SELECTION OF A HAULAGE TRACTOR

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Abstract

An exercise was carried out to find a tractor suitable for Sezela. Fitting a 12-speed gearbox with improved ratios improved the tons moved per hour by 20,9% and fuel consumption by 7,9%. Increasing hydraulic flow from 30 to 64ℓ.min^{-1} reduced trailer offloading time from 60 second to 20 seconds. A relationship between engine power, load, resistance and speed is used to define power and tyre rating to comply with legal requirements.

Introduction

Historically, cane growers have used 'ploughing' tractors to haul cane. Following the introduction of ADE engines, an exercise was carried out to find a suitable tractor for Sezela. This necessitated finding a match between engine, gearbox and differential which would give acceptable power and speed, as well as selecting the optimum tractor/trailer combination (including the tractor hydraulic requirements) to improve productivity, while taking safety aspects into account. The results of this exercise indicated that the type of tractor used by Sezela was not ideal and with the assistance of the major manufacturers, an improved haulage unit has been developed and tested.

Procedures

The first ADE powered tractor was delivered to Sezela for evaluation in April 1982. Initial tests showed that its performance, in terms of delivering cane from the field to the zone, was inferior to existing tractors with the same engine power. This led to the decision to study the haulage tractor thoroughly.

Before consideration can be given to tractor selection the haulage system must be defined. Two haulage systems are used at Sezela depending on the terrain; on the flatter slopes, a box trailer-no chain system is used and on steep sections side-loaders with bundles are operated.

The box trailers have a tare mass of 3,48 tons and rear tipping is by means of a single stage hydraulic ram. The Jacobyl side-loader trailers are cable winch operated and have a tare mass of 2,1 tons. Winches are pto driven. Some of the trailers have been modified to self tipping by means of a single three stage hydraulic ram. Trailers are hitched to the tractor approximately 100 mm behind the centre line of the rear axle.

The objective of a haulage system is to move cane from the field to the zone as quickly as possible at an economic rate. This is done by optimizing the following factors: tons moved per load; loading time; travelling time; and unloading time.

