.

2.5 Differential ginning

Differential ginning, a term coined in the 1950s allows for a reduction in saw teeth interaction and the ginning duration can be controlled allowing for partially ginned seed cotton. Differential ginning is also referred to as stage ginning or fractional ginning. This method of ginning allows for the investigation of the ginning process on fibre quality. The method of differential ginning is not feasible for ginning production.

During differential ginning, the lint is kept separate for each of the stages. The lint is shown to have different qualities for each of the differential ginning groups or segments.

An approach to differential ginning is illustrated in Figure 2-5.

Figure 2-5: Differential ginning schematic of protocol used by Columbus (1992)

Research has been conducted allowing for the cotton to be ginned for varied levels of time.

The USDA performed ginning trials in a manner that allowed for the ginning time to be controlled to within 15-second increments (USDA, 1958). Trial methodology involved emptying the roll box at 15-second increments and then reloading the roll box with enough of the said time ginned seed to allow processing for a further 15 seconds. The trial was continued until the seed cotton could no longer be ginned. Fibre length during the five stages of the differential ginning decreased with each stage as per the trials later carried out by Columbus (1992). Griffin (1960) research results indicated that the micronaire increased with ginning time. This may be indicating that the shorter, higher micronaire fibres are more firmly attached to the seed and require greater ginning time. It may also indicate that the shorter fibres are more difficult for the saw teeth to grasp and remove. Griffin (1960) carried out tests to determine if artificial changes made to decrease fibre length would create a micronaire value that differs from the true reading. Micronaire readings indicated that the length did not change the value. It was therefore acknowledged that the difference observed in micronaire was due to fibre development and not breakage.

During fibre formation on a single seed, fibre initiation does not start at an identical time. Fibre initiation may differ by two days from one end of the seed to another. Fibre length elongation ceases at about the same time for the fibres, therefore the later initiated fibres cannot achieve the same length as the earlier fibres. Fibre wall thickening will occur at about the same time for each fibre initiation group. Due to the reduced wall area of the shorter fibres, and closer proximity to vascular connections wall thickening occurs at a faster rate. As a result of this growing pattern, the shorter fibres within a single seed can have an increased micronaire (Constable 2011, pers. comm.).

Griffin (1960) further confirmed that short fibre content could be varied significantly by subjecting the seed cotton to varied levels of ginning time as found by the USDA (1958). Columbus (1992) researched differential ginning to determine fibre quality effects of the upper half mean length and short fibre content. The process involved delivering seed cotton into one side of the gin stand, which was slightly modified and allowed seed cotton to travel to the opposite end of the gin stand by means of a feed screw. The lint collected from the beginning of the ginning process was subjected to less ginning than that of the opposite end. Lint sample collection occurred at three zones from across the gin stand. The zones consisted of left, middle & right. Fibre length of the left-hand side zone, being the less ginned zone, was the longest. The research has indicated that fibre length varies with relation to ginning duration within the roll box. The length increase was retained during subsequent lint cleaning passages. The SFC increased from 6.5 per cent for the left-hand side to 9.5 per cent for the middle and 23.5 for the right-hand side. Subjecting the seed cotton within the roll box to increased ginning time substantially increases the number of saw teeth presented to any given fibre.

Fibre length properties demonstrate a decrease in length during the increase in staged ginning time that seed cotton was subjected to as described in Figure 2-6. Fibre length is shown as the upper half mean length in mm.

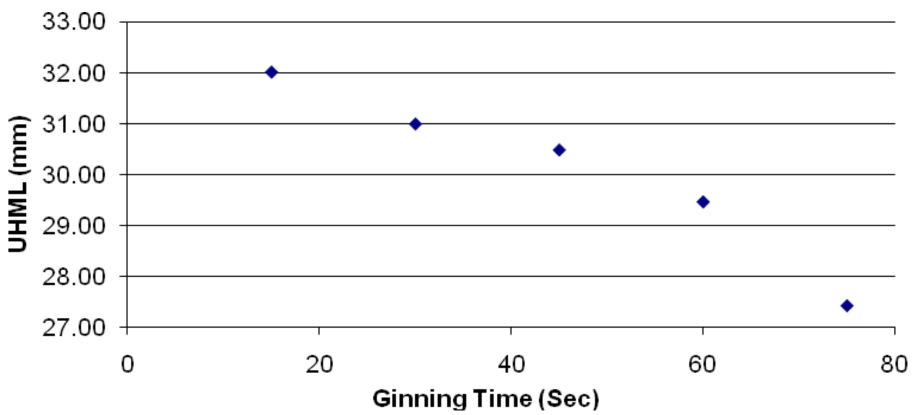


Figure 2-6: Fibre length/ginning time

Adapted from Griffin et.al (1960) indicates that the fibre length decreases at each additional stage of ginning time.

Research by Long (2006) investigated methods of ginning seed cotton. The two ginning methods used were hand ginning and saw ginning. Results are presented in Figure 2-7.

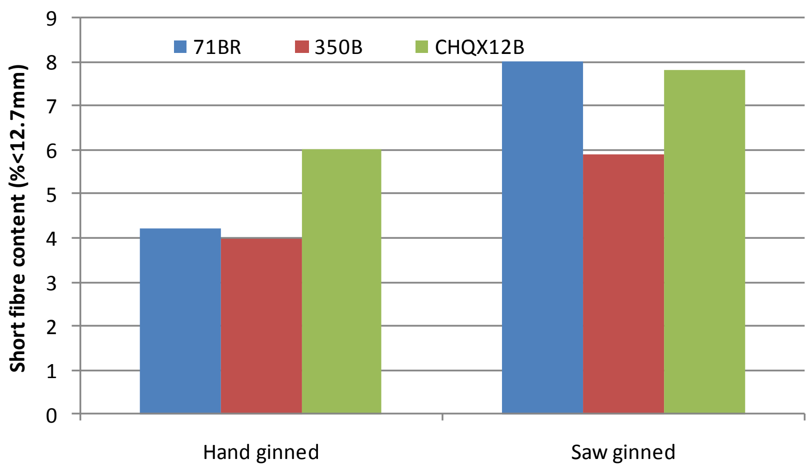


Figure 2-7: Hand ginning vs. saw ginning (SFC)

Adapted from Long (2006) shows that hand ginning, which occurred for three fibre varieties, greatly reduced short fibre content when compared to that of the saw ginned fibre.

The upper quartile length of the hand ginned and saw ginned lint was tested. Results are illustrated in Figure 2-8.

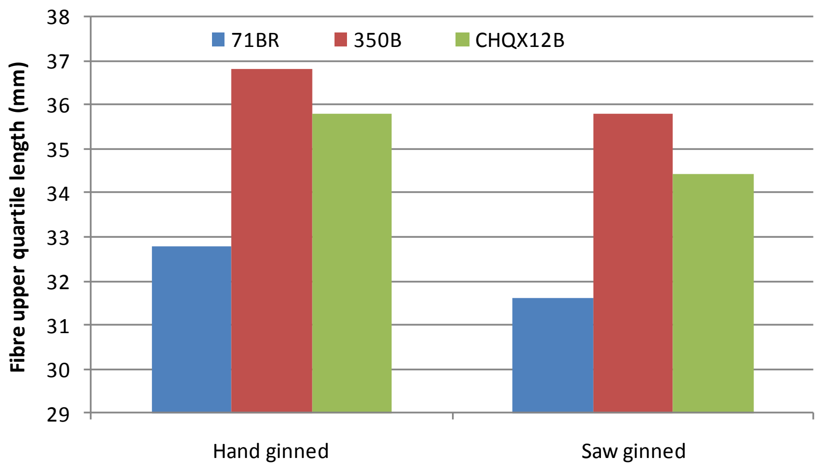


Figure 2-8: Hand ginning vs. saw ginning (UQL)

Adapted from Long (2006) indicates that hand ginning retains fibre length. The hand ginning and saw ginning occurred for three fibre varieties. The hand ginned cotton greatly retained fibre length when compared to that of the saw ginned fibre.

2.6 Seed roll drives

Within the seed roll contained by the roll box is an internal drive that assists the rotation of the seed roll. The seed tube as used in modern Continental Eagle gin stands is perforated allowing for fuzzy seed to enter the tube and subsequently removed from the seed roll. USDA (1966) research trials used gin stand seed roll accelerators together with saw speeds ranging from 400 to 1200 rpm. The trials performed used a 184 mm and a 120 mm diameter seed roll accelerator operated at 113, 154, and 186 rpm. Two accelerator surface types were used during this research, smooth surface and spiked surface. The smooth accelerator core was found to reduce velocity of the seed roll and gave seed roll velocities some 20 to 30 rpm less than the spiked accelerator core. The spiked accelerator core allowed for an increase in the ginning rate. Core diameters were compared and results indicated that a core diameter of 120 mm produced more lint than the core of a diameter of 184, which encapsulated so much of the roll box volume that it prevented a viable seed roll to be formed.

Increased saw speeds together with increased roll box core rotational speed, increases the gin mass production rate. The length of the fibre was not affected at increased mass as shown in Table 2-2.

Table 2-2: Saw and roll box core rpm and resultant fibre qualities together with production rates

Saw speed (rpm)	Roll box core	Production rate (kg/h)	UQL (mm)	SFC
700	N	77.11	32.77	10.5
700	Y	82.55	33.27	9.2
900	N	90.72	33.02	11.6
900	Y	92.53	33.02	11.1
1 100	N	94.8	33.27	11.7
1 100	Y	116.57	33.53	9.4

2.7 Power roll gin stand

The power roll gin stand (PRGS) is a type of seed roll drive that is retrofitted to existing gin stands. The PRGS was developed by the USDA and was patented in 2000. Laird (1999) claims that production in existing gin stands not modified with the Power Roll equipment is reduced by the inability of the seed roll to expel fuzzy seed. Ginners readily expose this inability for the seed to escape the seed roll as the reason that gin stands cannot increase in productivity. Laird further mentions that the cleaning ability of the gin stand suffers as the production rate increases. Laird states that this has led to the development of gin stands having more saws and of increased width in an attempt to increase production. Holt (2008) states that some conventional gin stands have seed tubes or agitators that are involved in laterally moving the seed roll but not actively turning the seed roll. What is not stated is whether or not that the seed tubes or agitators actually decrease the rotational speed of the seed roll. Holt (2008) performed research on the gin stand to determine the quality effects derived by using different saw speeds and paddle roll speeds. Trials were conducted at three gins and each of the gin stand settings was recorded. Saw speeds varied from 711 rpm to 870 rpm and the paddle roll within the seed roll was driven at speeds ranging from 205 rpm to 233 rpm.

The Power Roll Gin Stand creates a gentler ginning of the fibre by helping with the rotation of the seed roll, in turn, removing more lint, increasing fibre length and decreasing short fibre content. What is not understood is whether the softer seed roll is responsible for the improved fibre properties or whether it is the increased rotational speed of the seed roll.

Table 2-3: Power roll gin-stand rpm of paddle and saw shaft

Gin	Gin Name	Paddle Roll RPM	Saw Shaft RPM
A	McClendon, Mann & Felton	233	711
B	Minturn Coop Gin	223	824
C	Olton Coop Gin	205	870

Adapted from Holt and Laird (2008), indicates the paddle roll and saw shaft rpm during trials carried out.

The gin stand next to the experimental Power Roll Gin Stand was used as the control. An assumption is made that the saw speed of the control gin stand is the same as that of the Power Roll Gin Stand as it is not noted. Seed roll rotation speeds of the Control gin stand is not known.

Research results from trials utilising the three makes of gin stands together with the PRGS modifications are shown on Table 2-4.

Table 2-4: Power roll gin-stand fibre property results for Continental Eagle, Lummus and Consolidated gin stands

Gin	A		B		C	
Condition	PRGS	CE	PRGS	Lummus	PRGS	Consol'd
Length (cm)	2.796	2.733	3.124	3.098	2.692	2.718
Uniformity	83.9	83.9	84.4	84.3	82.9	83.1
SFC	7.98	8.07	10.79	10.99	11.4	11.9
Tonne/h	2.96	2.9	2.2	1.7	2	2.1

Adapted from Holt (2008) indicates the fibre properties of the tested fibre from trials carried out comparing the Power Roll Gin Stand to three makes of gin stands.

Holt (2008) research results indicate that the trial with the greatest results was that of gin "A". Gin "A" further had the highest rotational speed of the power roll and further had the slowest rotational speed of the saw (as per Table 2-3). The experiment that produced the most unfavourable results for the PRGS was gin "C". This result should have been expected as the gin configuration had a saw speed of 870 rpm, which was 159 rpm greater than gin "A". The paddle roll rpm on gin "C" was 205 rpm, which was 28 rpm slower than that of gin "A". These configurations of the gin stands demonstrate that the slower turning seed roll and the faster rotating saw shaft produce unfavourable conditions for extracting maximum fibre length. A comparative trial on Gin "C" where the saw speed was greatly reduced and the paddle roll rpm was greatly increased would have been beneficial to these experiments.

2.8 Seed roll surface speed

Ginning trials (USDA, 1966) that allowed for the surface speed of the seed roll to be measured were performed. A wheel was used in a modified roll box (slot cut out) to allow for a wheel to rub against the seed roll. The trial was carried out using a gin stand of low production rate. The results obtained indicated that at saw speeds of 600, 800 and 1000 rpm, the seed roll velocity did not change. It was calculated that the seed roll was travelling at a surface speed of 54.86 m/min.

Frictional properties as a result of the seed roll loading of that era were not observed. The trial indicates that at these mass ginning rates and unknown seed roll densities, there is insufficient change of force within the roll box to promote seed roll rotational speed. It is mentioned by the USDA (1966) that the effect of seed roll density and saw speed on quality of the lint quality was related much more closely to seed roll density than to saw speed. Further to this, it is mentioned by Griffin (1960) that increasing the seed roll velocity increases the ginning rate and that increasing the rotational velocity of the gin saws increases the ginning rate. Trials conducted by the USDA (1966) indicated that gin saw tooth loading is only 20 to 30 per cent efficient. From this, it is supported that increasing the velocity of the seed roll can increase the ginning rate. However, this research has been carried out on gin stands of significantly reduced mass production rates when compared to gins of the modern era. Therefore, these trials performed should be repeated at mass production rates suited to the modern era. The USDA (1966) observed that by timing the seed roll rotation speed, the seed roll rotation speed did not increase with saw speed, yet increased with seed roll density. It was further stated by the USDA (1966) that the low efficiency of the saw tooth was a result of the saw teeth cutting a path through the seed roll, in turn leaving no cotton for the following saw teeth to collect. Most importantly, the USDA (1966) noted that an increased rotational velocity of the seed roll would decrease the forces applied to each fibre. This could result in decreasing the amount of broken and short fibre, in turn, increasing the fibre length. The increasing of the seed roll rotational speed would also reduce the number of saw teeth that each fibre is subjected to.

2.9 Lateral distribution of seed inflow and fuzzy seed discharge

Seed cotton is delivered to the gin stand via an extractor feeder. The mass input distribution of the seed cotton determines the output distribution or discharge path of the fuzzy seed. Anthony (1990) states: “Located above the gin stand, the extractor-feeder meters seed cotton uniformly to the gin stand at controllable rates”. There is however, no evidence in any literature to justify this statement. The current industry standard for measuring the input distribution into a gin stand relies on pushing the fire door of the gin stand inwards to allow for the seed cotton to not enter the gin stand, but to simply gather on the floor in front of the gin stand. After a given time as decided by the gin operator, the feed delivery is stopped and the distribution of seed cotton on the floor is observed for its evenness. The reader may consider a fully loaded truck dumping a product onto the ground. The product distribution on the ground is significantly different from that of the distribution prior to unloading.

Fuzzy seed within the seed roll has two methods of release, yet three outlets of discharge. The first outlet of fuzzy seed is via the gin stand breast. The point at which fuzzy seed can release from the seed roll is referred to as the “burst point”, and is the point where the release of pressure within the seed roll allows for the fuzzy seed to exit the gin stand. The second and third point of fuzzy seed expulsion is within a seed tube found in modern Continental Eagle systems situated within the seed roll. The seed tube is built with a surface that has a series of holes. These holes have a raised lip on the leading edge of the hole that allows for the fuzzy seed to be scooped into the seed tube. The seed tube rotates and provides for a constant means of removing the fuzzy seed. Within the seed tube is situated a multi-directional auger that removes the fuzzy seed to a spill point at each side of the gin stand.

2.10 Gin stand component research

Research reviewed in this section encompasses mechanisms contained within the roll box. Components within the roll box include saw ribs, roll box skin type/frictional coatings, saw blades, together with their spacing, tooth design and density, diameter and exposure together with saw shaft rotational speeds.

2.10.1 Rib modifications

The major concern for ginners at the present is the gradual progression of smaller cottonseeds through the introduction of new varieties. An attempt to overcome this was trialled by Hughes (2002) who developed a simple plastic guide that was attached to the gin ribs, yet wider than the gin ribs and resultantly, much closer to the saw surface than a gin rib. The guide restricts the gin saw gap from increasing as a result of seeds flexing the saw blade to an extent that seed was able to pass through the gap between the saw blade and the rib. Results indicate seed damage was reduced for the experimental ribs from 8.3 per cent down to 5.3 per cent. Short fibre content was reduced from 9.9 per cent down to 8.1 per cent for the new rib guide. The upper half mean length increased from 2.95 cm up to 3.02 cm for the new rib guide. Hughes does not state the actual function that changes the fibre values, simply the change. Leaf grades were not reported. Although Hughes found the plastic guides reduce seed related issues with the lint, it is not understood what function the smaller gap between the guide and the saw blade plays in reducing the short fibre. These smaller cottonseeds are looked upon as a challenge for ginners.

2.10.2 Frictional forces in the roll box

The roll box of the gin stand is subjected to friction as a result of force applied to the stainless steel casing by the seed cotton. Friction is an important aspect of the workings of the seed roll and the ginning process. As the mass of seed cotton increases within the roll box, the density increases. With the increase in density comes an increase in forces that are applied to the surfaces within the roll box. These surfaces include the roll box stainless steel skin, the ribs, the seed fingers and the saw blades. The frictional force on the saw blade sides is often referred to as the "disk brake effect". This term suggests that the seed roll is preventing rotation of the saw blade. A more accurate description of this interaction between the seed roll and the saw blade sides would be to describe the action as a "clutch effect". A clutch relies on friction to drive motion, as does the seed roll.

Research was conducted to determine if coating the roll box would change the capacity of the gin stand (Parnell, 1969). In a trial performed, the roll box was coated with Teflon and the seed roll velocity was measured. Results indicate that the seed roll surface speed increased from 59.95 m/min to 62.88 m/min for the Teflon coated roll box. Seed roll density decreased from 173.3 g/m^3 loading to 152.8 g/m^3 loading for the Teflon coated roll box. No significant change was found in lint quality.

It was stated that seed roll density and velocity could be used in a gin stand to improve the fibre qualities (Parnell, 1969). This is further backed by the research carried out by the USDA (1966). Processing lint at the mass rate of 3405 kg/h would subject the fibre to $^{1}/_{15}$ of (32,000,000 saw teeth x 60 minutes), yet reducing the production rate to a mass of 2270 kg/h would increase the saw tooth ratio to $^{1}/_{10}$ of (32,000,000 saw teeth x 60 minutes), significantly increasing the opportunity for mechanical damage to the fibre. This is further backed by the USDA (1966).

2.10.3 Saw tooth design

Saw blades within the ginning industry have been used for over 200 years. The gin saw blade was first patented by Daniel Pratt in 1796. Web site accessed February 2012,<http://www.pratthistory.com/>.

Saw tooth designs have been evaluated significantly since its first invention. Such names of the saws have included the "wire teeth", Sheathing wire claws", "Brier thorn spikes", "gin saw with buckhorn needles" and "Wire teeth needles". By 1935 the selection of available saws was down to three. The new designs of the era varied in tooth pitch, roach and angle. The USDA (1939) evaluated available saw tooth design efficiencies. Discussion indicates that the number of saw teeth, pitch and tooth shape all effect ginning capacity. The USDA performed trials at Stoneville (USDA, 1966) and concluded that there should not be many more that 264 teeth on a 304.8 mm gin saw blade. Mayfield (1970) indicated that a complete analyses of the effects of each of the saws individual properties has never been achieved. Two saw types were researched by Mayfield (1970) a straight back saw and a roached back saw. Seed test results of the trials for the 304.8 mm saw blade indicated that the special saw had on average, 12.7 per cent of seed damage, while the control saw had 20.2 per cent of seed damage on average. This trial was repeated the following year and the results again indicated a reduction in seed damage. However, this time the seed damage results indicated 2.9 per cent damage for the special saw blade and 5.2 per cent damage for the control saw. There was no significant difference in length between the two trials. A trial carried out by the USDA (1966) on a Continental Eagle gin stand tested five different sets of 406.4 mm saw blades. The research indicated that the ginning production rates varied significantly for each of the five saw types, being a low of 29.9 kg/min of lint, to a high of 40.4 kg/min of lint. Length, uniformity and SFC were affected by saw types. It was unfortunate that there was no testing of the saw blade sides to determine the surface properties of the steel. The USDA (1966) concluded that the ginning rates were varied as a result of the saw tooth properties.

Saw blade plating research was conducted (USDA, 1966) to determine if coating or plating the saw teeth would allow for greater saw life. This research was a result of the decline in the ginning rate as the saws became blunt. The plated saws reduced ginning rates by 28 per cent. Upon inspection, the saw teeth were found to have a “ball” of the plating material on the tip of the teeth. This observation led to the conclusion that other means of increasing saw life are required should re-sharpening discontinue.

2.10.4 Saw teeth density

Research involving changing the amount of teeth on saw blades used in the ginning process was conducted (USDA, 1966). The saws ranged in teeth quantity from 264 up to 600 teeth. Trials were attempted at ginning with saws of 900 teeth however, only 4.45 kg of lint was produced in 90 minutes and produced a seed roll that was badly roped. A trial using 1200 teeth was abandoned after the effects of the 900-tooth saw. The conclusion of this trial was that the finer teeth produced inferior cotton. It was suggested that using more teeth than in present systems was not practical. The saw teeth quantity per saw blade together with the resultant fibre lengths are shown in Figure 2-9.

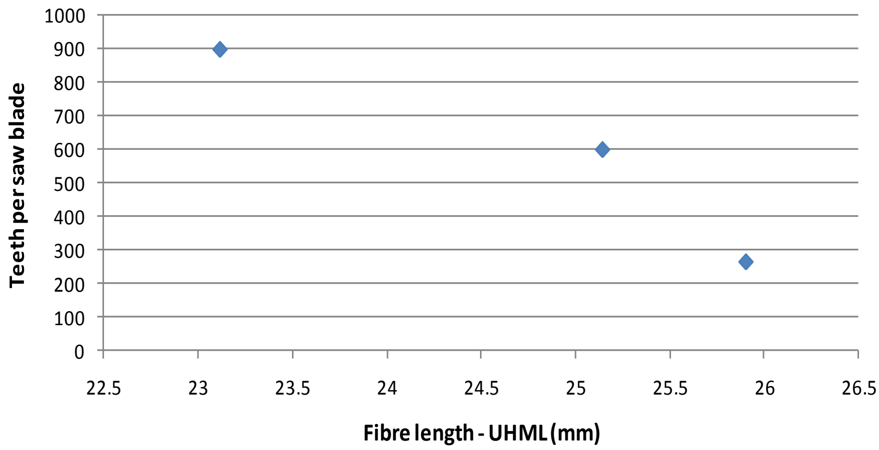


Figure 2-9: Saw blade teeth quantity/UHM

Adapted from USDA (1966) indicating that saw blades with fewer saw teeth allow for the fibre length to be more greatly retained.

