

THE EFFECTS OF TRANSMISSION OPTIONS ON THE PERFORMANCE OF TRACTORS HAULING SUGARCANE

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Abstract

Extensive tests have been carried out on the effects of optional transmission equipment on the performance of tractors which are used as the prime movers in hauling sugarcane. The results of the tests have indicated that the most important factor to consider is the performance of the tractor's engine followed by the effects of applying transmission options.

Introduction

The results of a programme of tests conducted on tractors indicated that there was a considerable difference in their performances when various transmission options were used. The effects of these transmission options have now been investigated more thoroughly and their effect on the performances of three tractors are explained in this paper.

Analytical Procedure

The results of the tests done on tractors by Boevey and Meyer¹ are summarised in Figures 1 and 2. In Figure 1, the relative performances of the MF275HT, F56TT and F5610 tractors all with the same specification ADE 236 engine are shown. The pto performances as measured are valid for the three tractors tested, and are not necessarily representative of other tractors of similar make and model. The 'Experiment Station' did not attempt to adjust the engine performance because outputs as

measured were acceptable to the distributor. The haulage capacity, which is a function of speed and load, is very similar for the MF275HT and the F56TT. The relationship between haulage capacity and gross load of the F5610 is very different from that of the other two. A comparison of the tractors' pto dynamometer tests (Table 1) indicates that the maximum power outputs of the MF275HT and the F5610 were similar, with the MF275HT producing 9% more power than the F5610. The F56TT produced 14% more power than the MF275HT and 22% more power than the F5610. Although the MF275HT produced less power than the F56TT its haulage capacity was greater for all loads with which it was tested.

TABLE 1

Results of pto dynamometer tests on three tractors

| Tractor | F56TT | F5610 | MF275HT |
|-----------------------------------|---------------|-------|---------|
| pto power (kW) | 47,1 (46,7)* | 38,5 | 41,2 |
| pto speed (rpm) | 650 | 620 | 620 |
| specific fuel consumption (l/kWh) | 0,368(0,355)* | 0,422 | 0,379 |

* at 620 pto rpm

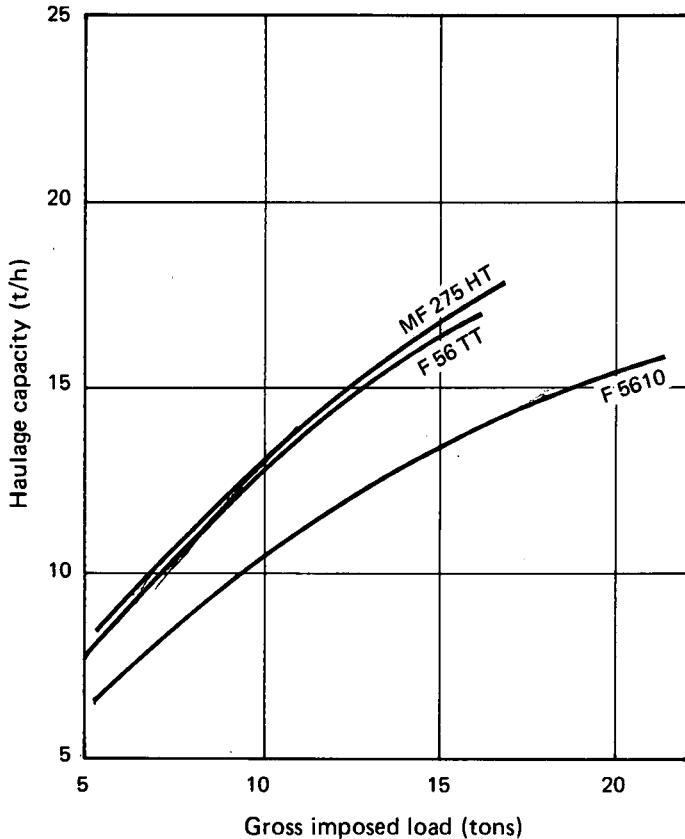


FIGURE 1 Haulage capacity vs gross imposed load over 23 km test circuit.

