Jörg Seeger, Brunswick

Ploughing with electronic engine controller and infinitely variable transmission

Increasing area performance through torque rise manipulation

Usually a maximising of the area performance is looked-for in ploughing. In order to achieve this, the tractor-plough combination has to be optimally matched. Essential, however, is that maximum performance from the engine be available. Using an infinitely variable transmission allows the torque rise, commonly stretched nowadays over a wide engine speed range, to be reduced to a small rpm range. Through this the engine performance can be increased which also means an improvement in ploughing area performance.

Dipl.-Ing. Jörg Seeger is a member of the scientific staff at the Institute for Agricultural Machinery and Fluid Technology, TU Brunswick (Director: Prof. Dr.-Ing. H.-H. Harms), Langer Kamp 19a, 38106 Brunswick; e-mail: ilf@tu-bs.de.
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Keywords

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When ploughing, maximum available engine power is a decisive criterium for area performance. Using the example of a simulated total load model, the area performance of a tractor-plough combination was investigated under the influence of characteristics shown by three different engine performance maps. In this investigation the optimisation of the tractor-plough combination was purposely dispensed with. With the changing soil and field contour conditions assumed in this test, the working width of the plough and tractor ballasting would have to change at every point of the total load model in order to achieve optimal traction.

Total load model

To produce large as possible load variations, ploughing on undulating land with changing soil types was chosen for the load model. The total load forces were calculated through a simulation model which took account of the following parameters: working width, depth and speed of the plough, soil type (loamy sand, sandy loam and clayey loam), incline resistance, rolling resistance, static axle load, tractor and plough weight, tyre performance values and wheel slip.

The type of the „field" and of the soil are presented in *figure 1*. The field has a „sine curve" hill with a length of 600 m and height of 25 m with maximum slope of 13.9%. At the same time, the distribution of soil types is illustrated. On the first 100 m the soil is 100% sandy loam. Within the next 50 m the soil type then changes to clayey loam so that an increase in plough resistance is experienced. Through this increase and the simultaneously experienced upward slope, very large changes in load take place on the drive components. From 250 m the soil type changes within 50 m back into sandy loam.

Engine performance map

In *figure 2* the investigated engine performance maps are presented through torque and power development.

The power curve 1 has a very large constant power range of 90 kW. This is achieved through a continuous torque rise from 2200 down to 1700 min^{-1}. This relatively high torque development stretching over a wide engine speed range is usual with today's tractors [1]. In most cases the point of the highest torque actually lies at even lower engine speeds. Through this, tractors with stepped transmissions have a large power reserve. Where load increases, the gear in which the tractor finds itself can be retained and, as long as the engine remains in the constant power range, the maximum power will still be presented. The danger of stalling is relatively small because the driver has a lot of time for reaction up to when maximum moment is reached at relatively low revolutions. In addition, the driver is warned „acoustically" through the change in engine noise.

With the torque curves 2 and 3, on the other hand, the limited drop in engine speed would mean that the driver would hardly no-

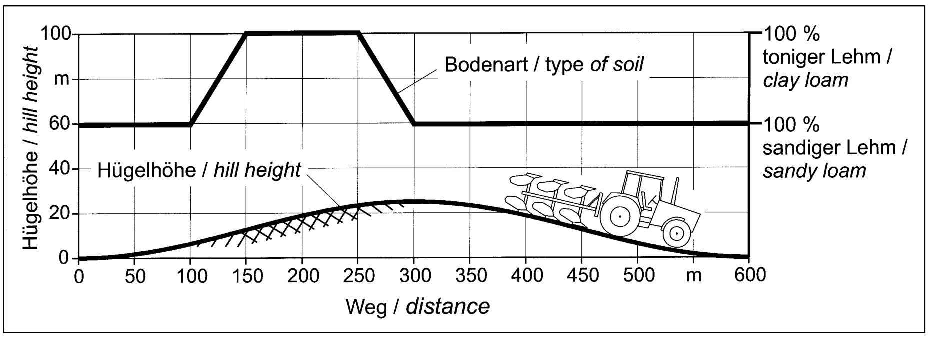

Fig. 1: Soil surface contours and soil type in the simulated „field".

map	max. motor power		area performance		area consumption	
	[kW]	[%]	[ha/h]	[%]	[l/ha]	[%]
1	90	100,0	1,175	100,0	20,17	100,0
2	98	108,9	1,254	106,7	20,89	103,6
3	107	118,9	1,310	111,5	22,48	111,4

Table 1: Test results

tice the load increase. But on reaching the maximum torque the motor would then very quickly stall. Because of this, torque developments with a short and steep rise are not to be found in tractor engines. They would, however, be especially advantageous in pto work or for application with self-propelled silage harvesters in order to avoid great changes in engine revolutions.