2.10.5 Saw diameter

Saw teeth are subjected to continuous wear and become worn as a result of the interaction of the saw teeth with the lint and other matter. Saw teeth sharpening before the 1930s (USDA, 1966) was a regular occurrence. Research at the Stoneville lab indicated that saws should be disposed of once they reduced in diameter by more than approximately 1.6 mm. A trial indicated that a saw blade that had been reduced to a 404.8 mm in diameter was ginning 9 per cent slower than a 406.4 mm diameter saw blade. This equates to 13.85 kg/h for the 404.8 mm diameter saw blade and 15.35 kg/h for the 406.4 mm diameter saw blade.

Columbus and Mangialardi, (USDA, 1966) carried out trials using large diameter saws. These trials indicated that increases in ginning rates caused an increase in seed damage. These trials were performed with saw loadings varying from 13.7 kg to 38.5 kg of seed cotton per saw, per hour. The seed damage was shown to increase with loading and the seed damage ranged from 19 to 33 per cent.

2.10.6 Saw spacing

Gin saw blade spacing research (USDA, 1966) was performed in order to understand the optimum spacing. Trials conducted used saw blade spacing of 19.05 mm and up to 38.1 mm. The research indicated that the wider saw spacing produced greater fibre length and less neps. The conclusion was that the reduction in saw teeth to fibre ratio was responsible for ginning the fibre better, and that current systems are applying too many saw teeth for the ginning action. The amount of lint produced per unit time decreased with the higher saw spacing. However, the wider saw spacing's were ginning at a higher rate (per saw) than that of the close saw spacing. A 30 per cent increase in the amount of saws on the gin stand for the same area increased the ginning rate by only 7 per cent. The effect decreased the ginning rate by 17 per cent per saw blade. The conclusion was that for a linear increase in production per saw, saw spacing must remain at the same distance apart when adding more saw blades. The saw blade lint mass per hour is described in Figure 2-10 for three gin saw spacings.

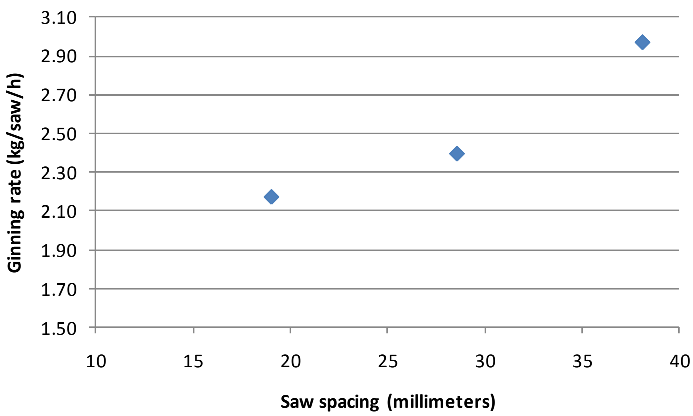


Figure 2-10: Ginning rate and saw blade spacing

Adapted from USDA (1966). The chart indicates that the available fibre for each saw blade increases as the saw blade spacing increases.

Research on the saw blade spacing concluded that saws were operating at low efficiency levels. High speeds photos from earlier USDA research indicated that some saw teeth emerged from the ginning point with no fibres attached. For this action to occur, it would suggest that the seed roll rotation speed would need to be increased to allow for a constant supply of fibre to be available.

2.10.7 Saw shaft rotational speed (rpm)

Research investigating saw rotational speed and the effect on ginning rate was conducted (USDA, 1966). Research concluded that saw speeds had a direct effect on production rates. Results further indicated increasing saw speeds from 700 to 1100 rpm had virtually no effect on fibre qualities. Results reveal the efficiency of the saw blades reduce as rpm of the saw blades increase (USDA, 1966). Saw speeds vs. lint mass results are shown in Figure 2-11.

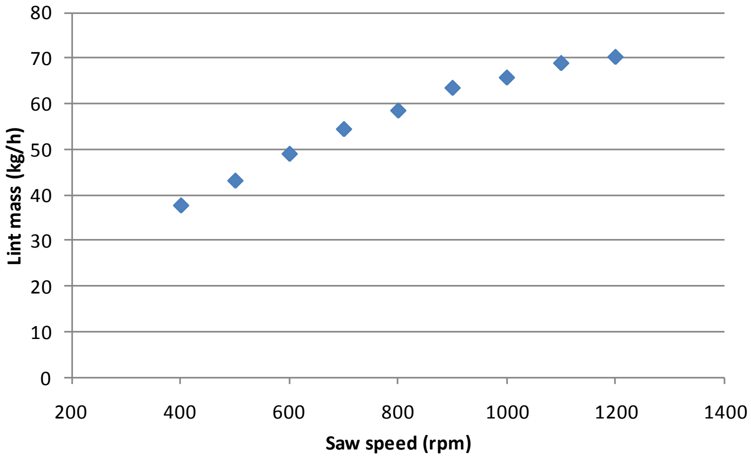


Figure 2-11: Ginning rate and saw shaft rpm

Adapted from USDA (1966) indicates that the rate at which the fibre can be ginned at increases as the saw rotation speed increases. Observations were made by the USDA (1966) that loading the saw blade teeth by means of turning the saw shaft by hand resulted in a per saw unit mass load of three to five times greater mass than achieved during normal production ginning.

2.11 Conclusions

The review of available literature has shown that has been no specific research on the performance of the gin stand using Australian cotton. Further, there is no literature that makes reference to:

1. The uneven spatial distribution of fuzzy seed being expelled from the gin stand.
2. The vertical temporal distribution of seed cotton to the gin stand.
3. There is no evidence of research of uneven seed rolls.
4. Mass production rate effects on fibre qualities using Australian cotton.

Chapter 3
Seed roll and roll box analysis

3.1 Introduction

Within chapter three, research concerning the seed roll and roll box is described, reported and discussed. Initially, three trials were conducted allowing for the correlation between the gin stand motor current draw and the mass output of lint per hour to be calculated. The research that followed from this initial calibration were:

1. Gin stand mass production rates were increased incrementally and the resultant fibre properties analysed.
2. Seed roll surface speed was measured at various mass production rates using purpose built equipment.
3. Seed roll forces acting against the roll box were obtained at various mass production rates using purpose built equipment.
4. Saw blade analysis allowed for friction together with surface finish to be observed. Further to this, the wear properties of individual saw teeth were observed.
5. Motor current draw logged and analysed.

3.2 Methods and materials

3.2.1 Data processing

Electronic data received during the processing trials together with the data collected from the testing of the cotton and the fuzzy seed was analysed using the Microsoft Office Excel program. The Excel program was chosen for data presentation as a result of knowledge of the program together with the compatibility of the electronics being used for data collection.

3.2.2 Statistical analyses

Data analyses were required to be statistically proven whether the variation, if any, was chance or real. To achieve this, a statistics method was required. The statistics method chosen for the data analyses was the two-tailed T test. The T test was originally devised for statistically testing small samples of data. The two tailed T test was chosen over the single tailed T test as it was not known on which side the results would fall. The two-tailed T test is useful in comparing two measurements and allows for robust data analyses, as the error as a result of the small sample size is reduced. Probability results from the T test indicate whether the sample differences are “chance” or “significantly different”. The probability result must be 0.05 or less to be considered significantly different. If the value is greater than 0.05 then the value is considered to be in a range of normal variation. The reasoning for the five per cent level is that this level is a conventional accepted level.

3.2.3 Motor current logging

The relationship between the motor current and the mass output of lint was not known. A motor current analysis was required for production rate conversion. To allow for the collection of gin stand motor current draw, a data logger (Onset Hobo data logger U12-006) together with a current clamp (Onset CTV-D transformer, 0-200 amp AC) was used. The meter was connected to one of the three phases supplying the motor.

To understand the relationship between motor amps and mass throughput, a correlation between the two was drawn. Lint mass production values at three motor current draw levels are shown in Figure 3-1.

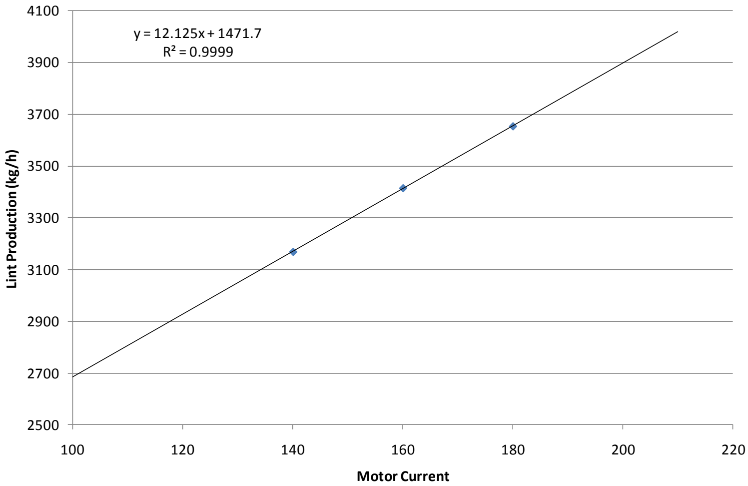


Figure 3-1: Motor current and lint production conversion chart

Results obtained through the use of the gin stand current logger together with the fuzzy seed weights over a one-minute period have allowed for the mass production rate of the gin stand to be calculated.

3.2.4 Methods for determining quality

Collected lint and fuzzy seed were tested for quality parameters. Lint samples were tested for length (mm), uniformity, micronaire and short fibre content using an Uster Technologies 1000 High Volume Instrument (HVI). HVI and classing results were the averages of two replicate tests per experimental sample. Lint was tested for neps content (number/ gram) using an Uster Advanced Fibre Information System (AFIS–PRO) instrument. Five test replicates were conducted per experimental sample.

The residual lint properties are required in order to determine whether the seeds are being more thoroughly ginned at higher or lower mass production rates. Results indicating seed damage are used to determine whether the seeds are being subjected to a harsher environment and in turn creating more damage to seeds at higher mass production rates.

For seed, the amount of residual lint left on the seed was determined as a percentage of total weight. This was conducted at Cottonseed Distributors, Wee Waa, New South Wales. The test method used at CSD is detailed on a CSD report number: CSD/QA/L/W02.

3.2.5 Mass production rate research

Gin stand mass production rate investigation into fibre qualities using long fine Australian cotton was performed. These trials were performed using a Continental Eagle 161 gin stand. The trials involved ginning the seed cotton at increments of mass production rates from 3150 kg/h to 3800 kg/h. Trials conducted involved the simultaneous use of two identical gin stands allowing for a constant mass output (control gin stand) and incremented mass output (experimental gin stand) to be measured. Samples were collected from the control and experimental gin stand simultaneously. This research was performed at the Auscott Ltd's gin nine, located near Narrabri, New South Wales, Australia. The cotton variety used for the research trials was CSX323BRF C1 and was sourced from a single grower.

Table 3-1: Mass production rate research trial table

Trial	Mass production rate kg/h	Collection points	Repititions	Tests conducted
1	3 200 > 3 500	A, B, C, D	5	HVI, R/L
2	3 200 > 3 800	A, B, C, D	5	HVI, R/L

Table 3-1 lists the mass production rate range at which Trials 1 and 2 were performed. Trial 1 had four mass production rates that ranged between 3200 and 3500 kg output of lint per hour. Table 3-1 indicates lint collection points, repetitions and tests conducted on the samples.

The collection zones were, "A" – after the gin stand and prior to the super jet.

"B" - After the first lint cleaner and prior to the second lint cleaner "C" – After the second lint cleaner and prior to lint amalgamation with other lint cleaners and "D" – Fuzzy seed residual lint, HVI: (high volume instrument), R/L: (residual lint).

3.2.6 Seed roll surface speed

The seed roll within the roll box rotates continually during the ginning process. Measuring the seed roll surface speed required a tachometer (model Hengstler Tico 731), digital sensor (model number QL-1808NA) and a tachometer star wheel model GR19 that was 40 mm in diameter and further contained a metal actuator. The tachometer was positioned in the void between the roll box door opening. Roll box door operation was not affected by the placement of the tachometer. The tachometer positioning was achieved at distances greater than 300 mm from the roll box end to avoid any possible interference from the roll box ends. The seed roll tachometer is shown Figure 3-2.

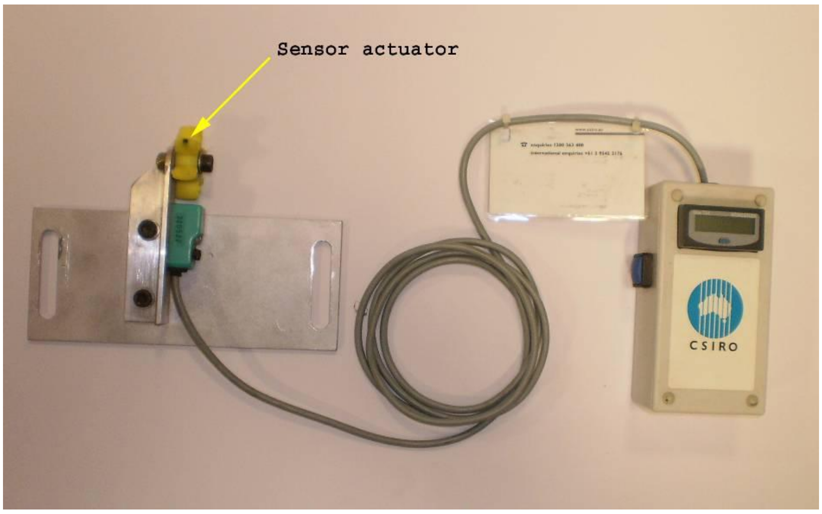


Figure 3-2: Seed roll tachometer

Figure 3-2 shows the tachometer style that was built for the purpose of measuring the seed roll surface speed. The tachometer system relies upon the star wheel making contact with the seed roll. The rpm of the star wheel is displayed on the hand held device.

3.2.7 Seed roll force

The seed roll within the roll box is subjected to forces resulting from seed roll mass. The greater the mass weight of seed cotton and fuzzy seed within the confined space of the seed roll, the greater the forces applied to the roll box. Measuring the force applied to the roll box skin by the mass of seed cotton, allowed for forces at various mass production rates to be recorded. Force measurements within the roll box allow for seed roll mass fluctuation to be observed and will further back-up data received through the use of the DAVS system.

The equipment required for the seed roll force analyses consisted of a load cell (Flexiforce model A201, 4.4 N), a backing plate and a soft outer cover exposed to the seed and seed cotton. The seed roll force sensor has been designed to fit within Continental Eagle 161 gin stands. The roll box door closing is not affected by the placement of the force sensor. Sensor plates were located at a height approximately at the midpoint of the seed roll.

Three variations of the sensor were built and trialled to obtain data. The design of the three sensor plates is shown in Figures 3-6, 3-7 and 3-8. The first design failed as a result of the force sensor stainless steel cover. The stainless steel cover masked much of the force being applied to the sensor. The stainless steel cover further allowed for the forces applied to the entire width of the sheet to be seen by the sensor. The second design of the force sensor plate failed due to the thickness of the metal that was positioned on either side of the sensor to prevent the sensor from being dislodged from metal base plate. The third sensor was a success as the metal on each side of the sensor was the same thickness as the sensor. There was also a slight gap between the sensor and the metal protection strip.

Calibration of the load cells was required and was achieved at twelve weight ranges. The method used to calibrate the sensors using a mass of known quantity was achieved through the use of scales and a load arrangement as shown in Figure 3-3.

Figure 3-3: Seed roll

The sensor was placed on the scales and zeroed. The load applied to the force sensor was precisely measured. The spring arrangement and spring “stop” did not make contact with the scales.

Calibration schematic

Schematic of the method used to calibrate the force sensors is as shown in Figure 3-4.

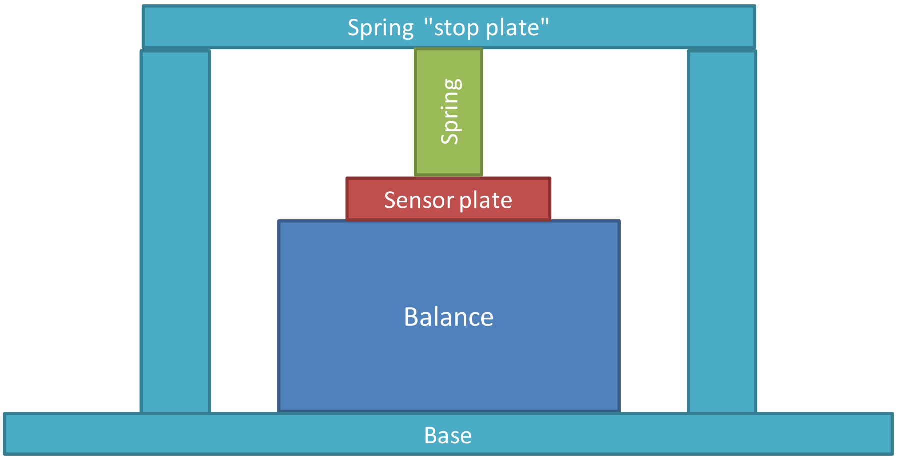


Figure 3-4: Force sensor calibration schematic

Schematic configuration of the calibration method used for the force sensors illustrates that the surrounding framework does not influence the load presented to the force sensor.

The seed roll force sensor required attachment to the roll box allowing for contact with the seed cotton mass. The working position of the force sensor is shown in Figure 3-5.

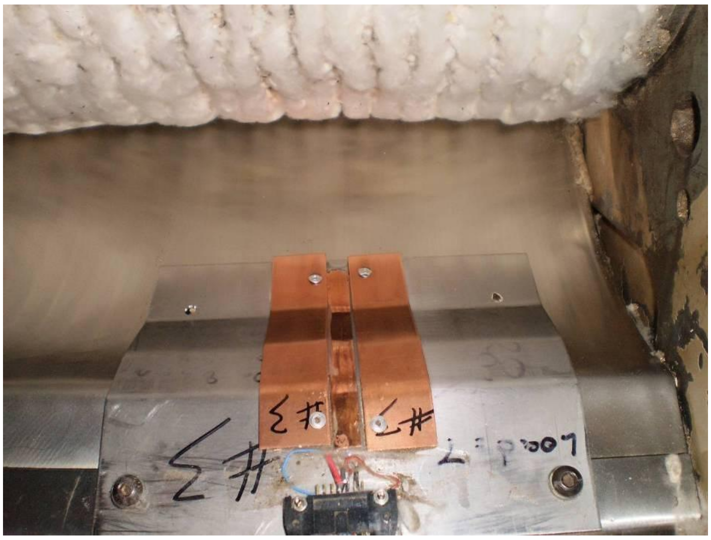


Figure 3-5: Seed roll force sensor positioned within roll box

The seed roll force sensor shown is number three of three. The sensor locations within the seed roll were left, right and middle. Note that the copper central plate is showing signs of wear as a result of prolonged exposure to seed cotton.

Figure 3-6 illustrates the third force sensor plate design.

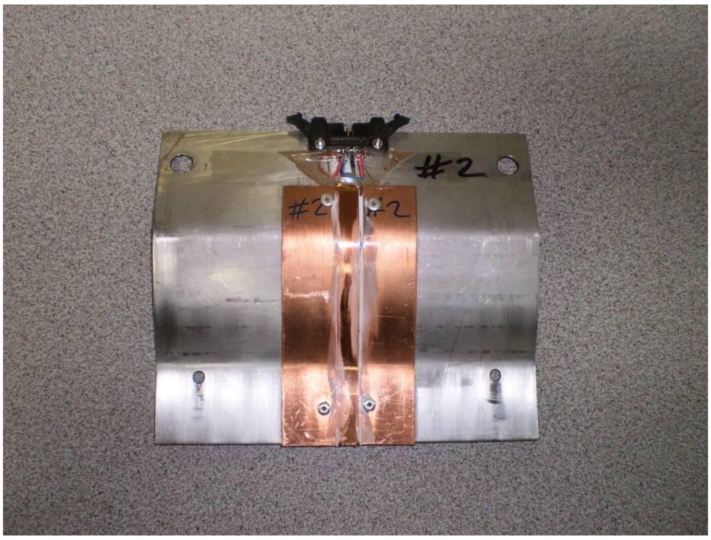


Figure 3-6: Seed roll force sensor Mk3

The seed roll force sensor Mk 3 required the use of copper segments on either side of the sensor. The copper strip thickness was matched to the thickness of the sensor.

Figure 3-7 illustrates the second force sensor plate design.

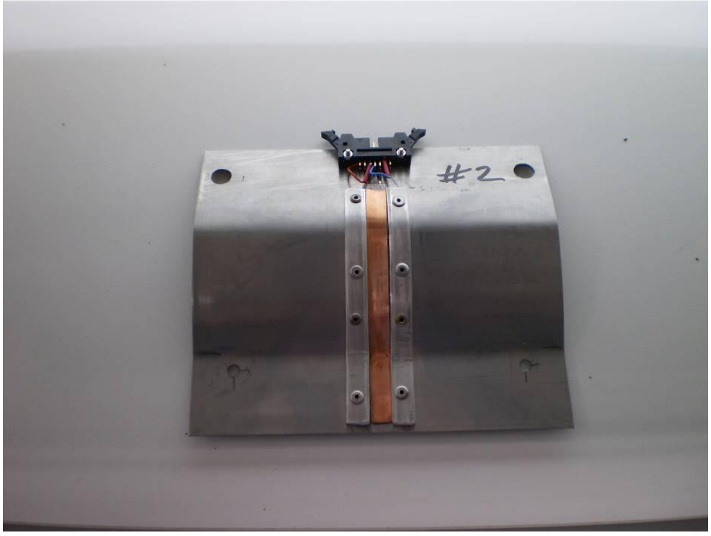


Figure 3-7: Seed roll force sensor Mk2

The seed roll force sensor Mk2 contained aluminium segments on each side of the sensor. The strips were approximately 1.5 mm higher than the sensor pad.

Figure 3-8 illustrates the first force sensor plate design.

