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Theoretical transport performances of truck and tractor trains

According to the theoretical vehicle performance figures and statistically investigated levels of rolling resistance there is a case for comparing transport efficiency and application possibilities of a truck and trailer with 40 t licensed gross weight with the popular combination of a tractor and two twin-axle trailers each licensed for 18 t and representing a gross train weight of 40 t.

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A twin-axle truck with three-axle trailer and a tractor with two trailers were chosen as vehicles for comparison (*Fig. 1 and Fig. 2*). The truck train in this configuration is especially interesting for agriculture in that the trailer with the high net load capacity of 17.5 t can, if conditions are difficult, be pulled by a tractor also. The basic data for the vehicles are collected in *table 1*.

Table 1: Basic data of vehicles

	Tractor-train	Truck-train
Engine power traction vehicle kW	127	290
Torque rise %	50	20
Net weight traction vehicle kg	7135	9000
Net weight trailers kg	8200 (2 x 4100)	6500
Permitted gross weight traction vehicle kg	11500	18000
Permitted gross weight trailers kg	36000	24000
Load kg	24665	24500
Transmission gears	19	16
Purchase price traction vehicle DM	135000	200000
Purchase price trailers DM	59500	80000
Total price train DM	194500	280000

Starting point for the calculations was in each case the traction vehicle driving speed diagram in the normal form which indicates the free pulling power of both vehicles in all gears based in each case on the licensed gross weight of the trains (*Fig. 3*).

The engine performance curves, with full load curve and fuel consumption curve, shown in *Fig. 4* help with further assessment of the vehicles.

The rolling resistance levels were simulated from frequency distributions in literature [1] and are presented in *Fig. 5*. Road types in the calculations were those regarded as appertaining to agriculture: rural roads and field ways. Comparative vehicle speeds and fuel consumptions can be calculated by using the frequency distribution, the rolling resistance and the traction power diagrams as well as the full load consumption curves. In that values used in the calculations included permanent driving on the full load curve or, where appropriate, the rpm limit curve, the consumption could be lower in practice.

Assessment of vehicle data

As can be seen from table 1, loading to full capacity is not possible for both vehicle trains because this would mean exceeding the maximum permitted gross weight of 40 t. Both vehicles allow, however, a loading of around 24 t. A train with two 18 t trailers has, however, an overall length of around 14 m and there's only a limited number of powerful tractors with a length of around 4 m from hitch point to the very front of the vehicle. More efficient in this case would be a triple-axle trailer. This type, mostly used as tipping skip with load capacity of 22.5 t and permitted gross weight of around 30 t, is limited in Germany to a gross weight of 22 t. This means that loads of around 18 t could be moved and thus the train of two 18 t trailers

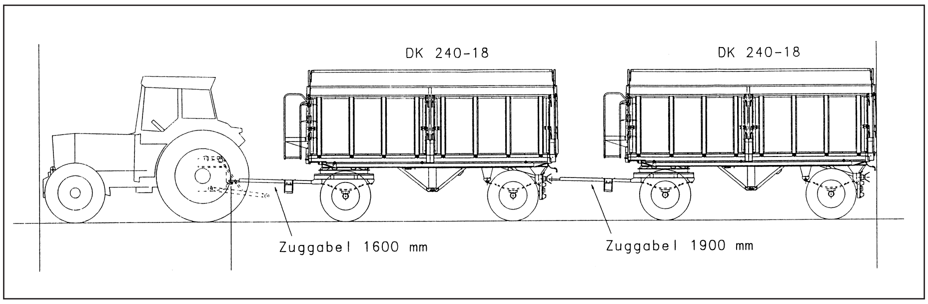

Fig. 1: train with tractor and two trailers, each with 18 t max. permissible weight

Fig. 2: train with two-axle truck and a three-axle trailer, each tipping construction

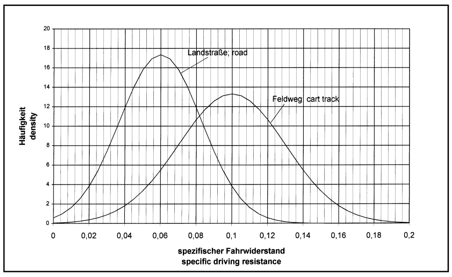

Bild 5: Angenommene Wahrscheinlichkeitsverteilungen für die spezifischen Fahrwiderstände auf Landstraßen und Feldwegen

Fig. 5: Assume frequency distributions for specific traveling resistance on roads and on field roads

