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New concepts for power lift control

Optimising energy use in tractor-plough systems

Around 90% of our farmers plough. With its time requirements and energy consumption this operation is one of the most cost-intensive in crop production. New power lift control concepts enable a measurable reduction in work-input and fuel requirement and at the same time are achievable with limited additional input. A pressure control in the hydraulic top link allows a complex optimised control strategy whereby load transfer onto the tractor definitely enables fuel consumption and driving wheel slip to be reduced.

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Common tractor-plough systems nowadays feature large power lift operated multi-furrow mounted or semi-mounted implements with support wheels. The top link of the three-point linkage is hereby fitted into the long-hole in the plough headstock and this is without power in normal ploughing or not present at all with semi-mounted implements whereby the load transfer system invented by Harry Ferguson [1, 2] with forces from the plough transferred via the top link onto the tractor driving wheels for reducing wheelslip dies not apply. Drive wheel slip can also be reduced when the top link is not power-free but instead – as patented by Ferguson – transfers draught forces. Earlier this was demonstrated by work at the FAL Institute for Basic Research [3 to 7]. New investigations by Case [8] and work at the FAL Institute for Farm Technology [9, 10] indicated area-related fuel consumption of tractors with a load-transfer top link are less than with a simple top link. The degree of efficiency with load-transfer in a tractor-plough system reached maximum when all vertical forces applied in the system were applied onto the driving axle of the tractor. The most important influence parameter here is wheelslip of the driving wheels which, with consistent draught force, could be reduced when load on the driving axle was increased [11]. In addition, the load-transfer from the plough onto the tractor also reduces the vertical forces on the support wheel and plough sole (*fig. 1*).

This leads to reduced support wheel rolling resistance and to smaller friction forces at the plough and thus to reduced draught requirement [12, 13]. This is an optimisation problem for the solution of which the role of the wheel forces has to be included, even with regard to the requirements of soil structure protection measures.

An additional aspect is use with the increasingly recommended on-land ploughing. With this, ground pressure is reduced under the tractor wheel sole where usually ground loosening does not occur [14]. A disadvantage is that with on-land ploughing the driving wheelslip is greater than with driving in-furrow. Here too, the aforesaid optimising problem has to be solved.

In that nowadays a hydraulic top link, and Electronic-Hydraulic-Control (EHC), are practically standard for high horsepower tractors, such top link cylinders can be electro-hydraulically pressure controlled at relatively little expense and through this have the ability of supplementary load transfer onto the tractor driving axle.

Aim of the work at FAL is to systematically investigate qualitatively and quantitatively different control strategies for the hydraulic top link towards increasing and optimising loads on the driving axle, reducing fuel needs and working time and to development an optimum control strategy.

Trials and results

Selected from the different control strategies was firstly control of pressure on the rod side of the top link cylinder (draught).

