Thorsten Lang, Brunswick

Mechatronics in mobile hydraulics

In development of technical systems for farm machinery, as in other mobile work machines, special attention is paid to automation of the work process. There are increased demands on the power production mostly with regard to dynamics and positioning accuracy. As in the past this is mainly supplied by hydraulic drive with mobile working machinery. In principle, however, an increase in dynamic requirement is barely able to be met through a normal hydraulic-mechanical LS system. In order to arm mobile hydraulic systems for future requirements a fundamental overhaul of the mechatronic aspects in known systems would appear to be a sensible move.

Dipl-Ing. Thorsten Lang is academic consultant at the Institute for Farm Machinery and Fluid Technology, TU Brunswick, Langer Kamp 19a, 38106 Brunswick (director: Prot. Dr-Ing. Dr. h.c. H.-H. Harms); e-mail: *tlang@tu-bs.de*

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Examples of the current trend towards automation or assistance systems are numerous and of many types, e.g. diverse assistance systems for headland manoeuvres, units for automation of front loader work or the electronic independent adjustment of process parameters in self-propelled or mounted implements. The development of management systems for the drive line („Tractor management„) is far advanced. Concepts such as „Implement steering tractor“ or teleservice are intensively discussed and the communication of system parts per BUS is, with LBS or ISO 11783, at a reliable performance stage. The hydraulic lift too, as mechanical interface between implement and tractor has been modified in recent years. *Figure 1* shows variants with integrated length sensors in top links, lift rods and stabilizers. This approach allows flexibility and functionality and offers substantial improvement of automation potential. The functions of hydraulic cylinders and motors known up until now as simple drives with high performance density and low dynamic demands are changing, however, increasingly to functions of controlled axles similar to those in stationary robotics. In order to synchronise movements with mechanically independent drives defined and dynamically controlled, speed and acceleration procedures are mostly necessary. However, such increased expectations, especially under critical operating conditions, are almost impossible to fulfil using the usual LS hydraulic systems.

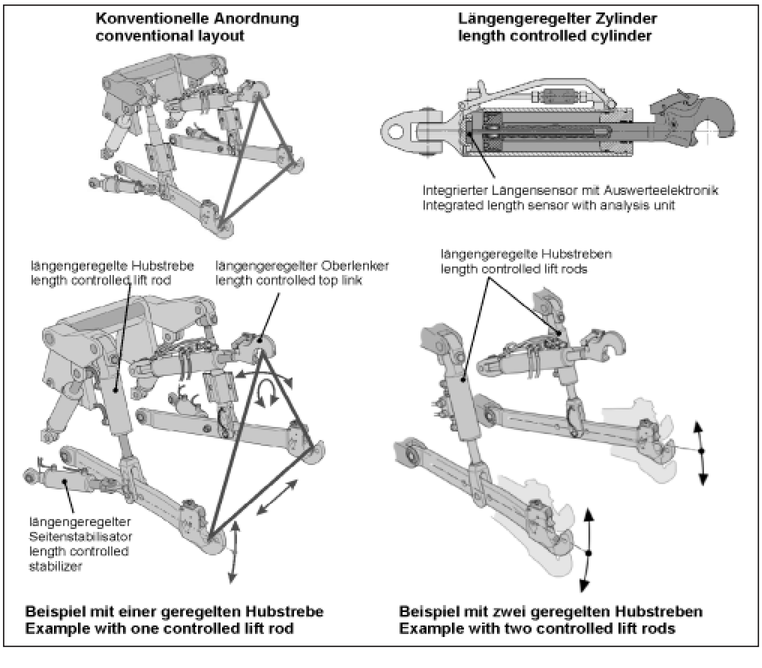

Fig. 1: Different set-ups of the powerlift using hydraulic links

Known hydraulic systems

Figure 2 shows a conventional aspect of a standard hydraulic system under partial load with presentation of performance use and loss. Constant flow and constant pressure systems have the disadvantages of larger power losses with associated temperature problems and strong dependency on effective volume flow from the applied load pressure. Additionally the constant pressure system is more expensive through application of a variable displacement pump in combination with pressure regulator. The load sensing principle improves the working efficiency and the controllability substantially, though, because a constant pressure difference of ~ 2 MPa is controlled over the connection valves.

With regard to the operation of hydraulic axles with defined speeds and accelerations, this application has, however, serious disadvantages. For one, it causes, especially with long pipelines, notable „dead times“ in reporting the static load pressure of all users as well as the reaction of the regulator and pump. Additionally for acceleration of the user and the standing oil column with a not

