Development of the Tandem Tractor

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Development of the Tandem Tractor

Abstract
In an effort to extend flexibility in farm power, provision has been made for combining two tractors as a single four-wheel drive unit or detaching for individual operation as the need exists.

Disciplines
Agriculture | Bioresource and Agricultural Engineering

Comments
Development of the Tandem Tractor

Rubber Tires, variable-speed engines, quick attaching wheel weights, and expansions in gear ratios have all contributed to the extension of flexibility in farm tractor power, whereby power and weight can be varied to fit the load. Further flexibility has been gained in the recent development of the tandem tractor—an arrangement in which two tractors are hooked together and operated as a single unit from the seat of the rear tractor.

Together, the tractors can do jobs not economical for small or medium tractors (plowing, disking) with a 50 percent reduction in labor, and yet, when taken apart, can be used to do jobs not economical for large tractors (planting, cultivating, pulling wagons, and farm chores). For light loads, the individual tractors are cheaper to operate than a big tractor, have better fuel economy, are most maneuverable, and the initial cost is less. The tandem tractor can do jobs usually reserved for track-type tractors such as terracing and land leveling, and save the cost of hiring an earth moving tractor.

The tandem tractor provides an economical four-wheel drive tractor. The purchase price of two medium size gasoline tractors normally is lower than that for one conventional four-wheel diesel tractor of equivalent horsepower. Since each motor supplies power to a set of drive wheels, the relation of one set of drive wheels to the other drive wheels is completely flexible so that a torque wind-up caused by one set of drive wheels overriding the other set common to most four-wheel drives, is not a problem in tandem tractors.

Mounted equipment (cultivators and mowers) may be used on the individual tractor. Trailing implements, (disks, field cultivators and plows) with sufficient capacity are available for the tandem tractor.

Method of Joining Tractors

The tractors are located one directly behind the other and the front wheels of both tractors are removed. In steering the tandem tractor, the front tractor turns with respect to the rear tractor about a vertical king pin in a manner similar to a fifth wheel. The vertical king pin (Fig. 2) consists of a superstructure bolted to the front axle of the rear tractor and has a trailer hitch ball located above the radiator of the rear tractor and a bolt below the radiator. The king pin is inclined forward to assist the front tractor in maintaining a forward direction. The lowest energy level in the steering quadrant, thereby, is straight forward. Tilting the king pin may be compared to caster in the Ackerman steering system.

A bearing is located close behind the rear axle housing of the front tractor to permit rotation of one tractor about a longitudinal axis with respect to the other tractor. This articulation is needed when one wheel encounters a rock. The journal of the bearing (truck rear axle) lying in the horizontal plane (Fig. 2) is attached by a structural member to the three-point hitch system of the front tractor while the bearing housing is attached to the vertical king pin.

Control of Tractor

Each of the controls operate simultaneously on the front tractor when the driver activates the control on the rear tractor.

Clutch

The hydraulic system of the front tractor was used to control the front clutch. A hydraulic cylinder (attached to the clutch pedal of the front tractor) a relief valve, and a globe valve are placed in series. As long as the globe valve is open, oil circulates to sump. When the rear clutch pedal is depressed, the globe valve closes and the oil enters the hydraulic cylinder depressing the front clutch pedal. When the cylinder reaches the end of its stroke, the oil flows through the relief valve returning to the sump.

Steering

The tandem tractor is steered by using two long single-acting hydraulic cylinders located under the rear tractor (Fig. 2). One end of each cylinder is hooked to the swinging drawbar bracket of the rear tractor and the other ends of the cylinders are hooked to each side of the drawbar of the front tractor. A hydraulic pump (front-mounted manure loader pump located on rear tractor) is used to operate the hydraulic cylinders. A four-way valve attached to the steering wheel of the rear tractor controls the steering cylinders. A follow-up rod is hooked between the top link of the front tractor and the valve control lever. This rod (Fig. 1) provides "feel" and precision control of the turning movement by giving a controlled relationship between rotation of the steering wheel and degree of turn at the king pin.

Throttle

The speed of the engines are synchronized by connecting a vacuum operated diaphragm to the front governor control rod. The diaphragm is connected to the intake manifolds of the front and rear tractor and operates in a manner to equalize the vacuum in the manifolds by loading or unloading the governor of the front tractor.
Ignition

A jumper wire was hooked between the rear and front ignition coils. Turning on the key of the rear tractor made both tractors operative; turning it off, killed both motors.

