SPINDLE PICKER HARVESDT SPEED EFFECTS

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Abstract

The gear drive of a modern John Deere Pro 16 picker unit was modified so that spindle speed was reduced without changing the drum speed. Three 1-row picking units were used in the study, one with the standard drive speeds, one with 25% reduction in spindle drive speed, and one with 50% reduction in spindle drive speed. Field tests were conducted in Corcoran, California, in the fall of 2010. Four replications of each of the three picker units were conducted on a Pima variety and an upland variety. Results show that the stalk loss was significantly higher for the unit with 50% spindle speed reduction, indicating that the spindle speed was too low for this unit. The other two units had no significant difference in values for stalk loss. In the near future, the seed cotton will be ginned and fiber quality analyses will be conducted.

Introduction

Beginning in 1850, over 800 ideas were patented for devices to mechanize cotton harvest before the first commercially viable cotton picker was developed in the 1930's. At this time, two picker designs were developed. John Rust observed that cotton could be picked by a smooth, small diameter spindle that was wet with water. The cotton could be doffed from the spindle by pulling it through two closely spaced plates. The Rust design was engineered by Mr. Rust, than produced and marketed by the Allis Chalmers Company and the Ben Pearson Company. The Rust picker worked well in dry, clean cotton, but eventually faded from production due to a lack of further engineering development (Holley, 2000). The International Harvester Company (and later The John Deere Company) developed a spindle picker design that used a tapered, barbed spindle, also wet with water, to pick the cotton. The cotton was doffed from the spindle using a rotating doffing pad made of rubber (later polyethylene) to grab the fibers and pull them from the spindle. This design was more successful than the Rust picker when harvesting wet cotton and in cotton fields that had excessive weed growth. Furthermore, the engineering provided by the two companies have allowed to picker design to evolve and meet the needs of producers for larger and faster machines (Holley, 2000).

The mechanical picker collected bits of leaves, burrs, stalks, and other trash that made cotton quality lower than if it were hand-picked. This necessitated the development of additional seed cotton cleaning equipment for use in the gin. Over time, spindle picking has become the preferred method of harvesting most cotton in the U.S. Improvements to spindle pickers over the years have primarily focused on increasing the number of rows that can be harvested with 1 pass of the machine from 1 row to up to 6 rows; as well as increasing the travel speed of the harvester from around 1.9 to up to 5 miles per hour.

As cotton harvesters have gotten bigger and faster, spindle speeds have increased. As the speed has increased, cotton fibers can wrap more tightly around the spindle. Spindle sizes have also decreased in both diameter and length in order to reduce the weight of the picker head. As spindle diameter decreases, cotton fibers will wrap around the spindle more and become tighter on the spindle. As spindle length decreases, cotton plants must be further compressed as they pass through a smaller picking zone. These changes may have resulted in decreased cotton fiber quality, particularly regarding spindle twists, preparation, and neps (Hughs et al, 2000 and Baker et al, 2010).

Spindle pickers require meticulous adjustment in order to minimize harvest losses and to maximize fiber quality (Williford et al, 1994). Avoiding the harvest of high moisture cotton is another requirement to minimize harvest losses and to maximize fiber quality (Mayfield et al, 1998). Deviations from these highly recommended practices will result in significant quality degradation and increased harvest losses, both of which can cost the grower.

Objective
The objective of this study was:

- To compare fiber quality, harvest losses, and trash content of spindle-picked cotton fiber over a range of harvest speeds on 2 varieties of cotton with a modern picker operating at approximately 4 mph.

Materials and Methods

Three very similar John Deere Pro-16 cotton picker single-row units were obtained for this study. One of the picker units was not modified and was used as the control. The other two picker units were modified so that the spindles and doffers operated at slower than the control speed, while the drum operated at the same speed as the control.

