

Tractor-Mounted Limb Shaker for Harvesting Citrus

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ABSTRACT

A tractor-mounted limb shaker was developed to reduce investment cost of a mechanical harvesting system for citrus. The shaker boom operated best over the tractor hood in high canopy trees, but was at a disadvantage when clamping low limbs. Harvesting rate was 40 trees/h at a 95 percent fruit removal efficiency in chemically loosened oranges, but only 12 trees/h in untreated oranges. Removing the shaker assembly from the tractor required 4.25 man•h and 9.5 man•h were required to remount the shaker on the tractor.

INTRODUCTION

Mechanical harvesting systems for citrus fruits have been under development for more than two decades (Hedden et al., 1977). However, acceptance of these systems has been limited, primarily, because of their marginal economics and an adequate supply of labor in the citrus industry.

Limb shakers for the removal of oranges have indicated merit when they were assisted by an abscission chemical for fruit loosening. Coppock (1967) reported on a tractor-mounted, hand-positioned shaker boom that required two operators and gave higher harvesting rates than did a catch-frame-mounted limb shaker. Development of a limb-shaker harvesting system for citrus has progressed from a catch-frame-mounted (Coppock and Hedden, 1968), trailer-mounted, semipowered positioned shaker boom (Coppock, 1974) to a self-propelled, full-powered positioned system (Sumner, 1977).

The objective of this study was to develop a full-powered positioned, tractor-mounted shaker that could be readily removed from the tractor so the tractor could be available for other operations, thereby reducing the machine's initial investment cost. This report covers the design and performance of the tractor-mounted limb shaker.

DESIGN REQUIREMENTS

Proven design features from previous shakers were incorporated in the design of the tractor-mounted limb

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shaker unit.

The major design requirements for the limb shaker were:

1 Mount shaker on conventional 52 kW (70 hp) grove tractor with provision for quick attachment and detachment to the tractor.

2 Maintain the operators' station on the tractor seat with full-power positioning of the shaker boom for attachment to the limb.

3 Isolate the shaker vibration mechanism from the tractor and positioning system.

4 Provide an independent, self-contained hydraulic system driven by tractor PTO (power-take-off).

5 Utilize proven components in the system design and construction techniques available in local machine shops.

DESIGN AND CONSTRUCTION

The tractor-mounted limb shaker designed and constructed in 1978 is pictured in Figs. 1 and 2. A John Deere 2640 diesel tractor (52 kW, 70 hp) with a 16-speed, Hi-Lo, manual shift transmission with 11 L-15

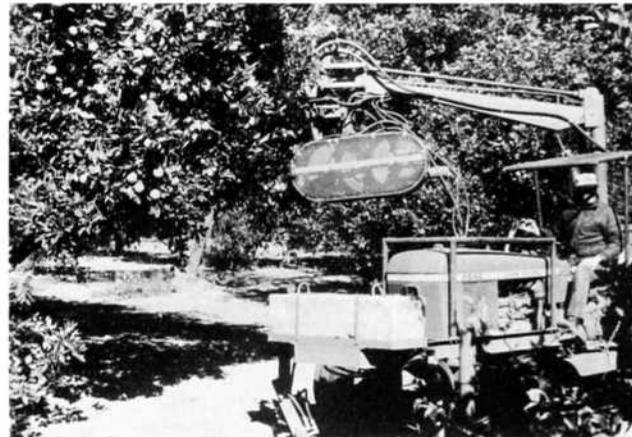


FIG. 1 Tractor mounted limb shaker operating over the tractor hood.



FIG. 2 Limb shaker in transport position.

front and 18.4-26 rear grove tires was the propelling and power unit selected for the shaker. Hydraulic power was supplied by the PTO through a tandem hydraulic pump, 114 and 57 L/min (30 and 15 gal/min) at 2100 r/min engine speed. The hydraulic flow diagram is presented in Fig. 3.

The main frame of the shaker assembly was positioned under the rear axle and engine clutch housing of the tractor and was attached to the tractor at those two points. A second frame attached to the engine clutch housing and to the front tractor frame supported a 250-kg (550-lb) counterweight mounted 1.1 m (3.5 ft) ahead of the tractor's front axle to counterbalance the tractor when the shaker was positioned to the rear. A shaker-positioning mechanism similar to an earlier design for a self-propelled shaker (Sumner, 1977) was attached to the main frame 76 cm (30 in.) behind the rear tractor axle. This arrangement allowed the operator to position the shaker boom over the tractor hood either to the left or the right side of the tractor for convenience in moving the shaker into a tree for limb attachment. Fig. 4 illustrates the positioning capability of the shaker clamp. The hydraulic oil reservoir was located next to the shaker pivot on the main frame and directly over the PTO mounted pump.

Three double-function control levers activated six hydraulic direction control valves to power cylinders and motors for positioning the shaker boom as it entered the tree. The control levers were to the right of the operator, within easy reach. The control function and positioning of the shaker were reported by Sumner (1977).

