THE HS/VS™ HIGH SPEED / VARIABLE STROKE TRAMPER Joe W. Thomas Ross D. Rutherford William D. Beeland

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<u>Abstract</u>

Gin throughput has steadily increased since the introduction of high-capacity gin stands. With this trend expected to continue, ever greater pressure will be put on press production. The days of one-minute cycle times have given way to forty-five-second cycles with thirty-second cycles just around the corner. To address the demand, the High-Speed Variable-Stroke (HS/VSTM) tramper has been developed. The HS/VSTM tramper utilizes technology first introduced with the Savannah ClassTM Press (U.S. patent 7,481,158). The HS/VSTM technology addresses time constraints attributable to ingress (lint slide accumulation) and egress (bale strapping profiles), control constraints at high speeds and precise positioning, bale weight fluctuations related to number of charges and charge size, and real-time data feedback for tuning and information systems.

Background

Production rates of cotton gins in countries with advanced ginning technology have spawned the "ultra-high" capacity gin plant. Advances in harvesting technologies is providing additional pressure with ginners upgrading to bigger and faster gin stands and multiple or faster baling presses. Multiple presses require greater up-front capital and higher operating costs although press production requirements are much less demanding given reduced throughputs. Single high speed presses, albeit more economical to install and operate, present unique challenges to design engineers. The challenge manifests as a time window of 30 to 45 seconds to produce a finished bale. During this time window several moving axes must be choreographed in such a way as to allow for the ingress of multiple charges of lint cotton (enough to accumulate 500 lb or 227 kg), cycling of the press boxes, and full compression of the bale followed by egress of the finished bale. One consequence of higher faster press production is difficulty maintaining reasonable bale weights.

Traditional ginning practices included a means of determining when an optimum amount of lint had been ginned and pre-pressed in the press box; usually this approximated 500 pounds. This process of "cutting" the bale was manual and relied on experienced input from growers and ginners alike. For the 5 to 10 bale per hour gins little drama was associated with achieving a reasonable bale weight given the amount of time provided between bales. As time progressed and gin throughputs increased new methods for determining bale weight were developed. Many ginners based bale weight on turnout for particular varieties of cottons. Seed scales were used to weigh the seed as the cotton was ginned. A predetermined seed weight total was the trigger for cutting the bale in the press. Yet more positive and reliable techniques came into demand as less experienced operators were left to oversee bale press operations. In the era of mechanical trampers the main driver, an electric motor, lent itself well to providing process variable inputs to an electronic receptor, usually in the form of an analog amperage meter. Lint resistance developed in the pre-compression box from successive charges of lint cotton proved proportional to the tramper main driver load. An analog signal from a transformer provided a signal to the analog meter registering the motor current load. As the signal increased a pre-determined set point would actuate a set of contacts within the meter thus signaling bale weight had been reached.

Hydraulic trampers came on the scene in the late 1950's. By 1980, they were the preferred method of charging precompression boxes on cotton balers. Although hydraulically driven the electric main driver load continued to be employed as the process variable for cutting bale weights. Pressure transducers had been in use on gin baling presses since hydraulics was introduced to the industry, but not as a means of determining bale weight. This changed in the 1980's with the advent of precision transducers, solid state meters and PLC controls. Programmable features and precision electronics made tuning transducers as bale weight controls very attractive to the industry thus contributing to the obsolescence of mechanical trampers. Yet one significant similarity remained. The pressure transducer as a bale weight control possessed all of the neat features of like devices of the time but the resilient resistance load of lint in the pre-compression box from successive charges of lint cotton remained proportional to the tramper main driver load. Given the main driver was electrically driven hydraulics the process variable signal fit the same curve as before albeit a pressure signal converted to electrical vs. current load from a transformer.

