Performance of Four Wheel Drive Tractor

By MASAYUKI KISU

First Research Division, Institute of Agricultural Machinery

Four wheel drive tractor is considered to be suitable for paddy field where soil is wet and soft and trafficability of tractor is serious. Few research on this subject has been conducted heretofore, and the performance of four wheel drive tractor was compared with those of two wheel drive, semicrawler and crawler tractor.

The specification of tested tractor was as follows:

Engine	25PS	Weight	1,340 kg
Length	2,335 mm	Front	570 kg
Width	1,380 mm	Rear	770 kg
Height	1,343 mm	Tire Front	6.00-16
Wheelbase	1,420 mm	Tire Rear	9-24

Drawbar performance

Strain gage type torque pickups and revolution counters were mounted on front and rear axles of test tractor, which pulls dynamometer car (on asphalt road) or measuring car (in soil bins) through strain gage type drawbar dynamometer. Drawbar pull, axle torque, wheel revolution, travel reduction, travelling speed were measured, and traction ratio, force ratio, drawbar horsepower, axle horsepower and traction efficiency were calculated by the following equations.

$$\text{Traction ratio} = \frac{\text{Drawbar pull(kg)}}{\text{Tractor weight(kg)}} \times 100(\%)$$

$$\text{Force ratio} = \frac{\text{Drawbar pull(kg)}}{\text{Traction force(kg)}} \times 100(\%)$$

$$\text{Tractive force} = \frac{\text{Axle torque(kg-m)}}{\text{Effective wheel radius at no drawbar pull(m)}}$$

$$\text{Traction efficiency} = \frac{\text{Drawbar horsepower}}{\text{Axle horsepower}} \times 100(\%)$$

The front, rear and total weight of tractor at the test were 648.5, 771.3 and 1,410.3 kg respectively.

1) Drawbar performance on asphalt road

The results of test on asphalt road are shown in Table 1.

The travel reduction of four wheel drive tractor is considerably less than that of two wheel drive, and the drawbar pull of the former is about twice of that of the latter at the same travel reduction. The maximum drawbar pull of four wheel drive tractor is 1.4 to 1.6 times as that of two wheel drive, and the maximum traction ratio of four wheel drive is 0.85 while that of two wheel drive is 0.5 to 0.6. Maximum force ratio of two four

Table 1. Tractive performance of two and four wheel drive tractor with and without differential lock on asphalt road

Item	4DL	4N	2DL	2N
Max. drawbar pull (kg)	1,250	1,250	870	780
Max. traction ratio (%)	85	85	59	53
Max. force ratio (%)	84	85	75	74
Max. tractive efficiency (%)	77	76	67	60

Note: 4DL : four wheel drive & differential locked
4N : four wheel drive & differential unlocked
2DL : two wheel drive & differential locked
2N : two wheel drive & differential unlocked

Table 2. Tractive performance of two and four wheel drive tractor with and without differential lock on wet soil.

Field	Item	4DL	4N	2DL	2N
Sandy loam	Max. drawbar pull (kg)	880	720	460	390
	Max. traction ratio (%)	60	49	31	27
	Max. force ratio (%)	70	63	47	42
	Max. drawbar horsepower (PS)	2.6	2.4	1.0	0.7
	Max. tractive efficiency (%)	41	42	23	21
Light clayey loam	Max. drawbar pull (kg)	620	500	500	300
	Max. traction ratio (%)	42	34	34	21
	Max. force tatio (%)	49	46	52	34
	Max. drawbar horsepower (PS)	2.0	1.4	0.8	0.8
	Max. tractive efficiency (%)	40	28	28	21
Clayey loam	Max. drawbar pull (kg)	545	380	225	225
	Max. traction ratio (%)	38	36	16	16
	Max. force ratio (%)	42	29	25	23
	Max. drawbar horsepower (PS)	0.9	0.4	0.5	0.1
	Max. tractive efficiency (%)	16	6	10	2

wheel drive tractor is 75 and 85% respectively, and the reduction of force ratio when the pull is small is less in four wheel drive.

The tractive efficiency of two wheel drive reaches its maximum value of 60 to 70% at the traction ratio of 0.4 to 0.5, and decreases rapidly at the larger traction ratio. In the case of four wheel drive the tractive efficiency hardly changes and keep the value between 70 and 80% during the traction ratio of 0.5 to 0.7.

No difference is recognized in fuel consumption per hour per drawbar horsepower at the same drawbar pull, but the minimum value is less in four wheel drive.

Generally speaking, the drawbar performance of four wheel drive on asphalt road is far better than that of two wheel drive.

2) Drawbar performance on soft soil

The drawbar performance on soft soil was measured in soil bins on three kind of soils: sandy loam (SL), light clayey loam (C'L) and clayey loam (CL). The fields were plowed, harrowed and flooded beforehand, and water was drained just before the test. The hardness of soil was measured by SR-2 soil resistance tester. The mean cone indexes in the range of 0–15 cm depth were 4, 3 and 2.5 kg/cm^2 for SL, C'L and CL respectively.

The test results are shown in Table 2.

The travel reduction of four wheel drive is far less than that of two wheel drive. The drawbar pull of four wheel drive is two to three times as that of two wheel drive at the same travel reduction. The maximum drawbar pull of four wheel drive is 1.2 to 2.4 (average 1.8) times as that of two wheel drive. The maximum tractive ratio of two and four wheel drive is 0.16 to 0.31 and 0.26 to 0.60 respectively.