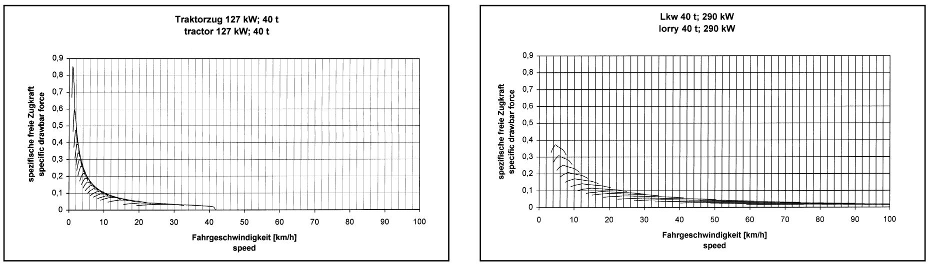

Fig. 3: Specific tractive power driving speed diagrams for tractor train (left) and for truck train (right)

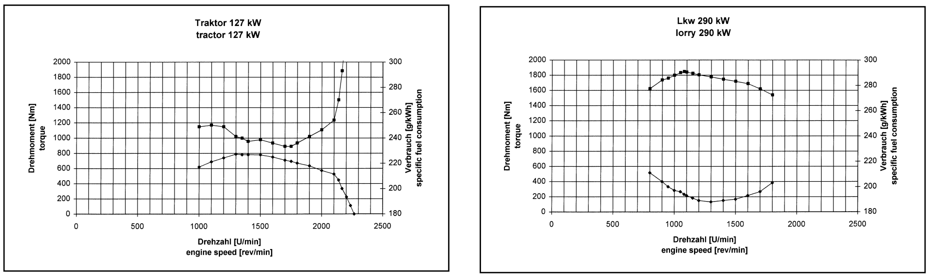

Fig.4: Full load characteristic curves and full load consumption characteristic curves - driving speed diagrams for tractor (left) and for truck (right)

therefore retains its attraction. On top of this, the weight limit would mean that one would try to ballast the tractor as little as possible. However, tractors in the 125 kW class are usually around 7 t so that in many cases heavier loads are only possible through using less powerful tractors.

The number of gears on both vehicles are similar although the transmission design is fundamentally different. As a traction machine, the tractor has the majority of gears with lower travelling speeds and associated higher tractive power. With appropriate ballasting, pulling power can roughly match train weight. The theoretical performance efficiency is a little better in the case of a tractor because of the higher number of gears. But because both transmissions have a relatively large number of gears, the difference is small. The truck, on the other hand, has the majority of its gears arranged in a higher range so that a speed of over 100 kph is possible and this acts as a rpm-sinking overdrive when the vehicle is running at permitted highest speed. With tractive power requirement thus reduced, the load on the motor can be kept high and economical consumption performance still achieved. Especially at the higher speeds, the greater engine power of the truck is advantageous because, even then, surplus tractive power is available. Simultaneously, the higher speed also plays a role in sinking consumption in that the same performance in comparison with a tractor can be produced at higher speeds. The maximum tractive power is restricted to less than 40% of the train weight. This means that in some situations there occurs restrictions in the manoeuvrability in disadvantageous countryside. Against this, the useful speed range of the tractor ends at about 40 kph and in the case of transport journeys the machine must in part be held at the engine revolution limit and thus into the performance areas with high specific consumption.

The engine characteristics also differ substantially. The tractor can offer a very high engine revolution rise of 50%, the truck engine can manage only 20% and thus when changing up a gear this means the tractor engine at first produces in fact more torque as at the rated rpm of the lower gear. Additionally, the engine offers power reserve. The rpm level of the truck engine lies lower than that of the tractor. But the torque, on the other hand, is very much higher which is naturally also related to the higher rated performance. Here is demonstrated a further fundamental difference in the vehicles' design in that tractors in Germany with rated power levels from 290 kW are rare large machines – only existing in very limited numbers and used for pulling very wide implements and not, as a rule, for transport jobs. For a truck, on the other hand, engine performance of 290 kW is completely normal. Additionally, the truck engine shows, under full load, a substantially more economical fuel demand with consumption over a broad revolution band substantially under 200 g/kWh whereas the tractor returns considerably higher consumption.

The price difference between the two vehicle types of around 90 000 DM (tab. 1) is notable. Additionally, the tractor can, as opposed to the monofunctional truck, undertake other jobs on the farm when not fully employed for transport. Taking a write-off period of ten years as a base, this gives an annual difference in the write-off of between 9000 and 22000 DM, depending on the amount of transport for which the tractor is used.

