Tractor Hitch-Control - History and Future

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1. Introduction

The agricultural tractor at the beginning was used to pull and to carry implements for soil-cultivation, most of them were ploughs. Ploughing is a field-operation with high energy requirements and consumption per area. With the mechanical power of the tractor the farmers could do ploughing quicker with only a few people and without animals. This was one of the most important steps to field-work mechanization. The hydraulic hitch-system was introduced for lifting and lowering the implements at the headland and for transportation. When ploughing the system was switched in the float position, so that the plough worked with constant working depth and could free follow the soil-surface even under undulated conditions. It was Harry Ferguson, a son of an Irish farmer, who invented in 1925 the so called “draft-control” for the plough. The principle of his idea is still used and it is one of the most successful inventions of the agricultural engineering history.

2. Principles of Control

Ferguson invented and used a 3-point-linkage to connect the plough with the tractor. This solution was standardized later on and is now used all over the world, **Figure 1**.

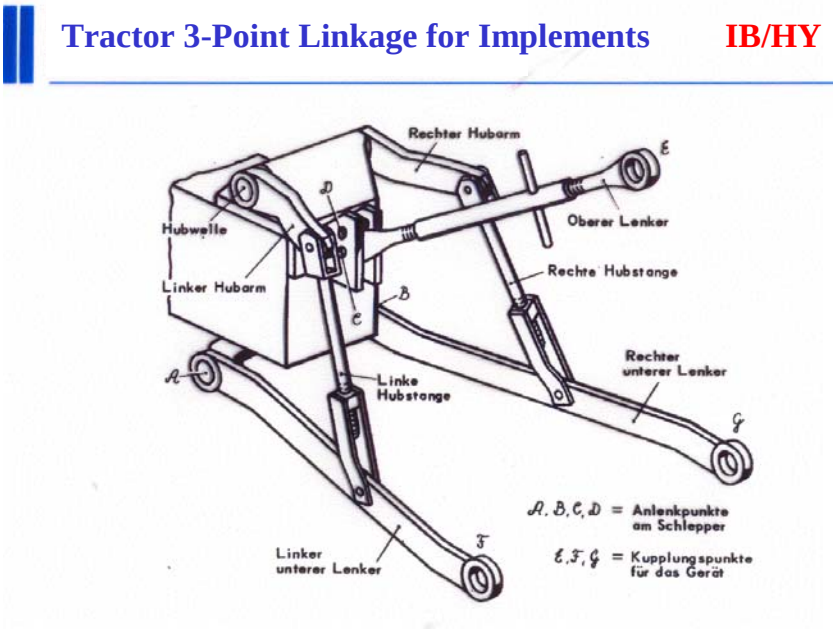

Figure 1: Tractor 3-Point Linkage for Mounted Implements

He found, that under wed field conditions the power of the tractor could not transferred to the soil because of high slippage. He knew, that the wheel-slip could be reduced or the pulling force of the tractor could be increased by higher vertical forces on the pulling tractor-wheels. This can be done by ballast-weights or by a procedure of weight-transfer from the pulled implement to the tractor, so that the tractor carries the plough partialy during ploughing, **Figure 2**. To realize this, the implement cannot be fixed in a constant position to the tractor, because of to large variations of the working depth of the plough on undulated soil-surfaces.