As gins consolidated and production increased throughput pressures mounted. Gins in the late 1980's through 90's were approaching the 60 bale per hour glass ceiling. During the same period bale weight sensing technology changed little. Significant changes came in the form of electronics but little else. Industry focused on fiber quality and controlling moisture in the lint. Bale weight control only became an issue once merchants or warehouses complained or the producer faced loan denial as the result of over or under weight bales. Gin capacities continued to increase finally breaking through the 60 bale per hour ceiling. With higher volumes and faster production pressure began to mount not only for presses to produce more bales per hour, but to do so while maintaining reasonable bale weights. These two features are not mutually inclusive. For a given number of charges per minute, the total number of charges per bale decreases as throughput increases. The end result is larger (heavier) charges of lint per stroke. Take a 60 bale per hour gin for example. Assume the gin has a single press with hydraulic tramper. The tramper has an electrically driven hydraulic system providing 10 strokes per minute or one cycle every 6 seconds. For this example one can assume all charges are of equal weight although this is not the case in practice (the first one or two charges after the press cycles are consistently larger due to the queuing of lint in the lint slide during cycling of press boxes). A single 500 lb bale produced in 60 seconds equates to ten 50 lb charges of lint. Depending on the accuracy and sensitivity of the bale weight control final bale weight could potentially be 500 lb +/- 50 lb.

Now imagine a gin production of 80 bales per hour. To achieve such a rate the bale press must clear a bale every 45 seconds with no time between bale cycles. Even more daunting is the pressure put on the same 10 stroke per minute tramper for now each charge consists of 72 lb of lint. The possible bale weight error is now +/- 72 lb. One could mitigate with a tramper system producing additional cycles per minute; in the 12 to 14 per minute range. At some point however it becomes a challenge to allot time necessary to charge the cotton into the tramping chamber (12 strokes = 5 second cycle; 14 strokes = 4.3 second cycle).

The challenge of charging the pre-compression chamber in a very limited amount of time with 500 lb of lint while maintaining reasonable bale weights provided the inspiration for the HS/VSTM.

Design Objectives

As an off-shoot of the "Savannah Class Press" technology many of the initial design objectives have been met, validated and verified. Current design objectives focus on application of proven technology to ultra-high capacity gin production. Time is the enemy of the bale press thus innovative means of trimming non-value added time from the bale making cycle have been researched, applied and demonstrated. Time reduction has had a negative effect on bale weight consistency. Complete and variable control of various axes provides opportunity to monitor and manipulate fiber throughput as a method to maintain reasonable bale weight expectations. As a retrofit to existing bale presses with retaining dogs the new technology offers an alternative to press dogs thus removing a major maintenance and production obstacle. To recap:

Design Objectives:

- 1) Eliminate non-value added time constraints on a tramper per-stroke basis while reducing overall cycle time. Target 12 cycles per minute.
- 2) Close the loop on monitoring and managing bale weight based on number of charges and amount of lint per charge.
- 3) Apply new technology as solution to retaining dog issues on short box presses.

Methodology

Eliminate Non-Value Added Time:

The volume of lint going to the press at any given instant is dependent on the throughput of the gin plant. Once one breaks through the 60 second cycle barrier there are few opportunities to trim time out of a baling cycle. At 60 bales per hour 500 pounds of lint is pre-compressed into a press box by the tramper every 60 seconds. Averaging that across 10 strokes (an arbitrary number of strokes per minute chosen for illustration purposes) each charge received

from the lint feeding mechanism and introduced to the tramper weighs 50 pounds, on the average. In the real world the first one or two strokes are always the larger of the aggregate but 50 pounds will suffice for the illustration. Decreasing the cycle time from 60 seconds to 40 seconds (90 bales per hour) has the following affect. Using the same tramper the number of strokes per bale is now limited to 7 (6.66 if one does the math). The bale weight remains 500 thus the weight of each charge is now 71.4 pounds, a 43% increase in volume and/or density. The resulting larger charges create processing issues, especially so for older lint feeding systems and trampers. One way to mitigate the impact of heavier denser charges is to increase the number of tramper strokes per minute. Addition of two strokes significantly increases throughput and processing efficiency. For one, the number of charges per bale increases to 8 and the weight of each charge drops to 62.5 pounds. However, the only way to achieve the additional strokes per minute is through speed; faster rod speeds and faster controls.

During production lint cotton from the battery condenser is in a virtual free-fall before entering the lint charging mechanism. Going from free-fall to manageable lint charges requires high axes linear speeds and response times, finite position control and feedback and the ability to manipulate lint charge sizes when approaching desired bale weight. Use of high speed/high temperature seals for all cylinders is crucial as rod speeds exceed 75" per second. Cutting edge hydraulics and electronics provide the speed and control necessary to provide 12 tramper strokes per minute enabling one to process a bale once every 40 to 43 seconds on a continuous basis.