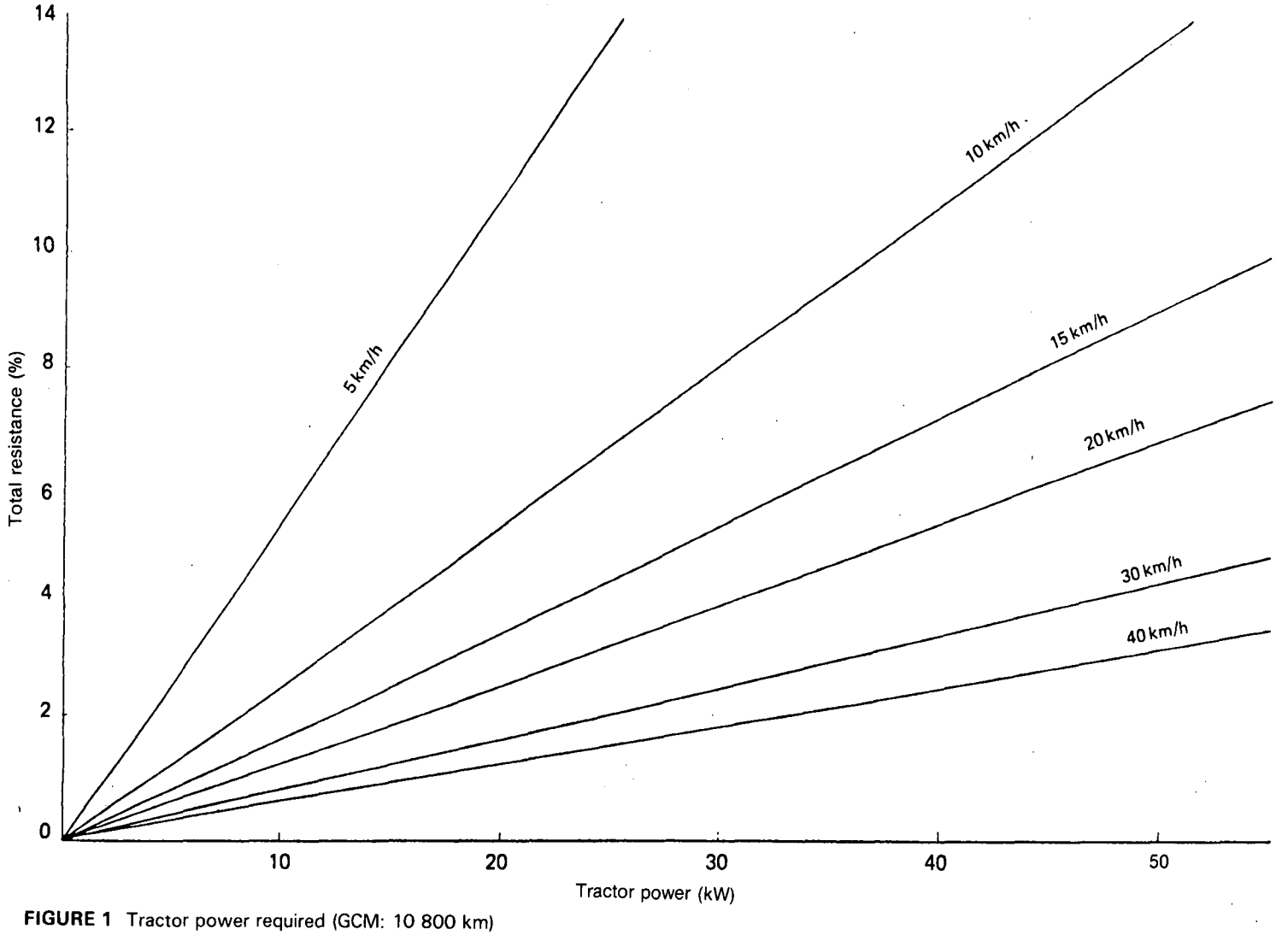

FIGURE 1 Tractor power required (GCM: 10 800 km)

In order to select the most suitable haulage tractor for particular haulage systems consideration will be given to numerous technical factors such as engines, gearboxes, clutches, hydraulics, type of hitch, fuel consumption, power steering, pto speed, wheels and tyres. Economic factors such as the price, the dealer, the back-up service and resale value would also need to be taken into account.

The major technical factors in tractor selection for the haulage conditions at Sezela are discussed.

Technical Factors

Engines

The ADE range of engines for agricultural tractors, with their maximum power and torque outputs is given in Table 1.

TABLE 1

Maximum power and torque outputs of the ADE range of engines

Engine type	Maximum output (kW)	Maximum torque (Nm)
ADE 152	34,5 @ 2 250 rpm	168,3 @ 1 300 rpm
ADE 236	56,0 @ 2 600 rpm	259,7 @ 1 250 rpm
ADE 236C	58,0 @ 2 300 rpm	305,0 @ 1 300 rpm
ADE 248	58,5 @ 2 500 rpm	255,0 @ 1 400 rpm
ADE 354	84,0 @ 2 600 rpm	369,0 @ 1 400 rpm
ADE 354C	82,5 @ 2 480 rpm	391,0 @ 1 400 rpm
ADE 354TI	111,5 @ 2 400 rpm	517,0 @ 1 600 rpm

It is necessary to determine both the power and the torque required for a particular haulage situation but because engine power is dependent on a number of factors it is difficult to determine exactly.

An established relationship between engine power, resistance and speed, for a specified gross combination mass (GCM), as expressed in Figure 1, can be used to estimate suitable engine power requirements.

For a gross combination mass of 10 800 kg, engine power requirements at different total resistance values and speeds can be obtained from the figure. For example, an engine developing 50 kW has sufficient power to achieve a speed of 20 km/h as at total resistance of 6%.

In terms of the Road Ordinance a tractor is defined as a motor vehicle when it is hauling cane but it may be argued that it can also be defined as a goods vehicle (Anon[2]). In that case a tractor/trailer combination would be subject to a regulation which states, with reference to engines, that the combined vehicle mass must not exceed 240 times the tractor's net power in kW. For example, the GCM of a tractor/trailer combination with an engine developing 50 kW at sea level should not exceed 50 × 240 kg, i.e. 12 tons.

The torque characteristic of an engine is also an important consideration. Figure 2 is the torque curve for ADE 236 engine (Anon[1]).

The torque curve for this particular tractor shows how far the engine can lug down over a particular speed range, to allow for increases in load without changing gear. If the engine is allowed to lug beyond maximum torque, it will stall. The torque curve considered with the specific fuel consumption curve indicates the rpm range in which the tractor should operate. The ADE 236 was finally selected in preference to the ADE 248, because it has the power requirements (Figure 1) and has good torque characteristics (Figure 2) in the economical operating range of 1 400 to 2 100 rpm.