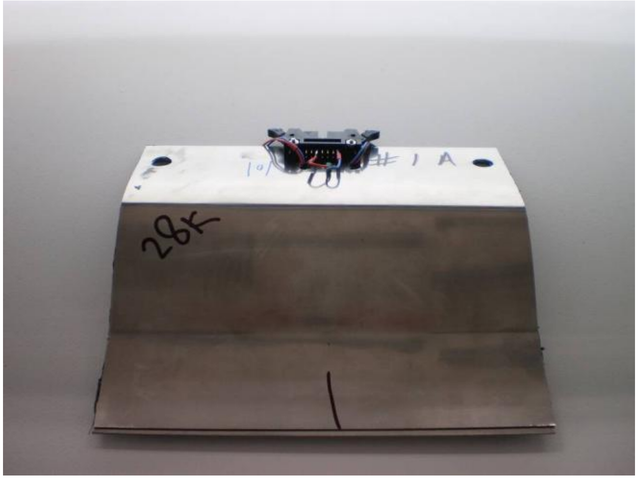


Figure 3-8: Seed roll force sensor Mk1

Seed roll force sensor Mk1 encased the sensor in stainless steel. The outer exposed section of the plate to the seed cotton used a stainless steel shim of 0.15 mm thickness.

3.2.8 Fuzzy seed sample collection

Fuzzy seed samples were required to be collected. The fuzzy seed collection zones on the gin stand are represented on the schematic in Figure 3-9. Collecting individual fuzzy seed samples from across the breast of the gin stand allowed for precise analyses of the gin stand fuzzy seed output.

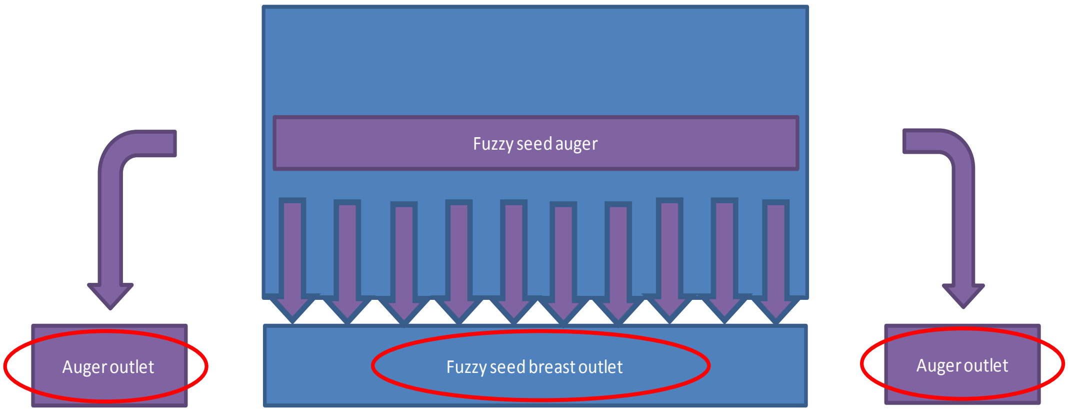


Figure 3-9: Fuzzy seed expulsion zones schematic

Fuzzy seed was collected from beneath the gin breast and from the seed tube discharge chutes. This allowed for samples to be collected and analysed. Samples for analyses were collected at different mass production rates.

The gin stand breast fuzzy seed exit is located along the lower section of the gin stand. Two methods of collection were required to collect fuzzy seed from the gin stand breast outlet. The first method involved collecting fuzzy seed from a approximately 200 mm wide centrally located point of the breast in-line with the collection point of seed cotton at the apron. Approximately 200 g of seed was collected per sample. The second collection method relied on collecting fuzzy seed from the entire width of the gin stand. To do this, the stand was equally divided into 12 segments with each being 200 mm in width. Sampling occurred at each zone for a 30-second period using a custom made collecting device as shown in Figure 3-10. Fuzzy seed collection time is limited as a result of the accumulation of fuzzy seed mass. Collection of the seed was replicated three times per trial.

The profile of the collection tray in Figure 3-10 was designed to enable the gin stand breast to open without subjecting tray and gin stand to damage. The tray was further made adjustable in height allowing for height change between stands to be overcome.

Figure 3-10: Fuzzy seed collection tray

The 200 mm wide seed collection tray is shown positioned in front of the gin stand prior to entering the fuzzy seed expulsion zone at the base of the gin stand. (Not shown is the fuzzy seed collection box and tray scraper).

Fuzzy seed further exits the ginning process via a seed tube auger allowing for seed discharge from either end of the gin stand. To allow for sample collection to occur, apparatus was required. Fuzzy seed collection occurred from each of these two outlets via a 50 mm tube. The fuzzy seed sampling method for the auger output is shown in Figure 3-11.

Figure 3-11: Seed tube fuzzy seed sample collection

The seed tube sample collection is carried out from under the gin stand prior to the seed entering the final seed auger at which point the fuzzy seed migrates with that of other gin stands. The collection point used ensures that the only seed that is collected using this device is seed that has been removed from the seed roll by the seed auger.

The seed collection within the sampling tube is shown in Figure 3-12.

Figure 3-12: Collected fuzzy seed from the seed tube

The fuzzy seed sample is collected and contained within the collection vessel ready for bagging. The collar attached to the tube allows for a constant seed tube insertion depth into the path of the fuzzy seed.

3.2.9 Lint collection

Located on the lint cleaners are openings that allow for a lint sample to be collected. Lint sample collection was required during trials so that the effect of the treatments could be tested for their fibre properties. Ginned lint was sampled after the lint had been processed through the second lint cleaner. See Figure 3-13.

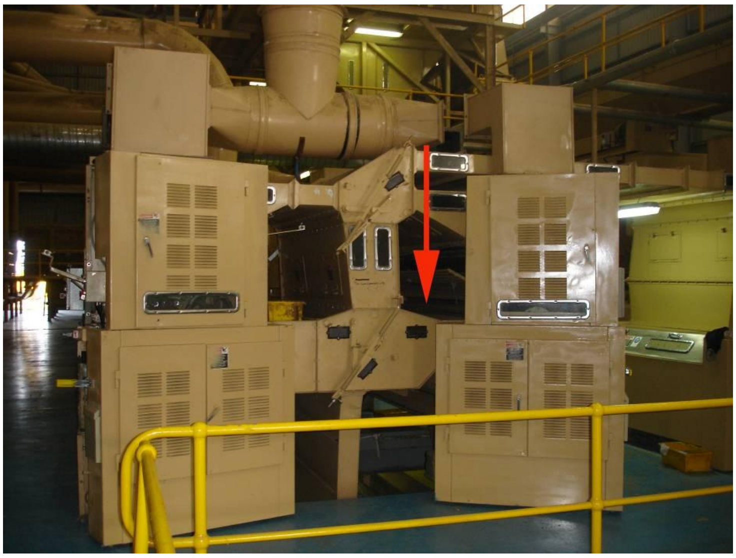


Figure 3-13: Lint sample collection availability after the first and second lint cleaners

3.2.10 Saw blade friction

Saw blades wear due to constant friction during their working cycle. The wear cycle depends on the leaf content of the seed cotton together with foreign matter such as dirt, the mass throughput that the blades are subjected to and the alignment or trueness of the saw blade on the saw shaft. Even when blades are optimally aligned, some contact will always occur between the blades and the rib inserts due to the trueness of the saw blade and further as a result of seeds lodged between the saw and the rib. This contact causes frictional wear and the blade is further polished through this action and further through contact with the lint. These polished surfaces do not transfer the same amount of friction from the saw blade to the seed roll potentially resulting in reduced seed roll rotation.

To gain an understanding of the saw blade properties, comparative tests were conducted to determine the frictional properties of the saw blade sides together with tests to determine the depth of the surface finish of the saw blade sides. Saw blade interaction with the lint and seed within the roll box creates friction. In order to determine the frictional properties of the saw blade in a worn and new state, a test method was developed. Saw blades that had been considered “worn out” by the gin operator were collected for testing. The saw blades were cut into a manageable shape (approximately 150 mm x 100 mm). Saw blade testing was carried out by the CSIRO NATA approved test facility. A friction measurement for each of the samples was achieved through the use of the Instron tensile tester (Model 1122). The test procedure was non-standard and involved the placement of a known mass on top of the cotton fabric sample as placed on the saw blade in the desired area. The fabric block was connected to the Instron and treated to lateral load to allow for the fabric block to move. A schematic of the procedure is shown in Figure 3-14.

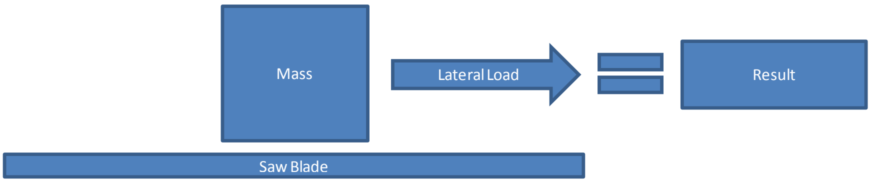


Figure 3-14: Configuration of saw blade test as used for friction analyses

Friction tests were performed on the worn section of the blade and further on the untouched section of the blade, which is closer to the centre of the blade. It was not possible to measure friction values, however, the force required to overcome the friction variation was observed between the new blade and the old blade.

3.2.11 Saw blade surface finish

New saw blade sides contain a ground finish as a result of the steel manufacturing process. When the steel is produced, it is subjected to surface grinding to ensure a high quality steel of uniform finish and thickness. As the saw blade wears, the ground finish that is present on the saw blade sides is removed and the metal becomes polished. The saw blade surface properties were analysed. A surface roughness meter (model TR110 TIME High Technology Ltd) was used to analyse the saw blade surface finish. The worn and non-worn sections of a saw blade were tested for surface roughness (Dr Delphine Cantin–CSIRO, 2010). The testing occurred at 5 mm increments (non-radial). The surface roughness meter displayed the surface finish as a mean surface finish in microns.

3.3 Results and analyses

The results and analyses of the trials carried out in chapter three are discussed in this section and follow immediately after each result. The topic areas are fibre properties, residual lint, seed roll surface speeds, seed roll force, motor current, saw blade analyses and followed by a conclusion.

Mass production rate trials conducted were listed as trial one and two. Trial One consisted of a mass production rate between 3200 and 3500 kg/h with a mean fibre length of 31.92 mm ($^{40}/_{32}$ of an inch). Trial two consisted of mass production rates between 3200 and 3800 kg/h with a mean fibre length of 31.67 mm ($^{39}/_{32}$ of an inch). The mass flow rate of seed cotton into the gin stand was affecting the amount of fibre being left on the ginned seed (residual lint). The reduction in seed roll force increased residual lint and thus lowered gin turn out. A reduced production rate increases the mechanical interactions between the saw teeth and the seed roll. With increased seed roll density there will be a greater saw blade seed roll friction effect, in turn allowing for an increase in the seed roll rotational speed. This increase in rotational speed allows for a decrease in saw teeth to fibre interactions. Saw blade wear allows for the blades to become polished and smooth and this is likely to deliver a lesser frictional influence on the turning seed roll. The saw blades are further analysed in "Saw blade analyses" in chapter 3.10.6.

Mass production research and resultant fuzzy seed collection led to the discovery of an uneven lateral seed discharge from the gin stand. The discovery of the uneven spatial distribution within the roll box was achieved through the design, manufacture and use of equipment specifically for the gin stand.

Research accomplished at varied mass production rates has exposed the seed roll dynamics and resultant fibre and seed qualities. The mass production rate trials allow for optimum processing efficiency and quality knowledge. Research trials were conducted as described in the methods and materials section of Chapter three. Research results of the cotton samples collected during mass production rate trials, reveal leaf grades, fibre length, uniformity, short fibre content and micronaire.

3.3.1 Effect on leaf grade

Leaf grade results of both the static 3600 kg/h mass output and the incremented mass output are described in Figures 3-15 and 3-16.

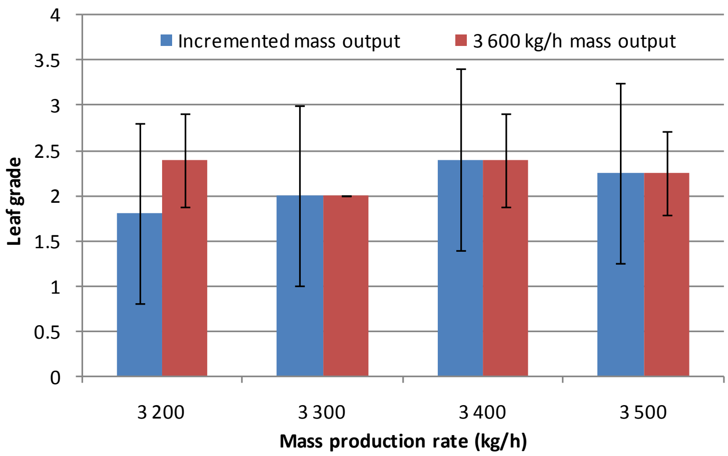


Figure 3-15: T1 Leaf grade results for static and mass production rates

Sample analyses representing leaf grade statistically state no increase in leaf grade occurred as a result of an increase in production rate. The observation has occurred for both trial one and two. Leaf grade values ranged from 1.8 and up to 2.4. It was expected that leaf grades would increase with the mass production rate, but did not occur. Leaf grades have been shown to increase with the rise of mass production rates. This has been shown by research by

Mangialardi, (1988). The possible explanation for this is the initial cleanliness of the cotton. The error bar values are means plus and minus standard deviation for five replicate observations. A paired two sample T test was conducted to compare the control gin (3600 kg/h mass output) with each respective treatment gin; probability results are reported on the respective bars in Tables 3-2 and 3-3.

Table 3-2: T1 T test results for leaf grades of static and mass production rates

Static production rate	Mass production rate	P(T<=t) two tail
3600	3200	0.21
3600	3300	0.40
3600	3400	0.39
3600	3500	1.00

Statistical results show that the variations were within the normal range. Probability values need to be 0.05 or less to be significantly different. Therefore, the effect on leaf grade at increased mass production rates is not statistically different.

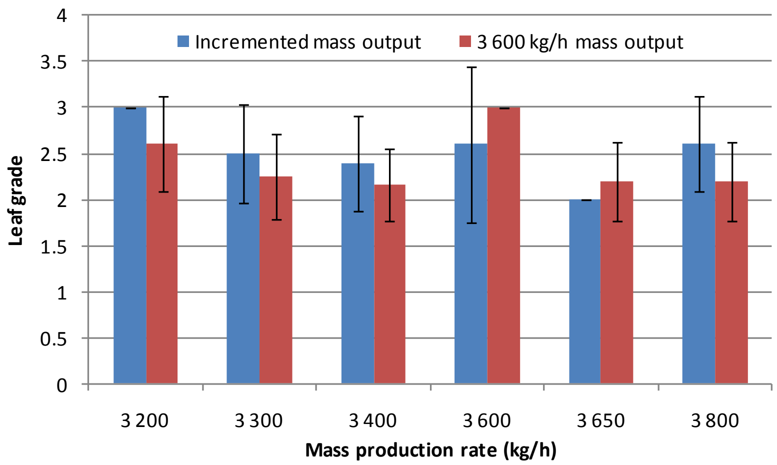


Figure 3-16: T2 Leaf grade results for static and mass production rates

Leaf grade results of the mass production rate trial show no change in the leaf grade. Previous research has indicated that the leaf grade increases with the increase of the mass production rate. The possible cause of the static leaf grade observed during this trial may be a result of the initial quality of the lint presented for ginning. A cotton grower renowned for quality supplied the lint. The cotton grower further has extensive knowledge of picking cotton and does so using their own equipment and further picks the cotton when they believe the crop to be in optimum condition.

Table 3-3: T2 T test results for leaf grades of static and mass production rates

Static production rate	Mass production rate	P(T<=t) two-tail
3 600	3 200	0.18
3 600	3 300	0.64
3 600	3 400	0.37
3 600	3 600	0.64
3 600	3 650	0.37
3 600	3 800	0.18

Statistical results show that the probability values are within the range of normal variation. For a difference to exist, the values would need to be 0.05 or less. Therefore, the increase in mass production was not statistically different for leaf grade.

3.3.2 Effect on fibre length

Trials conducted allowed for the fibre length of the lint to be measured.

Fibre length results of both static 3600 kg/h mass output and the incremented mass output are described in Figures 3-17 and 3-18.

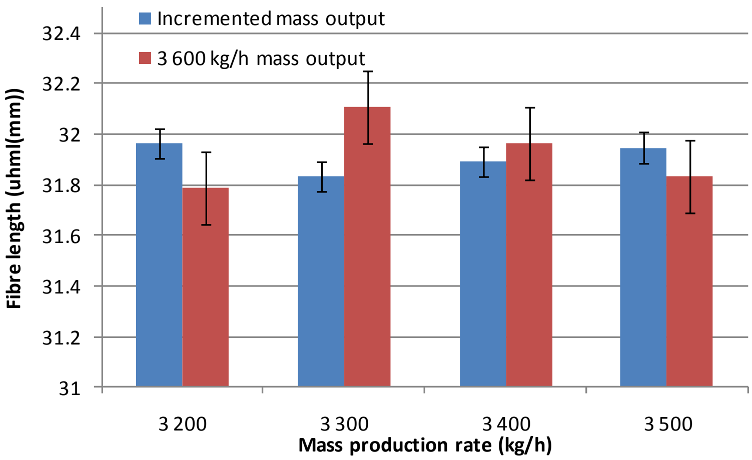


Figure 3-17: T1 UHML results for static and mass production rates

Sample analyses representing fibre length (UHML) statistically state that no degradation of fibre length occurred as a result of an increase in production rate. The observations of the fibre length of both the static 3600 kg/h mass output and the incremented mass output are as described in Figures 3-17 and 3-18. Trial one fibre length ranged from approximately 31.75 mm up to approximately 32.11 mm UHML, while trial two ranged from approximately 31.24 mm to approximately 32.00 mm UHML. Trial one observations show no change in fibre length as a result of an increase in mass production rate. Trial two length results indicate that the fibre length is declining with time. This is further witnessed with the increase in mass output. The results indicate that this decline in UHML for the incremented mass output is a result of an unknown event prior to the gin stand. Error bar values are means plus and minus standard deviation for five replicate observations.

A paired two sample T test was conducted to compare the control gin (3600 kg/h mass output) with each respective treatment gin; probability results are reported on the respective bars in Tables 3-4 and 3-5.

Table 3-4: T1 T test results for UHML of static and mass production rates

Static production rate	Mass production rate	P(T<=t) two tail
3 600	3 200	0.64
3 600	3 300	0.05
3 600	3 400	0.29
3 600	3 500	0.58

Statistical results for the UHML show that three of the four probability values are within the range of normal variation. For a difference to exist, the values would need to be 0.05 or less. Therefore, the increase in mass production has had no effect on the leaf grade. The mass production rate of 3300 kg/h is shown to be statistically different. The 3300 mass production rate may be at an ideal mass production rate for this particular lint batch. That is, the processing rate was precisely suited to the particular cotton at this given time.

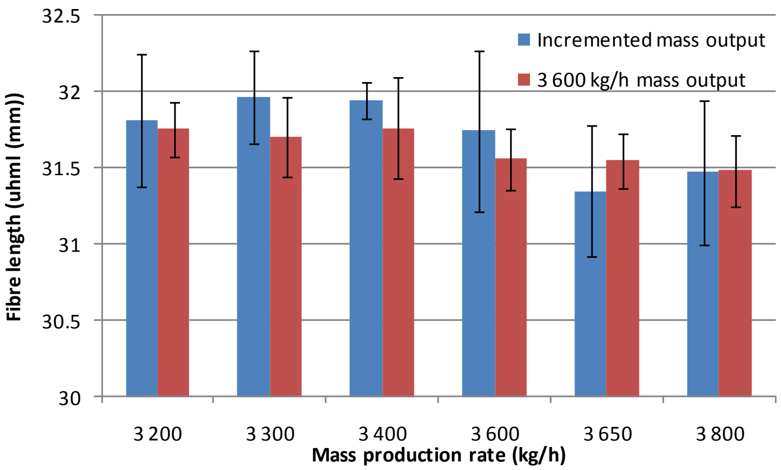


Figure 3-18: T2 UHML results for static and mass production rates

Results of each of the two trials show a decrease in fibre length. The decrease in fibre length was not due to the gin stand as the control 3600 kg/h mass output also produced a trend of a reduced UHML during the same time period.

Table 3-5: T2 T test results for the UHML of static and mass production rates

Static production rate	Mass production rate	P(T<=t) two-tail
3 600	3 200	0.84
3 600	3 300	0.33
3 600	3 400	0.46
3 600	3 600	0.41
3 600	3 650	0.36
3 600	3 800	0.96

Statistical results for the UHML show that the probability values are within the range of normal variation. For a difference to exist, the values would need to be 0.05 or less. Therefore, the increase in mass production has had no statistically significant effect on the leaf grade.

3.3.3 Effect on uniformity

Trials conducted allowed for the uniformity of the lint to be measured.

Fibre uniformity results of both static 3600 kg/h mass output and the incremented mass output are described in Figures 3-19 and 3-20.

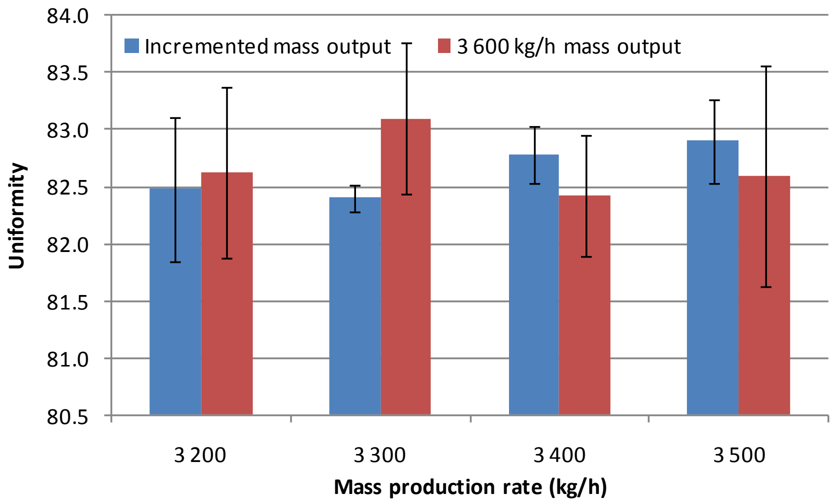


Figure 3-19: T1 uniformity results for static and mass production rates

Sample analyses representing uniformity statistically state no change in uniformity occurred as a result of an increase in production rate. The results of the uniformity of both the static 3600 kg/h mass output and the incremented mass output are as described in Figures 3-19 and 3-20. Both trial one and two state a static trend. Error bar values are means plus and minus standard deviation for five replicate observations.

A paired two sample T test was conducted to compare the control gin (3600 kg/h mass output) with each respective treatment gin; probability results are reported on the respective bars in Tables 3-6 and 3-7.

Table 3-6: T1 T test results for uniformity of static and mass production rates

Static production rate	Mass production rate	P(T<=t) two tail
3 600	3 200	0.81
3 600	3 300	0.12
3 600	3 400	0.33
3 600	3 500	0.67

Stati stical results for the uniformity of trial one show that the probability values are within the range of normal variation. For a difference to exist, the values would need to be 0.05 or less. Therefore, the increase in mass production has had no statistically different effect on the uniformity.