Design of modified picker heads
The standard drive system used for the John Deere Pro-16 picker unit is shown in Figure 1. The Pro-16 unit has two picking drums: a front one with 16 spindle bars of 20 spindles each and a rear one with 12 spindle bars of 20 spindles each. They are operated with a single gear box near the center of the unit that provides power for the drum, spindle and doffer rotation of both the front and rear picker drums. The drum speed is synchronized with the picker ground speed, but the spindle and doffer speeds will also vary in proportion to the ground speed. The gear on the center shaft drives the front and rear jackshafts which have both gears rigidly attached to the shaft (unless the slip clutch is activated by excessive torque on the shaft). The top gear on each jackshaft drives the drum rotation with a gear that is solidly attached to the shaft. The center gear on each jackshaft is the primary drive for the spindle rotation (the remainder of the spindle rotational drive is not shown). The driven gear in these pairs (the ones on the drum drive shafts) is mounted on a bearing so that it can turn at a different speed than the shaft, as are the doffer drives that are below them. The spindle rotational drive and the doffer rotational drive are rigidly connected to each other for power transfer from the spindle drive to the doffer drive.

Considerations in the design of the modified picker unit drive included: the drive and drum shafts could not be moved, the unit width could not be expanded, and the drum rotational speed must be nearly equal to the current design. The drive and drum shafts could not be moved because the positioning of the spindles, doffers, and moistener pads are very critical and must be precisely as designed. Also, the positioning of air currents in the chamber to facilitate seed cotton removal must not be changed. The picker unit width could not be expanded so that it could accommodate the picking of cotton with a 30 inch row width. The drum rotational speed could not be changed so that the drum picking speed would still be synchronized with the ground speed. In order to achieve different spindle speeds, it was decided to reduce the spindle drive rotational speed by 50% for one of the modified units and by 75% for the other modified unit.

The design process at first looked at changing gear sizes in the drive; however, the size of gears needed to reduce the spindle rotational speed while maintaining drum speed would not be able to fit within the standard unit width. Next, the design process looked at changing entirely to a sprocket and chain drive; however, the size of sprockets needed to maintain the drum speed would not be able to fit within the standard unit width. Only by considering a combination of gear and chain and sprocket drives could the design objectives be achieved.

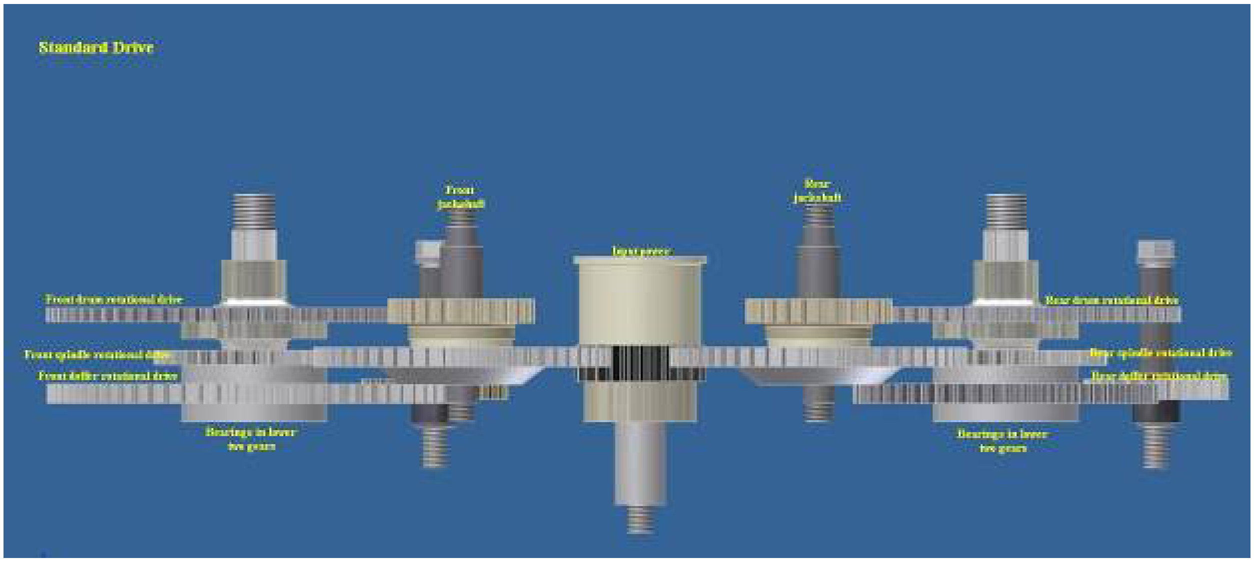

Figure 1. The standard drive system for the John Deere Pro-16 picker head. Power input is to the center shaft.