A safety frame was installed above the operator and below the shaker support to protect the operator in the event that hydraulic or mechanical failure should cause the shaker to drop. It was covered with a snap-on canvas to protect the operator from sun, rain, or falling fruit.

Padded fruit-deflector shields were installed over the tractor to cushion a falling fruit and deflect it to the side of the tractor. Cylindrical shaped wheel sweeps 1 m (36 in.) long \times 0.3 m (12 in.) in diameter made of rubber flaps were attached ahead of the tractor wheels to remove fruit from the path of the tractor tires.

A set of parallel-links 41 cm (16 in.) long and a coil spring 47 cm (18.5 in.) long provided a vibration isolation system between the shaking mechanism and the main frame of the shaker (Fig. 5).

A three-shaft-rotating-mass shaker having a total rotating mass of 90.7 kg at 14 cm center gravity (200 lb at 5.5 in.) was initially designed for use on the tractor-mounted positioning system. The shaker had a total mass of 385 kg (850 lb) and operated at a maximum frequency of 52.2 rad/s (500 rpm). An adjustable-stroke, crank-drive shaker with strokes of 15.2, 20.3, and 25.4 cm (6, 8, and 10 in.), a total weight of 470 kg (1035 lb), and a reciprocating mass of 345 kg (760 lb) was also designed for attachment on this positioning system for future harvesting tests.

PERFORMANCE AND DISCUSSION

The tractor-mounted, rotating-mass shaker was operated in several groves under varying conditions to evaluate its performance and to determine whether it met the established design objectives.

Approximately 20 trees were harvested at a variable frequency up to 52.5 rad/s (500 rpm) in a 'Pineapple' orange grove not sprayed with abscission chemicals. The trees were planted on 7.6 \times 7.6 m (25 \times 25 ft) spacing and averaged 6 m (20 ft) in height. Shaker positioning was difficult because the limbs were close together at the shaker attachment point. Approximately eight attachments were required per tree, and only 12 trees were harvested/h. Fruit yield averaged 286 kg (630 lb)/tree and fruit removal was about 90 percent.

In another test, more than 200 Parson Brown orange trees were harvested with the tractor-mounted shaker in a grove planted on 6 \times 6 m (20 \times 20 ft) spacing 6 m (20 ft) in height and yielding 212 kg (468 lb)/tree. The trees were sprayed five days before harvest with an abscission chemical and the preharvest fruit drop was 20 percent,

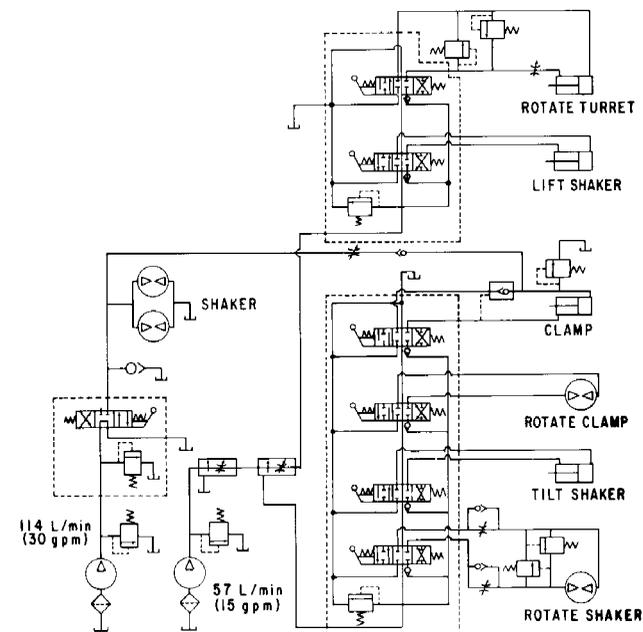


FIG. 3 Hydraulic diagram for the tractor-mounted limb shaker.

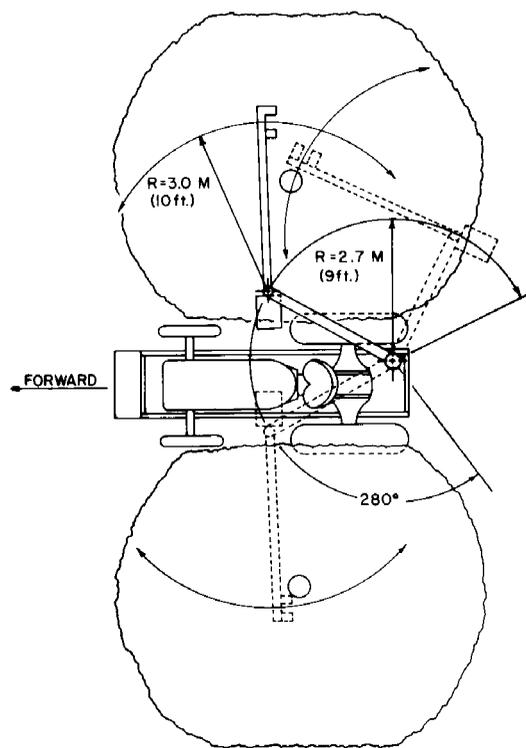


FIG. 4 Shaker positioning capability.

