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Comparison of powershift and stepless transmissions under heavy traction work

The stepless transmission is always able to operate continually at maximum speed. Increased power requirement reduces the speed, but fuel supply can also be increased instead.

The powershift transmission looses the disadvantage of individual gears where the engine can balance changing loads over a wide range. The „extra power" and the elasticity of the engine compensates for more than one gear in the transmission.

Stepless transmissions have advantages over and above the economic effect where constant revolutions are required for the pto. Additionally, the engine can be run with favourable fuel consumption at optimum output where speed is adjusted over the transmission alone.

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Keywords

Transmission balance, stepless transmission, powershift transmission, efficiency degree, engine elasticity

Modern tractor transmissions as well as engine-transmission drive systems encourage their testing for performances under practical conditions. The broad interest in stepless transmissions, here represented by the Vario from Fendt, justifies their presentation.

The stepless transmission comes with the reputation of returning a poorer degree of efficiency. Test stand measurements by the DLG support the view that this need not be so. In total, the efficiency degree of transmissions varies between 80 and 90%. Both stepless and powershift transmissions lie within this range.

Practical trials were carried out to indicate whether one system has advantages over the other.

Methods and measurements

Two tractors of the same power class were compared: a Fendt with Vario transmission and a John Deere with powershift transmission. Both machines were conventionally equipped and had comparable tyres and axle load distribution (*table 1*). Performance characteristics of both engines, measured at Eggers Power Centre, differed only minimally from one another.

A large field was chosen as working area. Soil and surface relief were heterogenic. Through this, angle of slope could be applied as an influence factor on the tractor and plough-relevant traction resistance. With the 7-furrow Vario Diamant plough from Lemken pressure in the first furrow adjustment cylinder could be measured. This served as indicator for alterations in traction power. The calibration gave a close linear correlation to traction power.

Specifications	Fendt Vario 926	John Deere 8400 Powershift
Engine rated-power [kW]	191	191
Max. power at pto [kW]	174	168
Axle load [kg]		
- front	4580	5340
- rear	4460	5210
Total weight [kg]	9000	10560
Tyres		
-front	600/65R34	600/65R28
- rear	650/65R42	710/70R38
Plough	Lemken - fully-reversible 7 furrow, 3.15 m width, 28 cm depth	

Table 1: Characteristics of the machines

Speed, rpm and critical load were variables. Altogether, ploughing speed was high. No additional share was mounted because wheelslip under difficult conditions was too high.

Field influence

The heterogeneity of the field could be assumed from measurements for traction resistance (measured as pressure), diesel consumption and wheelslip for variants with lower and therefore more constant speed at the tractor wheel. The curve progression (*fig. 1*) clearly showed parallels in the reaction to the traction power requirement reflecting the changing soil resistance.

This „ideal picture" was disturbed, however, when the demand on traction power and transmission increased with the speed (*fig. 2*). Then, the effects of the degree of slope and the more or less loosened surface of the harrowed field had an effect. The oversight of all trial variants showed that only in 40% of the cases was wheel slip influenced by traction resistance.

Variant Load limit	Field length [m]	Average speed [m/s] Vario	Powershift	Difference Absolute	%
Vario 5-25%	425	2.20	1.94	0.26	13.4
Vario 7-15%	422	2.20	1.94	0.26	13.4
Vario 9-5%	427	2.18	1.94	0.24	12.4
Vario 15-25	470	2.46	1.94	0.52	26.8
Vario 18-15	539	2.45	2.18	0.27	12.4
Vario 10-5	423	2.40	2.18	0.22	10.1
Vario 26-25	574	2.64	2.18	0.46	21.1
Vario 24-15	526	2.67	2.18	0.49	2.5
Vario 20-5	571	2.51	2.18	0.33	15.1

Table 2: Vario transmission speed and deduced from it the speed of power shift transmission on the test

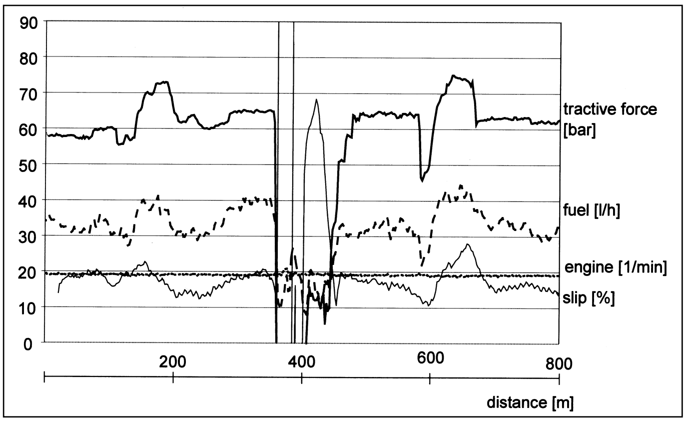

Fig. 1: Traction force versus fuel consumption at constant speed (7.8 kph)