Gearboxes

It is mainly in respect of gearbox characteristics that 'ploughing' tractors are unsuitable for haulage. Figure 3 illustrates the ground speed/gear shift patterns of tractors with 8- and 12-speed gearboxes operating in the most economical rpm range.

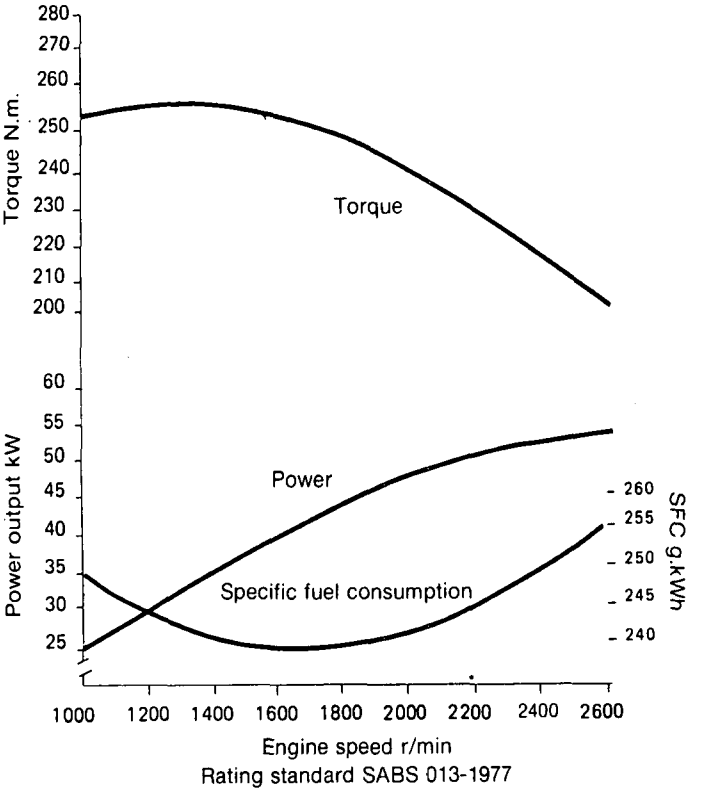

FIGURE 2 Torque, power and specific fuel consumption curves for an ADE 236 engine

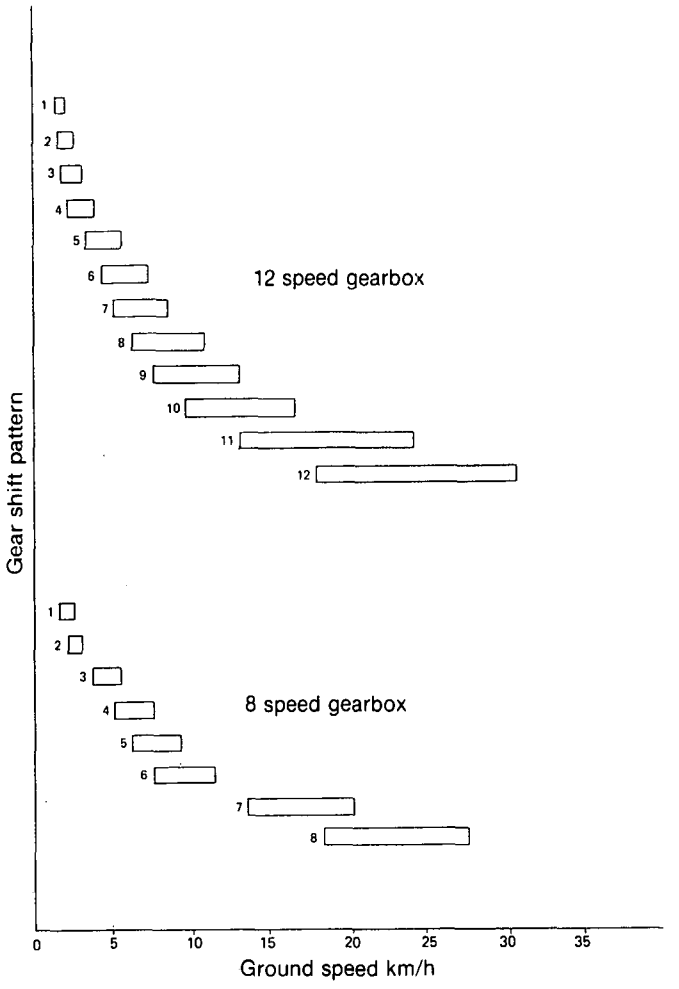

FIGURE 3 Ground speed/gear shift patterns of an 8-speed gearbox and a 12-speed gearbox working within the economical fuel range

It can be seen from Figure 3 that the 8-speed gearbox has suitable gear shift pattern overlap and spacing at the slower speeds (up to 10 km/h) required for tillage work but at higher haulage speeds the overlap is inadequate. To achieve good performance on haulage work with this type of gearbox a driver has to make frequent gear changes, furthermore fuel consumption will be high and productivity, in terms of tons per hour, will be low.