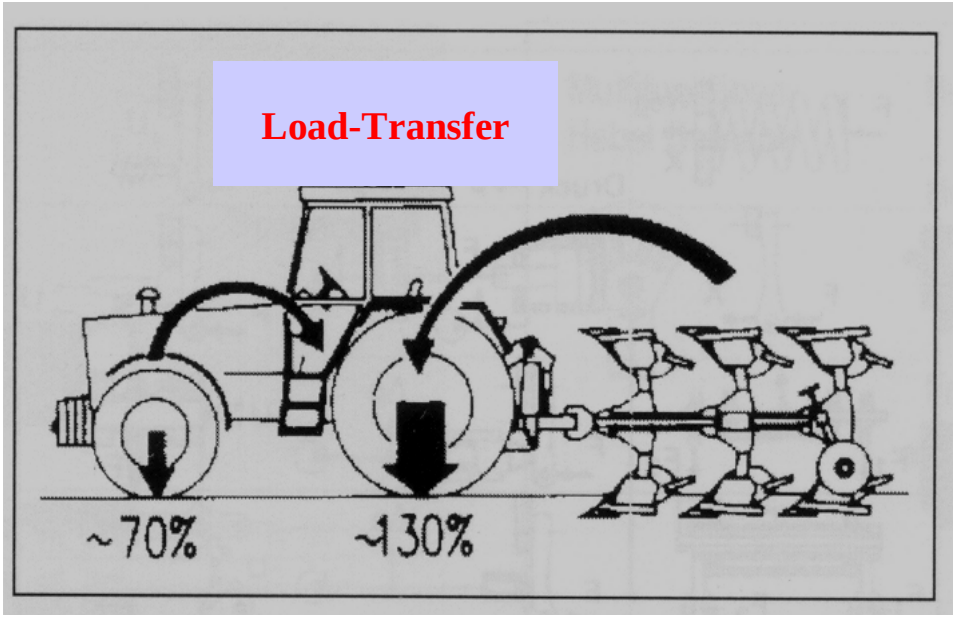

Figure 2: The Main Effect of the Draft-Control

To prevent this, a system-variable is needed, which can be held constant by a closed loop control-system, without the plough being in a fixed position to the tractor. To realize this, there are four basic system parameters, which can be used as a control-variable in a closed loop control-system. This parameters are :

* **the pulling-forces (draft) of links in the 3-point-linkage**
* **the pulling-torque of the tractor drive-axel**
* **the working-depth of the plough**
* **the pressure in the lift-cylinder**

All these possibilities have been used in control-systems, which were developed and used on their tractors by different companies. But only the Ferguson-System, which uses the forces of the 3-point-linkage has survived and is still used.

2.1 “Draft-Control” - Control of Forces in the 3-Point-Linkage

Fergusons original idea and his invention in 1925 was, to use the force of the top-link of the 3-point-linkage, which with smaller ploughs under homogeneous and constant soil-conditions is proportional to the working-depth of the plough, **Figure 3**.
The driver can set a desired value for the force what means for the working-depth. The control loop increases the working-depth if the link-force is too low and decreases it, if it is too high. **Figure 4** shows the first realization of Fergusons idea with top-link-sensing. An important point is, that the force of the top-link can be measured by a spring and the displacement of the spring can be transferred easily to a hydraulic control-valve.