The modified drive system for the two picker units is shown in Figure 2. Modifications included: Replacing the input drive gear with two drive sprockets, adding a fourth layer to the drive system, replacing the spindle rotational drive gears with appropriately sized sprockets, and adding idler sprockets for the chain drives (not shown in figure 2). The input drive gear was replaced with two drive sprockets so that the spindle rotational speed could be changed independently of the drum drive speed. As designed, the two chains must rotate in opposite directions. The fourth layer was added to the system so that the proper drum rotational speed could be achieved. Spindle drive gears were replaced with sprockets so that the speed ratios could be changed. Speed ratios (drive: driven) for the 50% speed reduction was 14:55 for the front and 14:46 for the rear. Speed ratios for the 25% speed reduction (75% of design speed) were 15:37 for the front and 15:33 for the rear. Adjustable idler sprockets were added for the chain drives in order to achieve and maintain proper chain tension.

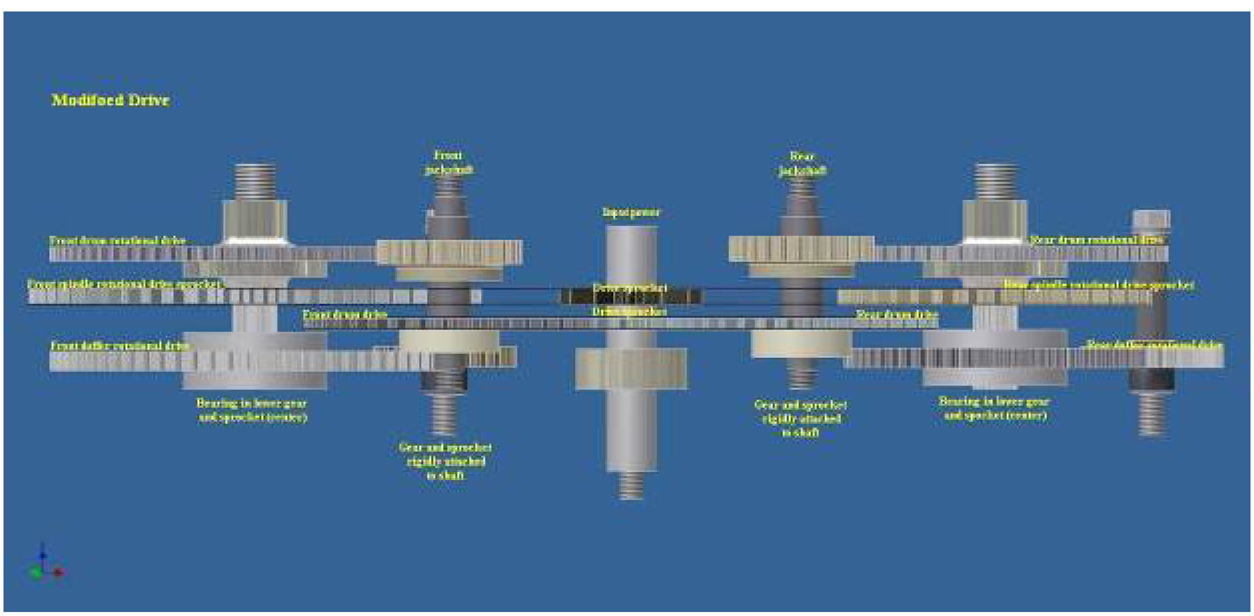

Figure 2. The standard drive system for the John Deere Pro-16 picker head. Power input is to the center shaft. Idler sprockets for the chain drives are not shown.

Field tests

Test plots of about 0.1 acres in area were selected from two commercial production fields near Corcoran, California – one plot was a Pima variety and the other plot was an upland variety. The cotton was planted in mid May, which was significantly later than the normal planting date. The delay was due to unusually wet and cold weather in the San Joaquin valley, California. The Pima cotton was grown on flat 30 inch rows and was flood irrigated as needed during the growing season. The upland cotton was grown on ridged 38 inch rows and was furrow irrigated as needed. Chemical herbicides and insecticides were applied as needed and in accordance to customary practice for the growing region including chemical defoliation.

