

# Load Transfer from the Fully-mounted Plough to the Tractor

## Reduction of Drive Wheel Slippage and Fuel Consumption by Increasing Rear Axle Loads

*State-of-the-art tractors with a low power-to-weight ratio need extra weight to have high traction. At the FAL Braunschweig, in collaboration with Bosch Rexroth AG, concepts were tested, which permanently shift implement weight to the tractor's driving axles and hence can increase field capacity.*

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### Keywords

Soil tillage, increasing wheel load, power requirements, soil conservation

### Literature

- [1] Steinkamp, H.: Ermittlungen von Reifenkennlinien und Gerätezugleistungen für Ackerschlepper. Landbauforschung Völkenrode Sh. 75, Braunschweig, 1975  
[2] Biller, R. H., G. Keuper und H. Hesse: Neue Konzepte für Kraftheberregelungen. Landtechnik, 56 (2001), H. 6, S. 398-399

The versatile and efficient use of tractors in agriculture requests a lightweight machine provided with numerous ballasting options. Primary soil tillage requires high draught power that the tractor tyres transfer to the soil surface by producing wheel slippage. Through a wheel load increase on the driven axles, this slippage can be reduced and the field capacity will be increased [1].

### Flexible Load Distribution

In the approach presented here, parts of the fully-mounted implement weight are permanently transferred to the rear axle of the tractor via a pressure controlled, hydraulically driven upper link. To carry out the tests, the institute's own Fastrac research tractor (engine power 128 kW, operating weight with front weight 7390 kg) was equipped with an electro-hydraulic pressure control system that actuates the hydraulically operated upper link. Wheel load can be adjusted during work operation. From an economic view, the wheel slippage reduction leads to a decreased fuel consumption. In terms of ecology the weight distribution enables the operator to reduce wheel load on more sensitive soil to avoid soil compaction [2]. Contrary to conventional ploughing operation, the hydraulically driven upper link is fixed to the

plough's headstock and this puts the tractor and the 4-furrow plough (weight 2180 kg) into a fixed position. The controller keeps the pressure, and thus the load on the rear axle, independent of the relative movement of the tractor and the plough. The manoeuvrability of the tractor and plough, necessary to keep the plough at the desired working depth, is ensured.

### Aim of the project

It is investigated whether with flexible load distribution an increase in rear axle load can be achieved without lowering the quality of the ploughing operation. The foremost aim is to gain a savings potential in fuel consumption and in working hours as high as with using static wheel weights. The flexible load distribution was tested with a fully-mounted plough. Here, in addition to the available implement weight, the vertical component of the ploughing resistance can be transferred to the tractor.

In a different approach, the hydraulically actuated plough depth wheel, which is mounted close to the centre of gravity, is pressure controlled. With the three-point-linkage in a fixed position, the increase in operating weight is caused by a decrease of the depth wheel load (Fig. 1, B).

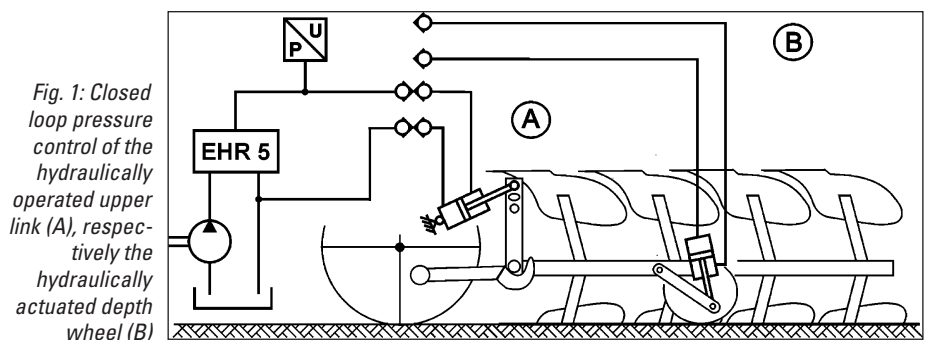


Fig. 1: Closed loop pressure control of the hydraulically operated upper link (A), respectively the hydraulically actuated depth wheel (B)

