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Double-acting hitch drives on tractors

A double-acting tractor hitch drive is controlled by a slightly modified electrohydraulic series mobile distributing valve. The single-acting function of the conventional EHR-valve with its different control strategies for the lifted array is fully copied. The realization of the double-acting hitch function in both the lifted and the pressed array requires adapted control strategies for the valve. For the presented concepts, it is necessary to measure the pressure within the hitch cylinder. The resulting additional functions and benefits of this double-acting hitch drive are described.

As compared with the single-acting („s.a.“) designs known thus far, double-acting („d.a.“) hitch drives additionally allow implements mounted to the tractor to be loaded actively in combination with corresponding load relief on the rear- or front wheels. As compared with conventional, single-acting hitch drives, the control strategies for the corresponding hydraulic valve, which are necessary for the operation of the hitch drive cylinder, require additional measures.

The additional work range of the hitch provides novel functional characteristics for implement operation. An additional benefit is the quick, active lowering of the hitch, especially without load. During operation with the d.a. hitch, load transfer from the tractor to certain implements allows work comfort to be increased. In addition, further soil protection potential can be opened up by transferring tractor weight to the contact surface of the implement.

Work Ranges of Double-Acting Hitch Drives

For a better description of the system behaviour in d.a. operation, it is useful to divide the different kinds of hitch actuation into ranges (*fig. 1*). These ranges are the lifted array, which has been used thus far, and the pressed array added by the d.a. function. S.a. hitch operation is characterized by the two classic directions of movement, i.e. lifting and lowering of the implement load. In d.a. operation, these kinds of actuation within the two work ranges must be divided more finely.

Soil Pressure of the Mounted Implement

Double-acting hitch drives enable a load which exceeds the implement weight to be applied to the soil. As shown in *figure 1*, the implement's own weight is applied exactly when the hitch is without lift force. This is the load limit of current hitch drives. If soil pressure is intended to be increased further, load can be transferred from the tractor axle to the contact surface of the implement, which has the effect of soil pressure distribution if appropriate implements are used. Which of the two effects (selective soil pressure increase or soil pressure distribution) is desired depends upon the work task and the implements used. Maximum soil pressure is applied if the tractor is lifted out at the front- or rear axle, which, however, must be excluded during practical operation. This position may only be used for wheel change.

Demands on Double-Acting Hitch Drives

D.a. hitch drives must feature all functions of s.a. hitch drives. Like in the s.a. EHR-valves, this requires proportional variability, load compensation, tightness in the neutral position, and sufficiently large dynamic force so that the known EHR-functions, such as position control, draught power control, mixing control, slip control, or active vibration damping can be realized.

In the new pressed array, the implements are mainly loaded using a pressure control system. Like in the mixing control usually employed in the lifted array, superimposed position control must be implemented here as well.

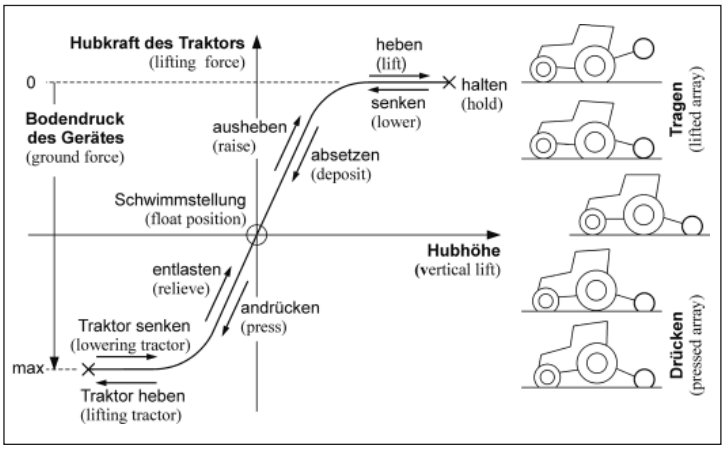

Fig. 1: Definition of working areas of double acting hitch drives

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Keywords
Double acting hitch drives, tractors