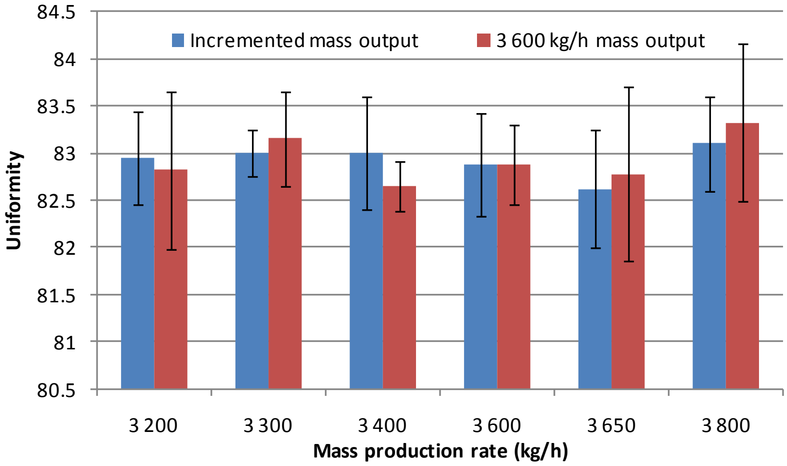


Figure 3-20: T2 uniformity results for static and mass production rates

The uniformity of the 3600 mass production trial and the incremented mass production trial has not changed. Therefore, the increase in the mass production rate of lint from 3200 kg/h to 3800 kg/h does not affect the uniformity of the fibre.

Table 3-7: T2 T test results for uniformity of static and mass production rates

Static production rate	Mass production rate	P(T<=t) two-tail
3 600	3 200	0.61
3 600	3 300	0.65
3 600	3 400	0.35
3 600	3 600	0.80
3 600	3 650	0.74
3 600	3 800	0.58

Statistical results for the uniformity of trial two show that the probability values are within the range of normal variation. For a difference to exist, the values would need to be 0.05 or less. Therefore, the increase in mass production has had no statistically different effect on the uniformity.

3.3.4 Effect on short fibre content

Trials allowed for the short fibre index of the lint to be measured. Short fibre index results of both static 3600 kg/h mass output and the incremented mass output are described in Figures 3-21 and 3-22.

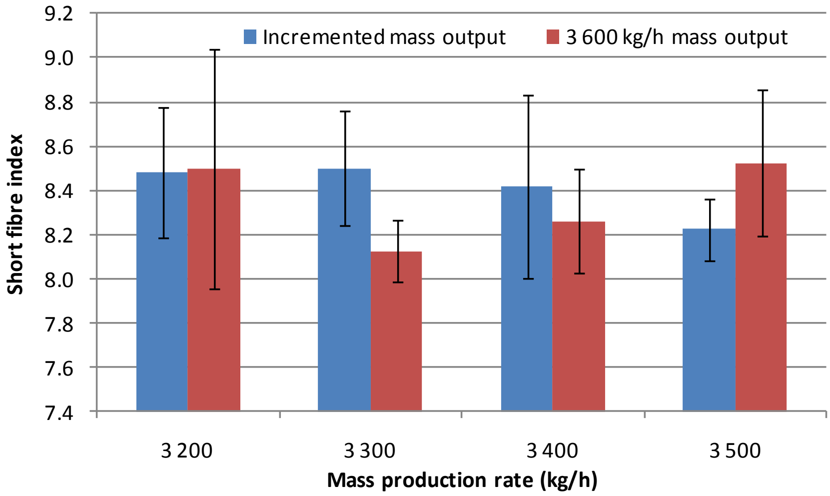


Figure 3-21: T1 short fibre content results for static and mass production rates

Sample analyses representing short fibre content statistically state no increase in short fibre occurred as a result of an increase in production rate. Although there is a visual appearance that the incremented 3200 to 3500 mass production rate results show a decline in the short fibre content. The favourable results observed are further highlighted through research result discussion regarding differential ginning. The results of the short fibre of both the static 3600 kg/h mass output and the incremented mass output are as described in Figures 3-21 and 3-22. Error bar values are means plus and minus standard deviation for five replicate observations. A paired two sample T test was conducted to compare the control gin

(3600 kg/h mass output) with each respective treatment gin; probability results are reported on the respective bars in Tables 3-8 and 3-9.

Table 3-8: T1 T test results for short fibre content of static and mass production rates

Static production rate	Mass production rate	P(T<=t) two tail
3 600	3 200	0.96
3 600	3 300	0.03
3 600	3 400	0.04
3 600	3 500	0.07

Statistical results for the SFC show that two of the four probability values are within the range of normal variation. For a difference to exist, the values would need to be 0.05 or less. The mass production rates of 3300 kg/h and 3400 kg/h is shown to be statistically different. These two mass production rates may be within an ideal mass production rate for this particular lint batch. That is, the production rate may have suited the cotton batch being processed at that particular time.

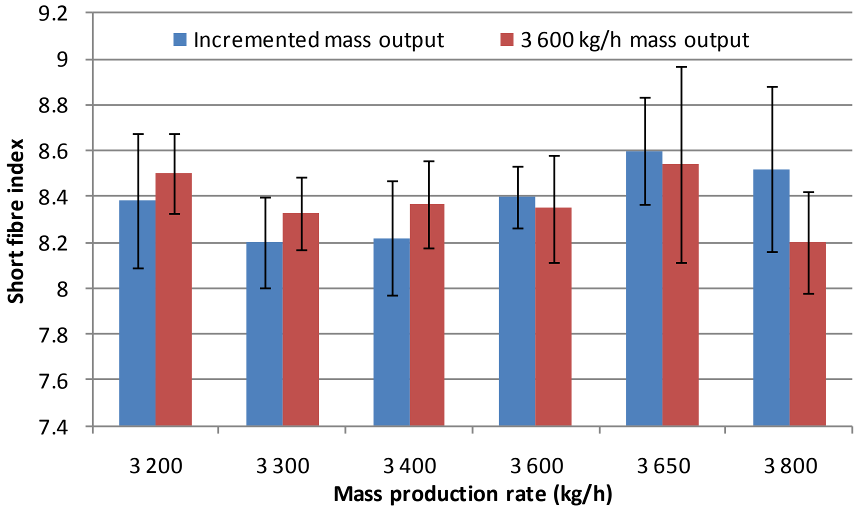


Figure 3-22: T2 short fibre content results for static and mass production rates

The short fibre index results show statistically that there is no change in the short fibre content for both the 3200 to 3800 mass production rate trial and the 3600 mass output trial. These results show that the SFC is not affected by the increase in mass production rate from 3200 kg/h to 3800 kg/h.

Table 3-9: T2 T test results for short fibre content of static and mass production rates

Static production rate	Mass production rate	P(T<=t) two-tail
3 600	3 200	0.24
3 600	3 300	0.19
3 600	3 400	0.35
3 600	3 600	1.00
3 600	3 650	0.82
3 600	3 800	0.13

Statistical results for the SFC of trial two show that the probability values are within the range of normal variation. For a difference to exist, the values would need to be 0.05 or less. Therefore, the increase in mass production has had no statistically different effect on the SFC.

3.3.5 Effect on micronaire

Sample of the lint from both the incremented and 3600 kg/h mass production trials have been analysed. The results are shown in Figures 3-23 and 3-24.

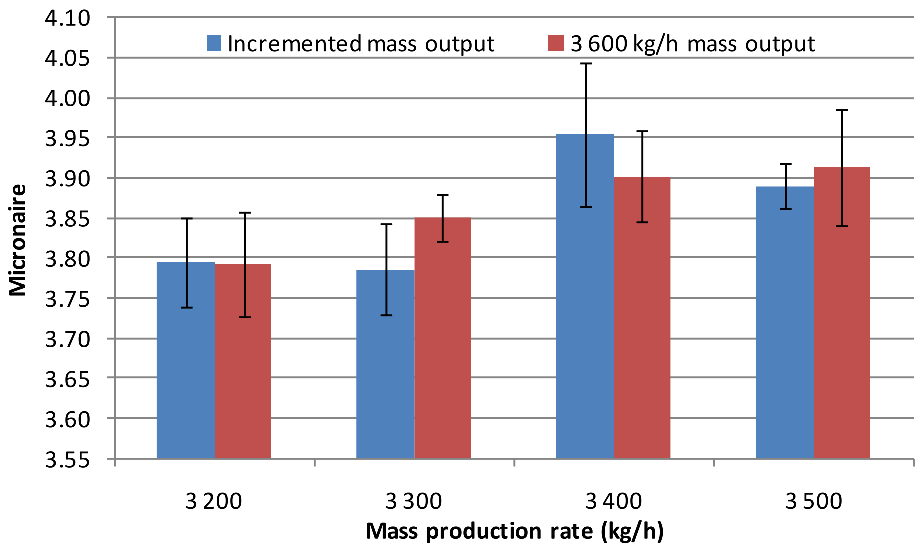


Figure 3-23: T1 micronaire results for static and mass production rates

Sample analyses representing micronaire statistically state no increase in micronaire occurred as a result of an increase in production rate. The values for the micronaire increase by approximately 0.1 for the duration of the trial. The values increase with both 3200–3500 mass production rate and the 3600 mass production rate trials. The production rate effect should be eliminated from the equation and only the 3600 kg/h mass output trial should be considered. The micronaire value of the 3600 kg/h trial has increased either as a result of the incoming cotton characteristic change or as a result of the processing conditions during the trial. Results obtained during research carried out by Griffin et al. (1960) further indicate that the further the seed is ginned, the higher the micronaire. Increased fibre removal occurs as a result of increased density within the seed roll. This is further observed during the increased seed roll density during varied mass production rates of lint. The values are means plus and minus standard deviation for 5 replicate observations. A paired two sample T test was conducted to compare the control gin (3600 kg/h mass output) with each respective treatment gin; probability results are reported on the respective bars in Tables 3-10 and 3-11.

Table 3-10: T1 T test results for micronaire of static and mass production rates

Static production rate	Mass production rate	P(T<=t) two tail
3 600	3 200	0.95
3 600	3 300	0.12
3 600	3 400	0.32
3 600	3 500	0.67

Statistical analyses of the micronaire values show that there is no change in the micronaire as a result of the change in mass production rates for this batch of lint. For a significant difference to exist, the probability value would need to be 0.05 or less. The probability values are within the range of normal variation and show no statistical difference.

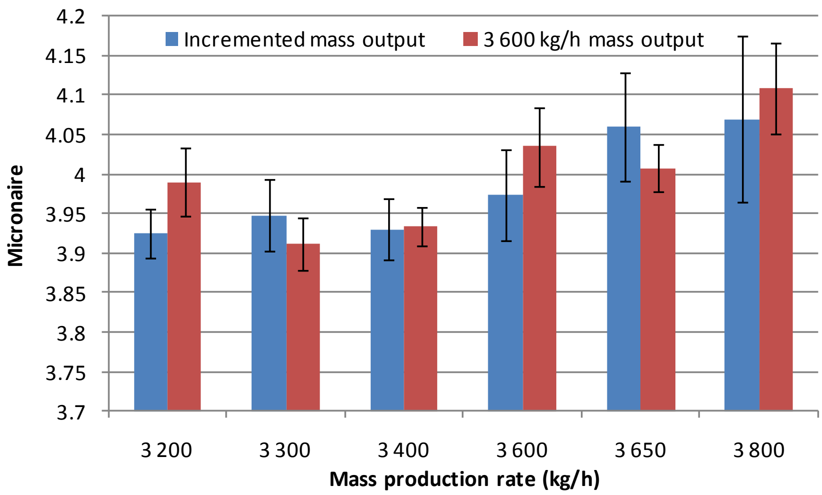


Figure 3-24: T2 micronaire results for static and mass production rates

Table 3-11: T2 T test results for micronaire of static and mass production rates

Static production rate	Mass production rate	P(T<=t) two-tail
3 600	3 200	0.05
3 600	3 300	0.06
3 600	3 400	0.51
3 600	3 600	0.23
3 600	3 650	0.21
3 600	3 800	0.53

Statistical results for the micronaire of trial two show that the probability values are within the range of normal variation for five of the six values. For a difference to exist, the values would need to be 0.05 or less. The mass production rate of 3200 kg/h shows a reduction in the micronaire when compared to the mass production rate of 3600 kg/h. The likely cause for this occurrence is that the reduced mass production rate produces higher levels of residual lint on the seed. The shorter fibres being left on the seed are of a higher micronaire, therefore, reducing the micronaire of the collected lint.

3.3.6 Effect on nep

A nep is the entanglement of cotton fibres. A nep contains on average 16 fibres (VanderSluijs, 1999). Neps can be present in the lint as a result of immature fibres and through mechanical interaction and fibre-to-fibre friction. Neps are created more readily in long fine cotton. Nep is further introduced to the lint at the gin stand. Neps are shown to increase with the use of dull saw blades when compared to sharp saw blades (VanderSluijs, 1999). However, when saw blades become dull, the gin operator is forced to increase seed roll density by means of seed finger adjustment to maximise the gin stand mass production rate (W Towns 2010, pers. comm.). Australian cotton is known for its elevated levels of nep (Gordon et.al 2006). Nep is undesirable to spinners and is considered waste as it cannot be processed into yarn. As well as nep, there is also seed coat nep present within the lint. Seed coat neps are small seed fragments of the outer shell of the cottonseed. These fragments further contain a quantity of attached fibres. Seed coat neps are very difficult to remove. Nep production at three production rates is shown in Figure 3-25.

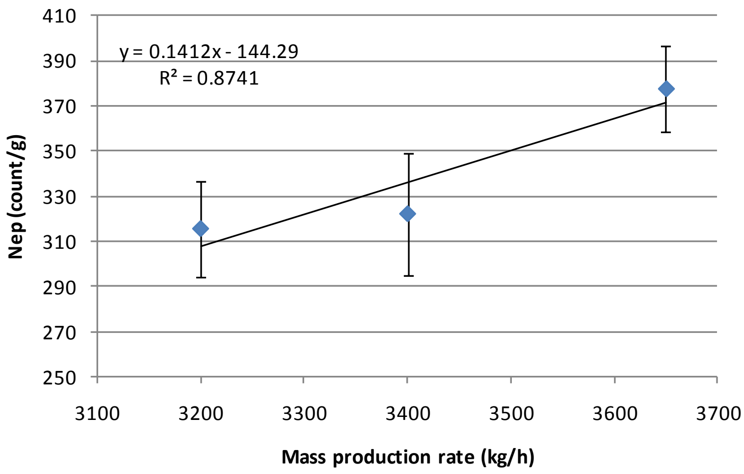


Figure 3-25: Nep formation levels at three mass production rates

Nep generation results obtained through the mass production research trial have shown to increase as the production rate increases. Nep values increased by more than 20 per cent when compared to that of the 3200 kg/h mass output ginning rate. During the increase in production rates, the seed roll increases in rotational speed. The ratio of saw teeth to fibres reduces as the production rate increases. Forces within the roll box increase as a result of the higher production rates. It is hypothesised that the increase of nep generation within the gin stand at increasing production rates is a result of the seed roll density and fibre to fibre forced interaction. It is hypothesised that the increase of seed coat nep generation within the gin stand at increasing production rates is a result of the seed roll density and prevented seed micro movement away from the saw teeth.

3.3.7 Residual lint

A portion of the fibre is not removed from the seed during the ginning process. The lint remaining on the seed is expressed as residual lint. Any fibre not removed during the ginning process is considered lost income. Research trials were carried out to determine the effects that mass production rate had on fuzzy seed fibre retention. The relationship between residual lint and mass production rate is shown in Figure 3-26.

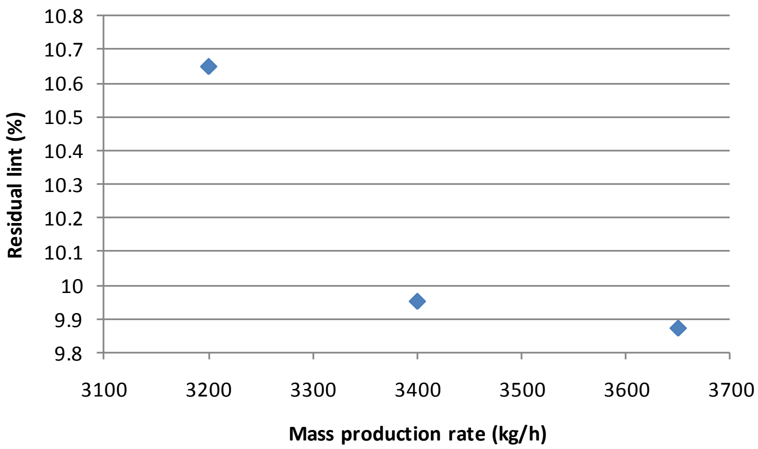


Figure 3-26: Residual lint percentage at three mass production rates

Residual lint was found to decrease as ginning rates increased. The cause of the decrease in residual lint is in response to the increase in density and reduced movement of the seed within the seed roll. Results analysis can be further understood through the effects encountered with the change in seed finger position. Opening the seed finger position allows for a decrease in the forces required to expel fuzzy seed and resultantly increases the residual lint value. Closing the seed fingers results in greater forces required to expel the fuzzy seed and resultantly reduces residual lint. It is hypothesised that the increases in forces within the seed roll prevent movement of the seed during the ginning process, allowing for greater fibre removal. Residual lint properties were reported from three mass production experiments. The lint mass production rates were 3200, 3400 and 3650 kg/h.

3.3.8 Seed roll surface speed analyses

The seed roll is a mass of ginned and non-ginned seed. Varying the mass input of seed cotton into the roll box influences the operating characteristics of the seed roll, such as density and surface speed. Seed roll velocity was measured for two gins in a side-by-side configuration. The measurements were collected within corresponding production characteristics. Analysed gin stands utilised a modified seed tube and a standard configuration seed tube. The modified seed tube consisted of metal lugs attached to the seed tube. The relationship between seed roll surface speed and mass production rate are shown in Figure 3-27.

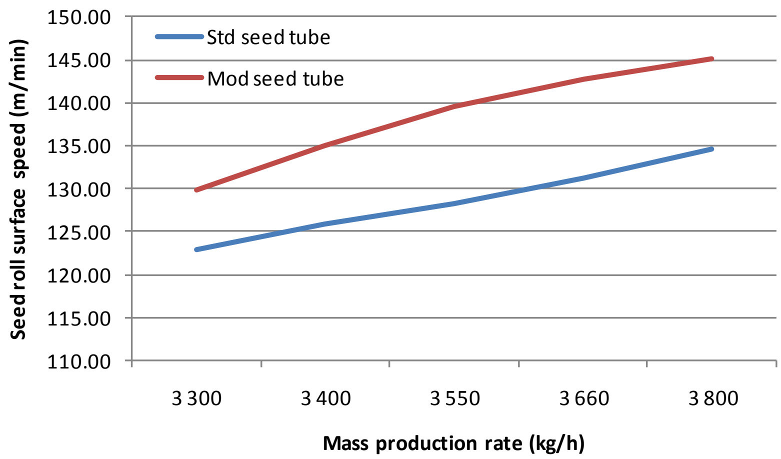


Figure 3-27: Seed roll surface speed

Seed roll surface speed analyses is reported at five mass production rates and calculated using the purpose built seed roll tachometer. Results obtained using the seed roll tachometer indicate that as the mass production rate increases, so does the surface speed of the seed roll. The results are a combination of the fibre to saw friction together with the seed tube configuration. The metal lugs provided additional drive to the seed mass inducing increased seed roll velocity. Faster turning seed rolls are beneficial for the upper half mean length together with a reduction in short fibre content. This is observed in research results for both the power roll gin stand research (Holt, 2008) and that of the roll box core research (USDA, 1956) within the literature review. Results indicate that providing additional drive to the seed roll through the seed tube increases the rotation of the seed roll allowing for improved ginning.

The seed tube within the roll box of the Continental Eagle gin stand is shown in Figure 3-28. The seed tube pictured is of the standard factory design.

Figure 3-28: Standard configuration of the seed tube

The perforations within the seed tube allow for fuzzy seed to enter the seed tube where the seeds are further removed by augers (not shown). The modified seed tube within the roll box of the Continental Eagle gin stand is shown in Figure 3-29. The seed tube pictured is of the modified design.

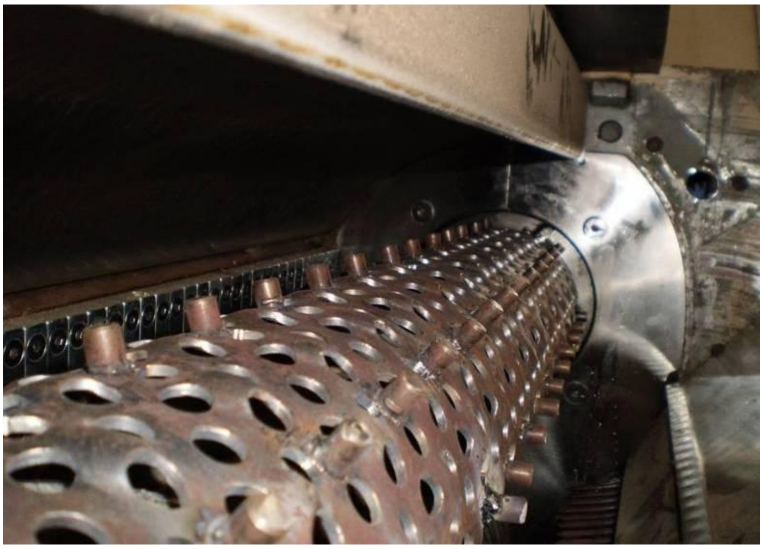


Figure 3-29: Modified seed tube

Figure 3-29 shows the modified seed tube containing metal lugs welded to the outer wall of a standard configuration seed tube. The results observed in Figure 3-27 show that the modified seed tube configuration increases the grasp of the seed roll, allowing for increased rotational speed of the seed roll.

3.3.9 Seed roll force

The gin stand roll box contains approximately 30 kg of seed cotton and fuzzy seed. The seed roll within the roll box is subjected to force during the ginning cycle as a result of the seed cotton mass contained within. Seed roll force sensors were used to record the forces within the roll box during a variety of mass of mass production rates.

Seed roll forces obtained during the ginning process have been analysed. The seed roll force shown is over approximately 20 minutes. The force variation is shown in Figure 3-30.

