Measuring the Drawbar Performance of Animals and Small Tractors

(II) Small Tractors

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Abstract

Using the pull-out test rig described in Part 1 of this paper and other locally made equipment, the fundamental parameters specifying tractor drawbar performance were measured for two tractors working on firm and soft soils (both dry and wet). The results are presented in a graphical form.

Introduction

The use of two-wheeled type hand or walking tractors for drawbar work in wet-land rice cultivation has been increasing in Asian countries. If field performance of such tractors is to be optimized — for example, by choosing suitable tractor weight, the correct size of implement for the available tracotr power or the correct gear for a good fuel economy — it is necessary to obtain tractor performance data under field conditions.

However, the performance data currently available are not suitable for these purposes because they are measured and expressed in such a way that they only present the performance of the transmission and of the combined performance of tractor and implement. To gain an understanding of the factors affecting the performance of the tractor, it is necessary to measure the fundamental parameters — such as drawbar pull, travel speed, drawbar power, wheel slip, and fuel consumption at various loading conditions.

This paper describes the method and results of testing the drawbar performance of small tractors, working on firm and also soft, wet soil, using the pull-out rig as a loading and measuring device (Pudjiono and Macmillan, 1992). This work is part of the programme of the development of locally made equipment for teaching and research in agricultural engineering and development technology (Macmillan, 1991).

Test Equipment and Methods

Tractors

Two walking tractors were tested in this experiment. One was a Howard brand powered by a gasoline engine of 9 kW nominal capacity; it had three forward gears. During the test the rotavator, which was fitted to the tractor, was lifted off the ground. The rear of the tractor was supported by a small pneumatic wheel.

The other was a Kerbau Besi brand tractor, which is manufactured in Indonesia to an IRRI design. It has a 5.6 kW Kubota diesel engine and is equipped with fast and slow ratios vee-belt driving a chain transmission. For testing with ballast, two metal blocks were mounted on its engine frame.

In testing on firm surfaces, the tractor ran on pneumatic wheels with a rim size of 5.00-12, and a rolling radius of 0.250 m; the pressure in each tyre was 170 kPa. With testing on soft surfaces, these wheels were replaced with cage wheels 0.70 m in diameter and 0.500 m in width.

The rear of the tractor was supported by a rectangular wooden skid when tested on the dry-cultivated and the flooded conditions; on all other surfaces, it was supported on a small 0.250 m diameter pneumatic wheel.

Both tractors were instrumented to measure the drawbar performance parameters, viz. drawbar pull, wheel slip, travel speed, and fuel consumption.

Other details of the tractors are as shown in **Table 1** and in Pudjiono (1988).

Test Equipment

Test rig — The 'pull-out' rig described in Part 1 of this paper was used to generate and measure the draught load necessary to explore the drawbar performance of the tractors under variable loading conditions. The rig was mounted on the three point linkage of a stationary four-wheel (anchor) tractor, which was located at one end of the test area.

The draught load was applied to the drawbar of the test tractor, as it moved across the test area, by means of a cord that was unwound from the drum which was also mounted on the brake shaft. This draught load was varied by the operator adjusting the clamping force of the brake pads on the disc brake and was measured as a reaction at the brake pads using a hydraulic force-cell mounted on the rig frame.

Hydraulic force-cell — While any type of force cell could be used, a 38.1 mm cylinder hydraulic cell and associated pressure gauge were chosen for this work. This cell was calibrated by plotting its force readings against those obtained from an Instron testing machine. The results **(Fig. 1)** indicate some hysteresis in the hydraulic cylinder but it proved satisfactory for this work.

Digital counter and timer — A combined digital counter and timer, powered from four dry cells, was built and used to measure and display fuel flow, wheel revolutions, and time. Simultaneous measurement of the data, taken over a known distance, was made by the tractor operator using a single start/stop switch. This gave readings from which travel speed, fuel consumption rate and wheel slip could be calculated.