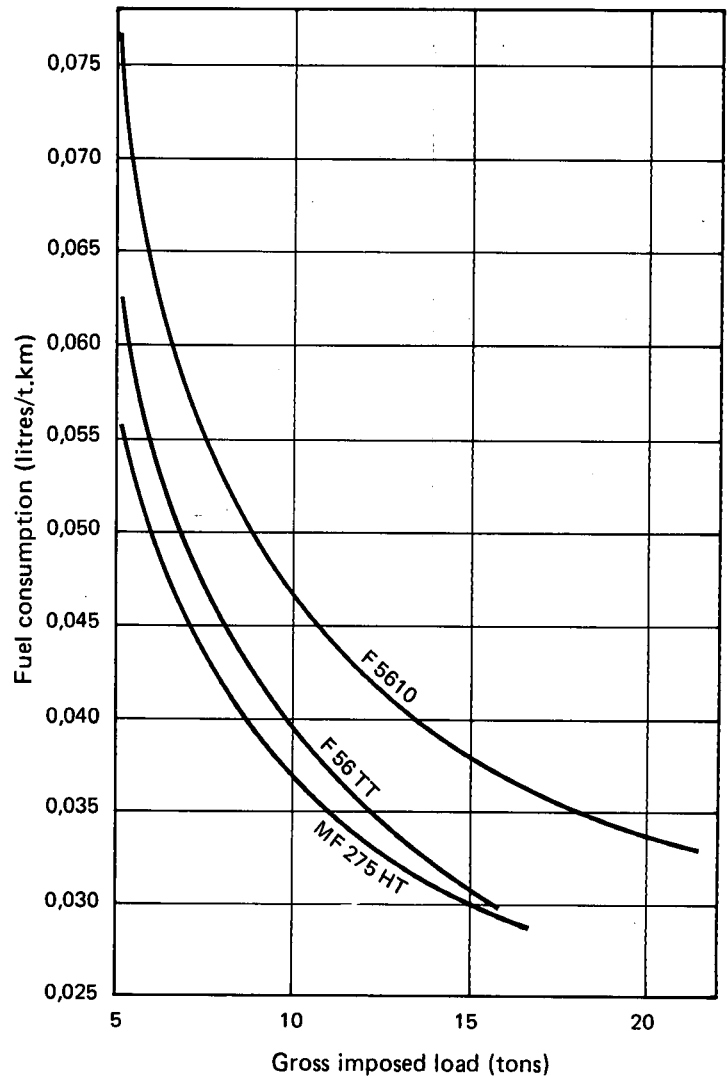


FIGURE 2 Fuel consumption vs gross imposed load over 23 km test circuit.

From Figure 2 is it also evident that the fuel consumption (ℓ/t.km) of the MF275HT is better than that of the F56TT and F5610 for all loads tested while the F56TT has a better fuel consumption (ℓ/t.km) than the F5610 for all loads.

The MF275HT has a 12 speed transmission, the F56TT an eight speed transmission and a high speed differential ratio and the F5610 has a 16 speed transmission with a conventional differential ratio.

Traction Characteristic

Grecenko² derived a characteristic for traction which illustrates the inter-relationship of drawbar power, drawbar pull and ground speed. This characteristic is useful for illustrating the effect of the various transmission options and for estimating the speed and fuel consumption of a tractor/trailer combination. The drawbar pull is a function of the engine torque (T)(Nm), the overall gear ratio (GR) and rolling radius (RR)(m) of the rear wheel:

$$\text{Drawbar pull} = \frac{T}{GR \times RR} \dots (\text{equation 1})$$

Speed (km/h) is calculated as a function of engine speed (S)(rpm), gear ratio (GR) and rolling radius (RR):

$$\text{Speed} = \frac{S \times RR \times \text{constant}}{GR}$$

The traction characteristic is determined by plotting the drawbar power (the dependent variable) against drawbar pull (the independent variable). Drawbar power is the product of drawbar pull (kN) and ground speed (km/h) for each gear ratio.

$$\text{Drawbar power (kW)} = \frac{\text{Pull (kN)} \times \text{speed (km/h)}}{3,6}$$

If wheel slip on a hard road surface is assumed to be negligible, the effect of tractive efficiency can be ignored and the traction characteristic will be as shown in Figure 3. Since power is equal to pull × speed, constant speed will be represented by lines radiating from the origin of the graph.