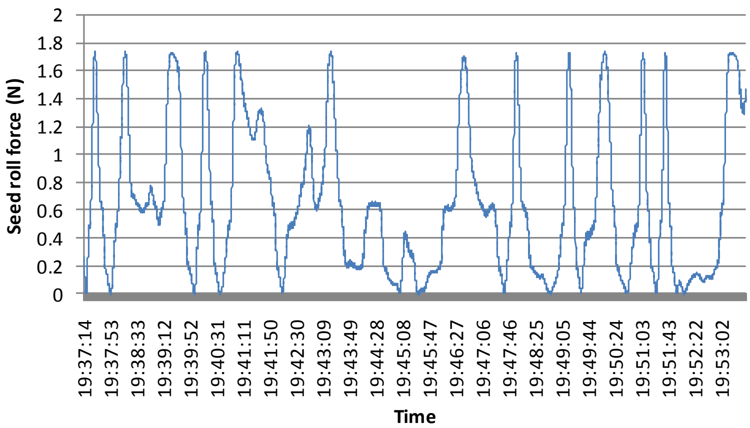


Figure 3-30: Seed roll force capture (20 minute duration)

The forces within the seed roll repeatedly fluctuate between 1.7 N and nil force over a 20-minute period. The likely reason for this is the continual over correcting of the feed motor that supplies the seed cotton to the gin stand. This is further observed with the flow of seed cotton using the DAVS system. Changing the mass flow rate further changes fibre properties such as the nep quantity. The standard deviation was 0.26. The force fluctuation mean was 0.64 N. The force measurements presentation of Figure 3-31 is a segment of that of Figure 3-30. Results are from a time set of 19:41:00 up to 19:45:00

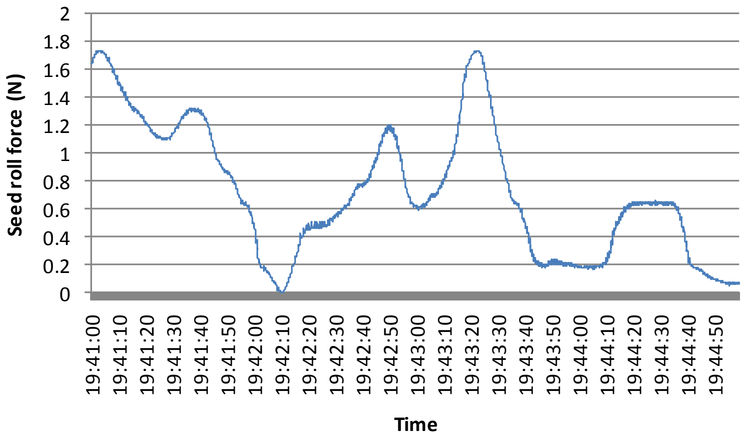


Figure 3-31: Seed roll force capture (4 minute duration)

The seed roll forces captured show a continuous fluctuation in the presence of product. Forces within Figure 3-31 show that the forces have peaked and lulled on two occasions over the four minute time duration. Modifications to the seed cotton delivery motor should overcome this. The standard deviation was 0.22.

3.3.10 Motor current analyses

Gin stand motors draw large amounts of current. The current draw can exceed 200 amps. Increasing the gin stand mass output increases the load that the motor is subjected to. The increase in load increases the demand of the drive motor and the result is an increase in the current that the motor draws. Gin stand motor current draw was recorded during production rate analyses and is shown in Figure 3-32. The current draw of the motor fluctuates as shown in Figure 3-32. Data capture occurred at three-second intervals.

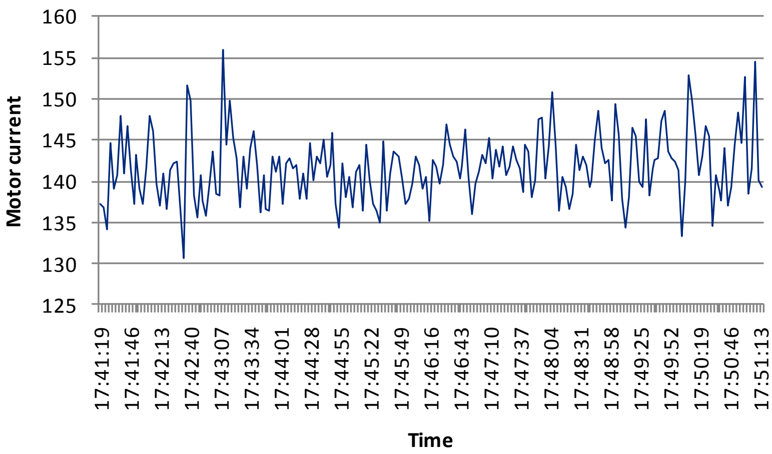


Figure 3-32: Motor current fluctuation during processing

During analyses of the data for motor current, it was observed that the motor current was continually and rapidly oscillating. The oscillating of the motor further adds to the fluctuating production rate. The fluctuating production rate is further allowing for varied levels of fibre quality. It is hypothesised that the fluctuating motor current occurs due to the feed motor continually over and under supplying seed cotton to the gin stand. The variation in the mass production rate changes fibre characteristics such as the nep quantity.

Further to the oscillations observed over approximately 20 minute time period, the oscillating was also observed during extended periods of run time over a period of approximately 2.5 hours together with a range of motor currents, oscillating continued. The motor's oscillations at amperages from 140 to 190 are observed in Figure 3-33. Data capture occurred on a three-second interval.

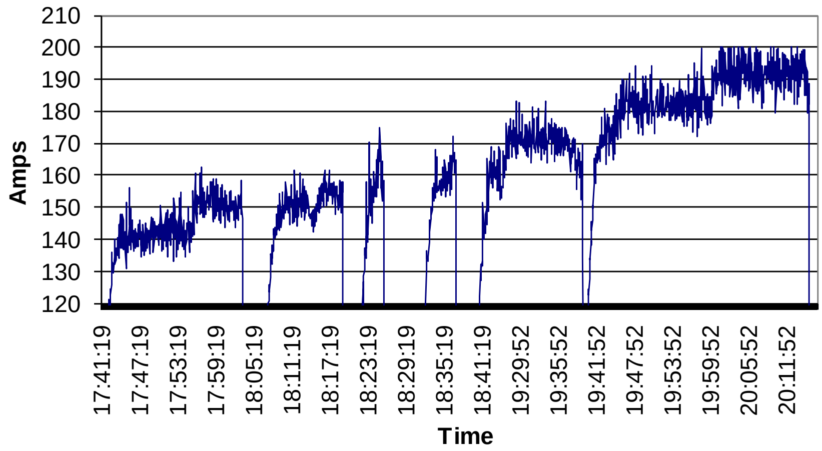


Figure 3-33: Motor current fluctuation at six mass production rates

Motor current fluctuation is observed to fluctuate during all production rates monitored. As mentioned, this is likely to be a result of the gin stand seed cotton feed motor over compensating for high and low mass feed rates.

3.3.11 Saw blade analyses

A comparative friction analysis of the saw blades was performed. The results obtained from the testing of the two test specimens are shown in Figures 3-34 and 3-35.

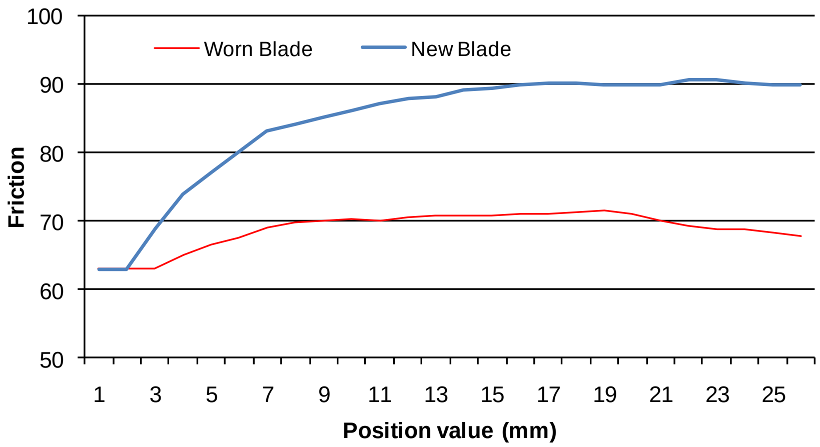


Figure 3-34: Saw blade surface friction – sample 1

Friction results obtained for blade sample 1 through tests performed using the Instron machine indicate that the worn section of a saw blade has at least 20 per cent less friction that that of an unused section of saw blade. The non-modified surface is the untouched area of the saw blade, while the modified surface is that of the worn section of the blade. Each sample was tested (as per the method described in the methodology of this chapter) for the properties of the worn section together with the properties of the new section.

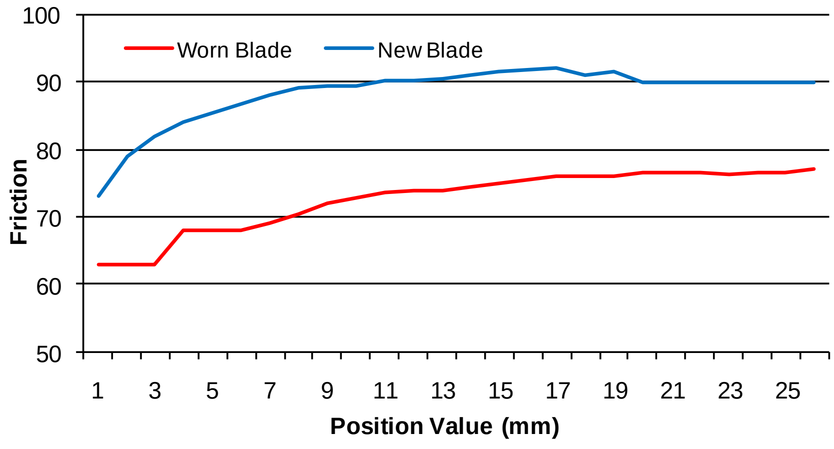


Figure 3-35: Saw blade surface friction – sample 2

The results show that the friction of the new blade had a peak nine mm from the outer edge of the blade. The worn blade result shows that the blade had an increased wear for the first three mm. This increased in wear may have been caused by an increase in the severity of contact between the saw blade and the rib insert.

The saw blade side section was photographed and has highlighted the worn section of the blade together with the new section of the saw blade is shown in Figure 3-36.

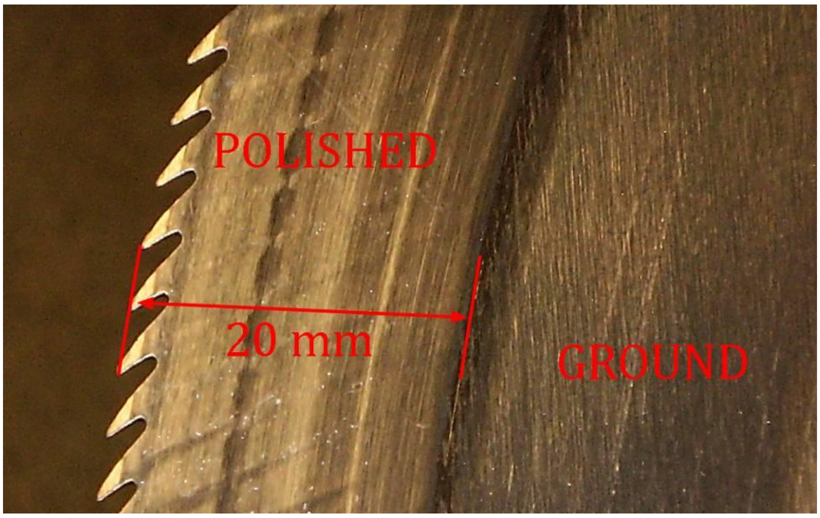


Figure 3-36: Saw blade surface finish

The worn section of the saw blade is shown together with the non-worn section. The worn saw blade indicates the polished area that comes in contact with the rib insert. The time required to polish the saw blade would be greatly affected by the severity of the saw blade to rib insert contact and duration.

3.3.12 Saw blade surface finish analyses

Three saw blades have been analysed for the depth of the surface finish grind markings. The results obtained are shown in Figure 3-37. Saw blade friction analyses determined that frictional properties decline as a result of the saw becoming polished as the saw blade wears. Roughness values of the saw blades varied from 0.2 micron up to 1.7 micron.

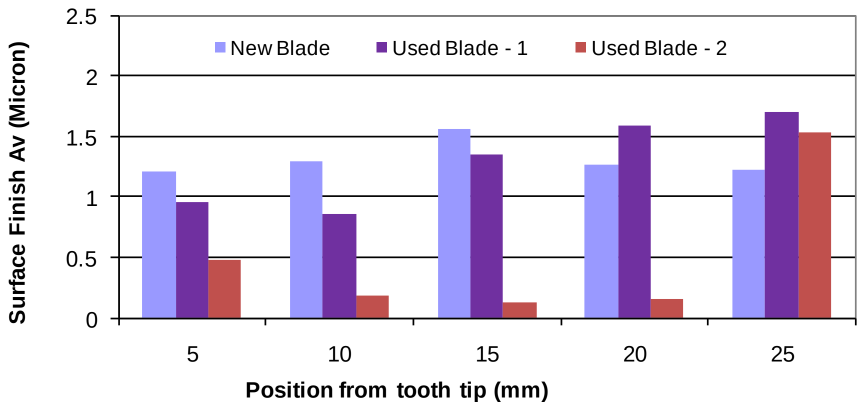


Figure 3-37: Saw blade surface finish (microns)

The result indicates that blade number two had significant wear while blade number one closely resembled that of the new blade. The wear is obtained primarily through the saw blade coming into contact with the rib insert.

3.4 Conclusion

Research results from mass production rate trials that ranged from 3200 up to 3800 kg/h indicate that leaf, fibre length, uniformity, and SFC do not alter as a result of mass production rate change.

Analyses of seed roll surface speed indicated an increase in surface speed as a result of an increase in the mass production rate. The increase in surface speed subjects the seed cotton mass to a reduced interaction with the saw teeth.

Nep test results demonstrate that increases in mass production rates from 3200 kg/h to 3650 kg/h result in an increased nep occurrence greater than 20 per cent. Results in this Thesis have shown that the seed roll surface speed increases with the increase in mass production rate. The increase in seed roll surface speed reduces the fibre interaction with the seed. The seed roll density further increases with mass production rate. Therefore, it is hypothesised that the increase in neps is a result of the increase in seed roll density.

The increase in seed roll density through increases in mass production rate reduces the amount of fibre left on the seed after ginning by approximately 0.5 per cent. The reduction in residual lint is hypothesised to be a result of the seeds reduction in micro-movements during the interaction with the saw teeth.

Analyses of both new and worn saw blades found that a worn saw blade has a reduced surface friction. The surface friction of the worn blade is reduced by 20 per cent when compared to that of the new untouched section of the blade. Saw blade teeth, upon inspection under a microscope were found to have a rounded tip in the new state and a chisel like shape in the used condition. The reduction in ginning performance of a worn saw blade is hypothesised to be a result of the reduced friction properties. Analyses of the seed roll operational forces together with the motor current and vertical flow analyses all indicate an interruption in seed cotton flow allowing for a conclusion that the drive motor that regulates the flow of seed cotton is continually fluctuating. Overcoming these motor fluctuations will allow for a stable flow of seed cotton and motor current draw.

Chapter 4
Input distribution mapping

4.1 Introduction

Research herein focuses on the event of the uneven expulsion of the fuzzy seed and further improving fibre qualities of Australian cotton during the ginning process. Gin stands should be delivered an even distribution of seed cotton from the gin stand feeder in order to operate as intended. Preliminary gin stand research found that the seed cotton distribution within the roll box was non-uniform laterally, yet the underlying cause was not evident. Initial trials conducted indicated some of the gin stand breast fuzzy seed expulsion zones were expelling a significantly greater mass of fuzzy seed than any other expulsion zones. The gin stand is therefore producing an output, which is a blend of lint of various qualities. In order to produce a constant lint quality from the entire width of the gin stand, the distribution of the fuzzy seed output must be made to a constant. The quality of the ginned seed, together with the percentage of residual lint left on the seed will also benefit from an even distribution.

Evenly distributing the flow of seed cotton to the gin stand is vital in achieving an optimal quality of both lint and fuzzy seed. In order to adjust the flow or distribution of the seed cotton prior to the gin stand, methods of manipulation were used to make these seed cotton flow adjustments. It is estimated that eliminating the uneven lateral flow of seed cotton to the gin stand will result in approximately a twelve per cent increase in throughput. The calculation was achievable through the evaluation of the production rate mass output distribution of the fuzzy seed output.

4.1.1 Experiments conducted in Chapter 4

Chapter 4's research direction focuses on the cause of the uneven seed roll. The trials that were carried out in order to understand the cause of the irregularity were:

- Analysis of the input lateral distribution of seed cotton of a standard configuration gin system – using both a film method and an electronic method of data collection.
- Methods of overcoming the uneven distribution together with methods of overcoming the uneven distribution.
- Analyse the flow of cotton, vertically on the gin stand apron. This allows for non-uniform flow to be researched.
- Mass production rate effect on seed cotton and fuzzy seed distribution.
- Saw shaft rigidity trials involving the stiffening of the saw shaft.

4.2 Methods and materials

The methods and materials employed cover lint collection, seed cotton distribution (industry practise, camera method and DAVS method) together with methods of manipulating the seed cotton distribution.

4.2.1 Lint collection –lint cleaner condenser

Lint collection requires the ginning operation to be stopped while fibre collection occurs. The process involved stopping the gin stand feed and then stopping the lint cleaner feed in order to allow for a mass of lint to form on the condenser. Gin operator discretion is required with the shut down sequence and timing to prevent machine damage. Lint was sampled from twelve sections that corresponded to the 12 gin stand divisions, each 200 mm wide. Fifty grams of lint (minimum) was collected per section. A schematic of the sampling sequence is shown in Figure 4-1.

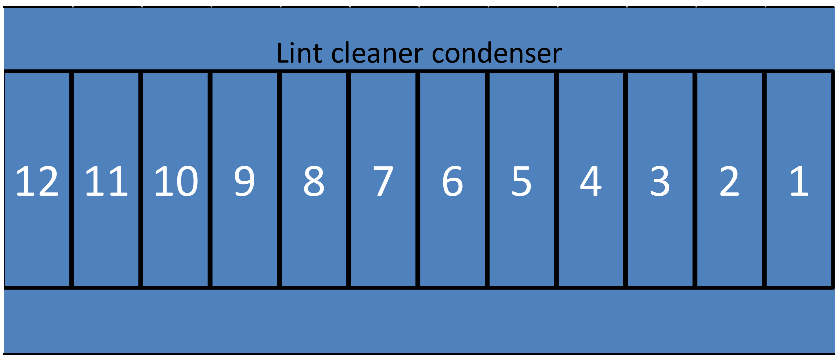


Figure 4-1: Lint cleaner condenser schematic

Lint collection occurred right to left allowing for samples collection corresponding to the gin stand fuzzy seed collection number sequence.

4.2.2 Gin stand extractor/feeder output distribution analyses – industry practice

Measurement of the lateral feed distribution into the gin using standard industry procedure was performed. The procedure firstly relied upon placing extended sides at the front of the gin stand in line with the flow of seed cotton. The gin stand fire door was opened and the seed cotton was allowed to flow into this area. Once sufficient seed cotton was present, the seed cotton feed was stopped and the accumulation of seed cotton was examined for any irregular distribution. Visually inspection of the seed cotton mass showed no signs of non-uniformity. A schematic of the process layout is shown in Figure 4-2.

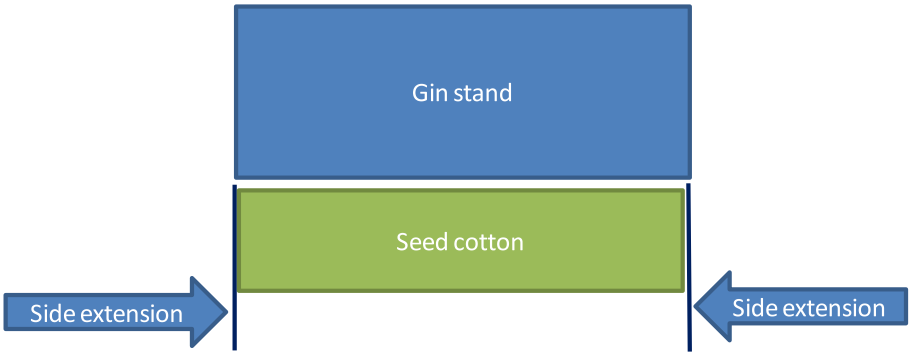


Figure 4-2: Input distribution test – industry method

The image highlights the side extension boards used to prevent the seed cotton from spilling outside of the delivery zone.

4.2.3 Gin stand input distribution analyses – camera method

Seed cotton mass lateral flow evenness analyses have previously not been studied in a scientific manner. To enable the scientific analyses of the seed cotton flow, the apron of the gin stand was required to be filmed. The input distribution of seed cotton was required to understand the source of uneven seed roll fuzzy seed discharge. To achieve this, the input distribution across the gin stand apron required filming to allow for image grey scale analyses of the seed cotton input lateral distribution. To achieve this, 100 per cent of the seed cotton flow across the gin stand feeder required capturing in the images. The data image collection was carried out on three production rates in order to understand any flow variation. Initially, 30 seconds of image of the feeder without any flow of cottonseed across the stand was captured. This was required as a background to remove light variation across the stand.

Apparatus – camera requirements

The camera type used was a (Guppy GF 080 B) together with a cosmicar lens, specifications (TV Zoom 12.5,1:1.8). The program used was an AVT SmartView (Allied Technologies) to record the data onto the computer. The camera was set to enable full view of the seed cotton on the Continental 161 gin stands. The camera was set at a height that allows for no interfering shadows, and set parallel to the ground. The camera was positioned in-line with the middle of the gin stand. Two floodlights were positioned allowing even illumination. A set number of 1000 frames were collected for each trial. Recorded images were saved to a portable hard drive. Optimas 6.51 software (Media Cybernetics) was used to analyse the images to obtain an input distribution pattern.

4.2.4 Seed cotton distribution analyses vision system (DAVS)

New equipment was manufactured to advance the capture of the lateral flow distribution of seed cotton on the gin stand apron. The camera system was labour intensive and required too much time to analyse the images. An imaging system was designed, and manufactured. An imaging system was used on gin stands during the 2010 ginning season. DAVS relies upon flooding the incoming cotton on the gin stand apron with light. Light reflectance is absorbed by the photo diodes and processed enabling a voltage value to be observed for each given zone. The DAVS consisted of eight panels, each panel allowed for 300 mm of lateral seed cotton flow coverage. Each panel supplied an output voltage that was recorded by the GL200 data logger. The DAVS allowed for rapid data analyses of the seed cotton lateral distribution. The DAVS provided a voltage output and was of ease to use. A schematic of the DAVS system is shown in Figure 4-3.

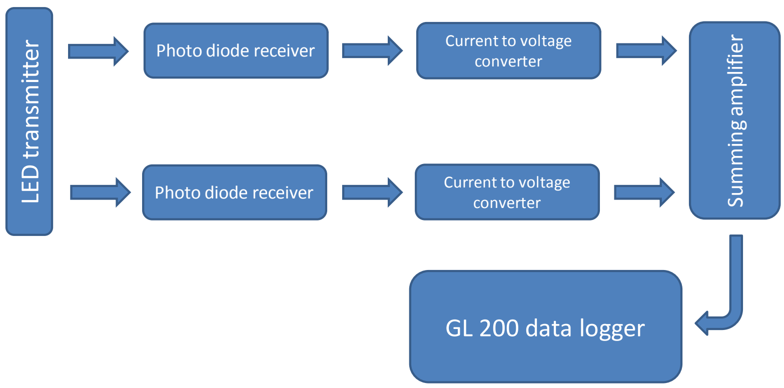


Figure 4-3: DAVS data processing configuration schematic

The DAVS system is shown in data collection mode position on the gin stand in Figure 4-4.

Figure 4-4: DAVS in position on gin stand apron

The DAVS system does not interfere with the operation of the gin stand.

