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Comparison of gear units for tractors during road transport

The demands of modern tractors for agricultural transport are of particular importance. Modern tractors have to be able to provide high speeds on the road with good acceleration and braking, as well as good power transfer on the field – with easy handling and good ride comfort. The engine of a tractor is, except for on slopes and under acceleration, never fully utilised. Therefore the tractor manufacturer must provide 50 km/h variants that allow fast transport with lower engine speed and better engine loading. If the maximum speed of 50 km/h is maintained during transport, then fuel is saved through transmission variants, but not time. The required transmission and motor management have been established in recent years by almost all manufacturers, and customers demand it. In particular, the efficiency of the transmission, and of the electronic engine control, have a strong impact on the costs of transport per kilometer.

Keywords
Gear unit comparison, dual-clutch transmission, automatic transmission, fuel efficiency, road transport

Abstract
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The increasing proportion of tractor time spent in road transport [1; 2] coupled to the rising costs for the fuel involved are leading to a rethink by both tractor owners and manufacturers regarding efficiency and ease of driving. Alongside the classic powershift transmission with its high efficiency and the already well-known continuously variable stepless variations with their increased ease of operation, dual clutch transmissions are also of increasing interesting for manufacturers. The trial described here was aimed at comparing the efficiency and economy of two different transmissions available in the John Deere R6219 tractor (over 150 kW class), the new direct drive dual clutch transmission and the already known stepless transmission AutoPowr. The two variations were subject to an intensive practical trial.

Practical transport comparison

The test route comprised public highways running through a rural area southwest of Kaiserslautern which passes through a number of communities and includes various traffic control situations: junctions, traffic lights and pedestrian crossings, with the slowing effects these have on vehicular flow. These influences were included as part of the test environment, as were prevailing weather conditions (precipitation, temperatures, etc.). In order to reduce the direct influences of these external conditions as well as of the individual drivers involved, four experienced operators from agricultural contractors were used on the trial route and each driver covered the stretch four times with each tractor.

The route used for the comparison trials covered 41.2 km and including altitudes from 268 m to 449 m above sea level with gradients up to a maximum approx. 13 %.

Table 1 includes all important technical specifications for the two tractors involved in the comparison.

Different methods were applied for recording the required information. Both tractors were assessed on the working test stand with an eddy current brake dynamometer on the pto according to OECD code 2 [3]. And each tractor was also driven over the already described route four times with trailer and load and four times with trail without load. For these transport recordings each tractor was additionally ballasted with a 960 kg front weight.

The recordings on the test stand were carried out with a mobile Eggers PT302 eddy current brake dynamometer (**Figure 1**). Hereby pto rpm, power and torque were measured for each tractor. Fuel consumption was volumetrically measured with a FM 3-100 sensor.

With the engine brake shown in **Figure 1** attached to the pto, tractor torque and power outputs were measured and recorded through the entire engine rpm range. Both tractors returned comparable performances in the recordings, the AutoPowr achieving a 3.6 kW higher maximum performance at the pto brake. This result lay within the manufacturer tolerance [4].

The recorded characteristics served as basis for the following transport comparison recordings on the road.

The road route tests delivered the results with which the economic evaluations were later calculated. So that traffic flow influences on tractor speeds and fuel consumptions could be more evenly spread in the conclusions, the route was driven over eight times by each driver. Four journeys were carried out with empty trailer and four with loaded trailer.

The 2 trailers were dumper tippers loaded with gravel to a gross weight of 18 tonnes. In that the two same-design trailers had different tyres (**Table 2**) with each set driven with the optimal air pressure for the gross weight, rolling resistance for each was different and this could possibly have influenced the end results. For this reason the tractors travelled the route twice with trailer Krampe1 and twice with trailer Krampe 2. The weights as shown in **Table 1** and **2**, plus the additional front mounted weights gave, for the transport comparison, the AutoPowr a gross weight of 27.71 t and the DirectDrive of 27.58 t.

