Günther Weise, Gießen

Practical driving performances of agricultural transport vehicles

In driving trials with tractor and trailer over a course simulating typical country roads in Hessia, driving performance in empty and loaded state was determined. Along with the load itself the most important influence parameter on speed and fuel consumption proved to be increases in gradient. On the relatively short gradient rise used in observations, dynamic effects had considerable influence.

Dr.-Ing. Günther Weise is a member of the scientific staff at the Institute for Agricultural Engineering, Braugasse 7, 35394 Gießen; e-mail:Günther.h.weise@agrar.uni-giessen.de

Keywords

Transport, driving capacity, loading mass, roadway gradient

In that only very few data are available over the actual driving performance of agricultural transport vehicles, a tractor-trailer combination were appropriately equipped at the Institute for Agricultural Engineering in Gießen to increase knowledge in this field through measured driving performances [1]. (*table 1*).

The tractor was equipped with a radar sensor for measurement of speed and distance covered, a Schaevitz AccuStar gradient sensor for determining inclinations in the direction of travel and a Mannesmann VDO Kienzle EDM 1404 flowmeter for fuel consumption recording.

The main point of observation in the measurements was the drive behaviour in gradients and in built-up areas. For this purpose a test course was chosen in the Gießen area which included different road categories with continuous tarred surfaces and some built-up areas and which was oriented on typical sugar beet transport journeys.The results presented here are from a partial journey of 4.7 km characterised by a broad, well-built road featuring two uphill gradients and downhill stretches.

The measurement course was driven-over three times for each trial with the vehicle train driven both loaded and empty.

Results

If one regards driving speed as a function of the uphill gradient and assumes a simplified constant engine power over driving speed and a constant engine efficiency, the theoretical driving speed as a function of engine power and gradient can be expressed in a simplified manner through the following formula:

(Formel einsetzen) (1)

with rolling resistance value f, speed v, vehicle weight M, gradient angle α, gravitational acceleration g and drive power at the wheels P_{eff}.

The measured values for driving speed and fuel consumption were recorded for the entire course and also for parts of the course. The results are shown in *table 2*.

There resulted a substantial difference in drive performance and fuel consumption between full and empty drive trains. Whilst the average speed dropped by around a third, the average fuel consumption almost doubled. Because of the well constructed roadway and lack of built-up areas in parts of the course where performances were additionally studied in more detail, the average speed here was a little higher than the total average speed, although these parts included two uphill gradients.

In *figure 1* the values are given for speed and gradient on the partial courses. The course consisted at first of a level stretch leading onto a slight undulation (uphill and downhill) followed by a longer uphill gradient which led up through an intermediate stage onto a plateau and finally followed a downhill stretch. In the presentation, these properties (repeatedly driven sequences of level stretches, uphill and downhill gradients) are characterised through ellipse-type hysteretic curves followed in a clockwise direction. Observing gradient effect on train speed in this case, it was shown that this decreased by around 3 m/s in the case of an uphill gradient of around 3.5° from a speed on the level of around 10 to 11 m/s.

There appeared no definite relationship between gradient and driving speed so long

Table 1: Data of vehicles

Tractor	**Fendt Xylon 524**
Engine power	103 kw
Empty weight	6.6 t
Power change gears	4
Manual changeable synchronised groups	6
Permitted top speed	50 km/h; 14m/s
Trailers (2 models)	**Krone DK 225-18**
Empty weight	4.1t
Permitted gross weight	18 t
Permitted top speed	60 km/h
Driving train empty	14.8 t
Driving train loaded	42.2t

Table 2: Mean consumption data and driving speed

Driving speed	
Train loaded over entire course	6.4 m/s
Train loaded over part 4	7.3 m/s
Train empty over entire course	9.4m/s
Average consumption	
Train loaded over entire course	80.9 l/100 km
Train loaded over part 4	81.4 l/100 km
Train empty over entire course	46.5 l/100 km

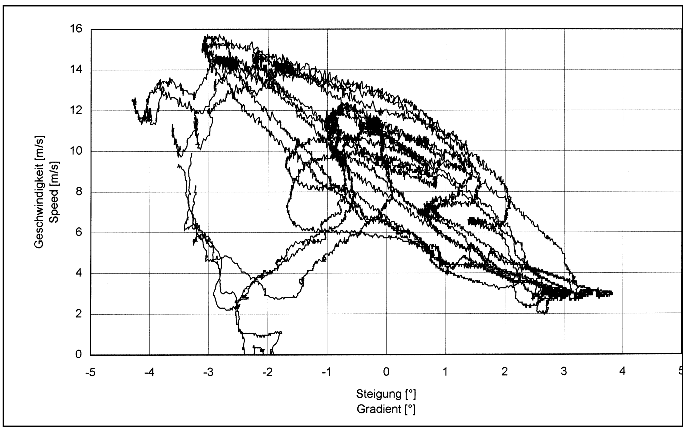

Fig. 1: Measured values of gradient and speed for the fully loaded road train (42 t) in the partition of the measuring circuit