The traction characteristic for the F56TT is shown in Figure 3, in which only those gears available in high ratio have been considered. Each graph on the traction characteristic has three regions; the 'governed' range which is described by the line from the origin to the maximum value of drawbar power, the 'overload' range which is described by the line to the right of the maximum power, and the 'part throttle' range is the area below the curve.

Figure 3 was plotted using the data from the pto dynamometer tests, from which engine torque is obtained by dividing the pto torque by the relevant pto ratio. The pull in each gear is calculated (using equation 1) and drawbar power is assumed to be 0,96 of the pto power (ASAE³).

The F56TT is a standard tractor which was fitted with an alternative high speed differential ratio. The standard differential ratio is approximately 5,27:1 and the high speed differential has a ratio of 4,63:1. This means that the F56TT is faster, but will have proportionately less drawbar pull in each gear ratio than the F5610. The effect of the different final drive ratio on the traction characteristic can be seen when Figures 3 and 4 are compared. The traction characteristic of a F5610, producing the same power as the F56TT is represented in Figure 4.

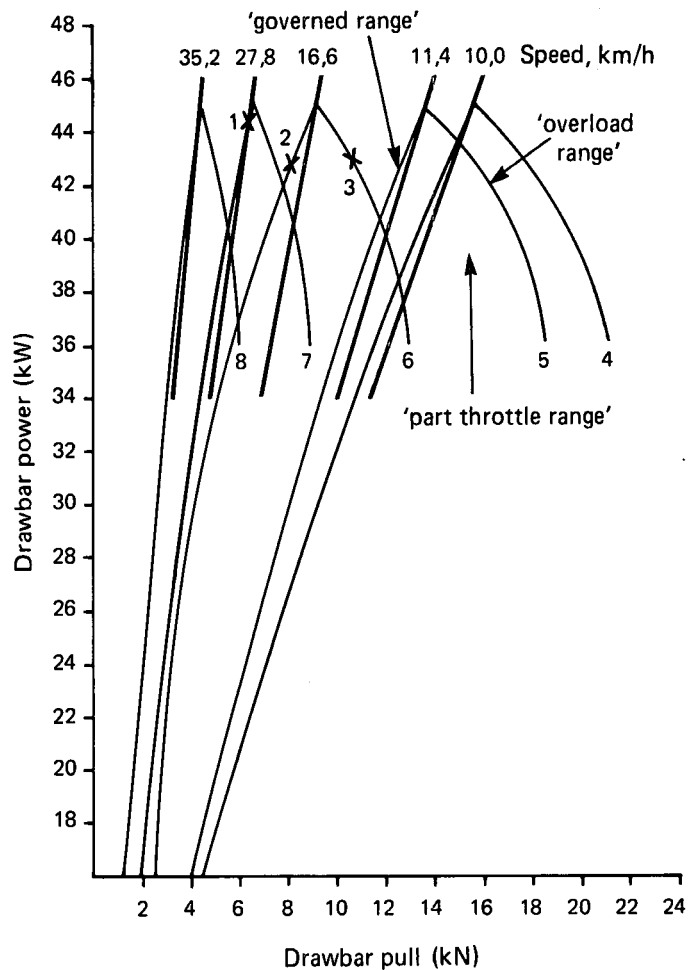


FIGURE 3 Traction characteristic for F56TT as tested.