Conversely, the ground speed gear shift pattern of the 12-speed gearbox, operating in the economical fuel range, shows that overlap and spacing is better at all speeds with the consequent better fuel consumption and productivity.

Hydraulics

One of the factors affecting total hauling time is unloading time. With the no-chain system, cane has to be tipped on the zone and this takes up to 60 seconds with the standard hydraulic flow of supposedly 30 litres/minute. The resulting stack is untidy and difficult to reload into Hilos. By increasing the hydraulic flow to over 60 litres/minute, unloading time can be reduced to about 20 seconds and furthermore a more compact stack is obtained.

Tyres

The range of rear tractors tyres is limited in this country and the dual purpose 'field/road' type is generally fitted. To comply with safety requirements it is necessary to take into account the load to be imposed on the tyres, inflation pressure, the tyre size and ply ratings and the speed of operation.

The Tyre and Rim Engineering Data Committee (TREDCO) has published[3] the relation between these factors in tabular form to facilitate the correct choice of tyres for various uses and conditions.

An example of load distribution on a 53 kW tractor, matched to a side-loader is shown diagrammatically in Figure 4.

In this example the load imposed on the rear tyres is 2 250 kg per tyre when the trailer is loaded and if 18,4/15-34 tyres are used at speeds up to 40 km/h the TREDCO tables indicate that 8-ply tyres would have to be fitted to comply with the legal safety requirements. The maximum load imposed on each front tyre is 500 kg for which the TREDCO tables indicate that 750-16 tyres with 4-ply rating would meet the legal requirements.

Trailers

It is generally recognised that there is considerable potential for improving haulage output on steep slopes by designing trailers for these particular conditions. The factors to be taken into account in such a design are as follows:

- a reduction in overall mass
- the maximising of payload
- using hydraulic, rather than mechanical, drive for the winch
- facilitating the bridge operation
- improving the tipping action
- using a weight transfer hitch
- increasing the braking capabilities.

The Experiment Station's Agricultural Engineering Division is designing and producing a prototype of such a trailer.

Field Tests

Various field tests were carried out to evaluate the difference between the 8-speed gearbox and the 12-speed gearbox.

In Tests 1 and 3 both gearboxes were matched to tractors fitted with ADE 236 engines.

In Test 2, the 8-speed gearbox was fitted in a tractor with an engine developing 64 kW and the 12-speed gearbox was fitted in a tractor fitted with an ADE 248 engine with a listed maximum output of 58,5 kW.

Test 1

Tractors were matched to Jacobyl side-loaders and taken over a 4,92 km route of which the first 1,2 km and the last 0,3 km were relatively flat while the remaining 3,42 km had an average grade of 1 in 12.

The speeds were first recorded while the tractors pulled empty trailers and then with the trailers carrying a 3,5 ton load. The empty trailer mass was 2,1 tons and the loaded gross mass was therefore 5,6 tons.

TABLE 2

Operating time in minutes for tractors with 8- and 12-speed gearboxes pulling empty and loaded trailers (Test 1)

	Speed (minutes)		Difference	
	8-speed gearbox	12-speed gearbox	Minutes	%
Trailer empty (load 2,1 tons)	13,62	11,62	2,00	14,68
Trailer loaded (load 5,6 tons)	20,42	18,87	1,55	7,59