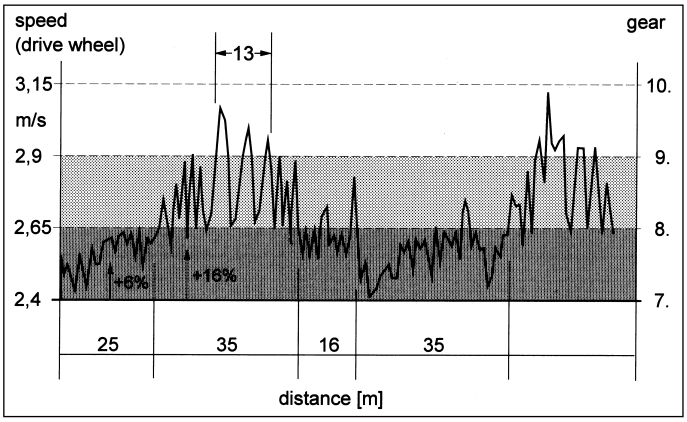

Fig. 2: Traction force versus fuel consumption and slip at constant engine rpm and speed (8.1 kph)

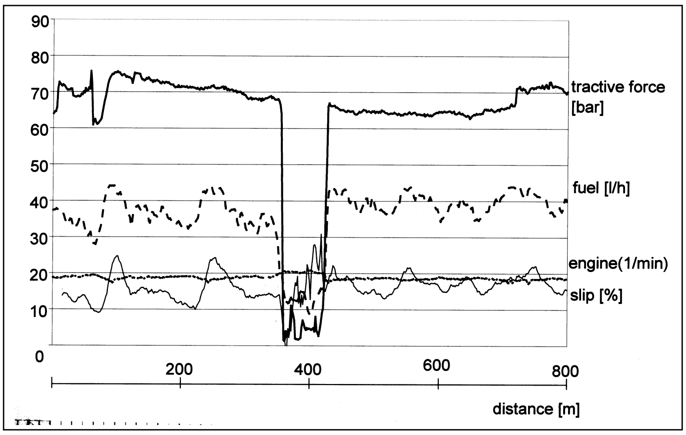

Fig. 3: Vario transmission speed and allocation of the power shift transmission

Influence of speed

The advantage of driving at higher speeds as much as possible was reduced by the complex conditions in the field. Individual measurements indicated that:

- wheelslip increased by 2% per km/h
- traction power increased by 10% per km/h
- rolling resistance increased by 15 to 35% per km/h
- diesel consumption increased by 20%

Comparative results

The comparison was divided according to the effect of the stepless transmission and that of the complete driveline of engine and transmission.

Transmission effect

The stepless transmission was compared with a powershift transmission with individual gear steps of 0.25 m/s, i.e. around 10% of that of the comparison tractor.

The curve progression of the Vario transmission was used as comparison basis. Within this was laid the grid of the powershift transmission (*fig. 3*). This method allowed the direct comparison within a field trial without distorting factors.

In the figure 3 example, the 8th gear replaced the 7th after 25 m. On this stretch the Vario is 6% faster and this represents the smallest difference. Still questionable is the extent of influence of the driver's gear change decisions. In reality, the longer section with 16% higher speed proved practical.

Length of furrow without changing gear in the trials was between 15 and 160 m. Gear changing was only worthwhile from 70 m, i.e. one to three times every furrow length. The less diligent driver ploughed with the lowest speed and in this case the Vario effect increased efficiency impressively (*table 2*).

Engine regulation

The comparison up until now was based on the fixed aspect of a manual transmission. However in reality the reaction of the engine has to be brought into the argument.

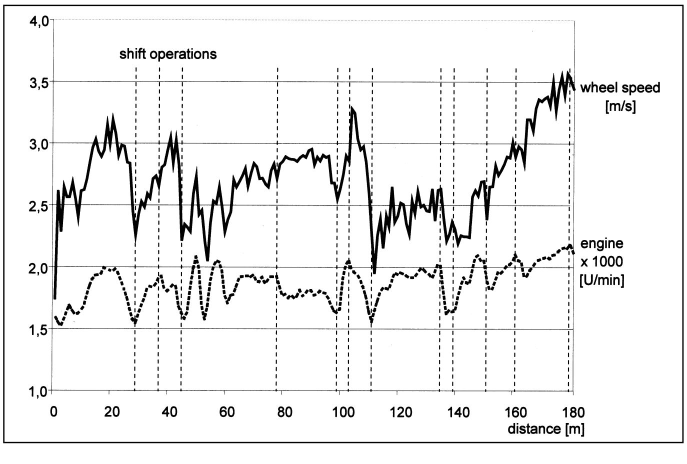

Fig. 4: Shift operations and speed during ploughing

- the rpm decreased according to torque progression
- the injection pump increased the fuel supply so that the engine produced more

With this, the John Deere tractor was able to meet the increased traction power demand. This led to traction power increasing by 15% with a significant up to 30% increase in fuel flow.

Changing gear

In competition with the stepless transmission it was required that the driver was diligent in shifting gear. It can be seen from *figure 4* that the driver carried this out even for short sections, i.e. 12 times along 180 m with changes after 15 to 75 m.

The curve progression indicates no marked leaps in transmission because the engine revs were depressed from +/- 2000 min^{-1} to 300 to 500 min^{-1}. In practice, the driver would use 8th gear (2.65 m/s) as basis with the higher demands on traction power being balanced by the engine governor. For both of the longer sections the higher gear paid off. This means the engine governor balanced-out at least the transmission steps. This 13% advantage for the Vario transmission (table 2) therefore did not apply and compared with the difference from two transmission steps, the difference is only 5 to 7%.