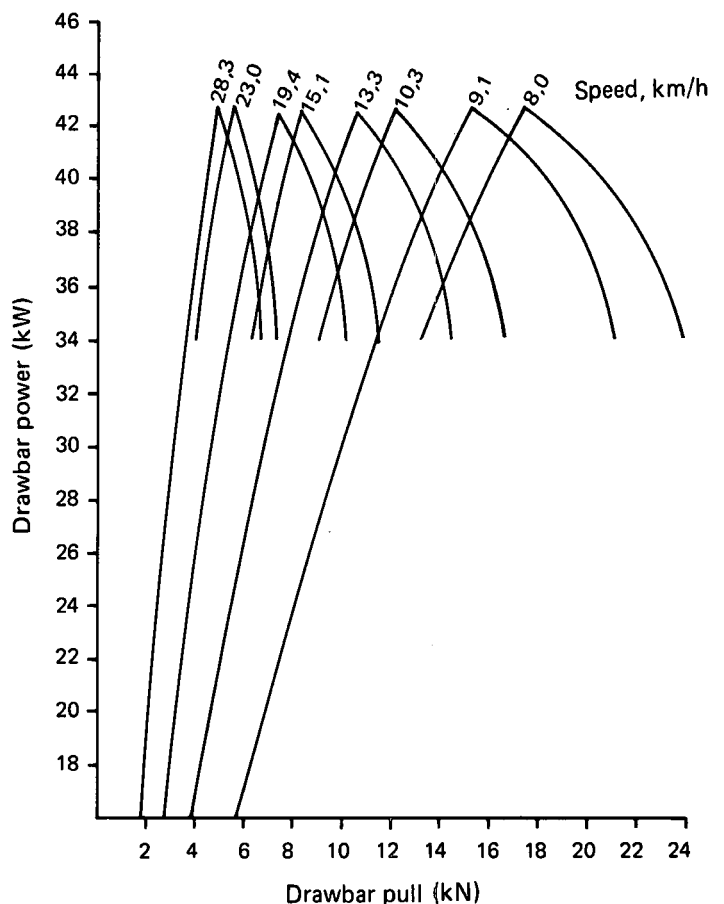


FIGURE 4 Traction characteristic for F5610 with dual power producing full power.

However the F5610 tested did not produce full power and its traction characteristic (Figure 5) therefore differs from that given in Figure 4. The tested F5610 was fitted with a 'dual power' option which effectively provides a 20% under-drive in each gear ratio, giving the tractor 16 forward gear ratios. Only the eight fastest ratios are plotted in Figure 5 because the lower ratios were not used in the tests. When the characteristics of Figures 4 and 5 are compared it can be seen that 'dual power', by doubling the number of ratios, allows the driver to use a higher proportion of the tractor's power over a wide range of loads.

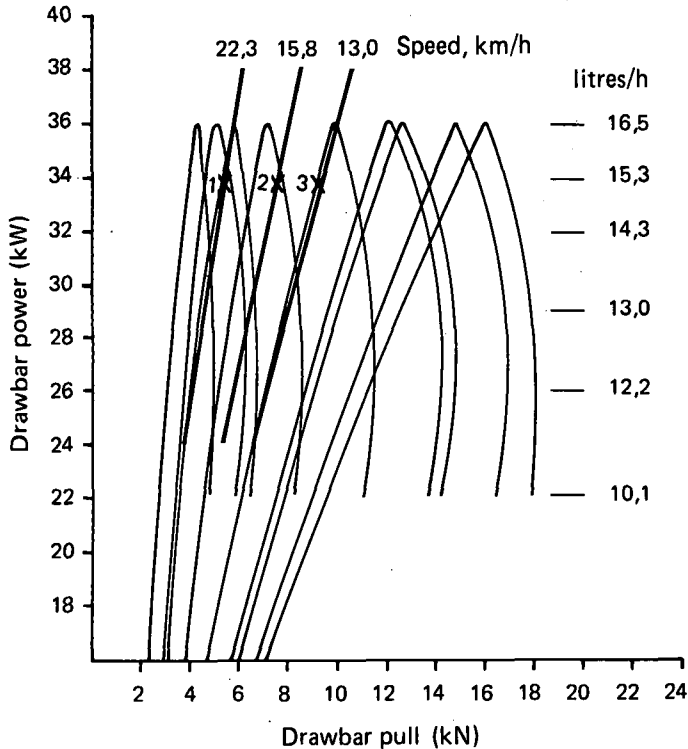


FIGURE 5 Traction characteristic for F5610 as tested.