DAVS calibration

The DAVS system required testing and calibration. The system was positioned on low sheen white Laminex boards that protruded approximately 50 cm beyond the DAVS system at each end. The boards were also protruding approximately 300 mm above the DAVS system during calibration. The white background was used as a means of reflecting light back at the DAVS system. DAVS calibration results prior to equilibration are shown in Figure 4-5.

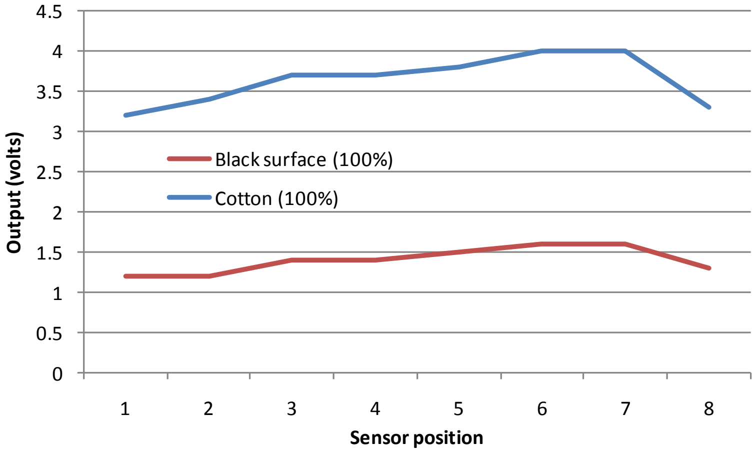


Figure 4-5: DAVS voltage output lab test

Sensor output voltage of the black surface and that of the seed cotton show a reduction in output voltage in position one and eight as a result of the reduced signal generated by the photo diodes. The reduction in signal generation has occurred as a result of the distance that the lights protrude beyond the area in view. Voltage output obtained for each of the eight panels after equilibration is shown in Figure 4-6.

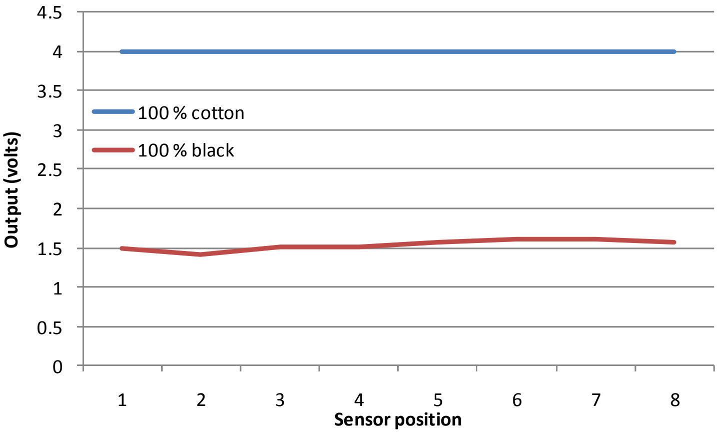


Figure 4-6: DAVS equilibrated calibration

Signal variation across the eight panels is shown to be within 0.1 volts after equilibration. Results show a smooth line after equilibration with a maximum output voltage of 4 volts when used on 100 per cent cotton.

The voltage signal calibration was tested over five effective surface areas of cotton. The surface areas of cotton were, nil, 41, 50, 75 and 100 per cent. The surface areas of cotton were achieved by placing perforated steel sheet of varying surface/holes ratios and further painted matt black The voltage output signals are as shown in Figure 4-7.

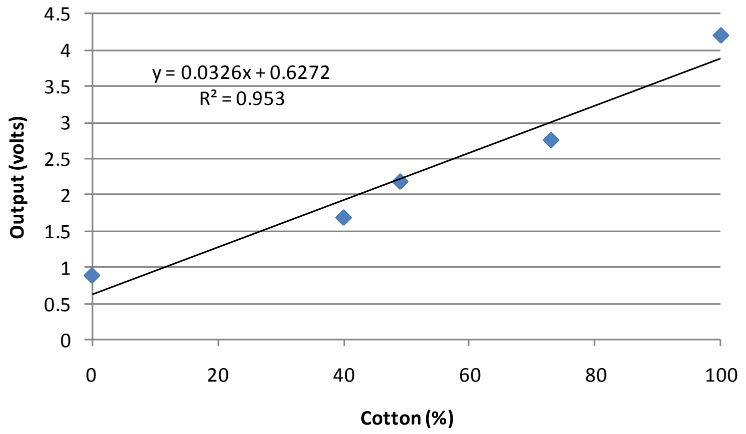


Figure 4-7: DAVS voltage output during five effective surface areas of cotton

Research results have shown that the DAVS system has responded well to the five effective voids. Results were obtained through the calibration of the DAVS system, which occurred within the electronics laboratory on matt white melamine board.

The voltage signal calibration was carried out within a laboratory as shown in Figure 4-8.

Figure 4-8: DAVS laboratory calibration

The DAVS system is shown in lab conditions in readiness for calibration.

Procedure of employment – DAVS

The stainless steel apron tray of the gin stand and feeder was cleaned of any fibre clumps in the joins and a approximately 100 mm wide matt black low tack tape was applied across the entire width of the apron tray in the zone of the DAVS. The tape was applied so that it extended at least 100 mm beyond the DAVS field of view. This equated to greater than a 300 mm section of tape. This eliminated any reflections caused by the lighting used on the DAVS. The DAVS was inspected prior to installation for any obstructions over the lenses such as dust build up. Upon installation, the system was centralised over the gin stand.

The data logger was set to 10 Hz. The data logger recorded for at least two minutes prior to any seed cotton flow. This recording stage was used as a control for the system and subtracted from further data recordings of seed cotton. It was important that each time that the DAVS was moved on the gin stand or moved to another gin stand that the control sequence was repeated in order to eliminate any error. The data logging was set to record for ten minutes. Longer record times allow for fibre and dust to collect on the DAVS lenses and could corrupt the signal. The data capture procedure is described in Figure 4-9. The process is repeated until the desired see cotton evenness result is achieved.

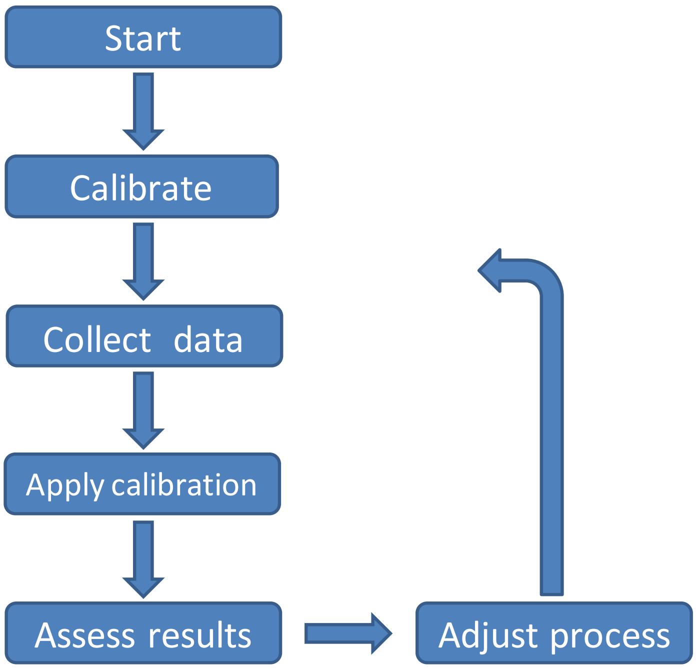


Figure 4-9: DAVS procedure of application

The system demonstrates an initial calibration of a matt black background followed by data collection and further application of the calibration. The process is required allowing for the initial calibration using a black background with no seed cotton flow to be subtracted from the data collected while seed cotton flow was captured.

4.2.5 DAVS circuit board schematic

The circuit board schematic of the components and layout of the components is described in shown in Figure 4-10.

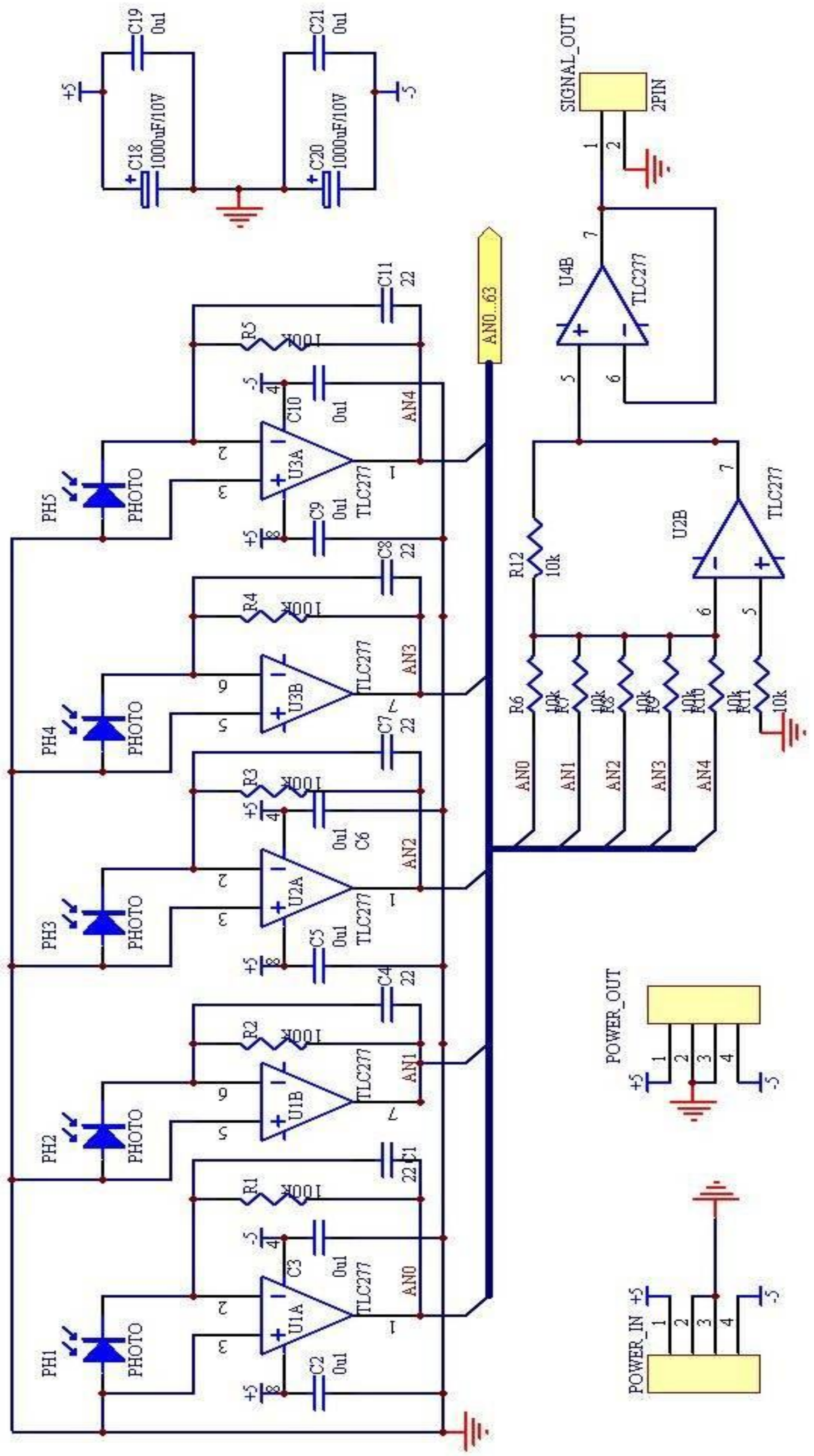


Figure 4-10: DAVS circuit board diagram

4.3 Methods of roll box manipulation

The roll box of the gin stand has a non-uniform lateral output distribution of fuzzy seed. The distribution cause of the fuzzy seed was investigated. Four procedures were performed allowing for the cause of unevenness to be discovered. The four procedures employed to solve the distribution irregularities were the use of a saw shaft stiffening device, gin stand apron deflectors, gin stand apron air deflectors and conveyor distributor modifications.

4.3.1 Saw shaft deflection

Deflection has been measured using a dial indicator attached to a magnetic base that was connected to a suitable position on the gin stand frame. The zero point of the shaft position was set while the saw shaft had the drive belts attached. The drive belts were removed and the shaft deflection was observed through the dial indicator. The amount of deflection observed was greater than 2.5 mm.

To determine if saw shaft flex created unfavourable processing conditions within the seed roll, a stiffening device was sought to overcome such issues. A saw shaft-stiffening device was manufactured and fitted to prevent shaft deflection. The stiffening device consisted of a shaft extension and brace. To ensure that the shaft was located at “dead centre”, a dial indicator through the aid of a magnetic base was fitted to allow for “dialling in” of the shaft. Once the shaft was securely fastened and the brace was positioned and fastened, the “V” belts were then fitted. The “A” frame is shown in position in Figure 4-11.

Figure 4-11: Saw shaft rigidity shaft and support in position

4.3.2 Input manipulation

Methods were required that allowed for the distribution of the seed cotton to be manipulated. It was envisaged that the manipulation of the seed cotton would lead to an advanced evenness distribution of the fuzzy seed expulsion.

4.3.3 Deflector manipulation

Gin stands can be equipped with two deflectors that can be used to reposition an unknown mass weight of seed cotton prior to leaving the gin stand apron. The ginner has no interface to allow for an insight into the correct positioning. Factory standard deflectors were fitted to the gin stand aprons as shown in Figure 4-12. The deflectors are adjusted as necessary and trials are carried out to visualise outcome.

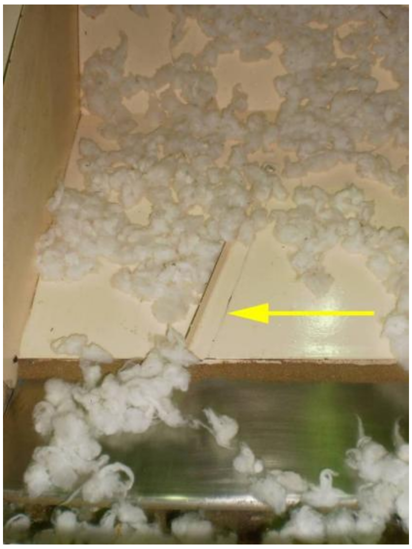


Figure 4-12: Gin stand apron deflector

The gin stand apron seed cotton deflector as shown in Figure 4-12 demonstrates that incorrect deflector adjustment can starve the adjoining zone of seed cotton if not adjusted correctly.

4.3.4 Air manipulation

A device was produced allowing for seed cotton displacement and utilised four nozzles of 6 mm i/d copper pipe. The nozzles were adjusted allowing for air to move seed cotton in a lateral direction. The airflow was restricted using valves at each outlet. An image of the air system in place on a gin stand is shown in Figure 4-13.

Figure 4-13: Air blowers in position to manipulate seed cotton distribution before the gin stand

The air blower system was connected to the compressed air system within the complex.

4.3.5 Conveyor distributor manipulation

The conveyor distributor deflectors consisted of steel angle of 50 mm x 75 mm x 75 mm in length. The steel was position on the leading edge of the conveyor distributor and placed directly over the area of the feed that was considered starved of seed cotton. Where there are two deflectors, they are placed 180 degrees apart. A deflector is shown in position on the auger in Figure 4-14.

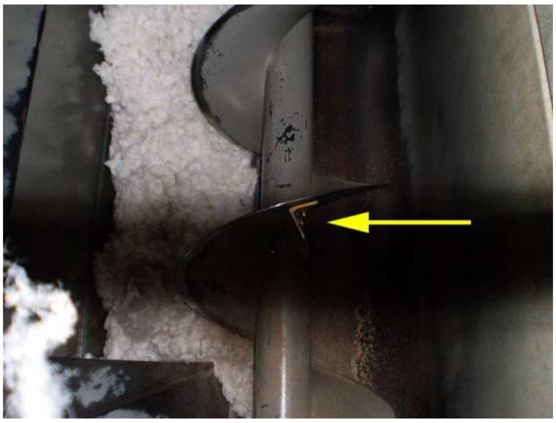


Figure 4-14: Conveyor distributor deflector mounted in position

4.4 Results, analyses and discussion

Chapter 4.4 provides results from the trials carried out. The analyses and discussion follow directly after each figure. Mass fuzzy seed collection indicated the discharge of fuzzy seed was not at equilibrium for the seed tube and breast. During the transformation cycle of the seed cotton to fuzzy seed, seeds migrate to the area of lesser density within the seed roll. At these areas of lesser density, the ability for the exiting of the fuzzy seed increases significantly. This occurrence is observed due to presenting the roll box with an uneven delivery of seed cotton. The seed roll locality of greatest mass input produces the lowest mass output of fuzzy seed.

4.4.1 Fuzzy seed outlet method analyses

Fuzzy seed – breast output

The percentage of the fuzzy seed that exits a Continental Eagle 161 gin stand through the breast is approximately forty per cent. Figure 4-15 presents a comparison of the fuzzy seed output of the breast compared to the seed tube auger.

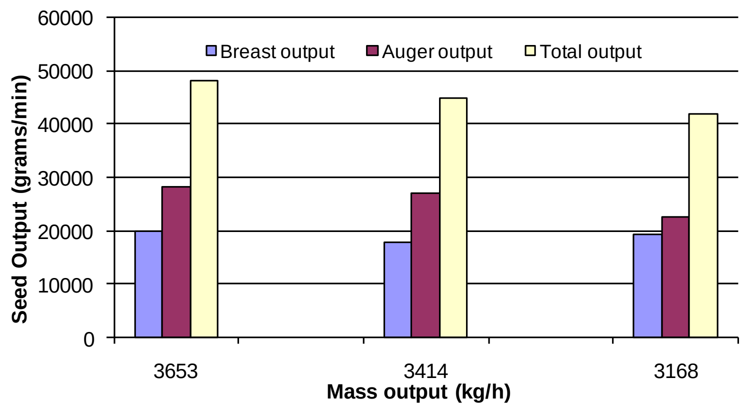


Figure 4-15: Mass fuzzy seed discharge from breast and auger

Results indicate that as the mass production rate decreases, the ratio of fuzzy seed that the auger removes from the seed roll reduces. The auger results are the combined output of both the left and right-hand side outputs.

Fuzzy seed output distribution – left-hand feed

It is possible for the seed cotton flow via the conveyor distributor to occur from either the left-hand side or right-hand side of the gin stand depending on initial build of the gin. The results shown in Figure 4-16 are from a gin stand that has a single pre-cleaner feeder together with a distributer conveyor feed delivery from the left-hand side.

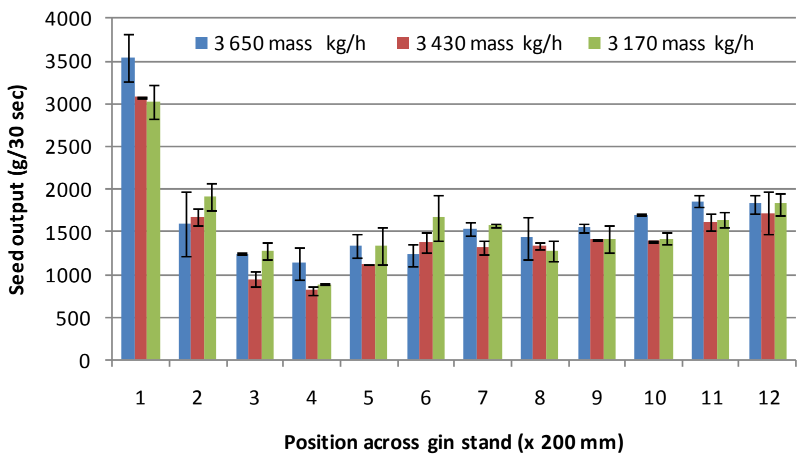


Figure 4-16: Fuzzy seed output distribution from gin stand breast

Results show a fuzzy seed output distribution across the gin stand breast over a 30-second cycle per 200 mm. The mass production rates for lint are stated as being 3.65 tonne, 3.43 tonne and 3.15 tonne of lint per hour. The results show that position one on the left-hand side of the gin stand is expelling up to 3.5 times the amount of fuzzy seed than position four. The increased mass of fuzzy seed is a result of a reduced density within the roll box. The reduced density results from the seed cotton flow into the gin stand being uneven. The position that the reduced mass is observed the greatest is at position one. Imaging equipment that measures the distribution of seed cotton entering the gin stand confirms this. The cause of the uneven distribution of seed cotton is discussed in chapter four. Error bar values are means plus and minus standard deviation for five replicate observations.

Fuzzy seed output distribution – right-hand feed

In a comparative study, a gin stand with seed cotton delivery from the right-hand side is shown in Figure 4-17. The results shown are from a gin stand that has a double pre -cleaning feeder system together with a distributor conveyor feed delivery from the right-hand side.

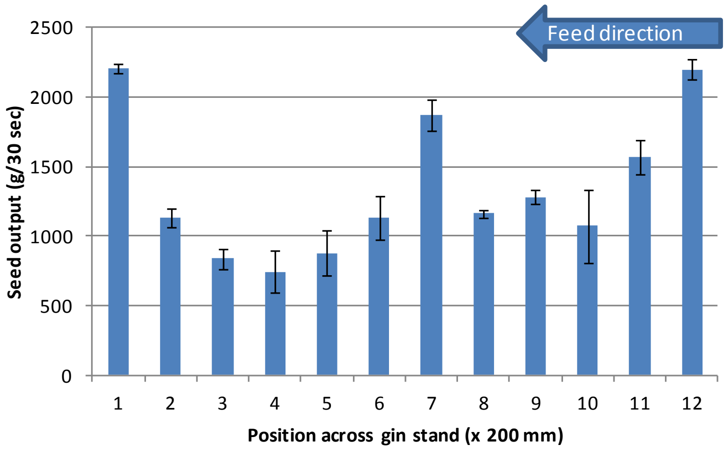


Figure 4-17: Fuzzy seed output distribution (right-hand feed)

The data was collected from a 161 gin stand at a mass output of lint of 3500 kg/h. Error bar values are means plus and minus standard deviation for five replicate observations. The results presented demonstrate that again there is an uneven output of fuzzy seed. There is again a large output at the delivery end (position 12) and here there is also a build up at the far end. The build-up at position 12 is equivalent to that observed at position 1 in the previous section. Observation of the gin stand found that the build-up in position one is a result of the conveyor distributor forming a nip point and removing the seed cotton out of the hopper at this point.

4.4.2 Fibre qualities

Seed coat nep effect

Seed coat neps are produced prior to ginning as well as during the ginning process. Lint was collected at the first lint cleaner, but prior to the lint cleaning by the first lint cleaner. The lint was collected from areas that corresponded to the drop zones of fuzzy seed. The lint was tested and revealed that the areas within the gin stand that had the higher expulsion rates of fuzzy seed also had higher amounts of nep and seed coat nep. There were also higher levels of short fibre content and a reduced fibre length. The seed coat nep distribution across the gin stand is shown in Figure 4-18. The results have been obtained at three mass production rates.

