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Design and Operation of the MSU Tandem Tractor

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A TANDEM tractor composed of two tractors hooked together and controlled from the rear tractor has been built at the Agricultural Engineering Department, Michigan State University. It was tested on sod, plowed, and plowed and disked land. Results indicate that the tandem tractor can provide the farmer with a versatile power unit: one four-wheel drive tractor for pulling heavy loads; and two two-wheel drive tractors for pulling light loads.

An analysis of farming operations shows that the farmer has, in general, two different power requirements: (a) Heavy work (plowing, disking, subsoiling, land leveling) for the large tractor, and (b) Light work (pulling wagons, planting, cultivating, chore labor) for light or medium tractors.

A study, began (6) in 1953, shows that the size of tractor purchased by the American farmer has been increasing at a rapid rate. Fig. 1 shows average tractor horsepower purchased by the American farmer between 1947 and 1957. The trend toward higher tractor horsepower actually began in 1952. In 1955 the American farmer purchased a tractor that had nearly twice as much horsepower as was purchased in 1951. The farmer buys a tractor to pull the heavier loads, then operates it at part capacity when pulling light loads. The high cost of labor and the availability of larger row-crop tractors (with replaceable wide front ends) contributed to the rise in horsepower per tractor.

The tandem tractor was developed to provide power units for the two types of loads found on the farm. Excluding plowing and disking, the tractor is used most for planting, cultivating, pulling wagons, and other chore labor. (Pulling a six-row cultivator would require a larger tractor.) If a tractor with sufficient horsepower were purchased for cultivating, it would be large enough for the other lighter jobs. For the heavy jobs such as plowing and disking, the light tractors would be combined and operated as a four-wheel drive tandem tractor. Larger loads could be pulled by hooking one or more tractors behind the leading tandem tractor.

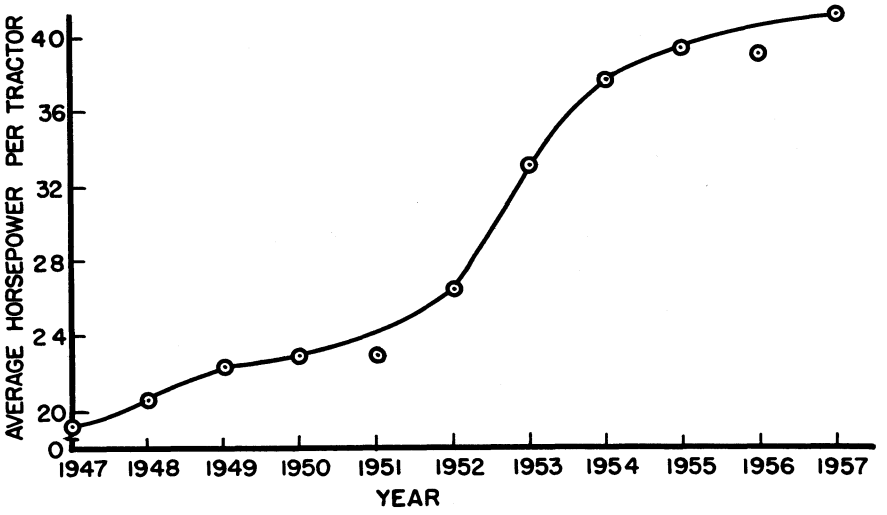

FIG. 1 The average horsepower rating of the tractors sold in the United States increased from 23 to 43 hp between 1952 and 1955.

As shown in Fig. 2, a farmer owning two tractors of different sizes – such as a 30-hp and a 45-hp tractor – could combine them into a 75 hp tandem tractor. A manufacturer with only the two above models could effectively span the 30- to 90-hp range. The larger units would be four-wheel drive tractors.

Special Uses Of Tandem Tractors

Michigan has many part-time farmers who need to combine loads to complete the farming operation in minimum time. The short growing season coupled with the growing of early planted crops (sugar beets and oats) make it necessary to complete spring primary-tillage operations quickly.

An analysis of the plow and plant research (3) shows the need for a practical two-row and eventually a four-row plow and plant system (large power unit), while soil compaction studies (2 and 5) indicate the need for keeping the width of the tractor tire to a minimum. These requirements dictate the use of a large four-wheel-drive tractor.