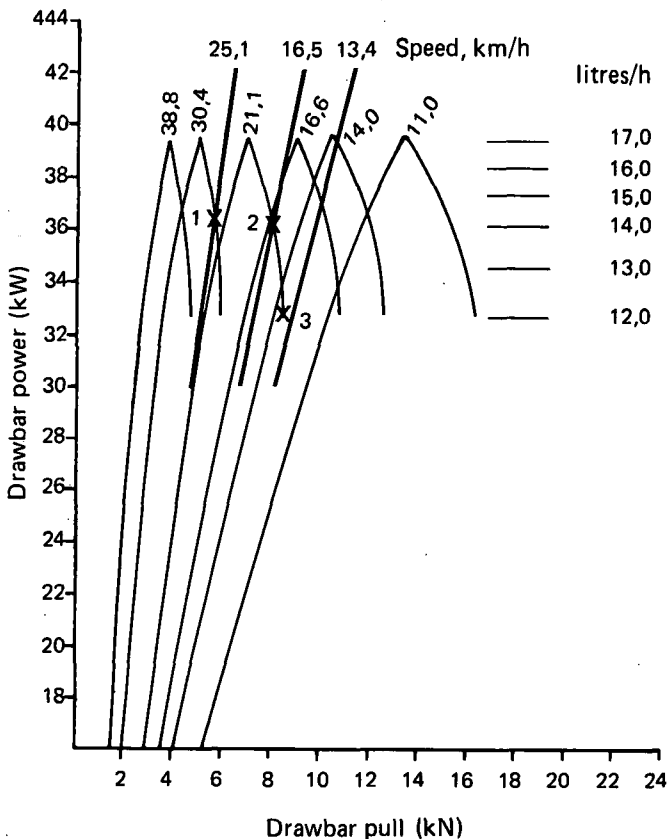


FIGURE 6 Traction characteristic for MF275HT as tested.

Figure 6 represents the traction characteristic of the MF275HT showing the top seven ratios which are more evenly spaced than those of the other tractors and provides 35 kW or more for the range of loads tested.

Results

The results obtained from the three tractors pulling a 10,4 t load are summarised in Table 2. Although the MF275HT is less powerful than the F56TT, the average speed of the two tractors was the same (29,8 km/h). The MF275HT was slightly slower on the inclines and was faster down hill and on the flat regions. The MF275HT used the least amount of fuel (ℓ/t.km) for the whole route. As expected, the F56TT was fastest on the inclines because it is more powerful. The performance of the F5610 was disappointing considering that its power output is very similar to that of the MF275HT and that there are 16 gear ratios which should provide better opportunities to use the engine to its full potential.

TABLE 2

Results of three tractors each pulling at 10,4 t load over a 23 km test circuit

| Tractor | Grade | Fuel | | Time | | Speed km/h | Fuel consumption ℓ/t.km |
|---------|-------|-------|------|-------|------|------------|-------------------------|
| | | ml | % | h | % | | |
| F5610 | - | 468 | 4,4 | 0,172 | 18,3 | 33,3 | |
| | +* | 5 278 | 49,3 | 0,353 | 37,6 | 16,2 | 0,0896 |
| | 620 | 4 962 | 46,3 | 0,415 | 44,1 | 27,6 | 0,447 |
| | 0,422 | | | | | | |
| | | | | | Ave. | 24,7 | 0,0447 |
| F56TT | - | 419 | 4,5 | 0,147 | 18,8 | 38,9 | |
| | +* | 4 536 | 48,8 | 0,293 | 37,6 | 19,5 | 0,0770 |
| | 650 | 4 333 | 46,7 | 0,340 | 43,6 | 16,8 | 0,0642 |
| | 0,368 | | | | | | |
| | | | | | Ave. | 29,8 | 0,0384 |
| MF275HT | - | 194 | 2,2 | 0,127 | 16,3 | 45,0 | |
| | +* | 4 427 | 51,3 | 0,328 | 42,1 | 17,4 | 0,0751 |
| | 620 | 4 012 | 46,5 | 0,325 | 41,7 | 17,6 | 0,0594 |
| | 0,379 | | | | | | |
| | | | | | Ave. | 29,8 | 0,0357 |

