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How can ≥ 200 KW efficiently be converted into tractive output?

There is a steadily increasing demand with regard to the transmission of tractive power. The tyres have to be adapted to the tractive power requirements of the tillage implement. By means of big volume tyres and the correct ballasting a high tractive power may be efficiently transmitted to the soil. For any transport work, the additional weights should be dismantled to avoid an extra fuel consumption.

Keywords

Tractor, Tractive power transmission, cost savings

Abstract

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Landtechnik 66 (2011), no. 4, pp. 294–296, 3 figures, 3 references

■ Growing size of agricultural holdings, reduced labour cost as well as a high transport volume and increasing distances will require the use of efficient tractors. There is hardly another vehicle that has to meet such manifold requirements. In the field, the tractor must have a high load capacity and, at the same time, the soil must be protected from being compacted. Passively working tilling devices with different tool combinations for intensive field work will require high tractive powers. These have to be efficiently transferred by the tractor aiming at little slippage only.

Road transport will, however, require high speeds. Driving safety must be guaranteed, and the tyres should have good suspension and damping properties.

The tyres are the link between the machine and the driving surface (soil). The requirements being really miscellaneous, the choice of the correct tyres depends on the kind of application.

Tyre development and soil protection

Some production managers, but more and more legislators as well, are worrying about strongly compacting the soil. During the past years, the tyre development industry has focussed big volume tyres. Thus, there is a general tendency to develop bigger outer and smaller inner diameters with the aim of increasing the air volume in the tyre and its load capacity. Consequently, this is connected with higher side walls that, especially in case of a lower inner tyre pressure, may lead to a decreased driving stability.

The load-bearing element in the tyre is the air as shown in the following example:

Both the tyres 650/65R42 and 650/85R38 have the same width. The outer diameter of

2070 mm of the tyre 650/85R38 is, however, by approx. 140 mm bigger and the inner diameter by 4 inches smaller. The resulting bigger air volume will increase the load by approx. 1,100 kgs when assuming a maximum speed of 40 kms/h and an inner tyre pressure of 1 bar. As to the tyre width, boundaries are set by legal regulations. The maximum tyre width amounts to 900 mm. The tractor remains within the 3 m limit as required.

Protecting the soil from compaction means not to exceed its inherent strength.

Due to the missing self-load capacity of the tyre, the air pressure in the tyre approximately corresponds to the soil pressure in a depth of 10 cm, i.e. near the contact surface. There is a close linear connection between the two parameters – inner tyre pressure and contact surface pressure [1].

At the time of cultivation, when the soil just has a reduced bearing capacity, the soil pressure should not exceed 1 bar and at harvest time, when the soil is in firm condition, it should not go beyond 2 bars. These data are guiding values and may vary depending on the kind and moisture of the soil [2].

To avoid any overload damages, with increasing speed the tyre will require a higher inflation pressure. This means that the pressure is changed from field to road. This change may be effected manually or by means of a control system adjusting the inflation pressure.

An alternative is to choose a tyre with a corresponding load capacity reserve. Changing the inflation pressure between road and field application will then not be necessary.

Tractive power transmission

The tractive power transmission is influenced by the tyre, the tyre load and the soil. The tyre parameters width, diameter, inflation pressure and type of construction are resulting in the

contact surface. The tyre load is correlated with the contact surface pressure. As to the soil, influence is exerted by the kind of soil, humidity and the tillage condition. These characteristics will influence the shear strength resistance of the soil.

In the tyre-soil contact area the tangential forces are transmitted by friction forces directly below the lugs and by shear forces in the area between the lugs [3].

What does this mean with regard to the choice of tyres?

In general, a tyre having a higher lug percentage in the contact area can transmit an increased tractive power. By a great number of contact points between the tyre and the soil, the tractive power transmission will be increased as well, i.e. due to larger footprints an increased tractive power will act upon the soil. This advantage will, however, only be achieved if the soil is loosened. The tyre will then also transmit forces via the area between the lugs (**figure 1**).