Flexible Power Project

A flexible power research project was initiated by the Michigan Agricultural Experiment Station in 1957. The tan-

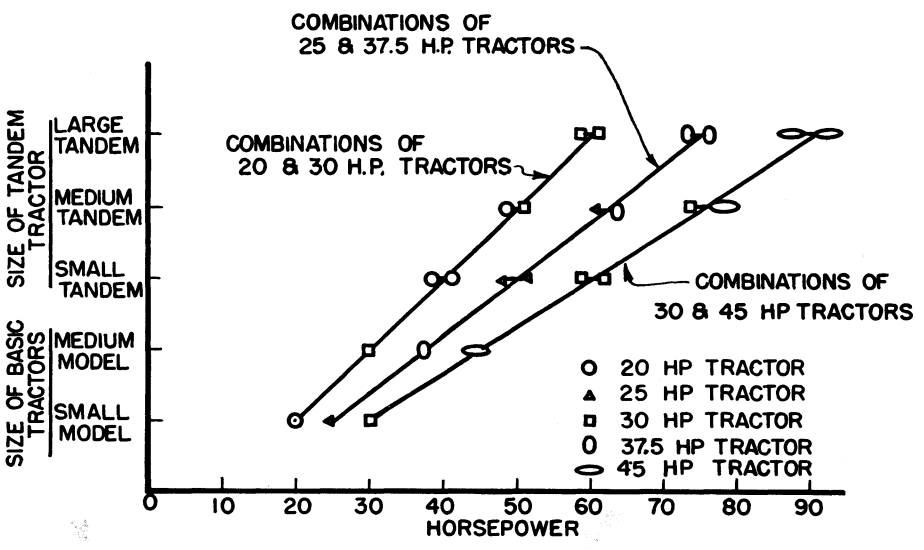

FIG. 2 Horsepower ranges which can be spanned by the manufacturer through the tandemization of two basic tractors.

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*Numbers in parentheses refer to appended references.

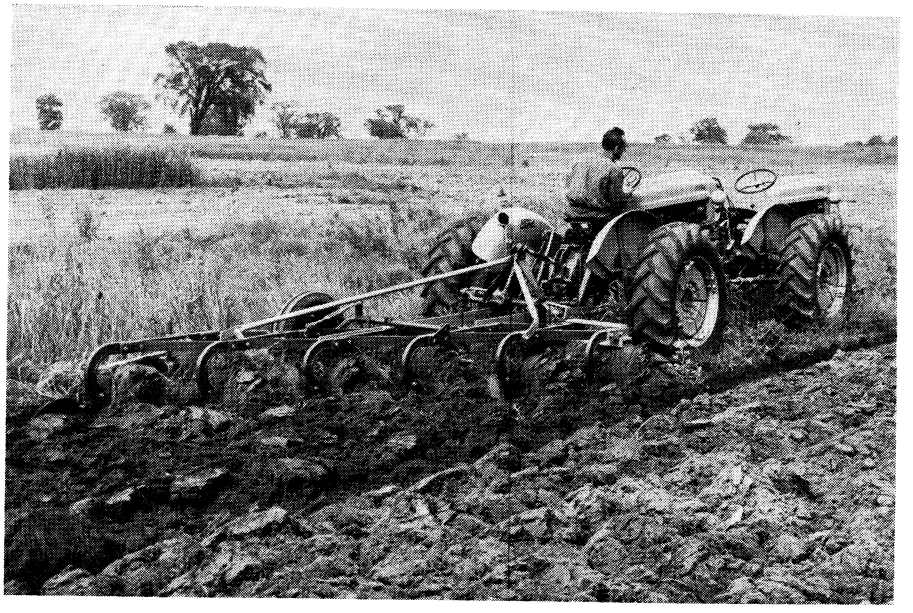

FIG. 3 Michigan State University Tandem Tractor pulling a 6-16 moldboard plow.

dem tractor shown in Fig. 3 was constructed under this project. A review of the 1956 tandem tractor tests conducted by Buchele and Collins (1) showed that the following problems needed further investigation:

1. Simplify the tandemization kit.
2. Fit tandemization kit to row-crop tractors with removable front pedestals.
3. Improve and simplify controls.

Construction Details

Design and fabrication of the tandemization kit was started in January 1957. Two 960-5 Ford tractors and parts to make a six-bottom plow were furnished by the manufacturer. The kit weighed 700 lb.