Table 1. Experimental Conditions

Surface type	Surface condition	Transmission setting	Wheel equipment	Tractor weight	Results
Howard Tractor					
Bitumen road	—	1st gear	Pneumatic tyres	With rotavator	Fig. 3
Kerbau Besi Tractor					
Bitumen road	—	Slow	Pneumatic tyres	No ballast	Fig. 4
			,,	With ballast	,,
	—	Fast	Pneumatic tyres	No ballast	,,
			,,	With ballast	,,
Dry field	Uncultivated	Slow	Pneumatic tyres	No ballast	,,
			,,	With ballast	,,
	Cultivated	Slow	Cage wheels	No ballast	Fig. 5
			,,	With ballast	,,
Flooded field	Uncultivated	Slow	Cage wheels	No ballast	,,
			,,	With ballast	,,
	Cultivated	Slow	Cage wheels	No ballast	,,
			,,	With ballast	,,

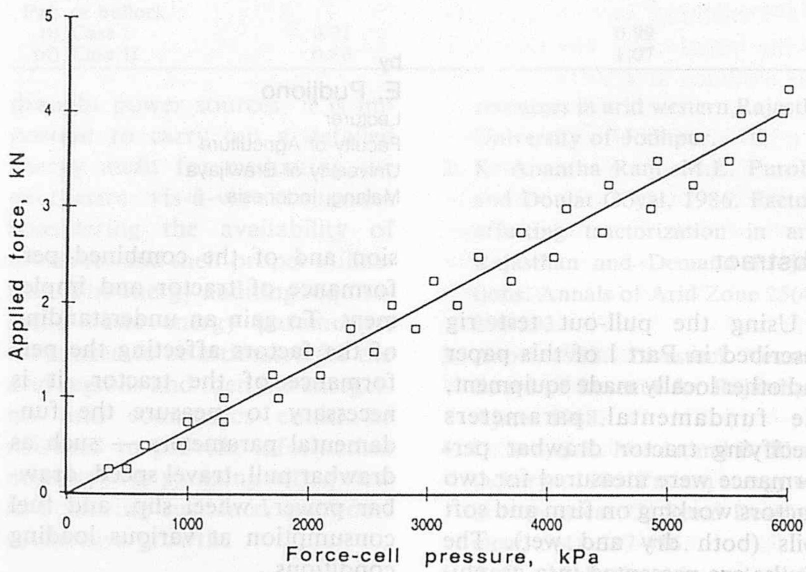

Fig. 1 Calibration of the force-cell.

Wheel revolution counter — The method used to determine wheel slip involves the measurement of wheel revolutions over a fixed distance for load and no-load runs. For this purpose, a pulse generator was built by mounting a small triggering magnet in a shaft mounted on bearings in an aluminium housing clamped to the body of the tractor. The shaft was connected by a flexible coupling to, and driven by, the tractor transmission at a point where there is a fixed ratio to the wheels.

A 'Hall Effect' switch mounted in the housing close to the magnet generated one pulse per revolution of the shaft; the signal was sent via cable connector to the digital counter. By counting the wheel revolutions and knowing the fixed transmission ratio, the accuracy of the counting system was confirmed.

Fuel flow meter — A Kero-mate flow meter (Model LS 4051), with a rated output of two pulses/mL, was chosen for measuring the fuel consumption of the tractors. This meter, which is specified as being capable fo measuring fuel flow 0.20 L/h (0.056 mL/s), covers the minimum flow rate of a walking tractor.

For the diesel engine, the meter was connected between the fuel tank and the injection pump; the return fuel from the injector was directed to the outlet line of the meter to avoid double counting of the return fuel. For the gasoline engine, the meter was fitted between the fuel tank and the engine carburettor.

The meter was calibrated using a burette and a stop watch, when measuring diesel fuel and gasoline at flow rates from 0.015 mL/s to 3.7 mL/s and at ambient temperature (19°C) for both fuels, also at 27° and 35°C for the diesel. The flow rate values were plotted against the pulse rates observed on the digital counter and gave the relationship shown in **Fig. 2**.