If, by choosing the corresponding tyres, the contact area is enlarged without adapting the wheel load (contact area pressure), this may lead to an “oversizing” of the machine. The adhesion between the lugs and the soil will no longer be sufficient for the power transmission. This effect is shown in the example of the tyre sizes 710/70R42 and

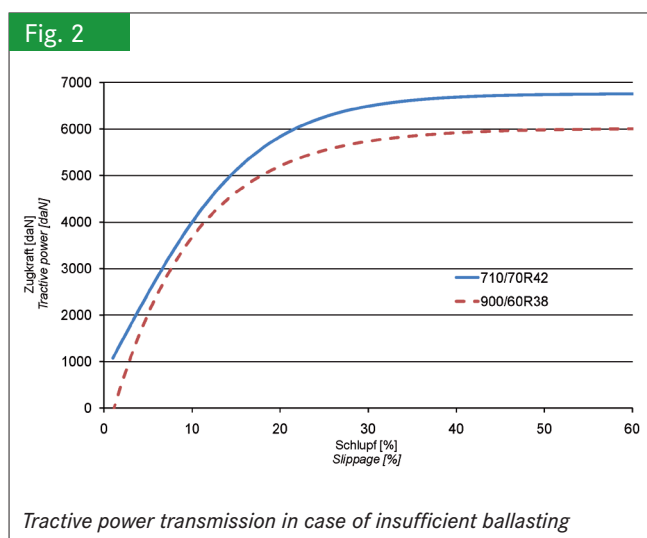
900/60R38 (**figure 2**). Over the total measured slip range from 0–60 % the narrower tyre 710/70R42 will transmit increased tractive powers.

The power-to-weight ratio (kW/kg) of the tractors has continuously gone down during the past years. A 135 kW tractor of a total weight of 7,500 kgs has a power-to-weight ratio of

55 kgs/kW. If this machine is ballasted to 11,000 kgs, the power-to-weight ratio will rise to 81 kgs/kW.

A tractor of 225 kW and a total weight of 8,000 kgs has an efficiency weight of only

35 kgs/kW. An additional ballasting of 3,000 kgs will result in an increase of the power-to-weight ratio to 49 kgs/kW. If the tractor is to achieve the same power-to-weight ratio of



81 kgs/kW, it will have to be ballasted to reach a total weight of approx. 18 t.

Just by means of the correct ballasting the tractor will be able to apply the tractive powers required upon the soil at a lower slippage rate (**figure 3**).

In the example, a tractive force of 6,000 dN is required the tractor being equipped with tyres of the size 800/70R38. In both the variants (ballasted and not ballasted) the tractor will be able to reach the tractive power. If it is correctly ballasted, the tractive power will already be reached at a slippage of 15 %, in the unballasted condition at a slippage of even more than 30 %. From the energetic point of view, an increased slippage means a decrease of the acreage performance which will result in a cost increase. On the soil this will be moved over a longer distance. Below the wheel, a horizon of compaction is formed that will interfere with the vertical exchange of water and air. This will be critical in so far if the following tillage implement or the seed drill just works flatly on the surface and this hori-