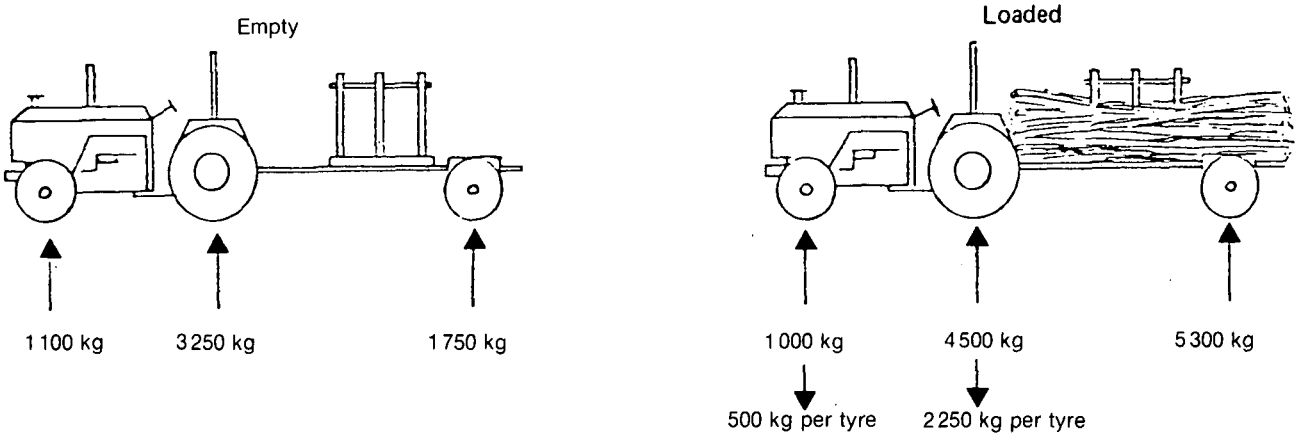

FIGURE 4 Load distribution on a 53 kW tractor matched to a side-loader

The results of these tests (Table 2) show that the tractor with 12-speed gearbox was 14,68% faster with an empty trailer (2,1 tons) and 7,59% faster with a loaded trailer (5,6 tons) than the tractor with the 8-speed gearbox. Since both tractors were fitted with ADE 236 engines the conclusion drawn is that the difference is due to the gearing. During this test it was observed that the poor ratios of an 8-speed gearbox resulted in loss of tractor speed and momentum at each gear change.

Test 2

Tractors were matched to 7-ton tipping box trailers and haulage was done over a round trip of about 2 km from field to zone under relatively flat but soft conditions. During the test month speed of operation and fuel consumption were measured.

The results of this test (Table 3) were that an increase in productivity of 8,4% in terms of tons/hour, and 23,5% in terms of fuel consumption were obtained from the tractor with the 12-speed gearbox in spite of the fact that the tractor fitted with an 8-speed gearbox developed 5,5 kW more power.

TABLE 3

Output (tons/h) and fuel consumption (ℓ/h) of tractors, with 8- and 12-speed gearboxes matched to 7 ton tipping boxes

	8-speed gearbox	12-speed gearbox	% improvement
Output (tons/hour)	19	20,6	8,4
Fuel consumption (ℓ/h)	6,8	5,2	23,5

Test 3

Tractors matched to Jacobyl side-loading trailers, loaded with an average of 4,1 tons were operated under steep field conditions for a period of one month over an average hauling distance of 2 km.

The results of this test (Table 4) indicate that a tractor fitted with a 12-speed gearbox can improve productivity by 20,9% in terms of tons/hours and 7,9% in terms of fuel consumption compared with the tractor fitted with the 8-speed gearbox.

TABLE 4

Output (tons/h) and fuel consumption (ℓ/h) of tractors matched to Jacobyl side-loader operating under field conditions

	8-speed gearbox	12-speed gearbox	% Difference
Output (tons/hour)	10,55	12,76	20,9
Fuel consumption (ℓ/h)	5,60	5,16	7,9

Discussion

During the process of selecting a suitable haulage tractor, fitted with an ADE engine, for Sezela, the inadequacies of standard gearbox ratios became evident. These were overcome by fitting a 12-speed gearbox with improved ratios.

Field tests conducted with a tractor fitted with an ADE 236 engine and an improved gearbox, pulling a Jacobyl side-loader under steep field conditions, resulted in an improvement of 20,9% in terms of tons moved per hour and an improvement in fuel consumption of 7,9%.

In addition, by increasing the hydraulic flow from 30ℓ.min.$^{-1}$ to 64ℓ.min.$^{-1}$ off-loading time of tipping trailers was reduced by 40 seconds. Among the legal and safety requirements of operating a haulage unit are enough power and the correct tyres to match its gross combination mass at defined speeds. A unit with a gross combination mass of 12 tons needs a minimum power requirement of 50 kW and, when fitted with a standard haulage hitch, rear tyres of at least 8-ply rating.

Acknowledgements

The co-operation of the manufacturers, Fedmech, Ford and John Deere who supplied the tractors and carried out modifications, is gratefully acknowledged. Thanks are due to field staff on Sezela where the tractors were evaluated.

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2. Anon (1966). Road Traffic Regulations under Natal Ordinance No. 21 of 1966 (as amended).
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