Calculation of comparative values for both vehicle combinations

The results of the comparative calculations are reproduced in *table 2*. As one can see, the basic rolling resistance levels stated indicate very unfavourable performances in that they were originally thought of for military vehicles. In that the truck is loaded whilst the tractor is unballasted due to permitted weight restrictions, the tractor can, despite single axle drive, transmit higher maximum traction power. Unballasted, the potential of the tractor is wasted and can only be exploited through load reduction (or overloading). This could be the case, perhaps, where the roads are in bad condition and trucks become stuck. The same applies to maximum climbing capability.

The average speed of the truck lies substantially over that of the tractor. The higher power of the engine makes itself noticeable here, on rural roads as well as in field ways. For transport demands, the tractor is undermotorised. Under a given loading time of 5 min., an unloading time of 30 min., with time-loss of 20 min. for a round journey with 35% of it as field way, there is given for both vehicles each an equivalent material flow as quotient from load and travel time over the distance according to *Fig. 6*. As can be seen, the truck train is superior to the tractor train in transport performance. For the average farm-field distance of 3.5 km [4] the advantage lies generally by 15%.

Because of its more complicated transmission and the reduced speed range, the tractor has a somewhat better performance efficiency. The difference between the two vehicles remains, however, small.

There also is a notable difference in fuel consumption of between 40 and 60 l/ 100 km travelling distance under the accepted difficult conditions. In practice, this difference may well be less. By accepting the difference as 50 l and a diesel price of around 1.10 DM, the difference in the writing-off would be amortized over a travelling distance of between around 18000 and 47000 km. Under real agricultural traffic conditions this value could lie notably higher. [3] gave practical consumption from 20 to 50 l/ 100 km for the tractor, and that for the truck is 30% lower. According to this, the travel distance must be multiplied by five to allow the truck to be amortized through the diesel price.

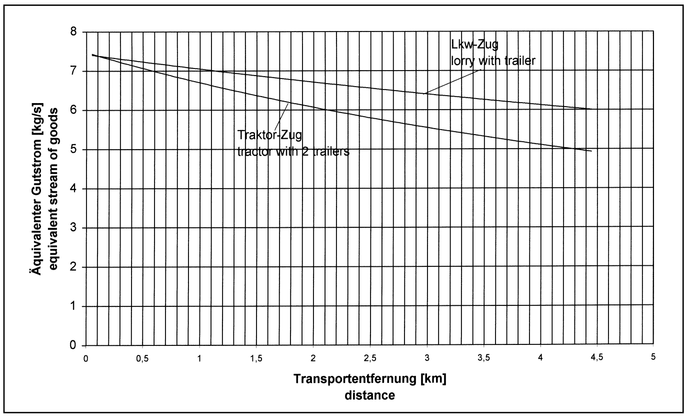

Fig. 6: Equivalent mass flow for vehicles investigated

Table 2: Computed parameters for vehicles examined

	Tractor train	Truck
Maximum transmittable tractive power N	55995	78480
Maximum driveable ascent train in °	8,2	11,5
Maximum driveable ascent train vehicle in °	53,1	26,3
Average speed under load, rural road kph	16,4	38,5
Average speed empty, rural load kph	36,9	60
Average speed under load, field way kph	9,8	23,4
Average speed empty, field way kph	25,7	56,0
Average consumption rural road l/100 km	212	172
Average consumption field way l/100 km	343	282
Average power efficiency %	98	97

Conclusions

The tractor train of two twin-axle 18 t trailers and the truck train both present a possibility with which to transport a net load of 24 t. Because of its design, however, the tractor is less suitable for transport in that its engine performance is really designed to be transmitted at low travelling speeds and high traction power demands and a lesser engine power for agricultural pulling work is required compared with that which is installed in a modern truck. Through the gearing which is optimised for this kind of work and the reaching of maximum speed at rated rpm, transport is often carried out at the engine's rpm limit curve. Through a rpm-decreasing transport gear (with reduction of maximum speed) a certain improvement could be achieved under some conditions. The maximum train length of 18 m poses a further problem here – it can be quickly surpassed when two trailers are used.

The most important decision criteria for the mechanisation of transport will always remain the costs. By average field-farm distances mostly around 3.5 km the total distances covered by the transport vehicles are often not so great so that the utilisation of a truck, with its high purchase cost and additional tax and insurance costs, can be made to pay. A truck could be interesting in an agricultural context especially for special uses with long transport distances as, for instance, in sugar beet delivery or when its use allows the saving of at least one working person.

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