Advantages

Four-Wheel Drive — In wet spots and on sandy soils, the four-wheel drive is superior to the two-wheel drive because, when one wheel slips, the other three wheels still have traction. Under heavy load, the four-wheel drive develops maximum drawbar pull without undue slippage. Compared with a two-wheel drive, the four-wheel drive reduces the tire size (width) and weight needed to develop full horsepower of the tractor. The tracking of the rear wheels in the tracks of front tractor reduces the power required in soft fields.

The characteristics of the four-wheel drive when turning under load improved the handling of drawn implements (disks and plows). The four-wheel drive provides a positive non-slip turn; i.e., differential brakes are not required for making a close turn under load.

The weight distribution of the tandem tractor is good. Table 1 gives weight distribution with five-bottom plow in lowered and raised positions.

Table 1. WEIGHT AND WEIGHT DISTRIBUTION OF MODEL 860 FORD TANDEM TRACTOR*

<table>
<thead>
<tr>
<th></th>
<th>FRONT WHEELS</th>
<th>REAR WHEELS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight</td>
<td>Weight</td>
</tr>
<tr>
<td></td>
<td>pounds</td>
<td>distribution</td>
</tr>
<tr>
<td>Plow lowered †</td>
<td>5680</td>
<td>62.9</td>
</tr>
<tr>
<td>Plow raised</td>
<td>4758</td>
<td>46.1</td>
</tr>
<tr>
<td>20% weight shift</td>
<td>3872</td>
<td>42.9</td>
</tr>
<tr>
<td>and plow lowered</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Weight of tandem tractor was 9035 lb.
†Weight of five-bottom plow was 1310 lb.

Dynamometer Tests — A preliminary dynamometer test was conducted with the tandem tractor (Fig. 4) on a loose cinder track with the tractors joined. Drawbar pull and speed were determined with only one tractor pulling at a time and then with both tractors pulling together.
### Tandem Tractor

**TABLE 2. PRELIMINARY DYNAMOMETER TEST OF A TANDEM TRACTOR COMPOSED OF A MODEL 8N FORD AND A MODEL 860 FORD TRACTOR**

<table>
<thead>
<tr>
<th>Drawbar pull of tractor pounds</th>
<th>Power developed by tractors horsepower</th>
</tr>
</thead>
<tbody>
<tr>
<td>1180</td>
<td>12.9</td>
</tr>
<tr>
<td>1380</td>
<td>12.1</td>
</tr>
<tr>
<td>2560</td>
<td>25.0</td>
</tr>
<tr>
<td>3450</td>
<td>28.2</td>
</tr>
</tbody>
</table>

The above data indicate that a tandem tractor is capable of pulling more load on a loose cinder track than the sum of the pulling effort of the two tractors pulling individually. The reason for this is, (a) force required to push front wheel is gained for drawbar pull and (b) the weight of the tractor is concentrated on the drive wheels. Because of the loose condition of the track, the dynamometer tests were discontinued. Additional dynamometer tests will be required to completely determine the performance of the tandem tractors.

**Power Take-Off** — Two tractors hooked in tandem can provide a completely flexible constant running power take-off. When pulling PTO-operated machinery, the front tractor is placed in gear. The PTO shaft of the machine is hooked to the rear tractor. The forward speed of the tractor is regulated by manually controlling the throttle of the front tractor while the PTO speed of the machinery is controlled by the throttle on the rear tractor.

Use of an overrunning PTO clutch permits the rear tractor to be placed in a lower gear than the front tractor. With this arrangement the rear tractor can take some of the load and help move through wet spots when the front tractor begins to slip or mire.

**Wheel Spacing** — Tractors with power adjusted tread combine to provide a tandem tractor with power adjustment of all four wheels.

**Field Operation** — In order to test the tandem tractor in the field, a five-bottom plow (Fig. 3) was built by adding two bottoms to a regular three-bottom mounted plow. The three-point hitch superstructure was relocated so that the plow would be in correct operating position with a 76-in. wheel spacing. The 76-in. wheel spacing permitted the tractors to be separated and used for cultivating corn without changing the wheel spacing. The center of draft was almost directly behind the center of pull. Rear mounted manure loader booster cylinders were mounted in parallel with the 3-point hitch system to assist in raising and controlling the mounted plow.

The tandem tractor (two Model 860 Fords) pulled the five-bottom (16-in.) plow in dry Webster-Clarion soil at a speed of 6 mph (4th gear). This speed proved to be too fast for good coverage of stubble, but at 4 mph (3rd gear—part throttle) good coverage was secured. Wheel slippage was not noticeable. It was observed that the rear wheels were actually geared to the tracks of the front wheels.

The width of the headlands did not have to be widened when the tandem tractor was used. The turning characteristics of the center-hinge steering of the tractor made it possible to plow to the headland and drop the plow after the headland is cleared when entering the field.