Infinitely variable transmissions, on the other hand, that are integrated within drive train management don't require torque rise over a wide engine speed range. Through the automatic adjustment of the gearing the revolutions of diesel engines can be held constant within a relatively short range, even in the case of large variations in load [2].

The maximum torque is important for the dimensioning of the engine and the transmission. If one wishes to increase the power of a diesel engine at constant moment, the only possibility is to raise the moment into the upper revolution range as illustrated in the curves 2 and 3. The maximum power of curve 3 lies at 107 kW and is with this about 18.9% higher as the 90 kW available from curve 1 at the same maximum moment.

Trial methods and results

In the trial series the transmission drive train was loaded in each case with the same total load model as described, and the engine performance map adjusted according to fig. 2.

The simulation model calculated the resistance forces of the plough and the tractor in association with the above-mentioned parameters. In all the trials the engine was operated at full throttle. The activation of the stepless transmission takes place in such a way, however, that the motor is always held against the full load line according to the engine performance line within the engine speed range where power is at maximum. In the case of engine performance map 1, the engine is held at 1800 min^{-1} because fuel consumption is lower at this level compared with at higher engine speeds.

In order to determine the data most important to the farmer, the area performance in ha/h and the area fuel consumption in l/ha, the time in which the 600 m test stretch is covered, and the fuel consumed in the operation, is measured.

Table 1 shows the absolute results and those from the trial with the standardised data according to engine performance map 1. Through the 8.9% higher maximum power, the area performance in the case of performance map 2 could be raised by 7.6% compared to performance map 1. At the same time, however, the area consumption rose by 3.6%. With 18.9% higher power the performance map 3 achieved a rise in area performance of 11.5% with at the same time an increase of 11.5% in fuel consumption.

Naturally, the increase in area performance can be attributed to the higher available engine power. That the area performance does not rise at the same rate as the engine performance can be explained through the following:

The higher engine power can only be presented through an increased driving speed because all other parameters, especially the working width of the plough, have been held constant. The higher driving speed has, however, the result of raising the specific plough resistance. With the same total load model this means the real load or the draught that has to be produced in the engine performance maps 2 and 3 is higher, so that a part of the increased power of the engine is once again lost. On top of this, with the same tyre performance parameters the higher draught can only be achieved with a higher wheel slip which also serves to reduce the performance increase. Another reason is that the maximum power with performance maps 2 and 3 is only produced by the engine within a very small engine speed range. Even through the control of the stepless transmission, it is not possible to remain exactly in this range.

The area-related fuel consumption rises minimally through performance map 2 and to a much greater extent through performance map 3 compared with performance map 1. On one hand, the higher consumption is associated with the higher achieved performance because of the higher plough resistance. On the other hand, the engine working rate at higher revolutions where the specific fuel consumption of the motor rises sharply.

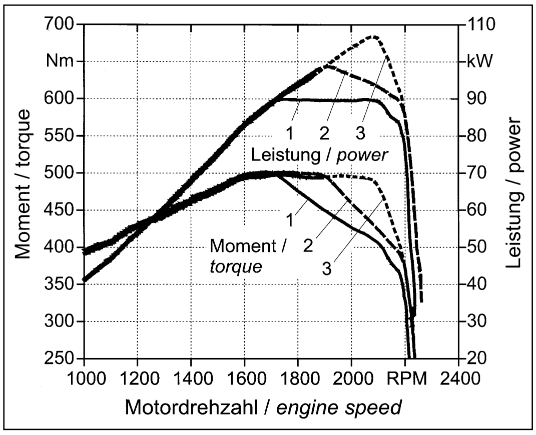

Fig. 2: Examined engine performance maps

Conclusion

The trials carried out show that the area performance of a tractor-plough combination is able to be substantially increased through the application of an infinitely variable transmission and an electronic engine control. In time-critical situations a considerably higher area performance is achieved with the engine performance shown in map 3 although at the same time a higher fuel consumption has to be accepted. Should value be given to a lower fuel consumption, then performance map 1 is to be recommended. Performance map 2 represents a compromise. From the economical point of view, however, a maximum area performance should be aimed for, especially in heavy draught work, because the diesel consumption does not represent as much expenditure as the savings in time involved.

In that an engine with a considerably higher maximum performance was used on the test station, there was no problem in maintaining a constant maximum moment of 500 Nm from 1600 to 2050 min^{-1}. Whether this region is technologically reachable in practice must be left to the motor industry to answer.

It would also be good if this report encouraged the tractor, engine and transmission industries to discuss future demands on tractor engines especially with regard to the obviously increasing trend of infinitely variable transmissions in farming.

Literature

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