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Load sensing system with alternating pump controllers

In this contribution, an upgraded version of a conventional hydraulic-mechanical load sensing is presented, whose goal is the improvement of the energetic and dynamic behaviour of the standard system in the main working range.
The presented system is controlled, depending on the operating point, either with the aid of a conventional volume flow controller or an electro-proportional volume flow limiter with reduced pressure difference between the pump pressure and maximum load pressure. This is intended to provide the necessary precision at smaller swivelling angles and lower overall power transmission as well as improved efficiency at a larger swivelling angle using conventional components suitable for mobile use.

Keywords
Hydraulic system, controller transition, transfer behaviour

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Driven by growing diesel prices and tightened emission regulations, a more intensive development of electronically controlled and regulated systems, which are intended to provide a higher degree of energy utilization while improving dynamic behaviour, can be observed in the area of operating hydraulic systems. For this purpose, in particular robust system design with the smallest number of sensor systems possible combined with great system flexibility for adaptation to the conditions of use, which are very different in mobile machines, plays a role.

System setup

Figure 1 depicts the system setup, which is based on the setup of a conventional LS system of a tractor with electronically actuated valves equipped with primary pressure compensators. Additionally, an electronic swash plate angle controller for the pump and a prototype of a hydraulic-mechanic (hm) pressure difference sensor for the measurement of the difference between pump pressure and maximum load pressure are used (legend highlighted in gray). The pressure difference is identified by determining the spool position of the pressure compensator on which the pump and load pressure as well as a spring acts. Since the pressure compensator does not control any volume flow, it has no direct impact on the dynamic stability of the system. In order to improve the efficiency of an LS system by reducing LS pressure difference, additional power losses must be avoided. Therefore the new system works without a bypass pressure compensator and without pilot pressure supply for the adjustment of pump displacement. This is problematic because the electroproportional (ep) adjustment of the pump displacement must be very precise. However, it is virtually impossible to fulfil this requirement at small swivelling angles and low pump pressure if the above-described device is used without pilot pressure supply and without a swash plate angle sensor. At the same time, an excess oil volume supplied by the pump has negative effects due to uncontrolled pressure increase in particular at small swivelling angles.

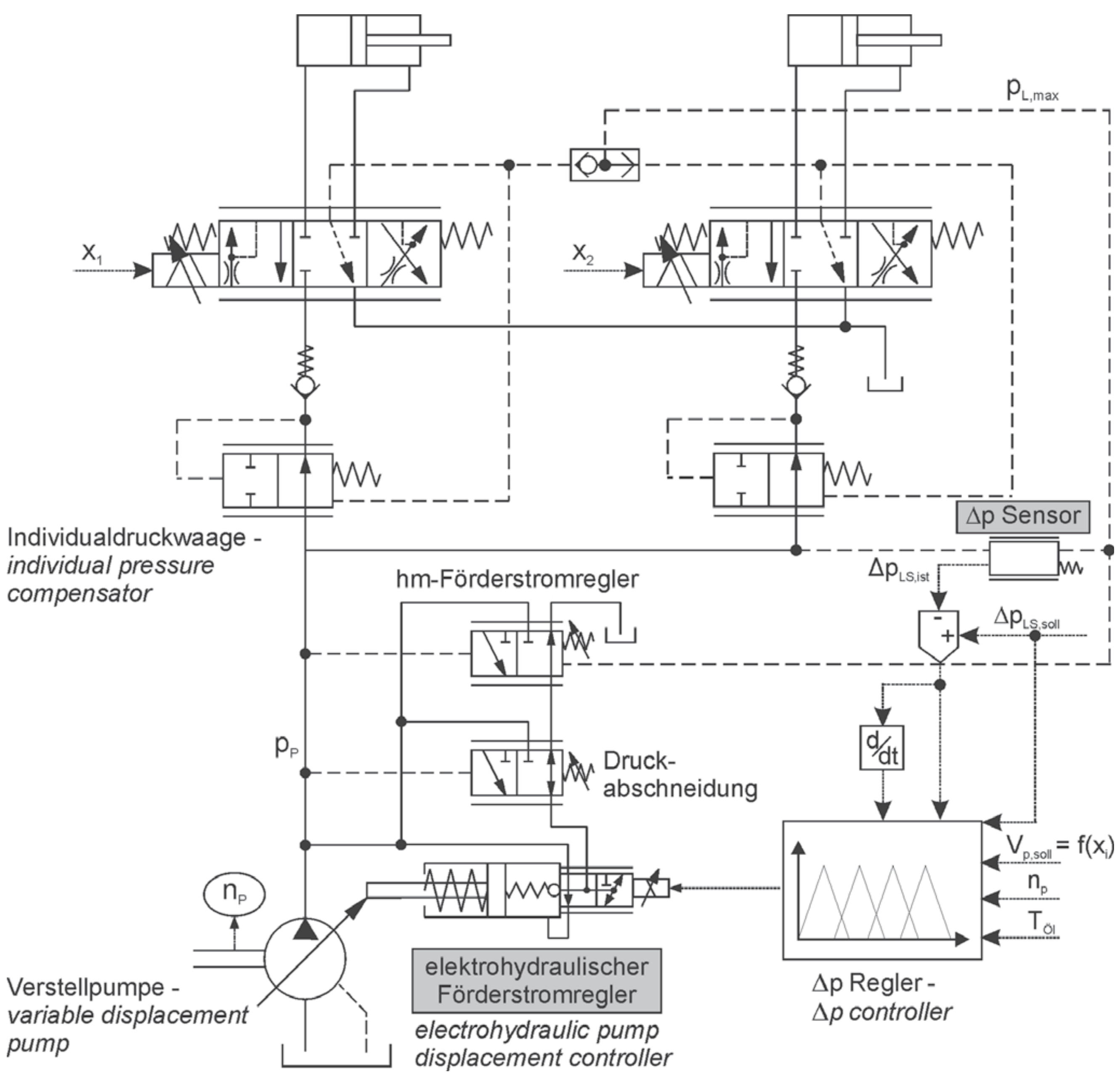
In order to overcome this problem and to achieve sufficient accuracy with the aid of conventional mobile components, the hm volume flow controller is used for the adjustment of the swash plate angle up to a specified limit, where this function is taken over by the ep controller.