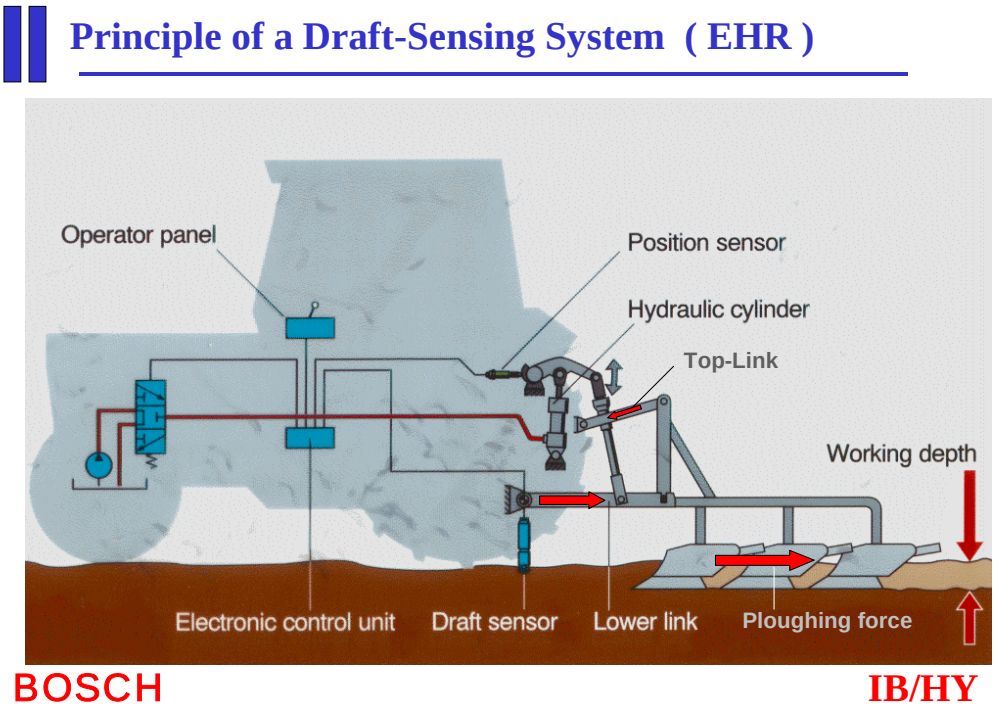

Figure 3: Principle of a Draft-Sensing System

Figure 5 shows an industrial realized solution, which was produced over several years by the Robert Bosch Corporation, Germany, for different European tractor-manufacturers. This system could work in the draft- and the position-control mode.