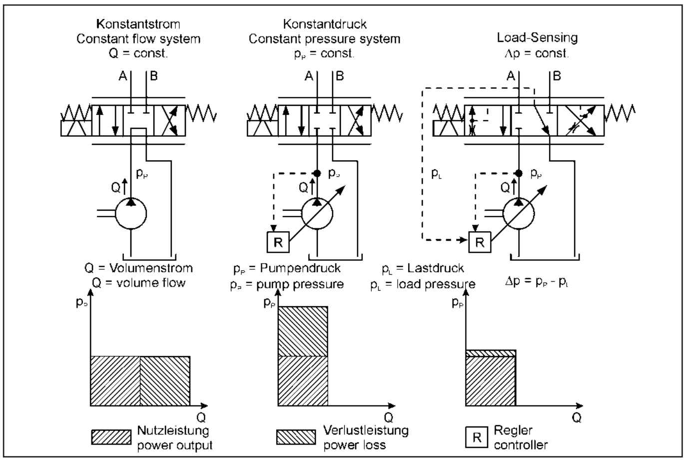

Fig 2: Simplified circuit diagrams and energy balances in part load of conventional hydraulic systems

insignificant mass inertia there is available only the relatively low LS pressure of ~2 MPa. A further problem is caused through the control of the double-acting cylinders in the case of following loads when, e.g. a load is being lowered or where the movement and load direction is the same. In such a case full pressure acts on the final edge (tank connection) of the valve whereas at the input end (pump connection) only the regulated LS pressure takes effect. This means that oil flow is far too low and can result in cavitation in a cylinder chamber. This effect can be still further amplified where differential cylinders are concerned, depending on the type with, under certain conditions, a cylinder chamber being completely empty for a time. Alleviation here can come from applying sink-brake valves and retro-suction valves, although these are difficult to match with dynamic cylinder movements.

For these reasons and to be able to integrate hydraulics with more power in the future into management systems overhauling of the hydraulic system with regard to future requirements is practical. In this situation the mechatronic point of view is especially useful.

The mechatronic concept

Alongside the generally known interdisciplinary interactions of electronics, informatics and mechanics one understands nowadays under the term mechatronics a series of special characteristics, methods and ways of thinking for systems to limit and to create. This aspect is, among others, characterised by thinking in terms of comprehensive integration. Under the *integration of components* can be understood the constructional design of systems into a compact ready-to-plug-in units, whilst the term integration of functions can be seen as the part-transfer of functionalities („Intelligence") from a management level into the local mechatronic system. So that functions can, to a large extent be automatically carried out there at the planned location as far as possible without data strain on the communications system. In this relationship the descriptions „divided intelligence" or the „object-oriented concept" become more important. The latter description comes from informatics where it has been established for years. Standing in the foreground before the introduction of this technique as a rule is a function („procedure" so-called „procedural concept") within which a case differential must be carried out according to the object type in question. In the object oriented concept the object is defined as a self-sufficient data structure which is equipped with functions only applicable for it and can also apply active influence on other objects. A large variety of systems, sustainable function extensions and compatibility problems can thus be controlled much more easily.

With regard to mobile hydraulic applications practical system limits („Objects") have at first to be defined. If one takes account of the cost-grounded growing interest in central availability of valves on the carrying vehicle, the limitation of three systems with the following examples of function potential is possible *(fig. 3)*.

Supply: A mechatronic supply includes not only the variable displacement pump but also all elements for the preparation of the oil. It also monitors the temperature development and can have active effect on the vehicle management (diesel rpm, vehicle speed) and the valves e.g., where the reverse cooling performance is exceeded, or where satiation is reached, or for adjustment of optimum pump oscillating angle, or for recovery from poor positions in the power supply. A temporarily pre-acceleration of volume flow and pressure to give better availability of wished for acceleration, is also possible.

Control: Although valves in the mechatronic sense are nowadays well developed a requirement can be formulated according to flexible adjustment to the requirements of different users. This applies especially to the automatic and independent adjustment of the input and output flow reduction for improvement in system behaviour in the case of following loads and non-symmetrical user volumes.

User: The users report their requirements regarding acceleration, speed or pressure according to the regulating circulation in question. Additionally they can report their type and specific characteristics (continuous action, differential cylinder) e.g., through a type of „Log in" and through other systems.

Outlook

The application spoken about here cannot be practicable for all users in farm machinery especially because the cost situation currently leaves very little playroom. But in order to be in the position to react to future requirements an early testing of the function potential seems to be practical. At the Institute for Farm Machinery and Fluid Technology the mentioned concepts, along with others, are being further investigated.

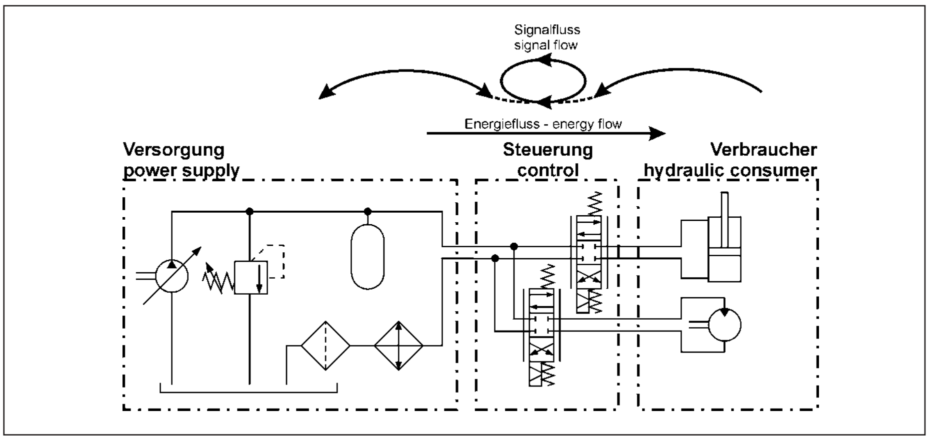

Fig 3: Conceivable constraints of mechatronical systems in mobile systems