For the recordings made on the transport route each tractor was fully tanked with diesel with the amount of fluid and the level in the tank recorded. Following four journeys in each case – i. e. 164.8 km - the tanks were refilled and respective amounts required were recorded. A Horn pump with fuel meter was used for these measurements. During the test stand recordings, as well as for the recordings made during the actual transport journeys, the fuel temperatures at beginning and end of each journey were measured by IR thermometer. The tractors were

Table 1

Essential technical data for of the used tractors

	John Deere 6210R AutoPowr	**John Deere 6210R DirectDrive**
Leistung [PS] *Horse Power*	240 PS (IPM(97/68EC))	240 PS (IPM(97/68EC))
Gewicht [kg] *Weight*	8760	8625
Leistungsgewicht [kg/PS] *Power* to weight	37	36
Reifen vorn (1,8 bar Luftdruck) *Front Wheel* *(1.8 bar pressure)*	600/70R28 Michelin	600/70R28 Michelin
Reifen hinten (1,6 bar Luftdruck) *Rear Wheel* *(1.6 bar pressure)*	710/70R42 Michelin	710/70R42 Trelleborg
Getriebe *Gear unit*	stufenlos *continuosly*	Doppelkupplungs-getriebe *dual clutch*
Abgastechnik *Emission technology*	gekühlte Abgasrück-führung mit Partikel-filter *cooled EGR with particulate filter*	gekühlte Abgasrück-führung mit Partikel-filter *cooled EGR with particulate filter*

Fig. 1

Dynamometer measurement - eddy current brake "Eggers dynamometer" at the PTO (Foto: Reckleben)

also equipped with GPS data logs for the transport comparisons so that actual speeds and stretch profiles were automatically recorded with the routes displayed as "paths" and utilised for the further evaluations.

Speed comparisons

The speed as major factor for road transport performance was continually measured every second by the GPS data log. **Figure 2** displays the speeds in relationship to distances covered for the John Deere 6210R DirectDrive. What catches the attention especially here are the speeds of over 50 km/h. These are possible because, unlike the AutoPowr transmission, the DirectDrive dual clutch transmission is not electronically braked. Average speeds calculated as a mean for the four drivers show, however, a slight advantage of 0.9 km/h for the AutoPowr which, with 43.8 km/h, achieved a higher speed than the DirectDrive over the test route.

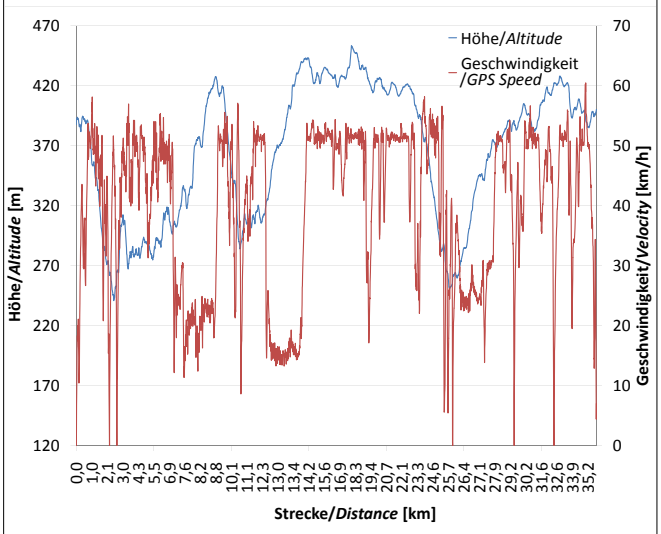
Finally, typical relief forms (downhill, level stretches, uphill) were used to achieve a precise evaluation of performance (**Figure 3**). It was demonstrated that both tractors were equally fast over the individual segments whereby the faster gear changing by the DirectDrive was of advantage pulling uphill and the AutoPowr transmission appeared more advantageous on the flat and downhill [5].