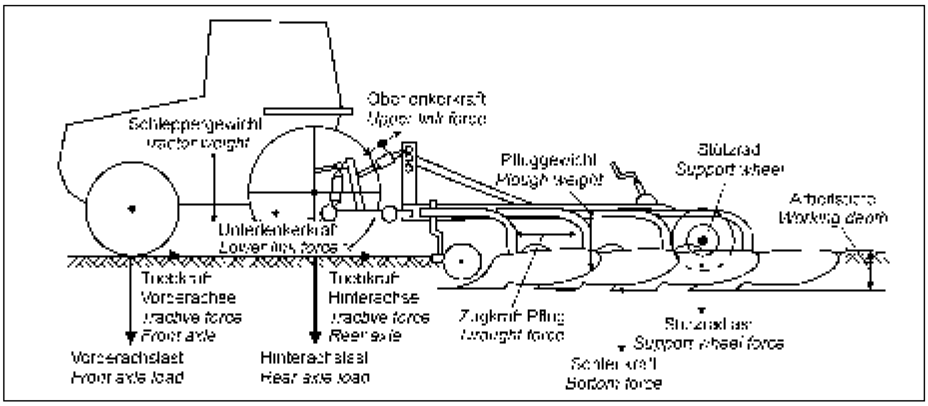

Fig. 1: Forces in the system tractor-plough

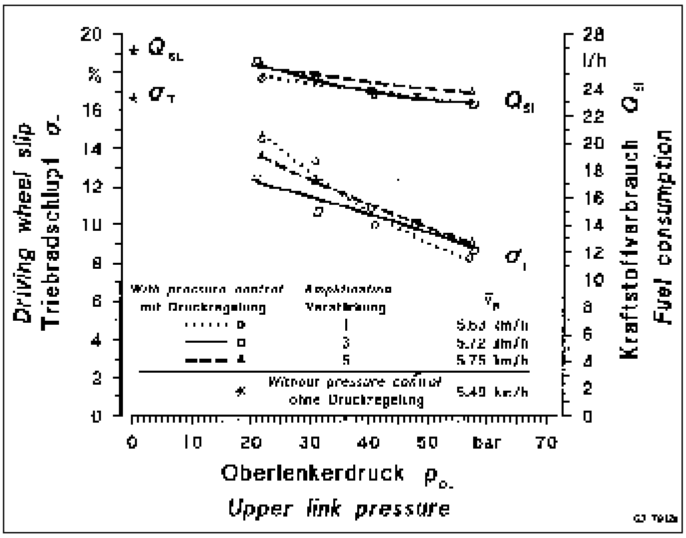

Fig. 2: Wheel slip and fuel consumption for ploughing with a 4-bottom plough: conventional and with a pressure-controlled upper link (working width 1,4 m; working depth 28 cm; soil: medium-heavy loam)

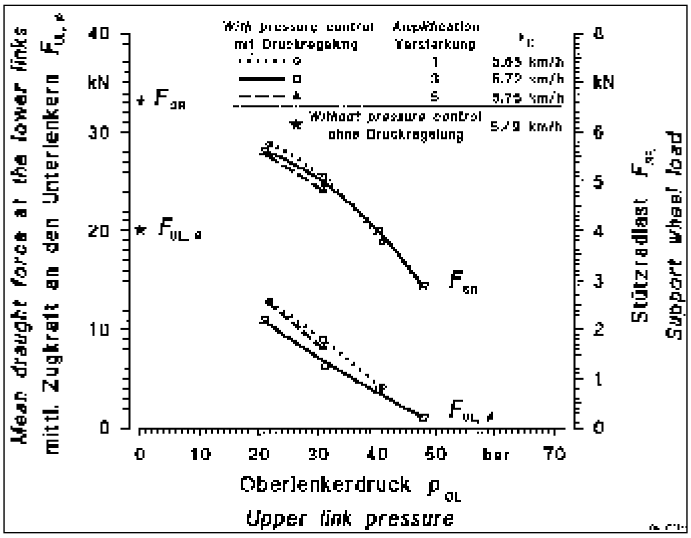

Fig. 3: Mean traction force at lower links and support wheel load for ploughing with a 4-bottom plough: conventional and with a pressure-controlled upper link (working width 1.4 m; working depth 28 cm; soil: medium-heavy loam)

For this, the pressure in the top link was measured with an electronic sensor and held constantly at a preset infinitely variable value with an electro-hydraulic pressure control system. Here, the top link was subject to draught forces and allowed load transfer from the plough to the tractor. For good depth control of the plough a certain amount of load must remain on the support wheel whereby draft force in the top link may be selected at a maximum value that still allows the plough to work perfectly and give the practically-desirable result with regard to ploughing depth and soil inversion.

For practical trials a power-controlled top link cylinder was compared with a non-hydraulic top link during ploughing with a four-furrow reversible implement. The trial was carried out on as level as possible land with homogenous soil and constant plough working depth whereby EHC was used in „position" control so there was no influence on draught control.

In all trials the interesting technical parameters such as fuel consumption, driving speed, wheelslip, engine power, draught power on the lower arms, pressure in the hydraulic top link, load on the support wheel and plough working depth at first and last furrow were all measured. The data recording system UNILOG, developed at the Institute for Farm Technology was used [15]. Alongside the online control, all the activated measurement channels allowed this system to visualise all recorded data immediately after every trial and thus to establish a direct comparison of the different trial settings on-site.

The first trial served to evaluating the setting possibilities of the control and to optimally fix the ideal leading point. Subsequently, comparative trials were conducted on different areas whereby the pressure in the top link – representing proportional draught force transfer – was varied.

Figure 2 shows the change in fuel consumption and in driving wheel slip when the pressure was increased in steps from around 20 bar to 50 bar, whereby the top link was subject to draught forces. Whereas fuel consumption whilst ploughing with non-hydraulic top link lay by around 27 l/h, this consumption was reduced in relationship to the applied pressure and the adjusted strengthening to about 23.5 l/h. Driving wheel slip was reduced at the same time from around 19% to approx. 10%. The result was a fuel saving of around 13% and a wheelslip reduction of almost 50%. These relationships were underscored through the reduction in average draught force on the lower links and the reduction of support wheel forces (*fig. 3*). Even at a pressure of 20 bar the average draught force on the longer links was almost halved and was further reduced with larger load transfers onto the tractor. The vertical forces on the support wheel experienced a reduction of 15% at a pressure of 20 bar and around 55% at 50 bar.

Summary

Through applying modern control technology and hydraulics a noticeable saving on fuel and reduction on labour input is possible during ploughing when forces are transferred from the plough to the tractor. This economically and ecologically desirable saving potential means a contribution towards improved farmland management and environmental protection, the achievement of which should be looked upon as an optimising exercise with regard to required soil protection. This targeted control is of a type particularly suitable for medium and smaller sizes of farms.

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