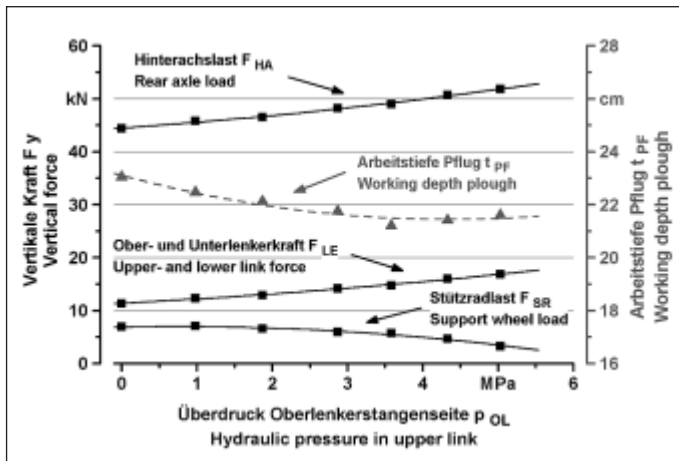


Fig. 2: Weight forces and axle loads versus upper link pressure

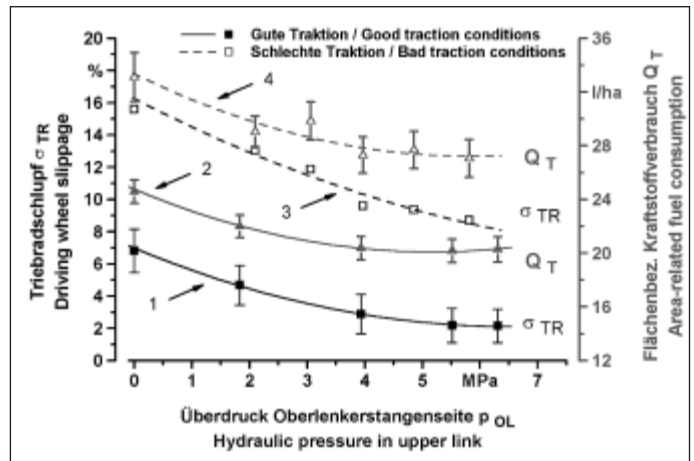


Fig. 3: Wheel slippage and fuel consumption versus upper link pressure: comparing soil conditions

### Measurements

To determine the saving potential of the distribution of weight, the Fastrac research tractor and a fully-mounted plough were equipped with a data acquisition system and sensors. The weight distribution between plough and rear axle is determined by measuring the pressure of the upper link and of the tractor's lifting cylinders (pressure sensor) and the vertical load on the plough's depth wheel (strain-gauge).

A flow meter is integrated in the feed line of the engine in order to quantify the fuel consumption. The wheel slippage is calculated by processing rotational and ground speed sensor data.

The position of the linkage and of the hydraulically operated top link are monitored to ensure the quality of the ploughing operation. Furthermore, the plough's working depth is measured by three angle displacement sensors located at the first and the last plough bottom.

### Results

In field tests, the general functioning of the flexible weight distribution was tested first. Knowing the hydraulic pressure and the position of the three-point-linkage, the vertical forces on the linkage as well as the tractor's axle loads can be calculated.

A pressure increase in the hydraulically operated upper link causes the distribution of implement weight to the tractor's rear axle (Fig. 2). The weight transferred is 6 kN ( $F_{LE}$ , left ordinate), while the vertical force on the plough FSR is reduced by 3.2 kN. Thereby the overall rear axle load  $F_{HA}$  is increased by 18 %.

The difference in the magnitudes is comprised of the non-measured implement support on the plough pan. The tyre pressure needed acts as a simple indicator for soil protection. Modern radial rear tyres can be used in the furrows despite the additionally transferred load with air inflation pressure below 1 bar. With the use of front weights, the reduction in front axle load is negligible (200 N). The working depth of the fourth plough share decreased by approximately 1.6 to 1.8 cm (right ordinate, Fig. 2), which equals an error of 6.5 % of the total working depth (28 cm).

Furthermore the field tests were to show the effects of the weight distribution on wheel slippage and fuel consumption. The in-furrow ploughing operations were carried out under different soil conditions (soil moisture, soil tillage intensity) with a working speed of 6.5 km/h and a working width of 1.4 m.

Figure 3 shows changes in fuel consumption and wheel slippage with the weight distribution in use (rising pressure in the upper link) compared to conventional ploughing operations. It is obvious that the application of weight distribution leads to a sizable savings potential. Under good tractive conditions (soil type silty clay loam, soil moisture 10 - 12 % gravimetric soil moisture content), the average wheel slippage (left ordinate) was at 7 % in conventional ploughing (forceless upper link, 0 MPa). With an increasing shift in weight load, the slippage is reduced by 4 % to 2 or 3 % (upper link pressure increased to 6.5 MPa, curve 1). While the area-related fuel consumption (right ordinate) was at 24 l/ha, this value is reduced to approximately 20 l/ha, which is a savings of about 20 % (curve 2).

Worse traction conditions usually require more wheel slip to provide drawbar pull. This is also apparent in Figure 3, where the upper link pressure of 0 MPa results in a wheel slippage of 16 % (silty clay loam, gravimetric soil content approx. 20 %, curve 3). With increasing weight distribution, the wheel slippage is reduced to 9 %. The area-related fuel consumption decreases from 33 to 28 l/ha (curve 4). Even under poor tractive conditions, it is possible to save fuel by the application of weight distribution.

Different working speeds (up to 8.5 km/h) and working widths (up to 1.8 m) yielded similar results. Decreasing the load of the hydraulically actuated plough depth wheel (Fig. 1, Version B) worked fine on even surfaces and attained a smaller savings potential.

### Summary

A new option for increasing the weight of a tractor is the flexible load distribution. A pressure controlled hydraulically driven upper link transfers implement weight to the tractor's rear driving axle. The flexible distribution of weight was tested with a research tractor and a plough under various soil traction conditions.

The higher rear axle load reduces wheel slippage and saves fuel and working time. The quality of work is not affected in comparison to conventional ploughing.