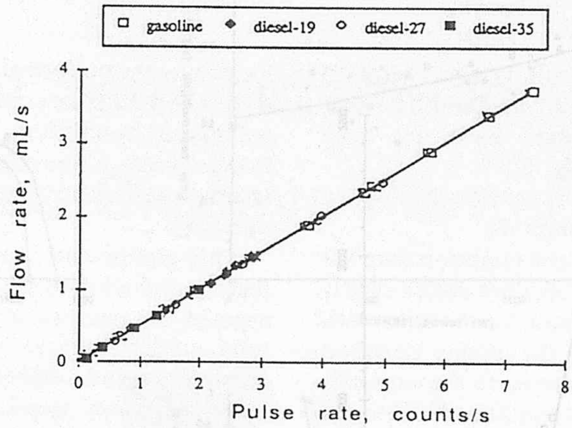

Fig. 2 Calibration of the Keromate fuel meter at various temperatures, °C.

This instrument measured the fuel flow consistently. However, when used for measuring low flow rates, it is necessary that the measurement be made for a sufficient time to avoid the error associated with the meter least count. This problem was experienced in some conditions during the field experiment, i.e., when measurement was made with the tractor in the fast gear.

Test Procedure

After warming the engine, it was adjusted to maximum governor setting and the tractor was driven over the test surface for the fixed test distance (20 m) under zero drawbar load, giving a defined zero wheel slip. This procedure was then repeated for the tractor running under various drawbar loads provided as the cord, attached to the tractor drawbar, was being unwoud from the drum of pull-out rig. The draught load was set and observed from the latter.

Measurements were made of the wheel revolutions, fuel consumption and elapsed time by activating the digital counter while trvelling over the test distance. The test was repeated by increasing the load in steps until the maximum drawbar pull of the tractor was reached, i.e., when the tractor wheel-slip was excessive or when its engine stalled.