The HS/VSTM installed at Southern Cotton, Whitton Australia in 2012 is such a tramper. The tramper main driver is a 5" bore x 3-1/2" rod x 134" stroke hydraulic cylinder. Due to a high rod length to diameter ratio of 38.3 hydraulic pressure is limited to 2300 PSI. As with any hydraulic tramper cylinder column strength is a critical design limitation. The tramper cylinder includes an internally mounted Temposonics® magnetostrictive absolute non-contact linear position sensor or transducer. Digital output from the transducer is communicated directly to a Delta computer Systems, Inc. MMC120 linear motion control module running DCS120-Win software. The motion controller is a complete dual-axis position control subsystem for the main Telamecanique BMXP342020 M340 PLC. The MMC120 relieves the PLC of the overhead needed for servo control by updating the positions and drive outputs of two axes simultaneously 1024 times every second thus assuring precise positioning and control at high speeds. The motion controller connectivity is direct with the magnetostrictive linear transducers mounted in the tramper and pusher cylinders as well as proportional system control valve(s). This eliminates communication and scan time delays associated with PLC direct control systems. Plus it makes PLC functionality much improved and straight forward.

The hydraulic power pack for the tramper is one variable displacement AA10V Rexroth piston pump and three fixed displacement Denison vane pumps. The vane pumps are strictly for speed while the piston pump is for speed and position control throughout the stroke and specifically at either end at which point the vane pumps have been unloaded. Control as stated previously is by the linear motion controller. This combination of high speed hydraulics and electronics with precise position awareness are essential to the performance and operation of the HS/VSTM.

Managing Bale Weight Based on Number of Charges and Charge Size:

Consistent bale weight control is difficult to manage in high capacity gins. Improper charge weight management and fluctuating tramper pressure are contributing factors to current bale weight management issues. Ultra-high capacity ginning exasperates the level of difficulty as the amount of lint per charge increases with every increase in throughput. At 50 pounds per charge the challenge is to cut the bale weight at less than plus or minus 50 pounds. Given that all charges are not the same weight (first couple of charges are always heaviest) and good gin operators find a "sweet spot" for optimal throughput, typical high capacity gins are able to maintain fairly reasonable bale weights with the occasional exception. Sudden changes in product inputs require quick reaction on the part of the operator. Otherwise bale weights may drift significantly depending on the characteristics of incoming product. The difficulty increases with every increase in throughput. Additional speed and responsive controls provide the platform for addressing the issues but only go so far in closing the loop. Closing the loop involves managing the final charges of lint so as to arrive at the most optimum bale weight obtainable.

The Savannah ClassTM press technology which is the basis for the HS/VSTM features a variable stroke tramper with constant compression. Constant compression implies the pressure input and force output remains constant, they do not vary. Heretofore hydraulic trampers relied on increasing compressive force as the process variable for bale weight determination. Measurement was provided by either pressure transducer or mechanical pressure switch.

Given HS/VSTM force is constant a new process variable had to be developed. One of the key outcomes of the Savannah ClassTM program was the use of magnetostrictive linear transducers in lieu of mechanical or proximity switches as axis position and control devices. The linear transducer provides a logical successor to pressure or amperage as process variables; platen separation as measured by the transducer. The premise behind the operation of the Savannah ClassTM tramper is simple; every extension of the hydraulic cylinder goes to full stroke unless a preset pressure setting is reached. As lint fills the chamber and generates resistance the cylinder will require additional force (pressure) to reach full stroke, yet it will continue to extend to full stroke unless the preset pressure takes control at the point of full compression. Each subsequent extension will be less than the previous as lint continues to be introduced and the preset pressure limits the stroke due to full compression. During the entire process the linear transducer relays current position to a controller which tabulates the data and signals a bale has been reached based on a pre-determined final position. Final position is the difference in platen separation from full extension to final extension.

Using position as a process variable, HS/VSTM becomes an extremely powerful and versatile tool. By segmenting the platen separation into zones certain functions can be integrated by zone to accomplish specific outcomes. One such outcome is final bale weight (closing the loop). If one can envision the platen separation as multiple zones and each zone is specific to each tramper stroke the final zones would be for bale weight determination (Figure 1).