Table 2

Used Krampe dump trucks for transportation comparison test

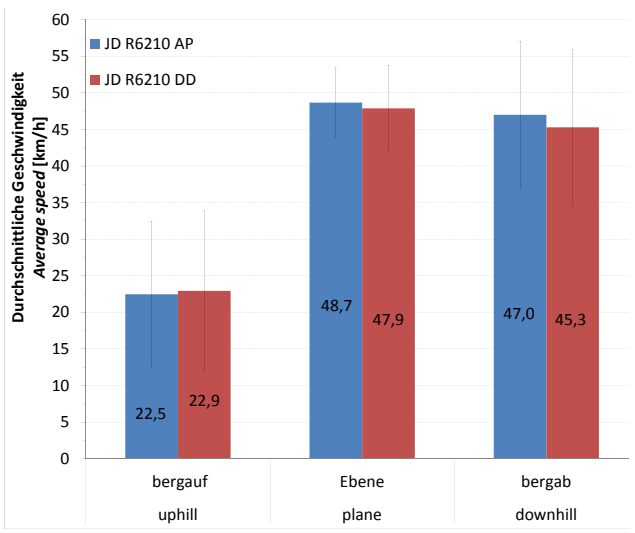
	Krampe 1	**Krampe 2**
Bereifung *Tires*	Trelleborg Twin Radial 680/55 R 26,5	Michelin Cargo X Bib 600/55 R 26,5
Luftdruck [bar] *Air pressure*	3.4	4.0
Gesamtmasse [t] *Total mass*	18	18

Fig. 2



Current speed in the course profile for John Deere R6210 DirectDrive

Fig. 3



Relief classes and the average speeds driven with the two tractors

Cost considerations

The costs for diesel fuel are crucial for judging efficiency in these tests. Used in assessing these costs were the recorded fuel consumption and its purchase price net of purchase tax (**Table 3**).

Costs for the individual tractors were calculated separately for the journeys with load and without load, as well as for a mean value calculated from both. The results show that under full load the John Deere DirectDrive was 0.94 €/km more expensive than the John Deere AutoPowr. The mean value from both load situations demonstrated a similar trend as produced by the full load journeys. The higher fuel consumption was recorded for the John Deere with AutoPowr transmission with the DirectDrive John Deere returning a lower cost of 0.74 €/km. As a percentage against the well-known AutoPowr, fuel costs for the John Deere DirectDrive are shown as 8.64 % less.

Conclusions

Comparison of two different tractor transmissions and engine management systems over the same transport route was used as a way of establishing road transport efficiency. The route involved was southwest of Kaiserslautern and the comparison carried out under different load conditions (travelling empty, fully loaded).

Table 3

Cost calculation for diesel and the measured consumption at various load situations

	John Deere 6210R Autopowr 240 PS (IPM(97/68EC))	**John Deere 6210R DirectDrive 240 PS (IPM(97/68EC))**
Vollfahrt/*Full ride*		
Gesamt Diesel/*Total diesel* [l]	539	499
Verbrauch/*Fuel consumption* [l/km]	0.822	0.761
Kosten/*Costs* [€/km] [1]	1.02	0.94
Leerfahrt/*Empty ride*		
Gesamt Diesel/*Total diesel* [l]	322	287
Verbrauch/*Fuel consumption* [l/km]	0.491	0.438
Kosten/*Costs* [€/km] [1]	0.61	0.54
Mittelwert/*Mean* [€/km]	**0.81**	**0.74**
Rel. Kosten/*Relative costs* [2]	**100**	**91.36**

[1] Diesel: 1,2385 €/l ohne MWST/*exclusive of VAT.*
[2] Index 100 = AutoPowr.

An important question to be answered by this investigation was the efficacy of the new semi-automatic dual clutch transmission "DirectDrive" available in the John Deere 6210R tractor. To learn more, a trial compared this transmission with the John Deere AutoPowr stepless transmission, also in a 6210R. The different transmission technologies and their respective efficiencies were clearly demonstrated as far as the transport question is concerned. The necessary rapid acceleration could be achieved by fast gear changes. Here is where the dual clutch transmission from John Deere demonstrated its advantages. These were also reflected in lower fuel consumption figures.

The results based on the described recordings, and the costs per km thus calculated, showed that the dual clutch transmission resulted in lower costs during transport. The stepless AutoPowr transmission led to higher costs in this trial. The John Deere 6210R DirectDrive performed better than the AutoPowr and costs were 8.64 % lower.

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