Central Hinge Steering

Central hinge steering with a forward tilting kingpin (3 in. diameter) was incorporated in the design (Fig. 4). This kingpin was welded to a single-shaft (4 in. diameter) tongue. The forward tilt of the kingpin tended to cause the front tractor to raise 4 in. in a 60 deg. turn. Due to the flexing of the inside tire and raising of the outside tire of the turn, the actual lift of the motor of the front tractor was 2½ in. The front of the rear tractor lowers 1¼ in. while turning.

Power Steering

Two single acting cylinders (Fig. 3) were located between the two tractors. The forward end of the cylinders was hooked to the front end of the final drive housing of the front tractor and the rear end to the welded box member. Universal joints were built at both ends of the cylinders to permit complete flexibility during the longitudinal rotation of one tractor with respect to the other.

The cylinders were hooked hydraulically to the remote cylinder valve located under the seat of the front tractor. The hydraulic pressure from each side of the regular power steering cylinder of the rear tractor controlled the cylinder of the two-way remote-cylinder valve. When the steering wheel of the rear tractor was turned, the power-steering cylinder-control valve was actuated and the power-steering cylinder tended to rotate the pedestal and turn the front tractor. The pressure in the power steering cylinder was transmitted to one side of the remote-cylinder valve-control cylinder. This cylinder positioned the valve and caused hydraulic oil to operate the appropriate single-acting-remote cylinder. Centering springs were placed on both sides of the valve-control cylinder to prevent weaving of the front tractor.

Throttle

An automotive booster air brake cylinder controlled the governor of the front tractor. The bypass port in the piston was closed. The air cylinder was located under and to the left of the front tractor seat. The piston was hooked in a manner similar to the diaphragm of the 1956 model tractor (1).

Ignition

A jumper wire was hooked from the primary coil terminal of the front tractor to the primary terminal of the rear tractor. The key of the rear tractor controlled the ignition system of both tractors.

Clutch

On the rear tractor, an automotive master-brake cylinder was located behind and attached to the clutch pedal. A slave cylinder was placed ahead of and attached to the clutch pedal of the front tractor.

To hold the front clutch in the declutched position while the tandem tractor was being backed up, a piston stop was placed on the master brake cylinder. This prevented the piston from retracting when the clutch was released. The piston stop was spring loaded for self-releasing when the clutch pedal was pushed to maximum position.

Starter

A starter button was located near the steering post on the rear tractor. A jumper wire was hooked to the terminal of the front tractor starter. The starter safety device was bypassed on the front tractor. The front tractor was started while in gear when the clutch was depressed. It was found desirable to start the front tractor before the rear tractor – the vacuum in the rear tractor would shut off the throttle of the front tractor.

Dynamometer Test

The tandem tractor was tested at Birmingham, Michigan in cooperation with Richey using the dynamometer equipment of the Tractor and Implement Division (4) of the Ford Motor Company. Table 1 gives the physical

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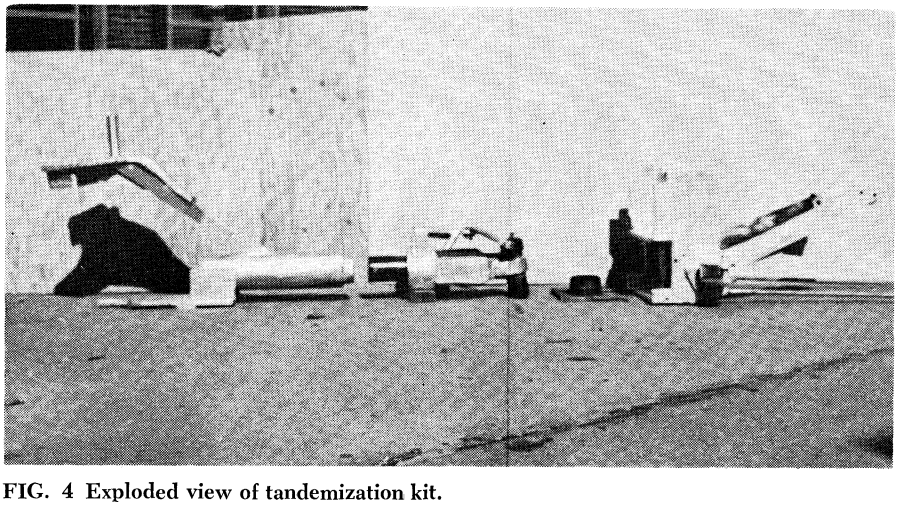

FIG. 4 Exploded view of tandemization kit.