Figure 1. Platen Separation by Zone @ 5% Moisture Content & 1000 PSI

The number of final zones will vary depending on the throughput of the ginning plant as each zone is position dependent. For instance an 80 bale per hour plant with a 10 stroke per minute tramper would cycle a bale every 45 seconds. The number of strokes the tramper will make per bale is 7, or .75 x 10 strokes per minute (there can be no

half strokes). The number of zones per bale at full production is 7. For this example assume the first two charges are the largest at 90 and 85 pounds respectively. Remaining strokes are 5 with 325 pounds of lint left to make a 500 pound bale. The next 3 strokes carry 75 pounds of lint each thus by the end of the 5th stroke there will be 400 pounds of lint in the box. At this point platen separation has progressed through 5 zones to a "position window" which encompasses the two final zones (Figure 2). Once the linear transducer senses the "position window" control



Figure 2. Zones 6 and 7 (Strokes 6 and 7) Constitute the "Position Window"

of the lint feeding device is transformed from fixed to variable run time. Multiple run time presets are available and tied to relative location of the tramper foot within the "position window". With 2 strokes remaining and 100 pounds of lint necessary to make a 500 pound bale the lint feeder run time is automatically adjusted accordingly. As one can see the fewer strokes available per bale the less opportunity there is to home in on final bale weight. As long as the final two strokes can be designated zones for the "position window" reasonable bale weights can be maintained under ultra-high and high capacity conditions.

Prediction models for different moisture content and force (pressure) have been developed based on plant throughput. The prediction models are the foundation for programming the HS/VSTM zone profiles. Programming variables are production rate, lint moisture content, cylinder bore, cylinder stroke length, press box length and press box cross sectional area. Each model is customized to a particular set of press variables. Figure 3 is a representation



Figure 3. Prediction Script - 5% Moisture Content & 1500 PSI

of one script from the prediction model. Individual scripts are developed for moisture contents of 1% through 8% in increments of 1% each and pressure from 800 PSI to 1500 PSI in increments of 100 PSI each.

An additional feature of the technology is the ability to adjust parameters to further tune bale weight. Position control is infinite and may be adjusted on-line by the operator or automatically based on specific rules. Not only is position tunable, pressure is also adjustable on-line within certain constraints. The flexibility of manipulating both pressure and position makes the feature an extremely powerful tool and the automatic aspect takes the guess work out of the operator's hands. Additional testing and validation is required before the automatic feature is 100% viable.

An Alternative to Retaining Dogs on Short Box Presses:

Retaining dogs have been recognized in prior literature as a "necessary evil" to counter the natural resiliency of compressed lint cotton. Retaining dogs are a feature of short box presses, both up-acting and down-acting. Presses with longer boxes negate the need for press dogs but at the expense of additional steel, deeper foundations or higher roof lines. One of the goals of the Savannah Class[™] program was to verify and validate the hypothesis lint cotton could be pre-compressed in the tramping chamber of a cotton baling press to the extent neither retaining dogs or an extended press box were required to keep lint from blooming out of the top of the box under normal operation. Indeed the hypothesis was validated to the degree a 60" deep press box proved capable of accommodating and

retaining 500+ pounds of lint without the assistance of retaining dogs. The technology has been operating successfully since 2003.

In early 2014, a HS/VSTM is being installed as a conversion to an existing up-acting high density 20 x 41 Dor-LesTM press in Queensland, Australia. The press as originally designed required retaining dogs to hold the lint in the box. Often times the dogs failed to perform adequately, especially should the moisture content of the lint be at the low end of the scale. The retaining dogs have been removed for the conversion as the HS/VSTM will pre-compress lint in the press box to an extent no retention device is required during normal operation. For the sake of definition, "normal operation" is in reference to normal production with no interruption. Should the press have a bale in the tramping box when production is interrupted, the tramper foot will remain in the box at the point of the final stroke until the press is ready to turn.

Prospects for future press designs point to shorter press box profiles as a direct result of pre-compression by the hydraulic tramper. Shorter press boxes imply lower installation costs and faster cycle times. As conversions to existing short box presses the HS/VSTM is an ideal solution to bale weight control and alternative to press dogs.

Summary

Ultra high speed production is the future of cotton ginning in the U.S. and Australia. Other cotton producing countries will follow suit. Baling press design will change in the near future driven by market shifts, logistics and handling requirements. The HS/VSTM is a unique technology designed specifically to address the future needs and anticipated changes of the ginning industry.

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