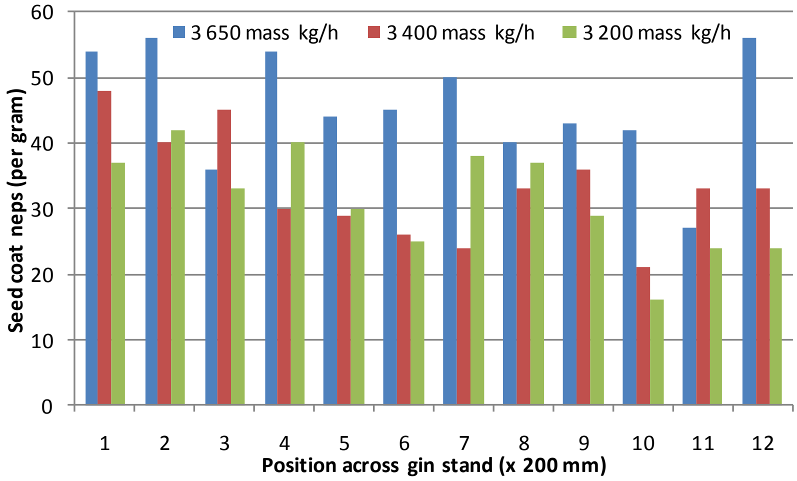


Figure 4-18: Seed coat nep distribution across gin stand

The conveyor distributor feed is from the left-hand side.

Research results obtained for the seed coat nep distribution at three mass production rates show that the seed coat nep proportion increases with the increase of mass production of lint. The increase in seed coat neps at the increased mass production rates is like to be a result of the increase in seed roll density at increased mass production rates. The increase in seed roll density is likely to be preventing micro movement of the fuzzy seed during contact with the saw blade teeth. The prevention of the micro movement during the saw blade contact appears to be responsible for the increase in seed coat neps.

Trash effect

Lint was collected at three mass production rates allowing for the trash content of the lint to be determined. The lint was further collected at twelve positions from across the lint cleaner condenser. The lint was collected from areas that corresponded to the drop zones of fuzzy seed. The trash content distribution across the gin stand is shown in Figure 4-19. The results have been obtained at three production rates. The conveyor distributor feed is from the left-hand side.

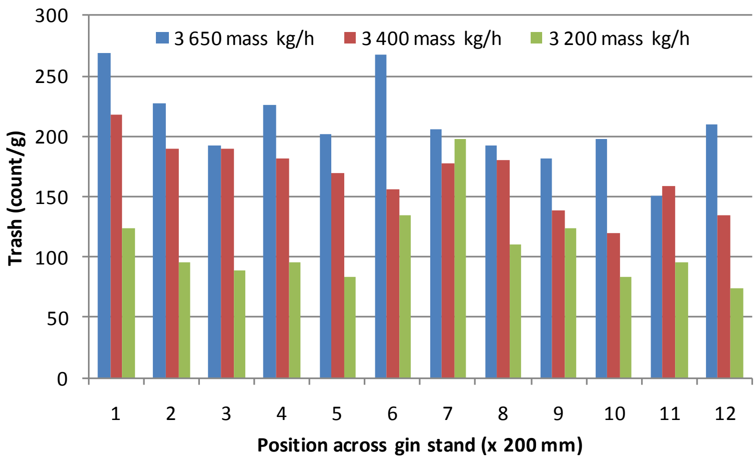


Figure 4-19: Trash count levels across gin stand

Results obtained indicate that the trash levels within the lint increase with mass production rates. The increase in the trash levels at increased mass production rates is likely to be a result of the increase in seed roll density at increased mass production rates. The increased density of lint within the roll box is possibly trapping the trash particles and transferring them with the lint.

4.4.3 Seed cotton distribution analyses

Industry practice

Lateral distribution of the incoming seed cotton was inspected using the industry-practiced method as described in chapter 4.3.3. The mass distribution of seed cotton showed no sign of unequal distribution. This current industry practice supposedly offering an insight into the distribution of seed cotton is of no assistance to the ginner.

Grey scale

Images captured enabled for analyses of the flow distribution of seed cotton on the gin stand apron in a lateral manner. An image, as captured using the film system together with the divisions required for the input distribution analyses is pictured in Figure 4-20.

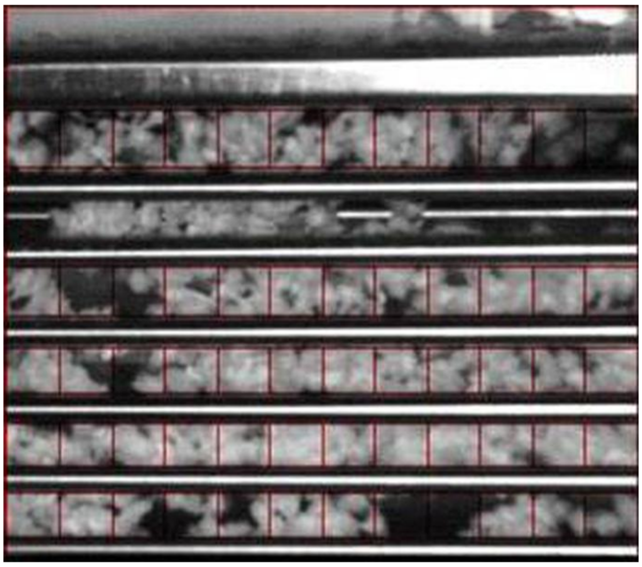


Figure 4-20: Image of seed cotton using camera method evenness distribution

This single image from the input distribution measurement (film method) is shown together with the divisions used in order to calculate the seed cotton distribution. Upon the analyses of the seed cotton lateral flow distribution, the distribution curve could be analysed. The seed cotton input mass lateral distribution on the gin stand apron showed that there are irregularities regarding the seed cotton flow into and prior the gin stand roll box.

The seed cotton distribution across the gin stand utilising a single feeder arrangement at five mass production rates is shown in Figure 4-21. Results were obtained from a gin stand with a feed flow from the left-hand side.

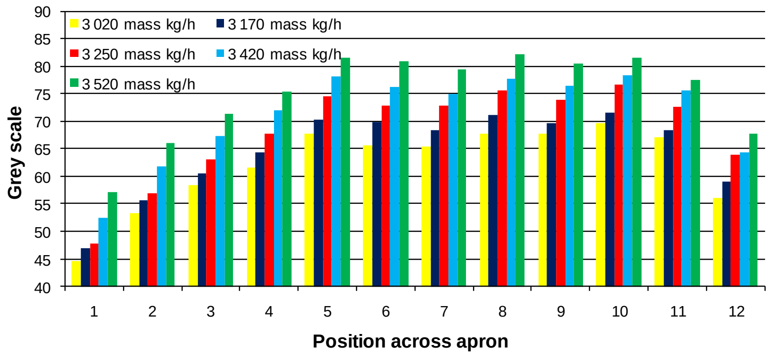


Figure 4-21: Gin stand feeder apron grey scale values

Filming of the gin stand apron allowed for images to be analysed and expressed as a grey scale value. The method has shown that the gin stand is being delivered an uneven feed of seed cotton with a significantly lower throughput at positions 1–4, an even distribution from 5–10, and a decrease at 11–12. This was observed at five mass production rates. As described earlier, the lower throughput at positions 1–4 is caused by the overshoot of seed cotton by the conveyor distributor, and positions 11–12 are a result of the nip point removing the seed cotton from the hopper. The film method has indicated that the procedure used by industry whereby the fire door is opened and its contents viewed, does not give an accurate representation of the cottonseed input distribution.

4.4.4 DAVS

DAVS analyses – gin stand right-hand feed introduction

Results indicate that the seed cotton flow distribution is of a reduced throughput at both the left-hand side and the right-hand side of the gin stand apron. Results are shown in Figure 4-22.

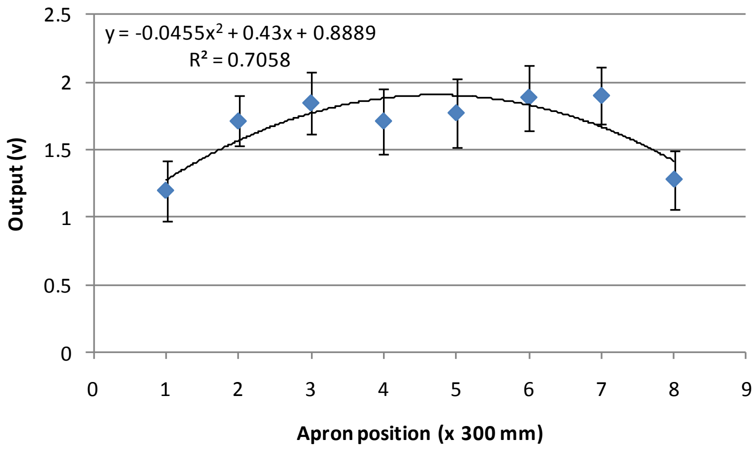


Figure 4-22: DAVS gin stand feed analyses–double pre-cleaner, RH seed cotton feed

Results obtained through the DAVS system demonstrate the distribution of seed cotton into the gin stand is not even. Positions one and two have a reduced feed mass. Each DAVS position covers a 300 mm width. The results obtained through the use of the DAVS closely resemble those of the film analyses system. The results further indicate that the lateral distribution of seed cotton is non-linearly distributed prior to the gin stand. Results shown in Figure 4-22 had not been equilibrated; simply the control had been subtracted from the results obtained during seed cotton flow. Error bar values are means plus and minus standard deviation for 5 replicate observations. Results were further equilibrated to show the extent of the uneven feed.

Output distribution analyses of the eight panels after equilibration are shown in Figure 4-23.

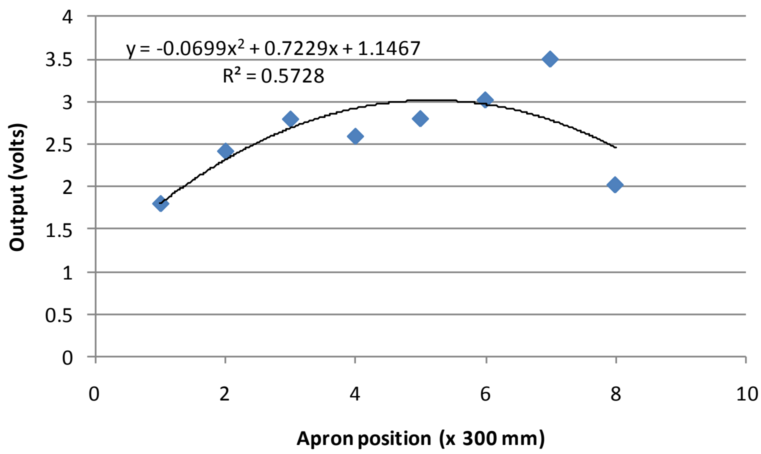


Figure 4-23: Equilibrated distribution analyses – double pre-cleaner, seed cotton feed RH side

Results demonstrate a reduction in seed cotton at positions one and eight, while position seven indicated a higher mass. Position one has a reduced flow of seed cotton. This reduction in the flow of seed cotton at position one is a result of the conveyor distributor overshooting the zone of initial placement of seed cotton. *The reader may consider that of a garden hose. If the water is flowing at a slow velocity, then the water will simply drop the moment it leaves the hose. However, should the water velocity be high, the water will travel a greater distance before hitting the ground.* This is effectively what is happening to the seed cotton at position one. Position eight however, does not initially incur a reduction in seed cotton. The seed cotton mass at position eight should have the highest voltage output and seed cotton mass. The cause of the reduction in seed cotton mass at this location is a result of the conveyor distributor forming a nip point and removing the seed cotton from this location back into the conveyor distributor trough. Position seven is likely to be high as a result of the feed flow by the conveyor distributor and further remaining high as a result of no possible nip point at this location.

4.4.5 Vertical flow – single zone DAVS

The flow of seed cotton into the gin stand at a single location was examined. For the purpose of this experiment, the apron has been divided into eight theoretical sections. These eight sections are as shown in Figure 4-24.

Figure 4-24: DAVS single zone vertical analyses schematic

The schematic highlights that the gin stand has been divided into eight sections for vertical seed cotton flow data analyses.

4.4.6 In-situ calibration analyses – zone two

Calibration of the DAVS system was performed as per description in chapter 4.3.5.1. Upon data collection the results were analysed. The control data for the input distribution is shown in Figure 4-25.

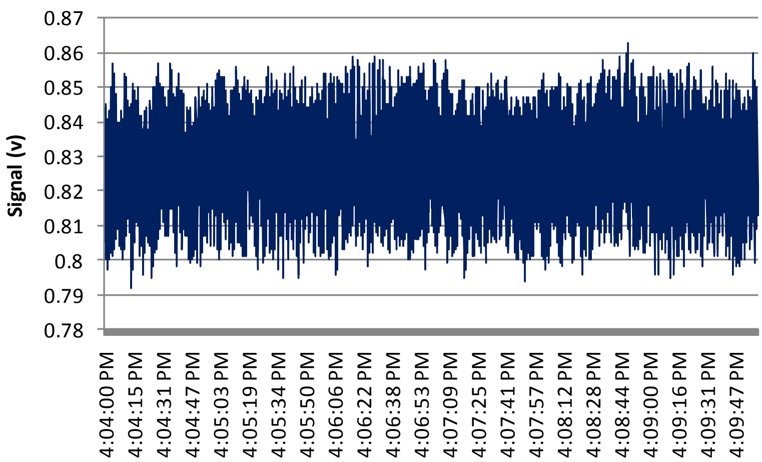


Figure 4-25: DAVS output voltage signal with no material flow

Upon installation of the DAVS system on the gin stand feeder, the system recorded without any seed cotton flow. The results indicate that the control data for the input distribution analyses signal fluctuation was approximately 0.1 volts. The reflectance value while no seed cotton was present was approximately 0.83 volts.

4.4.7 Seed cotton vertical flow analyses

Ten minute cycle

The flow of the seed cotton on the apron was captured. The distribution of vertical flow for a single position has been analysed. The duration of the data collection as shown in Figure 4-26 is 10 minutes.

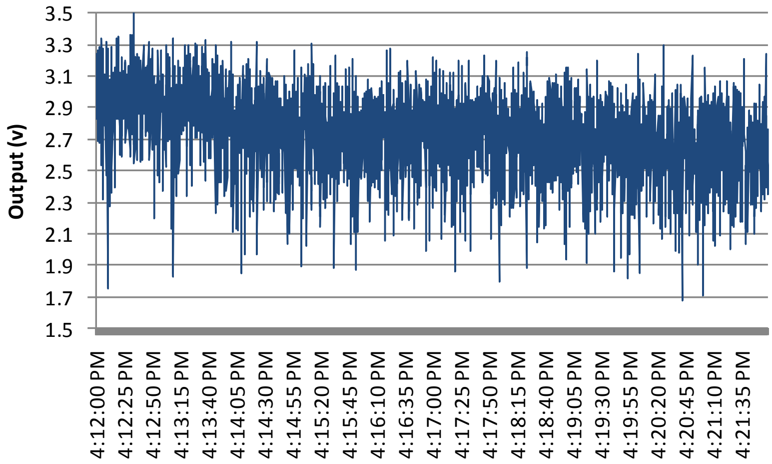


Figure 4-26: DAVS analyses of single vertical zone

The results presented in Figure 4-26 shows that the background response is low and variation is very small compared to the data showing the cottonseed flow through the stand. The variation is representative of the variation in cottonseed going through the stand. The flow is seen to vary with time, with a slight decrease in throughput being seen over 10 minutes. The flow of the seed cotton is seen to be erratic. This is most likely related to the feedback mechanism whereby the feed motor is constantly over reacting and therefore supplying too little followed by too great a delivery of seed cotton. The frequency of the data capture was set at four hertz and occurred over 10 minutes. The mean value of the voltage output is 2.74 volts. The standard deviation of the voltage output is 0.26

One minute cycle

The results obtained during the ten-minute cycle of the input delivery of seed cotton have been further analysed. A one-minute portion of the data was analysed. The results are shown in Figure 4-27.

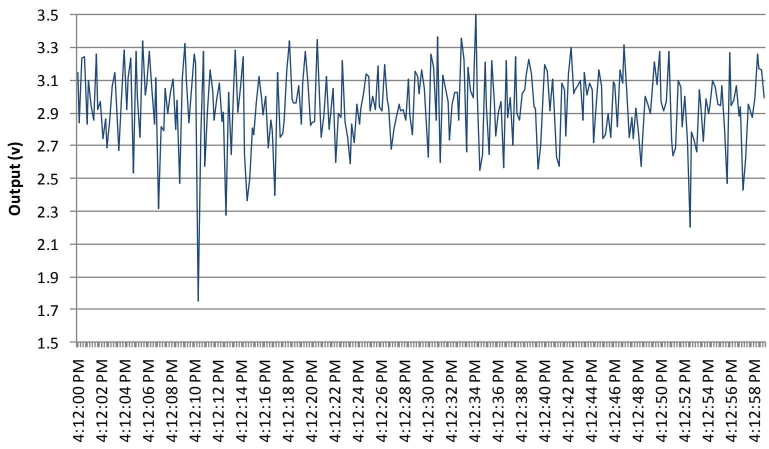


Figure 4-27: DAVS output voltage signal during material flow

Results analyses indicate that the seed cotton flow is varying significantly many times over a one-minute period. This result indicates that the seed cotton feed motor is varying continuously over a 1 minute period. The flow of the seed cotton appears to be supplied in an over compensated and under compensated manner. The frequency of the data capture was set at 4 hertz. The standard deviation of the voltage output is 0.22. The duration of the data collection as shown is 60 seconds. The mean value of the voltage output is 2.94 volts.

4.4.8 Seed cotton lateral flow manipulation

Saw shaft distortion

Due to the nature of the output distribution of fuzzy seed, a theory evolved that the saw shaft was flexing as a result of the torque that applied by the motor. The saw shaft exhibits approximately 3 mm of shaft deflection while in a stationary mode. This deflection is a result of the necessary load applied to the drive belts in order to prevent belt slippage. It was hypothesised that saw shaft flex would be significant while operating at load. Flex in the shaft may then result in saw blades being non-perpendicular to the saw shaft. This could then displace the seed cotton and fuzzy seed, forcing it towards the outer edges of the roll box as a result of the saw blade motion and non-perpendicular direction of the saw blade. A saw shaft support was fitted to the drive side of the saw shaft and supported in an A frame containing a bearing support and further fastened to the ground. Results are shown in Figure 4-28.

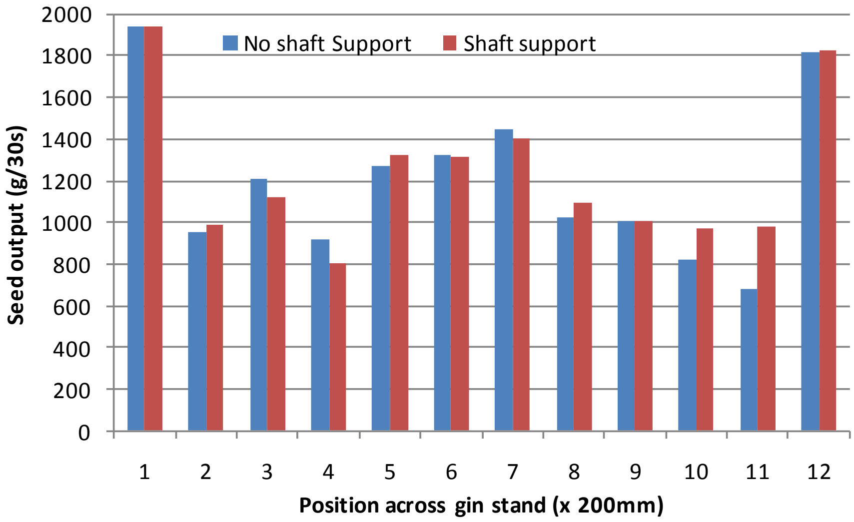


Figure 4-28: Saw shaft support

The results show that the fuzzy seed mass in position one and twelve have not changed as a result of the application of the saw blade shaft support. Results show that the saw shaft flex was not responsible for the output distribution curve of the fuzzy seed. It was further not possible to determine if there was any deflection in the saw blade shaft. No further action was taken.

Gin stand apron deflectors

Ginners are provided with a means of adjusting the mass flow rate of seed cotton on the apron through the form of apron deflectors. The apron deflectors are used to re-direct seed cotton prior to entering the gin stand. Positioning of the deflector is for the purpose of improved cottonseed input, and thus ginning efficiency. The ginner has no interface to allow for an insight into the correct positioning. The positioning of the apron deflector is optimised through trial and error alone. In the data presented in Figure 4-29 is shown the output of seed laterally along the gin stand with larger deflectors added.

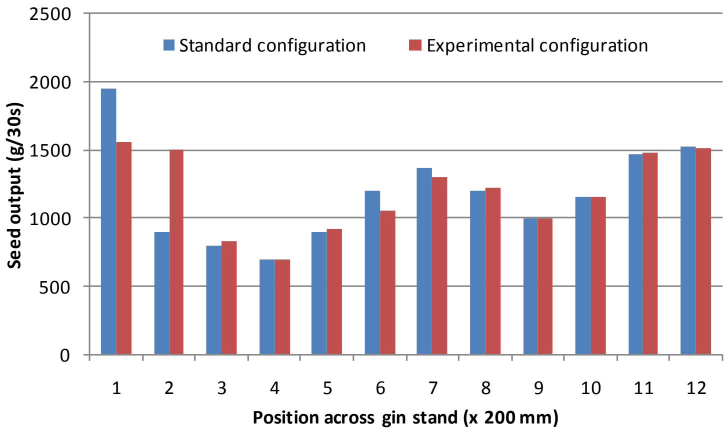


Figure 4-29: Gin stand deflector input distribution

Research results have shown that position one of the roll box has had a decrease in fuzzy seed output which equates to an increase in seed cotton volume. This can be further investigated by examining positions one and two of the fuzzy seed output. The control data (blue bars) have values of 1959 and 938 grams of mass output. Once the deflector was added (red bars), the deflector starved position two and forwarded that removed mass to position one. The values of the modified output mass of 1565 and 1507 grams indicate that position one is being supplied with an increased mass of seed cotton, while position two has had a reduced input of seed cotton mass. The standard deviation of the output distribution of fuzzy seed is: standard configuration 356, and experimental configuration 291

Air displacement

To maximise the ability for the seed cotton lateral motion, disperse local seed build up, and allow for a uniform distribution of seed cotton to the gin stand, air blowers were added. Figure 4-30 presents the fuzzy seed output over the 12 zones out of the gin stand. Standard (control) distribution is presented in blue and this is compared to 2 configurations, which differ by the positioning of the air blowers. The two configurations – which include air displacement – both show uneven seed output, like the control; however, seed build up at the boundaries was significantly reduced. Clearly manipulation of the seed cotton with air does not fix uneven seed distribution, but does seem to improve evenness near the ends of the gin. This was not sufficient to overcome the problem.

The gin stand was configured with a double pre-cleaner feeder system and the distributor conveyor delivered the seed cotton from the right-hand side.