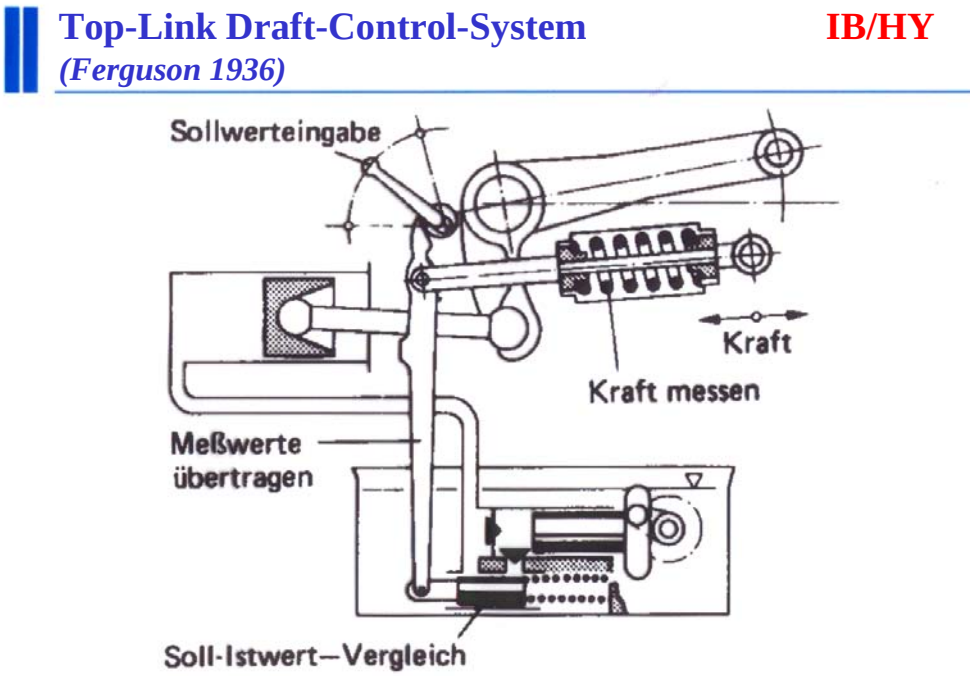

Figure 4: Fergusons Draft-Control-System 1936

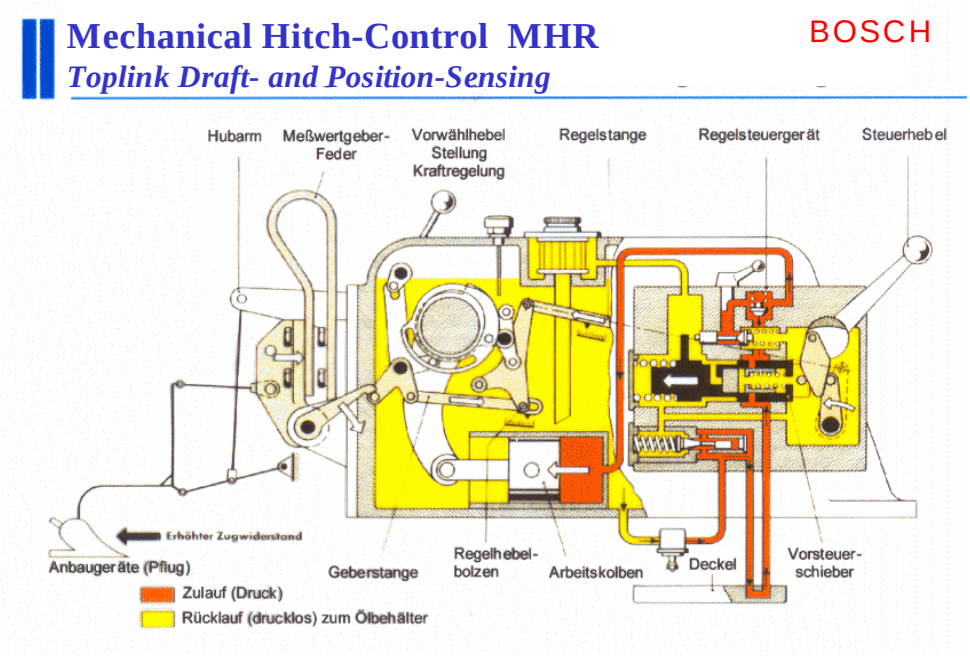

Figure 5: Bosch Mechanical Hitch-Control MHR

The two most important advantages of this system are the slip reduction by load-transfer and the fact that the engine, because of constant load, is prevented from stalling and can allways be driven at full power.