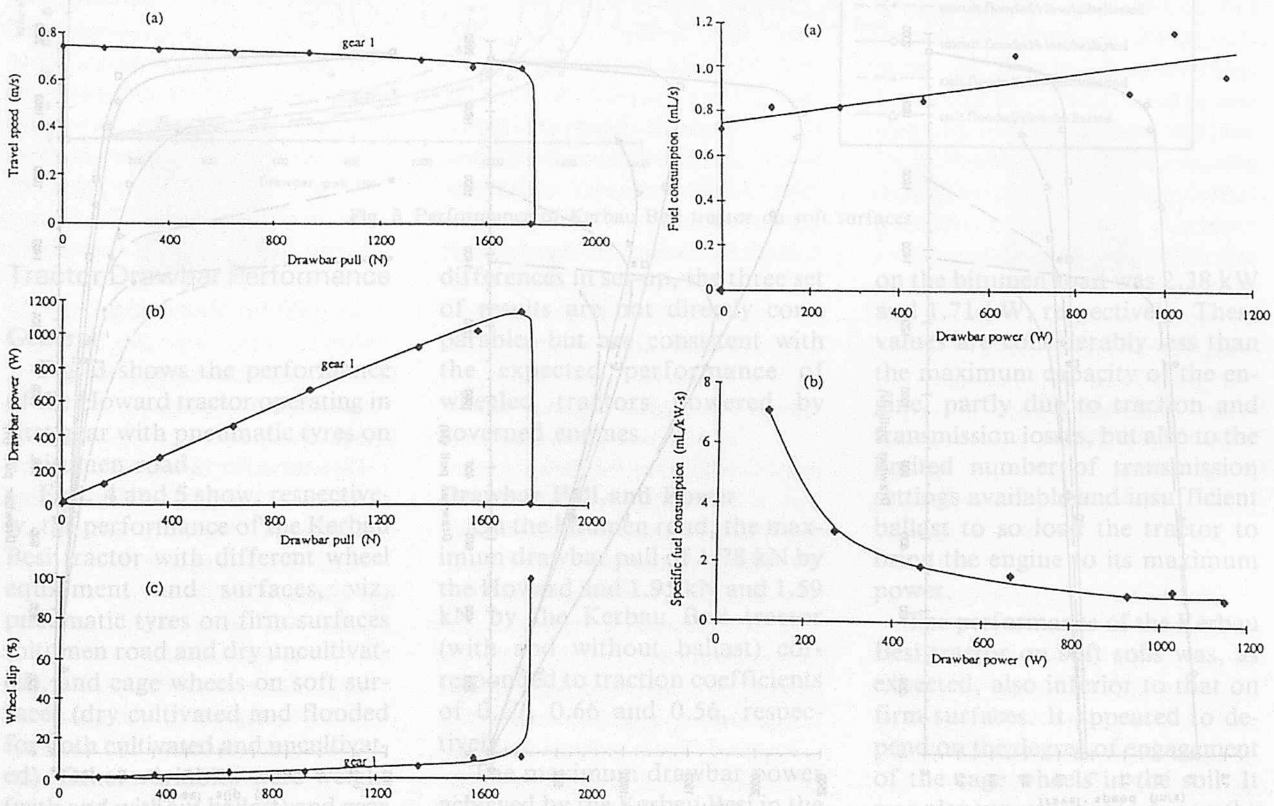

Fig. 3 Performance of Howard tractor on bitumen road.