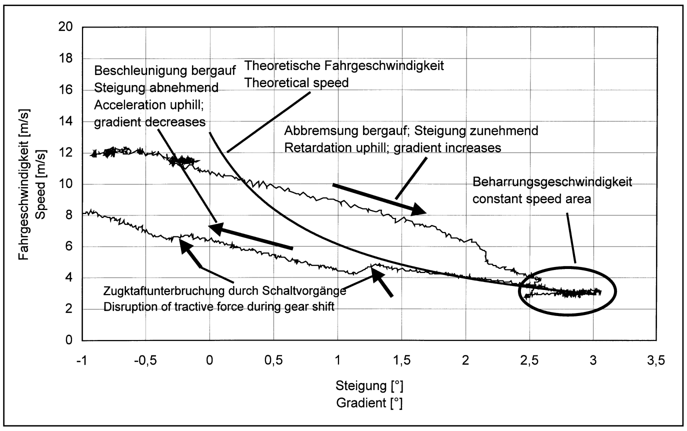

Fig. 2: Measured values from driving into a gradient to the summit and theoretical speed acc. [2]

as the train was travelling up a progressively increasing gradient where at first no constant speed under load was applied. The reason for this involved the changes in gradients and the fact that the kinetic energy stored in the train in this phase helped to achieve a higher speed than that theoretically possible.

This relationship is worked out in *figure 2* for travelling over an incline. Presented are the theoretical values according to [1] with the parameters $P_{eff} = 0.8 \cdot P_{nenn} = 82$ kW, f = 0.015, M = 42 t, as well as the measured values.

The measured driving speed at the beginning of the uphill 0.25° slope lay above the theoretical capacity of the vehicle. It was carried along, therefore, by its own momentum: kinetic energy was utilised and the speed continually reduced. In the gradient stretch of 2.5 to 3° the maximum gradient was reached along which a longer stretch had to be covered so that for the train, a constant speed under load applied. This agreed well with the theoretical potential for the train engine power. When the gradient was once again reduced leading to the top of the rise, the train began to accelerate; the power required for this reduced the theoretically-available driving performance so that in this phase, speeds were below the theoretical constant speed under load. During the acceleration phase, a disadvantageous effect was caused by the fact that the transmission had only four power-change gears and this meant the gear group had to be manually changed twice.The draft interruption which occurred during this led to speed penalties of around 1 m/s.

The results of the fuel consumption measurements in *figure 3* produced characteristic triangular curves from the uphill gradient stretch in the representation of the kilometre-based consumption over driving speed which, in the observed driving manoeuvres – at the beginning of the slope, driving at constant speed under load on the slope, reaching the top of the slope and beginning the downward slope – where carried out anticlockwise direction. So long as the upward slope increased and the train travelled under its kinetic energy the kilometre-based consumption increased only relatively slowly. As soon, however, as a constant condition was applied the kilometre-based consumption immediately increased to the values in conditions of constant travel under load. During acceleration where the degree of uphill slope was decreasing, the kilometre-based consumption, in relationship to maximum value, reduced in a linear manner. In that the train was accelerated in this phase, and therefore once again increased kinetic energy, there resulted a substantially higher consumption compared with that at the beginning of the uphill slope. The range of the measured kilometre-based consumption stretched from < 50 l/100 km for load-accelerated stretches through values of around 75 l/100 km on level stretches up to 250 l/100 km in constant speed under load conditions during uphill gradients of around 3°. These very large differences are caused by the increasing climbing performance and the strong speed reduction where the engine worked at full power despite reduced distances covered.

Summary

The driving performance and fuel consumption of transport vehicles on good roads was substantially influenced by uphill gradients on the road. Additionally, the loading has a substantial influence. The journey-based consumption can be almost doubled when empty travel is compared with loaded, whilst the average transport speed is reduced by a third. The speed of a fully-loaded tractor train reduced by over 60% during an uphill gradient of 3° whereby the kilometre-based consumption increased by more than three times. In the slowing-down phases, where the vehicle was still in momentum-drive, the driving speed achieved can be higher than that actually possible according to engine power. At the same time, a noticeably reduced fuel consumption was produced in this situation compared with that when under constant speed under load.

Literature

Books are signified with •

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[3] *Fröba, N.*: Landwirtschaftlicher Transport. Sonderdruck der Kartei für Rationalisierung 3.0. RKL, Rendsburg-Osterrhönfeld, 1999

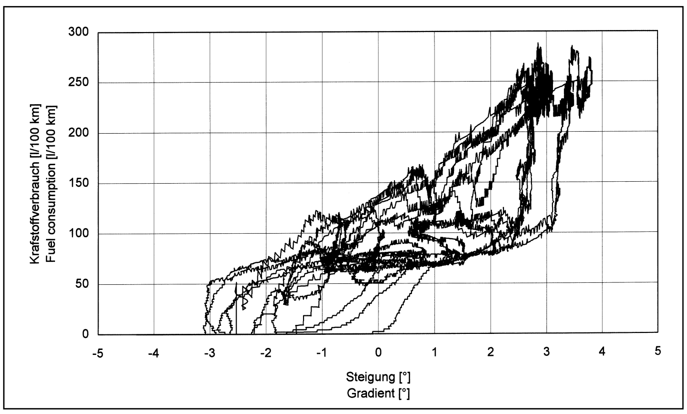

Fig. 3: Measured values of gradient and fuel consumption for the fully loaded road train (42 t) in partition of the measuring circuit