*pto dynamometer test results at maximum power: respectively power (kW), speed (rpm) and specific fuel consumption (ℓ/kWh)

For a fuller analysis of the tractor's performances, the data for their speed on each gradient (3,5%, 5% and 8%) and the amount of fuel used, expressed as ℓ/h (Table 3), were superimposed on the traction characteristic so that the relationship between drawbar pull and drawbar power developed on those slopes could be established.

TABLE 3

Speed and fuel consumption for three tractors pulling 10,4 t on inclines

| | Grade % | Tractor | | |
|------------------------|---------|---------|-------|-------|
| | | MF275HT | F56TT | F5610 |
| Speed (km/h) | 3,5 | 25,1 | 27,8 | 22,3 |
| | 5 | 16,5 | 17,5 | 15,8 |
| | 8 | 13,4 | 15,5 | 13,0 |
| Fuel consumption (ℓ/h) | 3,5 | 14,2 | 17,1 | 15,1 |
| | 5 | 14,0 | 15,4 | 15,2 |
| | 8 | 12,4 | 14,9 | 15,6 |

Fuel consumption (in ℓ/h) which is measured during pto dynamometer tests can be used to estimate the amount of power

being produced. Therefore the data on fuel consumption and speed (Table 3) can be used to locate the point on the traction characteristic at which the tractor was operating. These points, marked as (1), (2) and (3) on Figures 3, 5 and 6 for the 3.5%, 5% and 8% slopes respectively, indicate that the operator chose the appropriate gear except at point (3) in Figure 6 where two other gears would have resulted in more power being available. More of the potential power of the F56TT was used as shown in Figure 3 and it was therefore faster on the three slopes. The MF275HT did not use as much power as the F56TT and was therefore not as fast on the three slopes. The three points on Figure 6 occurred well into the overload range; therefore the specific fuel consumption (ℓ/kWh) for the MF275HT would be much better than the consumption of the other two tractors.

The position of the three points in Figure 5 for the F5610 relative to its characteristic are satisfactory for the state of adjustment of the engine. Because this tractor should have produced considerably more power, the points on Figure 5 should be related to the characteristic of the engine of the F56TT, and then the three points occur in the part throttle range. This indicates that specific fuel consumption is likely to be very poor.

A set of the curves for specific fuel consumption for a typical diesel engine is given in Figure 7. The outer solid line represents the boundary usually imposed on an engine by adjustments to the fuel pump. The dotted line represents the limit of operation imposed by a maladjustment of the fuel pump's metering mechanism. Such a maladjustment results in a significantly higher specific fuel consumption range in which the tractor engine must operate. This occurred in the F5610 (if it is assumed that the engine was badly adjusted and not faulty), therefore its fuel consumption was very poor.

The results of the dynamometer tests on the F5610 and F56TT are illustrated in Figure 8.