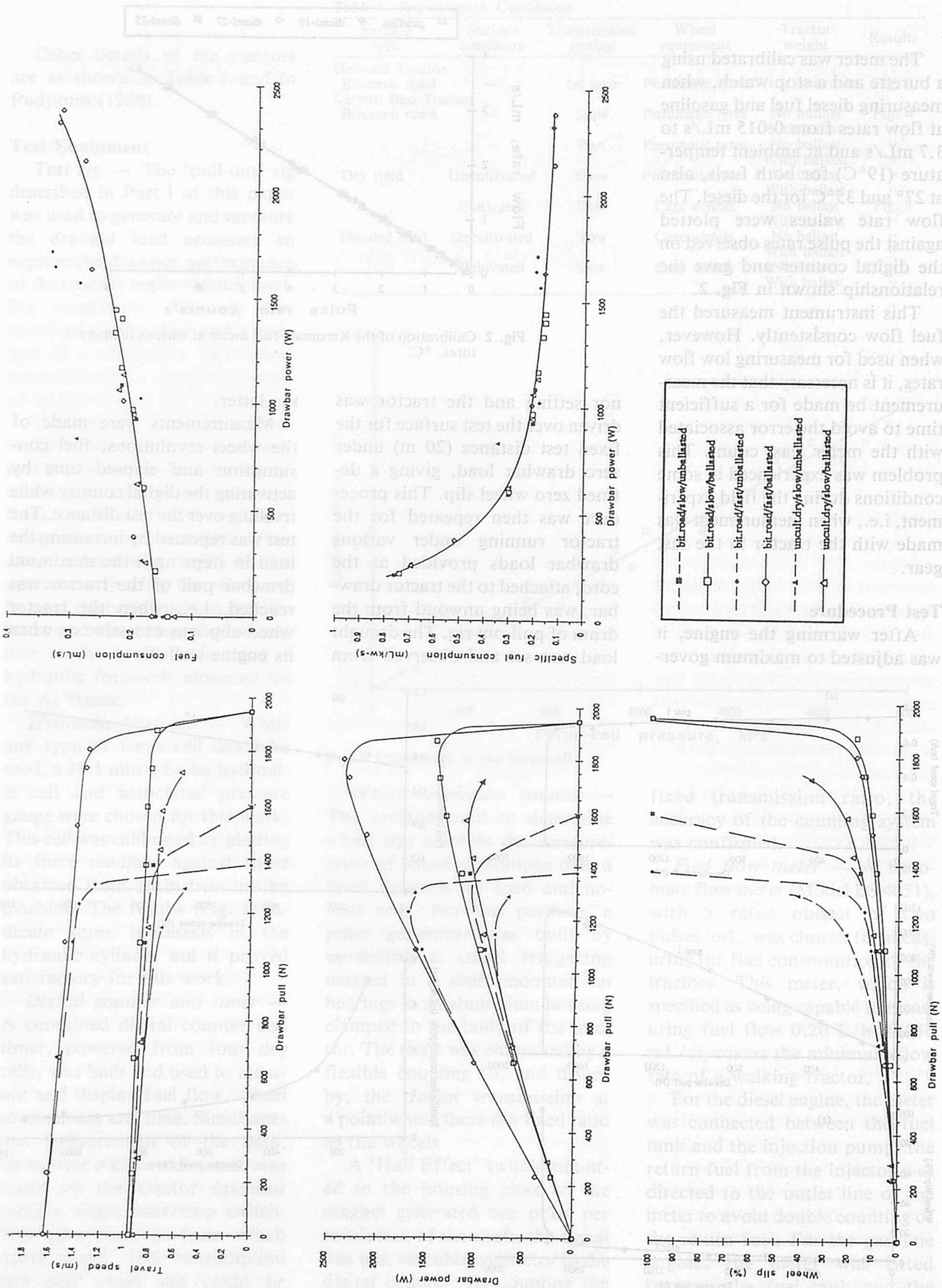

Fig. 4 Performance of Kerbau Besi tractor on firm surfaces.