MSU TANDEM TRACTOR

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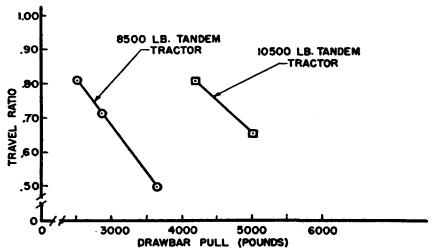

FIG. 5 Increasing the weight of the tractor increases the drawbar pull at any given travel ratio on plowed and disked soil.

dimensions of the tandem tractor. Table 2 gives the weight and weight distribution of the MSU 960 Ford tandem tractor. A weight transfer of approximately 20 percent equalized the weight on the four drive wheels. The tractor was tested on soil with three types of surface conditions: sod, plowed, and plowed and disked (4). The drawbar pull at various travel ratios are shown in Table 3. During the tests the diaphragm throttle control was disconnected and the rpm's of each engine adjusted by hand to 1750 while under load.

TABLE 1. PHYSICAL DIMENSIONS OF TANDEM TRACTOR DURING DRAWBAR TESTS

Drawbar height	23 in.
Wheel base	110½ in.
Distance from front axle to central hinge	40 in.
Total weight	10,520 lb.
Tire size	12 by 28
Angle of turn	120 deg.
Turning radius to outside tire	13 ft. radius
Minimum clearance	18 in.
Forward tilt of kingpin	8 deg.

Testing Tractive Efforts

The tandem tractor was tested on plowed and disked soil at two different weights (8,500 lb. and 10,500 lb.) The draft versus travel ratio data has been plotted in Fig. 5. At 0.80 travel ratio, 2,000 lb. of weight increased the drawbar pull 1,750 lb. and at 0.70 travel ratio, 1,900 lb.

The coefficient of tractions of the 8,500 to 10,500 tractors at 0.80 travel ratio are 0.305 and 0.401. At 0.70 travel ratio, they are 0.332 and 0.450 respectively.

Mis-Match Dynamometer Tests

To determine the performance of two tractors in tandem with different forward speeds at rated rpm, the 8,500-lb. tandem tractor was deliberately mismatched (placed in different gears). The governors of each tractor were loaded by hand to fast idle at 2000 rpm. As the tandem tractor began to pull the load, the governors took over and controlled the speed of each engine.

TABLE 2. WEIGHT AND WEIGHT DISTRIBUTION OF 960 FORD TANDEM TRACTOR*

	Front Wheels		Rear Wheels	
	Weight, pounds	Weight distribution percent	Weight, pounds	Weight distribution percent
Static weight	6870	65.3	3650	34.7
20 percent weight shift	4766	45.4	5754	54.6

* Total weight is 10,520 lb. All tires contained liquid and had 400 lb. of wheel weights per wheel.

TABLE 3. DRAWBAR PULL OF TANDEM TRACTOR AT VARIOUS TRAVEL RATIOS ON DIFFERENT SURFACE CONDITIONS

Soil surface condition	Travel ratio		Average coefficient of traction	Drawbar pull, pounds
	Front	Rear		
Sod	0.888	0.915	0.437	4600
Plowed and disked	0.790	0.823	0.398	4190
Plowed	0.785	0.847	0.338	3560

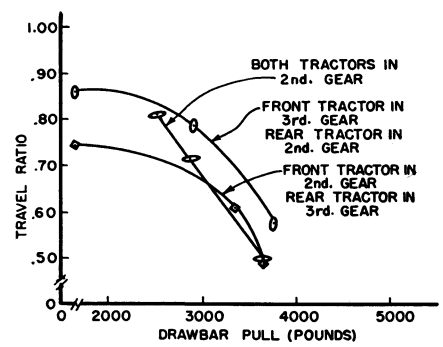

FIG. 6 Drawbar pull of 8500-lb Tandem Tractor when gearing of tractors are deliberately mismatched.

The total tractive effort is plotted in Fig. 6 against average travel ratio. The data pertaining to the 8,500-lb. tractor shown in Fig. 5 is also plotted in Fig. 6. A study of the data indicates that the performance secured when the front tractor was in third gear and the rear in second gear was as good as when both tractors were in third gear. Inferior performance was secured when the front was in second gear and rear in third gear.

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