The cotton was harvested from October 26-28, 2010. A modified John Deere model 9976 spindle picker was used to harvest the cotton (Figure 3). The picker was designed to be a 6-row picker, but for this test, only one of the picker nits was mounted and used at a time. The five remaining air lines were left open so that the air would be nearly the same as if all six units were being used. The 1-row picker used 1/2 inch spindles that had 2.1 inches of the spindle tip extending into the picking zone. Picking zone width for the picker was adjusted to 2.15 inches at the narrowest part. The picker was operated at a ground speed and drum speed of 4.0 mi/hr. Each of the three picking units which represented different spindle speeds was operated randomly. Results from the three speed combinations were compared for both varieties tested. Each test lot consisted of 1 row of cotton, either 1130 feet long for the 38 inch rows or 1500 feet long for the 30 inch rows. Four replications of each combination of test conditions were conducted. Seed cotton harvested from each lot was bagged in 3 to 5 polyethylene bale bags for temporary storage. Two seed cotton samples of about 60 grams each were randomly selected and placed in sealed metal cans for subsequent seed cotton moisture determination. A seed cotton sample of about 500 grams was randomly selected and bagged for spindle twist analysis. Ambient air temperature and relative humidity in a shaded location were measured with an aspirated psychrometer during the five to ten minutes required to harvest each lot (Table 1).

Figure 3. The John Deere model 9976 spindle picker with 1 picking unit active.

Table 1. Harvest dates, air conditions, and cotton moistures for the field study.

Cotton variety	Harvest dates	Air temperature, degrees F	Air relative humidity, percent	Seed cotton moisture at harvest, percent w.b.	Lint yield from harvested seed cotton, bales/acre
Pima	10/26 & 27/10	63 - 70	60 - 70	7.8 - 10.4	2.22
Upland	10/28/10	71 - 84	44 - 58	6.6 – 8.4	4.28

Ambient weather conditions were mild and somewhat humid with the ambient air dry bulb temperature ranging from 63 to 84 ^{o}F overall (Table 1). The ambient air relative humidity ranged from 44 to 70 % overall. Seed cotton moisture at harvest ranged from 7.8 to 10.4 % (wet basis) for the Pima variety and from 6.6 to 8.4 % for the upland variety.

Results and Discussion

Stalk loss, or the amount of seed cotton that was not removed from the plant by picking, was significantly different across spindle speed for both varieties (Table 2). Stalk loss at the 50% speed reduction was visually and measurably greater than for the other two speeds tested. These results led to an analysis of the actual spindle picker speed. Apparently, because the spindle drive is on the same shaft as the drum drive, the actual spindle speed is reduced from the apparent spindle speed, due to the counter effects of the drum itself revolving. Spindle speeds calculated for the study are listed in Table 3. Earlier studies have shown that spindle speeds below 2000 rpm will increase stalk loss (Baker et al., 2010).

Table 2. Stalk loss (%) for the field study.

Cotton variety	Spindle speed Standard	75 %	50%
Pima	5.1b	5.3b	22a
Upland	4.9b	4.8b	25a

Note: When comparing across rows, different letters denote statistically significant differences using the Student-Newman-Keuls test at the 5% level.

Table 3. Calculated spindle speeds (rpm) for the field study.

Picker drum		Standard	75 %	50%
Front	apparent	6160	5230	3290
	actual	4480	3550	1610
Rear	apparent	5780	4250	2850
	actual	4280	2760	1360

In the near future, the seed cotton will be ginned and fiber quality of the ginned samples determined.

Summary

Spindle picking of cotton was developed in the 1930's to 1940's as a means to speed up and reduce the cost of harvest. Improvements to spindle pickers over the years have primarily focused on increasing the number of rows that can be harvested with 1 pass of the machine from 1 row to up to 6 rows; as well as increasing the travel speed of the harvester from around 1.9 to 5 miles per hour. As cotton harvesters have gotten bigger and faster, spindle speeds have increased. As the speed has increased, cotton fibers can wrap more tightly around the spindle. Spindle sizes have also decreased in both diameter and length in order to reduce the weight of the picker head. As spindle diameter decreases, cotton fibers will wrap around the spindle more and become tighter on the spindle. As spindle length decreases, cotton plants must be further compressed as they pass through the picking zone. These changes have resulted in a general decrease in cotton fiber quality, particularly regarding spindle twists, preparation, and neps.

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Disclaimer

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