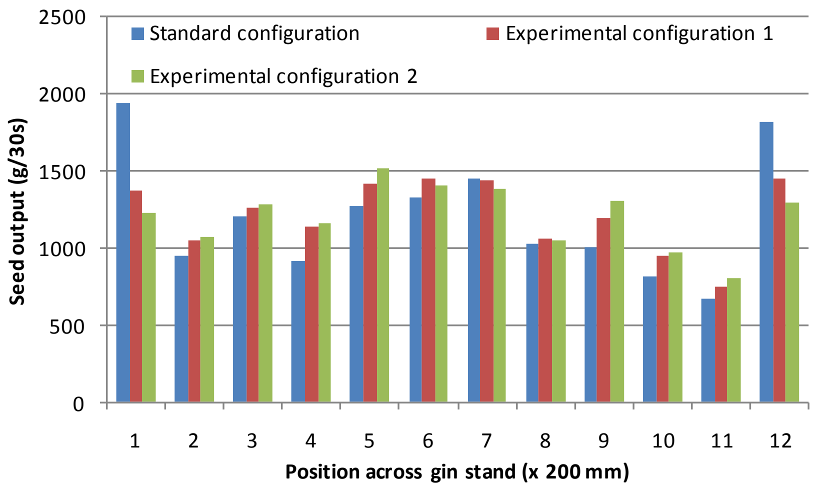


Figure 4-30: Seed cotton flow air manipulation – double pre-cleaner RH feed

Research results have shown that the seed cotton distribution in positions one and two have been reduced. The initial configuration of the air blowers reduced the standard deviation for the width of the fuzzy seed from 385 down to 227. Position one had the fuzzy seed output mass decrease by approximately one-third, while position twelve had a reduction in seed mass of approximately one-fifth. The experimental configuration two saw the air blowers adjusted slightly to further reduce the unevenness of the fuzzy seed flow. The results saw the standard deviation further decrease to 203.

Conveyor distributor modification

The trials conducted allowed for conveyor distributor modification effects on seed cotton flow to be observed. Trials were performed to change the way in which the seed cotton was being distributed from the conveyor distributor. Trials involved the addition of metal deflectors on the auger flight allowing for increased seed cotton density at desired locations. The gin stand used a single pre-cleaner with a distributor conveyor delivering seed cotton from the left-hand side. Results are shown in Figure 4-31. The deflectors were situated above positions one and twelve.

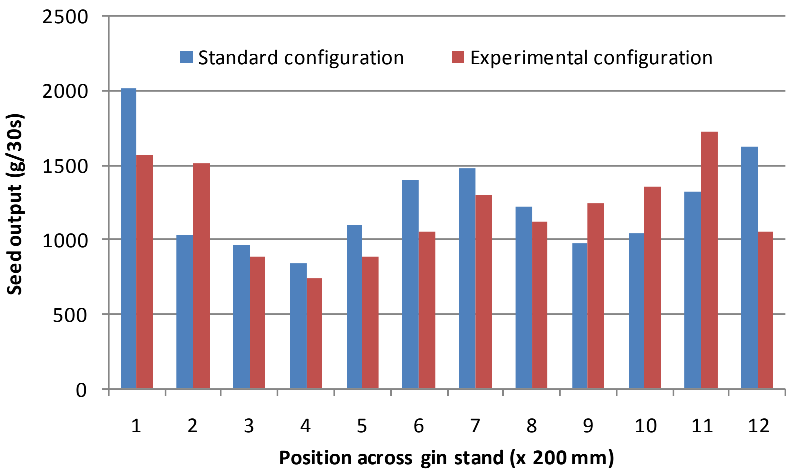


Figure 4-31: Gin stand conveyor distributor modification analyses

Research results have shown that the addition of deflectors situated above positions one and twelve have reduced seed outputs at positions one and twelve. This has occurred as a result of the increased mass of seed cotton entering these positions. The addition of the seed cotton at these zones prevents the fuzzy seed from the neighbouring zones migrating to seed exit areas of least resistance. The seed output mass for positions two and eleven have increased as a result of the deflectors diverting a portion of the seed cotton away, in turn, increasing the void at these positions. The remaining positions show a ripple effect. The standard deviation was 335 for the standard configuration and 299 for the experimental configuration.

4.4.9 Gin stand fuzzy seed lateral mass output distribution of three manufacturers

Consolidated gin stand

Results obtained through trials conducted on a Consolidated gin stand highlight that an uneven lateral mass output of fuzzy seed is being expelled from the gin stand breast as shown in Figure 4-32.

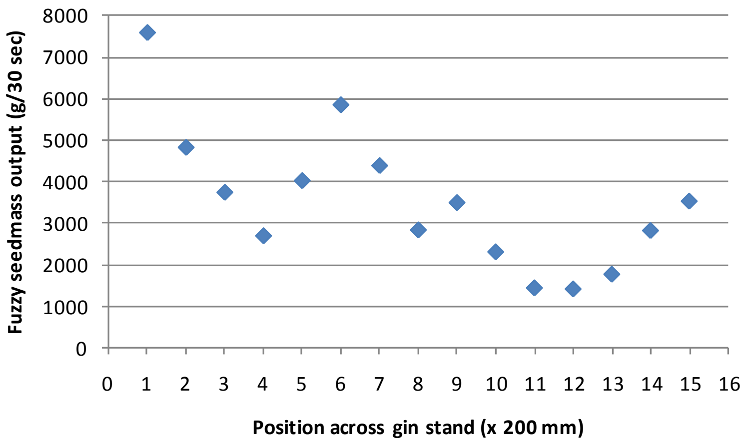


Figure 4-32: Consolidated gin stand fuzzy seed output lateral distribution

The output distribution of the fuzzy seed from the gin stand breast is greatly uneven. The result of the mass output of fuzzy seed at positions one through to four is a result of the overshoot of the seed cotton into the gin stand. Positions one to four have had restricted mass input. The restriction in the mass input has created an area within the seed roll of reduced mass. The reduction in mass has created an area of fuzzy seed expulsion of a greatly reduced resistance. Positions five and up to twelve are not explainable at this time. Positions thirteen to fifteen are likely to be a result of the nip point formed within the conveyor distributor at the point where the auger and trough meet. The mass output of lint from the Consolidated gin stand during the trial was 3100 kg/h.

Lummus gin stand

Results obtained through trials conducted on a Lummus gin stand highlight that an uneven lateral mass output of fuzzy seed is being expelled from the gin stand breast as shown in Figure 4-33.

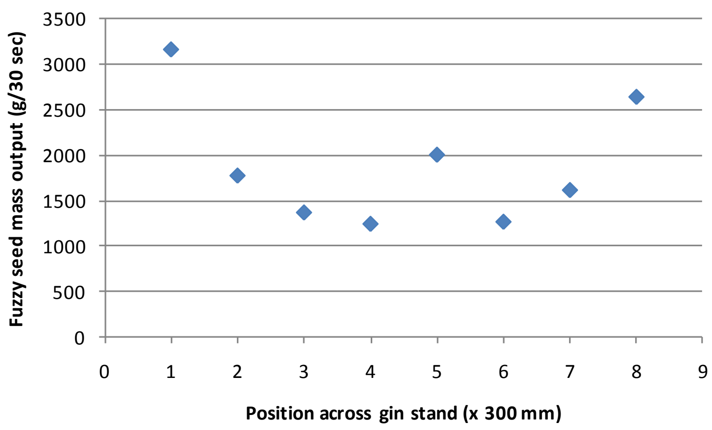


Figure 4-33: Lummus gin stand fuzzy seed output lateral distribution

The output distribution of the fuzzy seed is non-uniformly expelled from the gin stand breast. Position one mass output of fuzzy seed is significantly greater than positions two and up to position seven. The reason for the high level of fuzzy seed mass at position one is a result of the restricted seed cotton mass entering this zone. The restriction in mass input of seed cotton has created an area of lesser density within the seed roll. The reduction in density has created an area of reduced resistance for the fuzzy seed to be expelled from the roll box. As a result of this, the fuzzy seed from the neighbouring zones within the seed roll travel to this area of least resistance. Position eight has an increase in the expulsion of the mass output as a result of the seed cotton being dragged out of the feed hopper, creating an area of reduced mass input. The seed cotton is removed from position eight as a result of the auger forming a nip point between it and the auger trough. Position five peak cannot be explained at this stage. The mass output of lint from the Consolidated gin stand during the trial was 2260 kg/h.

Continental Eagle gin stand

Results obtained through trials conducted on a Lummus gin stand highlight that an uneven lateral mass output of fuzzy seed is being expelled from the gin stand breast. Results are shown in Figure 4-34.

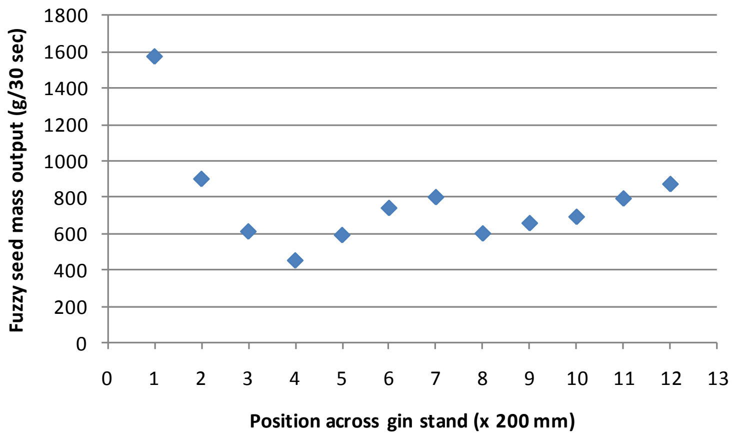


Figure 4-34: Continental Eagle gin stand fuzzy seed output lateral distribution

The mass output of fuzzy seed from the gin stand breast is shown to be uneven. The increased output of fuzzy seed from the gin stand breast in position one is a result of the mass input of fuzzy seed overshooting the initial drop zone of position one, in turn restricting the throughput. This restricted throughput has created a seed roll that is non-uniformly loaded. This non-uniformity has created an area within the seed roll that creates an area of least resistance for the seed to be expelled. The reduction in resistance for the seed to be expelled results in the seed from neighbouring locations within the seed roll travelling towards the area of least resistance for expulsion from the roll box. The mass output of lint from the Continental Eagle gin stand during the trial was 2300 kg/h.

4.5 Conclusion

This chapter has focused on the occurrence of an uneven lateral flow of seed cotton to the gin stand. It was also realised that the vertical uniformity of seed cotton was non-uniform. Through various means of manipulating seed cotton distribution, seed cotton lateral uniformity can greatly improve. Use of airflow through a series of adjustable malleable pipes allowed for the manipulation of the seed cotton uniformity. The standard deviation of the lateral uniformity reduced from 385 to 227. Other methods of overcoming the uneven lateral distribution of the seed cotton, being the use of deflectors on the gin stand apron and further on the conveyor distributor proved to be not as successful. The use of the air flow has demonstrated that the evenness of the seed cotton distribution can be significantly improved, however this method should not be considered as an industrial method of overcoming this.

The fault within the process that is responsible for the distribution problem lies within the conveyor distributor and the hopper system. The leading edge fault cause is a result of seed cotton momentum. The rate at which the seed cotton flows within the conveyor distributor results in the seed cotton overshooting the initial drop zone into the hopper. Overcoming the initial overshoot of the seed cotton is likely through the modification of the conveyor distributor “U” shaped body. Initially, the conveyor distributor in conjunction with the proceeding feed hopper will require the initial drop zone of the seed cotton to be extended prior to the current configuration.

The feed of seed cotton is further witnessed to change within the central zone of the hopper. This reduction in the central zone of the hopper is a result of the position of the auger hanger arm within the conveyor distributor. Overcoming the affect of the auger hanger would be achievable through the re-positioning of the auger hanger.

The trailing/exiting edge of the feed hopper is further starved of seed cotton. At the point where the seed cotton flow in the conveyor distributor moves beyond the hopper, a nip point is formed between the “U” section, the seed cotton, and the auger. This nip point extracts seed cotton out of the feed hopper creating a reduced seed cotton mass at the hopper edge. Overcoming these points should allow for an increase in production of twelve per cent. The modification to the conveyor distributor should further allow for a reduction in seed coat nep. The seed coat nep increase is thought to be a result of the fuzzy seed migrating across the saw blade teeth to an area of least resistance. The seed roll area of least resistance results from the reduced seed cotton flow. The method commonly used in industry to determine the distribution of seed cotton on the gin stand apron is of no use whatsoever. The use of a fuzzy seed collection tray will allow for an indication of the seed cotton distribution.

Analyses of the gin stand motor load indicate that the motor current is constantly fluctuating. The motors energy wave form indicates that the mass output of seed cotton from the extractor feeder is continually fluctuating, in turn providing an uneven flow of seed cotton to the gin stand.

Chapter 5
Thesis conclusions

5.1 Literature review

Differential ginning has shown that the longer the time that the seed cotton is present in the roll box of the gin stand that fibre length is decreased. The fibre length upper quartile length has shown to decrease by almost $^{6}/_{32}$ with increased ginning duration from 10 to 70 seconds. Micronaire was further shown to increase with prolonged ginning times. Increasing the ginning time from 10 to 70 seconds increased the micronaire reading by 1.2. The increase in ginning time has further increased the saw teeth exposure to the lint. The exposure has increased from eight million teeth over a ten second period to forty million teeth over a seventy second period. The increase in micronaire is considered to be a result of the shorter higher micronaire fibres withstanding greater periods of saw interaction prior to their release from the seed.

Research performed on the Power Roll gin stand has shown that a reduction in fibre breakage occurred when the ratio between the paddle roll and saw shaft was reduced. The research highlighted that higher ratios reduced the fibre length by as much as $^{2}/_{32}$. This research highlights that an increase in the seed roll rotation speed together with a reduction in saw speed, there for creating a reduced ratio, is beneficial to fibre length.

Reducing the quantity of saw teeth on the blade, effectively reducing the mechanical interaction, has further demonstrated that a further $^{3}/_{32}$ can be gained. Increasing the mass production rate increases the seed roll density. This increase in density further increases the quantity of seed coat fragments.

5.2 Seed roll and roll box analysis

Research results from mass production rates from 3200 up to 3800 kg/h indicate that leaf, fibre length, uniformity and short fibre content do not change. Seed roll surface speeds increase as the production rate increases. This increase in surface speed subjects the seed cotton to a reduction in mechanical interaction of the saw teeth. The increase in production rate increases the seed roll density. The increase in seed roll density increases nep by approximately twenty per cent. The increase in seed roll density reduces the amount of fibre left on the seed after ginning by approximately 0.5 per cent. Seed is further subjected to greater damage during increased force within the seed roll. The damage occurring to the seed, together with the reduction in fibre on the seed is thought to be a result of the seeds reduction in micro-movements from the saw teeth during interaction. Worn saw blades are thought by ginners to reduce the production rate of the gin stand. Upon analyses of both new and worn saw blades, it has been found that a worn saw blade has a reduced surface friction. The surface friction of the worn blade is reduced by 20 per cent when compared to that of the new untouched section of the blade. The saw blade teeth, upon inspection under a microscope were found to have a rounded tip in the new state and a chisel like shape in the used condition. The reduction in ginning performance of a worn saw blade is thought to be a result of the reduced friction properties.

5.3 Input distribution mapping

Chapter 4 focuses on the occurrence of an uneven lateral and vertical flow of seed cotton to the gin stand. Through various means of seed cotton flow manipulation, the seed cotton lateral flow can have a far greater even distribution. Through the use of air to manipulate the seed cotton flow, the standard deviation of the distribution was reduced from 385 to 227. The fault within the process that is responsible for the distribution problem lies within the conveyor distributor and the hopper system. The rate at which the seed cotton flows within the conveyor distributor results in the seed cotton overshooting the initial drop zone into the hopper. This should be overcome through the modification of the conveyor distributor "U" shaped body. The feed is further witnessed to reduce within the central zone of the hopper. This reduction in the central zone of the hopper is not known. The exiting edge of the hopper is further starved of seed cotton. At the point at which the seed cotton moves beyond the hopper, a nip point is formed between the "U" section and the auger. This nip point pulls seed cotton back out of the hopper creating a light seed cotton mass in the hopper. Overcoming these three points should allow for an increase in production of twelve per cent. The modification to the conveyor distributor should further allow for a reduction in seed coat nep production. The increase in seed coat nep is thought to be a result of the fuzzy seed "dancing" across saw blade teeth while moving to a area of least resistance within the roll box. The roll box area of least resistance results from an under-loaded seed roll as a result of the seed cotton flow. The method commonly used in industry to determine the distribution of seed cotton off the gin stand apron is of no use whatsoever. The use of a fuzzy seed collection tray will allow for an indication of the seed cotton distribution. Analysis of the gin stand motor current draw indicates that the motor is constantly cycling in current draw. This cycling in current draw is an indication that the extractor feeder is continually cycling in the flow of seed cotton to the gin stand. The fuzzy seed output distribution is contradictory to the input distribution. Results obtained suggest that the gin stand, laterally, is producing lint at variable mass discharge while set at a constant input rate.

Previous research was conducted by Bagshaw (2008–2009) using Continental Eagle, Consolidated and Lummus gin stands to gather an appreciation of the mass output distribution of fuzzy seed. The results revealed that all three manufacturers gin stands experience an uneven lateral mass output of fuzzy seed.

5.4 Future research direction

5.4.1 Seed cotton distribution

Research carried out in this Thesis has discovered the uneven distribution of seed cotton into the gin stand. The research carried out has identified the source of the uneven feed. The uneven feed source is a result of the design of the conveyor distributor system. No modifications trialled on the conveyor distributor totally eliminated the uneven feed. Therefore, further research is required into the final design of the distributor conveyor to eliminate the uneven feed of seed cotton.

The use of an oar like shape, capable of moving on a hinged system attached to the conveyor distributor wall, and further weighted may allow for the momentum of the seed cotton to be reduced to allow for an improved dispersal of the flow.

The trailing edge of the conveyor distributor forms a nip point with the seed cotton. In turn, this nip point extracts seed cotton back out of the feed hopper. A mechanism to potentially overcome this would be the removal or reduction in diameter of the auger flight directly over the current nip point location.

5.4.2 Saw shaft and saw blade dynamics

Saw shaft rotational speed may be able to be reduced significantly, reducing mechanical interaction of the saw teeth with the cotton fibres. Reducing the saw shaft speed will result in a slower rotation of the seed roll. To overcome this, the seed tube may require an increase in rotational speed or the seed tube could be fitted with a flat longitudinal bar to help "push" the seed roll. This action will allow for an increase in production together with a decrease in mechanical action. Saw blade design could be changed to allow for a reduction in saw teeth. This reduction would allow for less mechanical action together with saw teeth of greater loading (not capacity). Saw blade frictional property change may allow for a faster rotating seed roll. As stated in this Thesis, a worn saw blade has a reduction in friction of approximately 20 per cent. Increasing the frictional properties of the saw blade may be achieved through the modification of the saw blade sides, not teeth sides.

The addition of stamped grooves on the surface of the saw blade may allow for an increase in the ability of the saw blade to increase the rotational speed of the seed roll. This increase in seed roll rotation could allow for an increase in mass production or a nil affect in production with the desire of decreasing seed coat neps and neps as a result of the seed roll density reduction.

REFERENCES

Anthony, WS 1990, 'Performance characteristics of cotton ginning machinery', American Society of Agricultural Engineers, vol. 33 (4), July-August, pp. 1089-98.

Bel, PD 2004, 'Cotton quality – fibre to fabric', PhD thesis, University of Southern Queensland, Australia.

Bennett, CA 1960, 'Whitney or Holmes?' September 10, 2010, <www.pratthistory.com/whitney_or_homes.htm>

Boykin, JC 2008, 'Tracking seed coat fragments in cotton ginning', American Society of Agricultural and Biological Engineers, vol. 51 (2), March, pp. 365-77.

Byler, RK 2005, 'Engineering and ginning-the effect of modest addition to seed cotton before the gin stand on fiber length', The Journal of Cotton Science, vol. 9, pp.145-54.

Columbus, EP & Backe, EE 1992, 'Improved fiber and yarn quality through differential ginning', American Society of Agricultural Engineers, vol. 8 (2), March, pp. 175-8.

Continental Eagle Limited 2012, Gin stand diagram, <www.coneagle.com>

Cotton Australia 2012, 'Secondary education kit', January 5, 2012, <www.cottonaustralia.com.au>

Gordon, SG & Bagshaw, KM 2006, 'Australian gin survey', CSIRO.

Griffin, AC, McCaskill, OL, Tallant, JD & Fiori, LA 1960, 'Differential ginning – Effect on cotton fibers and yarn properties', The Cotton Gin & Oil Mill Press, June 11.

Holt, GA & Laird, JW 2008, 'Initial fiber quality comparisons of the power roll gin stand to three different makes of conventional gin stands', American Society of Agricultural and Biological Engineers, vol. 24 (3), March, pp. 295-99.

Hughes, E 2004, 'Evaluation of selected gin saw tooth designs', Proceedings of the 2004

Beltwide Cotton Conference. January 5-9, pp. 969-72.

Hughes, E 2002, 'Ginning Rib modifications to reduce seedcoat fragments', American Society of Agricultural Engineers, vol. 18 (1) pp. 13-16.

Laird, JW 2000, 'Powered roll gin stand', US Patent number 6,061,875

Lakwete, A 2003, 'Inventing the cotton gin', John Hopkins University Press.

Long, R 2006, 'Linking farming systems to fibre quality and textile performance' Presented at the Australian Cotton Research Institute, Narrabri, Australia, 2007.

Mangialardi, GJ & Anthony, WS 2004, 'Cotton saw gin developments', The National Cotton Ginners Association.

Mangialardi, GJ, Bargeron III, JD & Rayburn, ST 1988, 'Gin-stand feed rate effects on cotton quality'. American Society of Agricultural Engineers, vol. 31 (6), November-December, pp. 1844-50.

Mayfield, WD & McKaskill, OL 1970, 'An evaluation of the performance of two gin saw tooth designs', United States Department of Agriculture, November, ARS 42-175.

Moore, VP & Shaw, CS 1967, 'Mechanical damage to cottonseed- ginning effects', The Cotton Gin and Oil Mill Press, March 11.

Parnell, CB & Garner, WE 1969, 'Using a fluorocarbon-resin film as a coating for seed-roll boxes- its effect on gin-stand capacity, seed-roll density, and rotational velocity', United States Department of Agriculture, December, ARS 42-152.

United States Department of Agriculture 1969, 'Gin-stand research at Stoneville, Miss 1956-66'. Technical bulletin No. 1407.

Uster 2011, 'Uster HVI', <www.uster.com>.

Van der Sluijs, MHJ 1999, 'Neps in cotton lint', The Textile Institute, Textile Progress vol. 28, Number 4.

Van der Sluijs, MHJ, Gordon, SG & Prins, MW 2004, 'Quality issues for Australian cotton from a mill perspective', Cotton CRC & CSIRO.

Webber 2006, 'Delinting fuzzy seed', Cottonseed Distributors report number: CSD/QA/L/W02.

Yafa, S 2005, ‘Big Cotton-how a humble fiber created fortunes, wrecked civilizations, and put America on the map’, Penguin Group (USA) Inc.