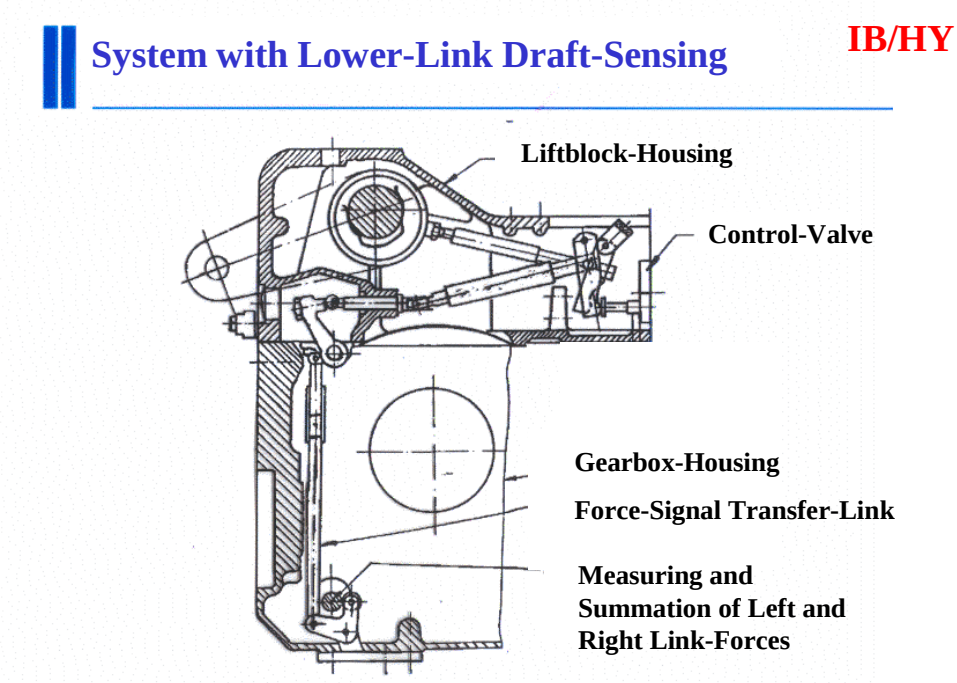

Figure 6: System with Lower-Link Draft-Sensing

To get a good working result, the correlation between working depth and link-force must be clear and without changes in the direction of the force. This is the case with small ploughs, but not with larger multi-furrow ploughs. Therefore in the draft-control system the controlled variable was changed from the top-link-force to the sum of the lower-link-forces, **Figure 6**. To measure this forces and to realize the summation of both forces, a lot of different mechanical solutions were invented and realized. Another disadvantage of a force-measuring system is the fact, that the working depth varies too much under large changes of the soil-conditions. To improve this, John Deere invented the so called force-position-mixed control, which limited the depth variations.

2.2 Torque-, Working-Depth- and Pressure-Control

The draft-control was realized in the USA and in GB after World-war II. In the USA only Ford used a different solution for some years, which was called "Load-Monitor". This mechanical system measured the torque of the rear-axel of the tractor and changed the working depth so, that this torque was always held constant. Problems occurred because of working-depth variations during downhill- and uphill-driving. In Germany two other solutions were developed and realized in series. One was the so called "Hanomag-Pilot"-System, which was realized by the German tractor manufacturer Hanomag, **Figure 7**.

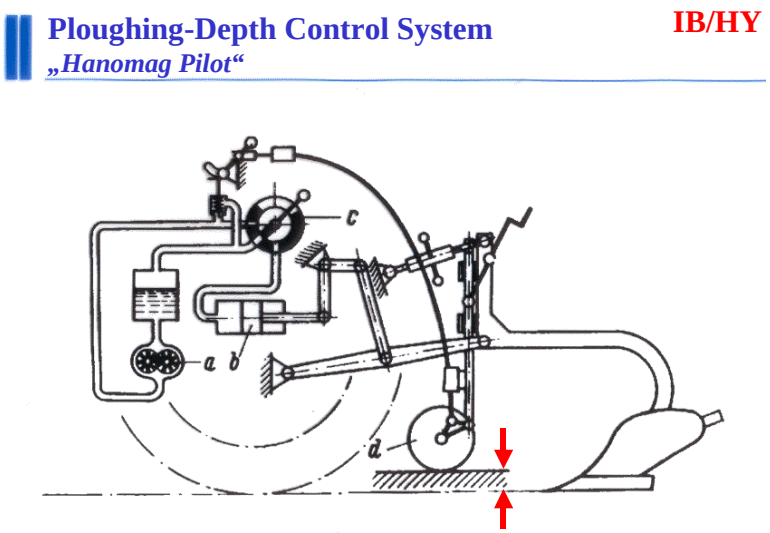

Figure 7: "Hanomag-Pilot" System for Controlling the Ploughing-Depth

The basic idea was to measure and control the working depth of the plough. This was realized by a wheel, which measured the working depth of the plough. This mechanical "depth-signal" was transferred by a cable to a hydraulic closed-loop system. The main problems occurred through mechanical friction in the system. Therefore its lifetime was only a few years. Some other German manufacturers developed a system, which was called "Wheel-Force-Amplifier" in German "Raddruck-Verstärker", RDV. This was realized by an open loop pressure pressure-control, for which a manually adjustable throttle for the oil-flow from the control-valve to the reservoir was used, **Figure 8**.