**Disadvantages**

**Coupling** — The time required for coupling and uncoupling is a disadvantage. Improved design, quick-attaching self-sealing hydraulic and electrical coupling will speed the operation.

**Ties Up Small Tractors** — While the tractors are coupled together jobs requiring single tractors may be delayed. This will call for advance planning to do the heavy jobs while the tractors are together and light jobs while apart.

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great force on the film between the roll and the pressure rollers, and so unwind the film. A belt brake attached to the shaft will control the unwind speed. The pressure roller should press the film to the soil at a point slightly behind the film roll, but far enough in front of the rubber tires so that no contact can be made between the roller and the tires. This would cause a brake action resulting in unsatisfactory unwinding of the film. For this reason the swivel point of the attachment bar for the pressure roller was brought forward.

**Operation**

With minor changes on the demonstration equipment, one-man operation is possible. With the “mulcher” in the raised position, the film is brought back behind the rear disks so that it passes underneath the pressure roller and rubber tires. The implement then is lowered onto the film. The first foot of film is covered manually with soil to anchor it firmly in the ground. The film is then laid mechanically over the whole row and is cut at the end of the row. A full roll of polyethylene film is always carried on the tractor so that an empty core can be replaced anywhere along the row. To accomplish this, film from the full roll is overlapped over the last two feet of the laid film while the implement is in the raised position. It is then lowered slowly onto the film. The overlapped film is then anchored manually, and the mulching operation can be resumed. Replacing of a roll of film requires approximately three to four minutes. However, with modifications in the film handling system, this time can be cut in half.

**Application**

This mulch-laying equipment has been used successfully on a seven-acre field of sandy loam soil to lay 4-ft-wide film on 7-ft center at a rate of more than one acre per hour. The film was laid during windy weather, but no difficulties were experienced during or after the mulching operation. Tomatoes and melons were planted through this mulch and no dislocation or loosening of the film was reported during or following the operation.

The simple design is of practical advantage to farmers mechanically inclined. This feature will permit them to assemble their own mulching equipment from suitable cultivators until such time as “mulchers” are sold commercially.

**Grape Harvester**

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**Energy Requirements** — All harvester components were powered, either directly or indirectly, with hydraulic motors. This energy source not only provided flexibility of operation but also made energy analysis simple. Motor performance data are shown in Table 1. Of special interest is the difference in horsepower requirement between the sickle cutter bar and the saw-chain unit. The advantage of the saw chain over the sickle was its stability in cutting efficiency as ground speeds increased. Conversely, the sickle cutter possessed the distinctive advantage of not stalling when obstructions were met.

The internal tractor hydraulic system provided oil to two hydraulic motors (continuous operation) and all the cylinders (Fig. 10). The front-mounted pump operated cutter bar and blower. The temperature rise of the oil with respect to time is shown in Fig. 11.

**Field Performance** — The design speed was 1.5 mph. This harvest rate would yield 14 acres of raisins or 17 acres of wine grapes per day. Using one driver-operator, a manpower advantage (6, 7) of 70:1 and 63:1, respectively, was calculated when comparing machine harvest to hand harvest. Because of the steering problem, and also because of cutter inefficiency, a ground speed of 0.5 mph was used for most of the 1957 trials. The maximum speed used was 1.6 mph. Performance of the 1957 harvester proved that it was capable of commercial harvests.

**Future** — Further research will be directed toward improving cutter-bar efficiency, trash removal, tractor guidance, and vine breeding-training.

**References**

7 Lamouria, Lloyd H. Wine grape handling, labor and cost analysis. Paper presented at the 33rd Annual Meeting of the Pacific Coast Section of ASAE, Fresno, Calif. (Mimeo), Jan., 1955.

**Tandem Tractor**

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**Tractors May Be Overloaded** — Because the four-wheel drive places all the weight on the drive wheels, the drive wheels do not function effectively as slip clutches, as a result, excessively high torques may develop in the rear axle shaft.

**Summary**

A tandem tractor was constructed to test the basic concept of a flexible powered tractor — that the power and weight of a tractor can be varied according to the size of the load. The tandem tractor provides a large tractor for the heavy work by combining two small or medium-sized tractors which can be quickly uncoupled into regular tractors.

The front tractor (all front wheels of both tractors are removed) is turned by hydraulic cylinders about a tilted king pin located above and below the radiator of the rear tractor. A longitudinal pivot was located between the two tractors and attached to the three-point linkage of the front tractor.

Controls were developed for simultaneous operation of the clutch, ignition and throttle from the seat of the rear tractor.

Dynamometer tests and field tests indicate the superiority of the four-wheel drive over the conventional two-wheel drive. The tandem tractor is a versatile and economical system for pulling both large and small loads.