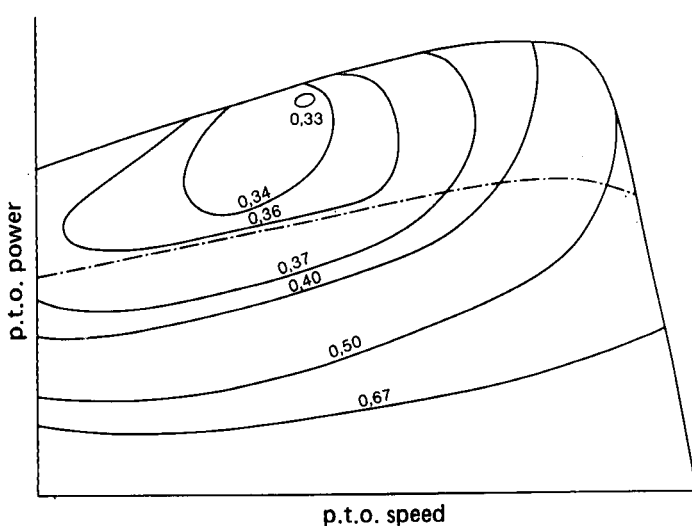


FIGURE 7 Contours of constant specific fuel consumption for a diesel engine.

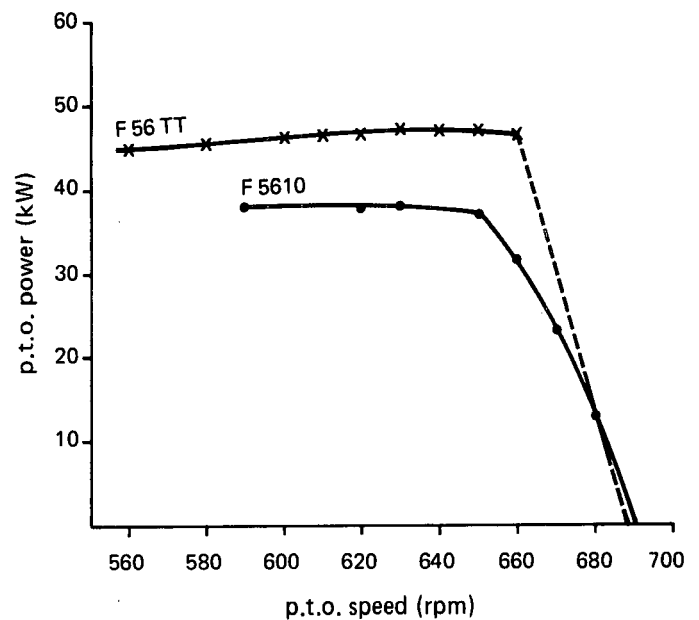


FIGURE 8 Pto dynamometer test results for the F5610 and F56TT.

Conclusions

The final drive ratio was changed on the F56TT. The effects of doing this could be illustrated by superimposing Figure 3 on Figure 4. One effect is that a single overall ratio which is faster than any of the previous standard ratios is produced. (The 8th gear with the high final drive ratio is faster than the standard 8th gear, but 7th gear, with the high final drive ratio is not faster than the standard 8th gear).

A second effect is to 'compress' the characteristic by reducing all the drawbar pulls through changing the final drive ratio, thereby providing more gear ratios which can be used for haulage.

The addition of an under-drive gear ratio ('dual power') generally provides a bridge between the standard gear ratios which should allow the operator to change gear without losing as much power as would be the case without the dual power facility. This feature is illustrated when Figures 3 and 4 are compared. However the F56TT has the advantage of a higher gear ratio but this was of no consequence on the inclines because it could not be used. The standard F5610 with its dual power facility, should have out-performed the F56TT on the inclines. In fact, the F56TT was the better performer, probably because of the higher output from its engine. The very good performance of the MF275HT must be due to its close gear ratios and satisfactory engine performance. If the F56TT had either the MF275HT or the F5610 gearbox, it may have performed even better than it did.

The importance of checking the pto output of every tractor before taking delivery is highlighted by this work.

REFERENCES

1. Boevey, T. M. C. & Meyer, E. (1984). Testing haulage tractors. *Proc S Afr Sug Technol Ass* 58 (in press).
2. Grecenko, A. (1968). Predicting the performance of wheel tractors in combination with implements. *J. agric Engng Res* 13: 49-63.
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