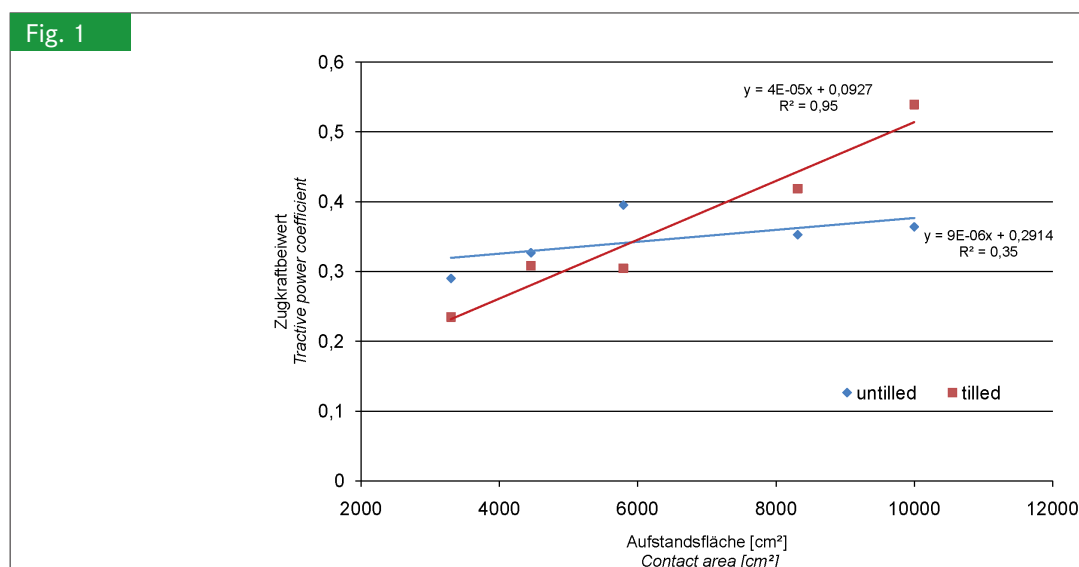
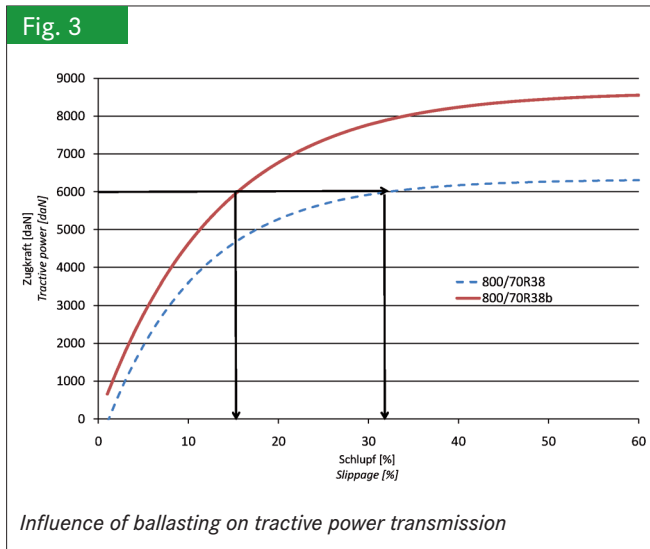


Fig. 3



zon is not completely broken up. In these areas, the emerging seedlings will react with a growth depression.

A tractor optimized while considering tyres and ballasting characteristics will be able to essentially increase the acreage performance.

This is shown in the following example with regard to a tractor-cultivator combination (working width: 5.8 m, working depth: 15 cm): The tyres optimized from standard to dual wheels without any additional ballasting will increase the acreage performance from

4 to 5 ha/h. The same tyre optimization in connection with the correct ballasting will increase the acreage performance from 4.5 to 6 ha/h.

There are the following ballasting alternatives:

- water filling of the tyre
- front weight
- wheel weight
- shifting of weight via the upper linkage to the machine
- rear weight

The use of water fillings is declining more and more. There are two aspects against it:

1. The water will strongly influence the vehicle handling on the road.
2. The sodium chloride addition for anti-freeze protection will cause serious corrosion damages which may detract the load capacity of the wheel.

Besides the ballasting advantages mentioned, there will also be some disadvantages. Some additional parts will be attached to the tractor. Thus some additional mass will have to be accelerated and decelerated. Due to the wheel weights added, the wheel may be out of balance which will affect the performance of the tractor at higher speeds.

During several tests carried out in common with the University, Braunschweig, the ballasting influence on the fuel consumption was measured during transport. Three alternatives were compared: tractor without any weights, tractor with weights in the rim and the tractor with weights in the lifting

unit. The mass of the tractor amounted to 9,000 kgs, that of the additional weights was 2,000 kgs. Rides through built-up areas, on country roads and field paths were included in the reference cycle.

As expected, the consumption rose due to the additional weights. Surprisingly, there was no difference with a view to the weights added in the rims and the weight in the lifting unit. An extrapolation shows the extra fuel consumption that may be required due to the ballasting operation.

Assumptions:

Working hours of the tractor:	1,000 h/a
Percentage of road driving:	approx. 50 % = 500 h/a
Diesel costs	1.10 €/l

The extra consumption amounts to approx. 980 l. This will cause extra charges of approx. 1,000 €/a.

Summary

The tyre equipment will affect the tractive power performance considerably. Especially in case of big volume tyres it will be important to ballast the tractor adequately. Otherwise, there will be a risk of oversizing, i.e. the tractive power performance will be reduced.

We recommend to weigh the tractor/tilling implement combination during a period of reduced volume of work, make a note of the wheel load, inflation pressure and ballasting data and to keep this information in the tractor. For any work, the additional weights should be removed to avoid any extra fuel consumption.

Literature

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