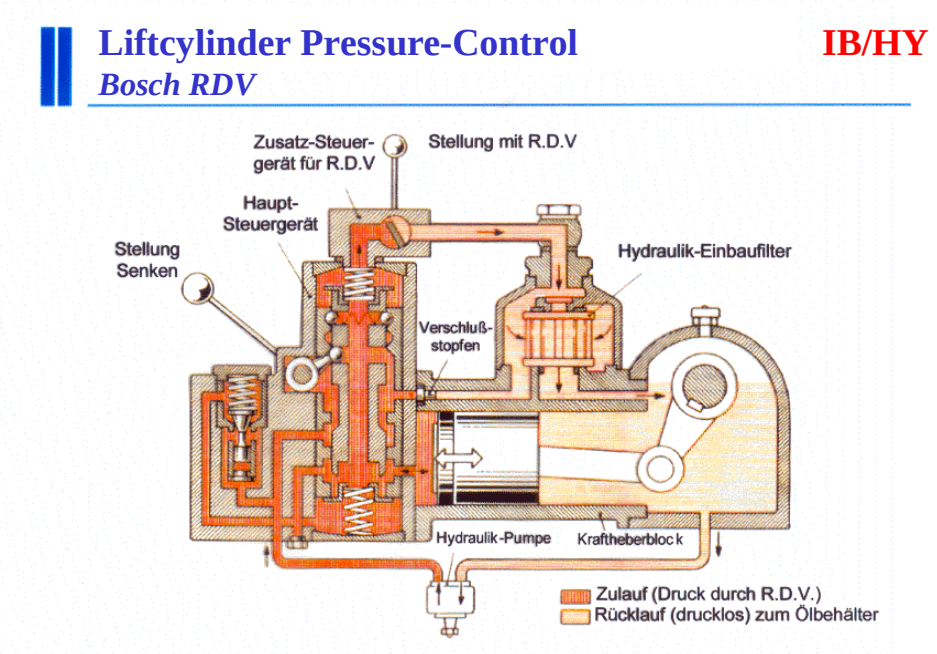

Figure 8: Bosch Pressure-Control for the Liftcylinder (RDV)

In this system the working depth of the plough was held constant and a load-transfer was realized. But through the continues throttling of the oil-flow heat-problems occurred. At the end of the fiftieth all manufacturers in the western world introduced the Ferguson draft-control system in their tractors.

3. The Technical Solutions: MHR, SHR, EHR

At the beginning of the hitch-control usage there was no doubt, which technical solution would be the best. This was the mechanical-hydraulic system MHR. Because of competition a lot of different solutions were realized by the companies. With the introduction of lower-link-sensing in the draft-control-systems and the draft-position-mix, systems got more complicated and problems occurred with the precision of force-measuring and flexibility of the systems. At the end of the sixtieth research-institutes and companies investigated different pure hydraulic, or electro-hydraulic systems, EHR. The SHR-System was developed by Rexroth together with International Harvester Company and was only used by this company. The production of this system was finished at the end of the ninetieth. Today MHR is used for smaller tractors and EHR is standard for all tractors with more than 70 KW, with a trend to use it even for smaller tractors. The EHR, **Figure 9,** was developed by the Robert Bosch Corporation in Germany. The first company, which introduced it, was Massey-Ferguson in USA in 1978. The EHR- system can use the potential of modern micro-electronic. That means easy measuring draft and position and even other variables like hydraulic pressure and true working speed by a radar-sensor. Other features are high flexibility, display-, menu-, and bus-technique and easier operation by the driver.

EHR - Front- and Rear-Hitch-Control

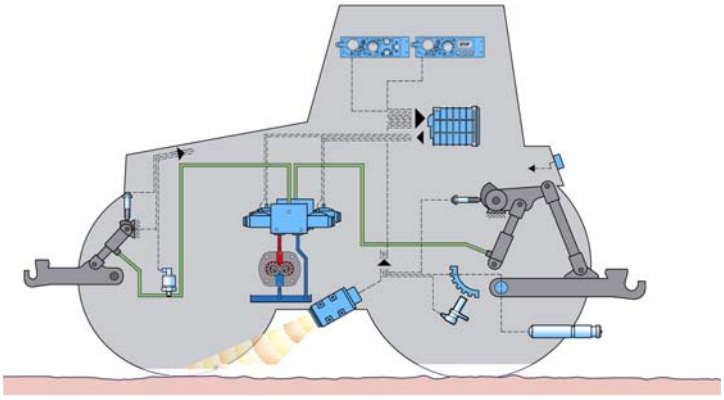

Figure 9: Tractor with Front- and Rear-EHR

These possibilities have lead to the realization of some important new functions of the tractor-implement control-system:

* **slip-control**
* **active oscillation damping**
* **pressure-control for weight-transfer**
* **weighing system**
* **lateral levelling system**
* **diagnostic system**
* **electronic bus connection**

4. Future Developments

Normally technical solutions have a limited lifetime. But the electro-hydraulic system for the control of the tractor-hitch will have a long future, because it can contribute a lot of benefits to solve existing and future problems.
The 3-point-linkage is the most important and standardized idea for coupling implements to the tractor. But the mechanical linkages have a fixed length or must be adjusted mechanical and manually. If we look at large multi-furrow mounted or semi-mounted ploughs, we find, that the load-transfer is not optimal. These ploughs are normally used with load-free- or even without top-links. If the top-link would be a hydraulic cylinder, its position could easily be adjusted and even a load transfer could be realized by pressure-control in one of the cylinder-chambers, **Figure 10**. Other functions, which have already been realized, are the independent control of the rear wheel of semi-mounted ploughs and the lateral controls of sprayer-booms.

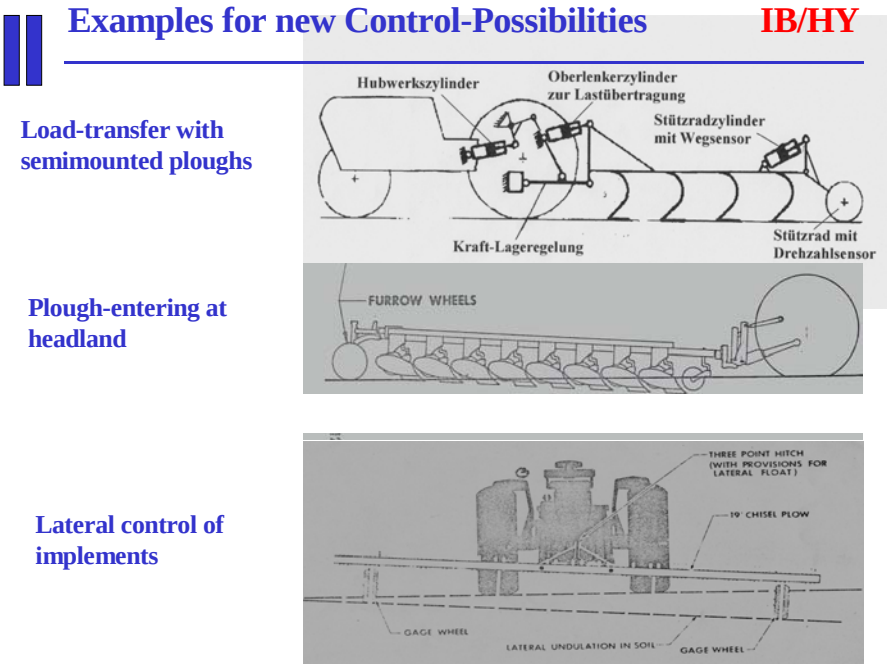

Figure 10: Control Possibilities on Large Ploughs or other Mounted Implements

Walterscheid in Germany has presented an idea with flexible adjustable linkages with electro-hydraulic position control, **Figure 11**.