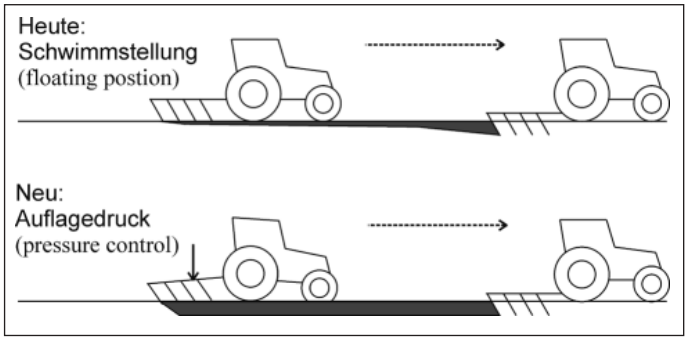

Fig. 2: Shortened distance by pressuring the plough during setting-in

Control of the d.a. hitch drive using the d.a. distributing valve

As part of a collaborative research project with Bosch Rexroth AG at the Institute of Agricultural Engineering and Fluid Technology of the Technical University of Brunswick, a tractor was equipped with a modified, double-acting SB23LS-EHS valve disc („EHS-valve“) for experiments with the double-acting hitch drive. The EHS-valve is a double-acting 4/4 distributing valve with a distributing valve slide electrohydraulically operated in position control and an individual pressure balance.

For the control of the EHS-valve, a conventional s.a. EHR-controller is used, which requires position- and tensile force sensors. The lifting- and lowering signals of this controller are evaluated. These signals do not take a single acting or double acting function into account because current hitch drives feature a one-sided floating position without an upper limit due to their design. The full d.a. function requires pressure sensors on both cylinder sides for load direction sensing. This enables two necessary kinds of operation to be evaluated and carried out:

1. Control of positive and negative loads
2. Control at the return flow control edge

Positive or negative loads require throttling at different control edges. The pressure sensors sense what kind of load is applied and move the slide to the appropriate initial position.

If negative loads are applied, only the return flow control edge throttles. A pressure balance like at the flow control edge does not exist so that the entire consumer pressure must be throttled at the return flow edge. This does not allow the volume flow to be set independently of the load pressure using the position-controlled slide. A control edge opening adapted to the return flow pressure enables the function of the pressure balance to be taken over.

This EHS-signal adaptation allows the lifting- and lowering signal from the EHR-controller to be adapted such that movements can be controlled in a coordinated manner in both the lifted and the pressed array.

Use of the d.a. hitch drive during ploughing

In pure plough operation, the d.a. hitch drive was operated like a single acting hitch drive. For this purpose, the functionality of the double-acting hitch drive was electronically limited to the behaviour of a single acting hitch drive by using contact pressure control with a neutral set value in the case of pressing. As an alternative, the 4th switching position of the valve (floating position) can be chosen, which results in the „one-sided floating position“ known from normal hitch drives.

This concept was tested in practical operation during ploughing. The use of the EHS-valve as a hitch valve did not cause any problems. During ploughing, neither the plough pattern nor subjective impression on the tractor allowed any difference to be found as compared with the normal EHR-valve.

Contact pressure control during the drawing-in of the plough

In addition to normal s.a. plough operation, the pressure control function enables the plough to be actively pressed into the soil at a set pressure. This is useful on firm soil when it is very difficult for the plough to draw into the soil using its own weight. For this purpose, active pressing with a contact pressure of 50 bar, for example, offers itself for the acceleration of the drawing-in process. The result is very beneficial for practical operation: instead of the drawing-in distance of approximately 15 m for an unloaded plough under poor soil conditions, set working depth was already reached after just 30 cm (0.3 m!) if load was applied actively (principle in figure 2). As of this point, the normal controller resumed its work. This in particular enables the compacted headland area to be loosened.

Further Applications

Packer rollers are known. However, they are used only statically with hydraulic accumulators today. In d.a. operation, active loading and load relief – with the particular possibility of controlled switching to real pressing while lowering – allows the soil pressure to be more widely distributed. Here, combinations with slip control are conceivable as well.

Since no controlled d.a. hitch drives are available so far, there are no implements which exploit this potential. The designers of agricultural machinery, however, gain more freedom, which they will use. Some examples will be given below:

In combinations of a rotary harrow and a drill, part of the tractor weight could be transferred to the pressure roller. In addition, the variable grain tank weight on the rotary harrow could be compensated for using tractor weight. In biological farming, other implements for mechanical weed control can be developed.

With the aid of the front hydraulics, blades can penetrate actively. Potential applications are the distribution of silage, the clearing of snow, or levelling.

Summary and Future Prospects

Specific signal adaptation of the additional distributing valve in the double-acting hitch drive provides reliable operation. This requires pressure sensors at both operating connections of the valve. Experiments have shown that signal adaptation can in principle be used without alterations for contact pressure control, load relief pressure control, position control, and draught power control during ploughing.

During single-acting operation in a practical test, no difference in comparison with the EHR-valve was discernible. One advantage of the EHS-valve is the possibility of pressing the plough actively into the soil. This allows the plough to fully compensate for potentially poor drawing-in behaviour. Future implement functions which provide new degrees of freedom for design by transferring tractor weight to the implements have been described.