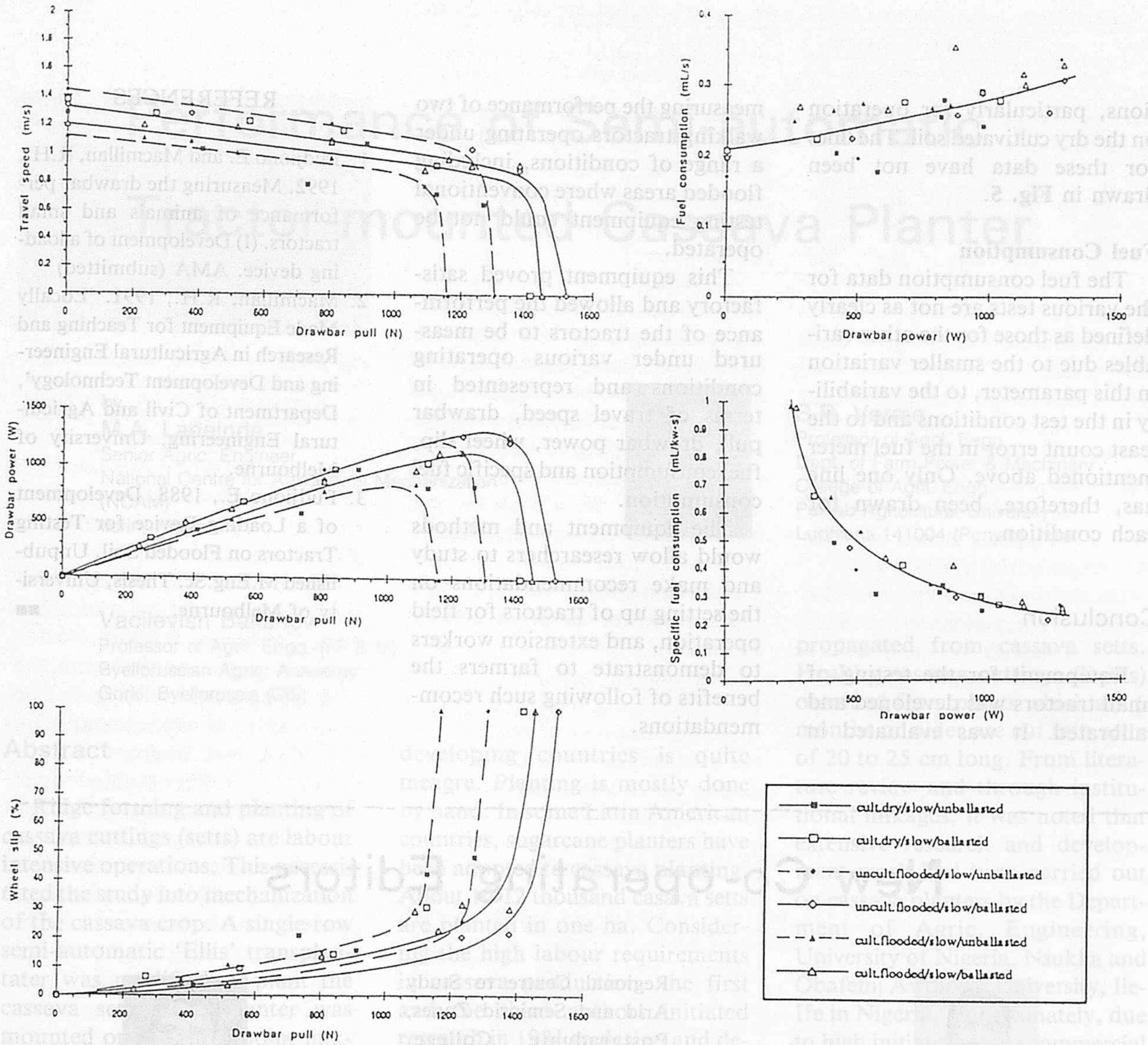

Fig. 5 Performance of Kerbau Besi tractor on soft surfaces.

Tractor Drawbar Performance

General

Fig. 3 shows the performance of the Howard tractor operating in first gear with pneumatic tyres on a bitumen road.

Figs. 4 and 5 show, respectively, the performance of the Kerbau Besi tractor with different wheel equipment and surfaces, viz. pneumatic tyres on firm surfaces (bitumen road and dry uncultivated), and cage wheels on soft surfaces (dry cultivated and flooded for both cultivated and uncultivated). Other variables were weight (with and without ballast) and gear (fast and slow). Because of these differences in set-up, the three set of results are not directly comparable, but are consistent with the expected performance of wheeled tractors powered by governed engines.

Drawbar Pull and Power

On the bitumen road, the maximum drawbar pull of 1.78 kN by the Howard and 1.95 kN and 1.59 kN by the Kerbau Besi tractor (with and without ballast) corresponded to traction coefficients of 0.67, 0.66 and 0.56, respectively.

The maximum drawbar power achieved by the Kerbau Besi in the fast gear with and without ballast on the bitumen road was 2.38 kW and 1.71 kW, respectively. These values are considerably less than the maximum capacity of the engine, partly due to traction and transmission losses, but also to the limited number of transmission settings available and insufficient ballast to so load the tractor to bring the engine to its maximum power.

The performance of the Kerbau Besi tractor on soft soils was, as expected, also inferior to that on firm surfaces. It appeared to depend on the degree of engagement of the cage wheels in the soil. It was also more variable due to the variability in the surface conditions, particularly for operation on the dry cultivated soil. The lines for these data have not been drawn in **Fig. 5**.

Fuel Consumption

The fuel consumption data for the various tests are not as clearly defined as those for the other variables due to the smaller variation in this parameter, to the variability in the test conditions and to the least count error in the fuel meter mentioned above. Only one line has, therefore, been drawn for each condition.

Conclusion

Equipment for the testing of small tractors was developed and calibrated. It was evaluated in measuring the performance of two walking tractors operating under a range of conditions, including flooded areas where conventional testing equipment could not be operated.

This equipment proved satisfactory and allowed the performance of the tractors to be measured under various operating conditions and represented in terms of travel speed, drawbar pull, drawbar power, wheel slip, fuel consumption and specific fuel consumption.

The equipment and methods would allow researchers to study and make recommendations on the setting up of tractors for field operation, and extension workers to demonstrate to farmers the benefits of following such recommendations.

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