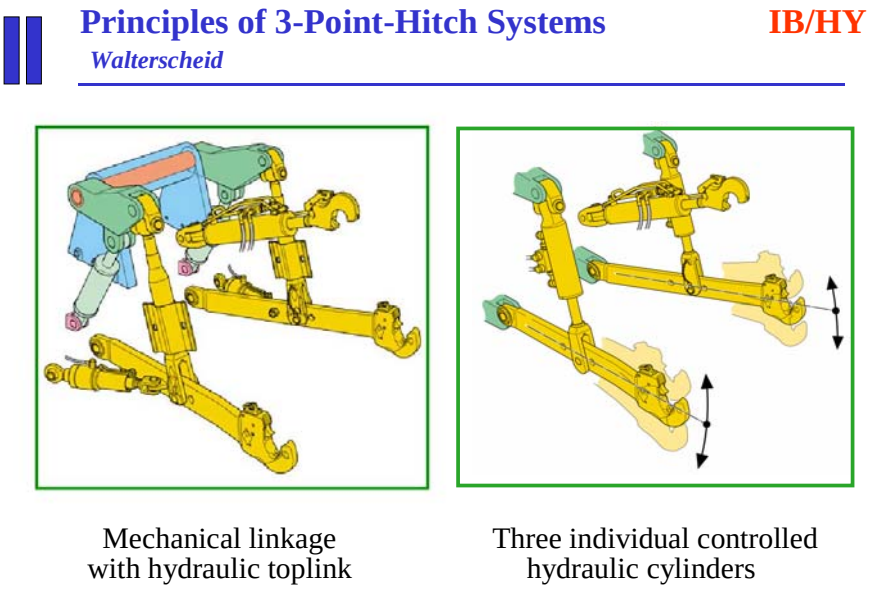

Figure 11: Flexible 3-Point-Linkage

Such a flexible and controllable linkage will give a lot of new ways to a better adaptability of the tractor-connected implements to different working conditions, **Figure12**. By this there are great chances to fulfill the requirements of the "Precision Farming" challenge to realize an optimum of working quality with a minimum of energy-consumption.

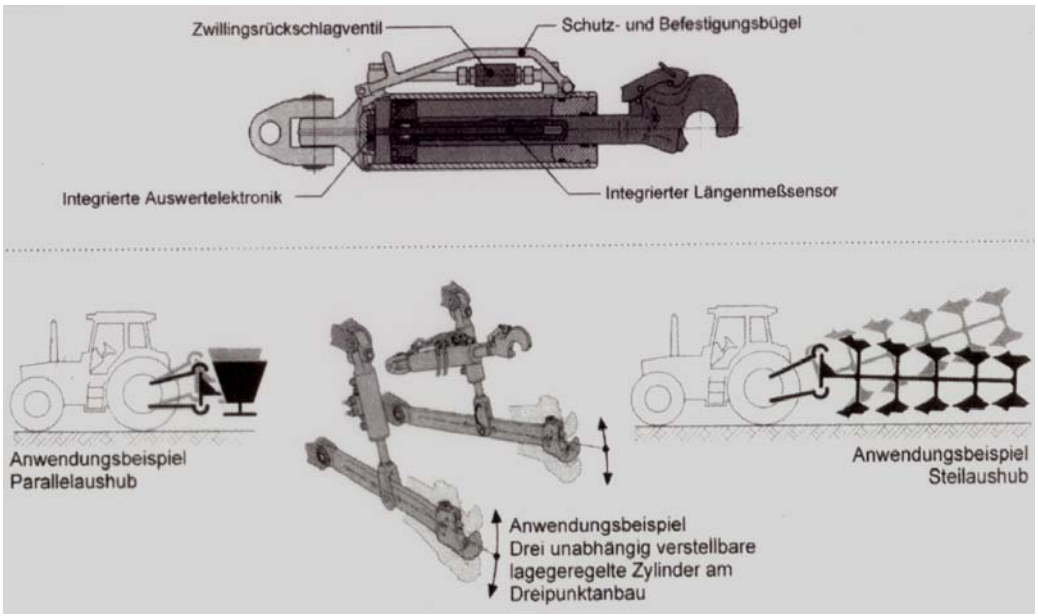

Figure 12: Possible Usage of a Flexible 3-Point-Linkage

5. Literature:

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