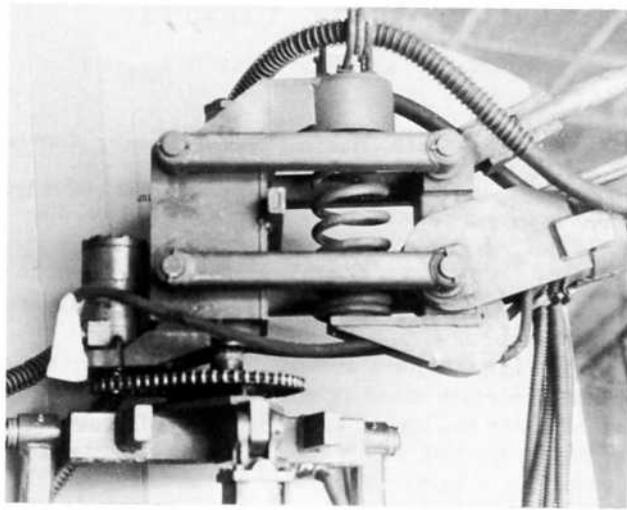


FIG. 5 Parallel-link isolation system for the shaker's support mechanism.

indicating good fruit loosening. This test was the first time the shaker had been operated for an extended time. On the first day the operator worked out the procedure for positioning the shaker and became familiar with the operating controls. An average of 4.5 limb attachment/tree were required, and 26 trees/h were harvested. The fruit had loosened further by the second day, and the operator had established a harvest procedure that resulted in increased efficiency. The number of limb attachments necessary was reduced to 2.7/tree, and the harvesting rate was increased to 40 trees/h. Fruit removal was 95 percent or above.

With the positioning system the shaker boom could be swung forward into a tree, at a 45 deg angle, similar to the positioning method used on the self-propelled shaker unit (Sumner, 1977). However, when the shaker boom was operated from the right side of the tractor, the shaker pushed into the adjacent tree and the shaker operator, at times, had to move the tractor unit forward and backward to get the shaker in and out of the tree canopy. To move to the next tree, he had to move the shaker boom over the tractor hood. In tight tree rows, the operator had to back the tractor away from the tree to allow the shaker to swing past the tree just shaken. The best position for the shaker boom when operating in high canopy trees was over the tractor hood from where the operator could swing the shaker clamp into the tree on the right side (Fig. 1). Positioning was also accomplished (after practice) by moving the clamp into the tree as the tractor approached the tree. With the boom over the hood, the operator had an excellent view of the limb the shaker was clamping. Trees on both the left and right sides of the tractor could be shaken as the shaker was moved across the tractor hood to the left and to the right. The major disadvantage of the over-the-hood position was that the sharp downward angle of the boom that was necessary to clamp low limbs reduced the effectiveness of the shaker. A secondary disadvantage was the care that was necessary to prevent the shaking mechanism from making contact with the tractor as it passed over the hood.

The shaker pivot and oil reservoir on the rear of the tractor provided a compact system; however, this arrangement added weight to the rear of the tractor. When the shaker boom was positioned to the rear, additional



FIG. 6 Overhead hoist attached to the front counterweight assembly for attachment to the tractor.

weight was transferred from the front of the tractor. The counterweight on the front of the tractor gave stability to the shaker positioning mechanisms in all positions.

Attachment and detachment of the shaker from the tractor was difficult and required excessive time. To improve the situation, balance points were located on the front counterweight assembly, the two rear tractor wheel fenders, and the shaker pivot assembly including oil reservoir and pump. Lifting straps were then attached at the respective balance points to allow a 1364 kg (3000 lb) capacity overhead hoist to be used to assist in the attachment or detachment of the complete system to or from the tractor (Fig. 6). Quick-coupler fittings were installed in the hydraulic lines to the front wheel sweeps which allowed the entire front assembly to remain intact. The initial bolted fasteners for the rear fenders were replaced with pinned hinges for ease of removal. These modifications reduced the attachment and detachment time by approximately 50 percent.

An average of 9.5 man/h were required to attach the four assemblies of the shaker system to the tractor and 4.25 man/h were required to detach the system from the tractor using an overhead chain-hoist.

CONCLUSIONS

The self-contained, limb shaker positioning system met the original design requirements. Minor modifications improved the ease of shaker system attachment and detachment from the tractor so that the task could be performed in a farm shop with a 1364 kg (3000 lb) capacity hoist. The tractor could then be utilized approximately six months of the year for other citrus production operations, thereby reducing the initial investment cost of the mechanical harvesting system.

A 250 kg (550 lb) counterweight attached to the front of the tractor was needed to stabilize the machine when the shaker boom was positioned to the rear of the tractor.

A harvesting rate of 40 trees/h at 95 percent fruit removal efficiency was obtained in a grove suited for limb shaker harvesting.

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