The force ratio of two and four wheel drive is 0.23 to 0.52 and 0.29 to 0.70 respectively, the latter being 0.9 to 1.7 (average 1.4) times as that of the former..

The maximum drawbar horsepower of four wheel drive is 1.8 to 4.0 (average 2.7) times as that of two wheel drive. The maximum tractive efficiency is 2 to 28% in two wheel drive and 6 to 42% in four wheel drive, the latter being 1.3 to 3.0 (average 1.8) times as that of the former.

When the differential gear is locked the maximum drawbar pull is 1.0 to 1.7 (average 1.3) times, maximum force ratio is 1.1 to 1.5 (average 1.2) times, maximum drawbar horse-

power is 1.0 to 5.0 (average 2.0) times and maximum tractive efficiency is 1.0 to 5.0 (average 2.1) times as those when it is not locked. power is 1.0 to 5.0 (average 2.0) times and

Generally speaking, the effect of four wheel drive and differential lock is remarkable on wet soft soil. In addition, the improvement of drawbar horsepower by the reduction of travel reduction is effective.

The drawbar performance of two and four wheel drive with differential locked are compared with semicrawler (39.5PS, 1,800 kg) and crawler (33PS, 2,550 kg) on soft soil. The soils are sandy loam and clayey loam and cone indexes were 3.5 and 3.0 kg/cm^2 respectively.

The results of test are shown in Table 3. It is not appropriate to compare maximum drawbar pull and horsepower as the engine horsepower and tractor weight differ each other, and maximum traction ratio, travel reduction at maximum drawbar horsepower and ratio between maximum drawbar horsepower and engine horsepower are to be compared.

According to Table 3, it can be said that the performance of crawler is the best, followed by semicrawler, four wheel drive and two wheel drive.

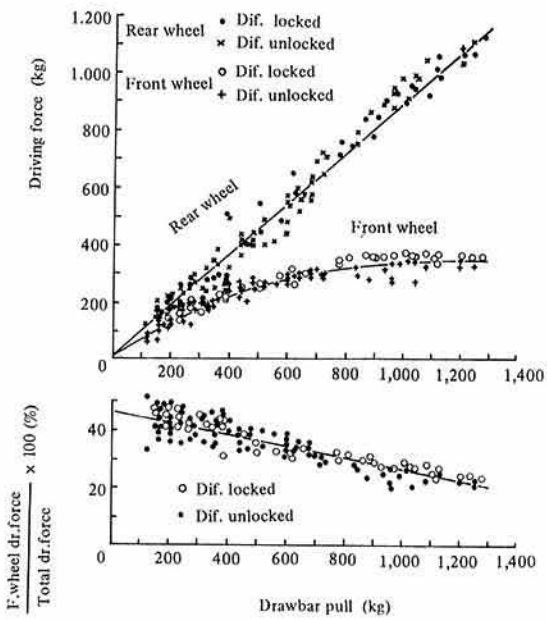

Fig. 1. Distribution of driving force on front and rear wheel in relation to drawbar pull on asphalt road.

3) Front and rear wheel tractive force

The front wheel tractive force on asphalt road is about 46% of the total tractive force as shown in Fig. 1. It is almost the same percentage as the front wheel weight distribution. The percentage of the front wheel tractive force decreases linearly as the drawbar pull increases, and finally it becomes 20% when the tractive ratio is 0.93.

The percentage of front wheel tractive force on soft soil is around 30 to 40% even if the tractor does not pull at all because of weight transfer as the rolling resistance is large. This percentage decreases as the pull increases.

Trafficability

The trafficability of tractor was compared by sinkage coefficient, the ratio between wheel sinkage at no drawbar pull and sinkage of rectangular plate (25×100 mm) at 30 kg normal load.

The effect of four wheel drive and differential lock on the sinkage coefficient when the tractor travels on soft soil without pull is not recognized, but the sinkage coefficient of four wheel drive tractor pulling a load is considerably small and the effect of differential lock is recognized a little.

When the sinkage coefficient of two and four wheel drive is compared with crawler and semicrawler, the value of crawler is the smallest, followed by semicrawler, four and two wheel drive.

Steerability

The minimum turning radius and the steering force were measured on asphalt road and paddy stubble field.

The minimum turning radius of four wheel drive is a little longer than that of two wheel drive, 1.02 times on asphalt road and 1.09 times on stubble field. But when the four wheel drive tractor, of which two wheels are driven, is compared with the two wheel drive

tractor, the radius of the former is about 1.3 times as that of the latter.

The force required for steering the four wheel drive tractor is about 1.8 times as that for two wheel drive. The steering force when the inner wheel is not braked is about 1.2 times as that when braked.

The steering force on asphalt road is 1.2 times as that on stubble field in two and four wheel drive.

Working performance

Plowing and rotary tilling performances were measured on the paddy field of alluvial clayey loam. The cone index of the soil was 7.5 kg/cm^2.

Plowing

The travel reduction of the four wheel drive is remarkably small, and the differential lock is also effective. Therefore, soil volume plowed per hour is fairly large and the fuel consumption per 10a is little. The horsepower distribution on the front and the rear axle when plowing is 42:58. This means the rear axle horsepower is less than that of two wheel drive, but the total horsepower of front and rear axle of four wheel drive is larger.

Rotary tilling

The effect of four wheel drive and differential lock is not recognized. The horsepower distribution on PTO shaft and wheel axle is 95:5.

Reference

1) Kisu, M. et al.: Studies on trafficability, tractive and rotary tilling performance of tractor. *Technical Report, Inst. of Agricultural Machinery*, 68–85 (1966) [In Japanese with English summary].