System function

In a previous study [1], demand-oriented volume flow control for the hydraulic system of a tractor was realized in which the swivelling angle of the pump is controlled as a function of the volume flow required by the valves and other variables. Since control is not necessary, this system does not require additional sensors and is less susceptible to vibrations due to the open control chain. The system features a pump bypass in order to be able to adjust dynamic system behaviour with the aid of a volume flow reserve and to compensate for unavoidable deviations, such as hysteresis errors of the components, leaks, etc. However, in the latter case a bypass means additional volume flow losses. These losses can be avoided with the here presented new system with alternating pump controllers.

This is possible due to the superposition of the above described demand-oriented volume flow control with a closed loop

Fig. 1



System setup of load-sensing-system with alternating pump controllers

control of the swivelling angle, which is intended to compensate the mentioned variances, such as hysteresis errors or power beyond operation. According to the conventional hm-LS system, the control is based on the control of the pressure difference of the pump and the highest load pressure. The flow demand system is then used as a disturbance feedforward. Therefore the pressure difference controller has to control only small deviations and works with small controller gains. This combined controller structures leads to fast system responses at changing flow demands and a high system damping at the same time. A second advantage of the epc is the possibility to adapt the digital controller to the non-linear behaviour of a hydraulic system. Therefore the digital controller possesses adaptive controller gains, which adapt to the operating point with the help of fuzzy logic.

Change of active controller

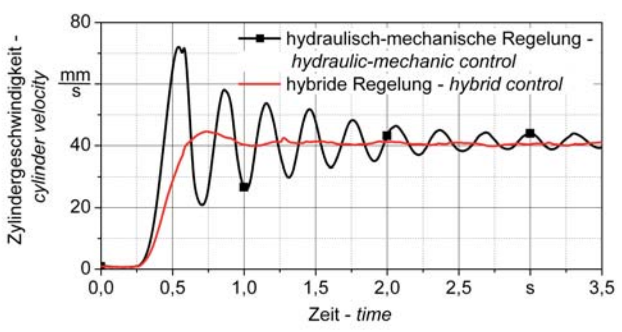
The basis of the controller transition is their arrangement. The epc is mounted between the hmc and the pump positioning cylinder and possesses an own pump pressure connection. Through this the epc is able to reduce the pump displacement and the pressure margin independently. For an increase of the delivery flow, the epc is dependent on an opened tank connection of the hmc. Additionally, the hmc is able to reduce the pump displacement independent of the epc via a check valve. The result is that the controllers are combined in such a way that the minimum displacement volume of the two controllers is set.

Experimental results

The system was developed with the help of a co-simulation for the optimal modelling of the hydraulic system and the fuzzy controller structure. For the verification of the results, the system was realized at a test rig, available at the Institute of Agricultural Machinery and Fluid Power. This test rig consists mainly of typical components for tractor hydraulic systems. These are for example a variable displacement axial piston pump, electronic actuated control valves with primary pressure compensators and realistic consumers such as a front-end loader and a hydraulic motor. The test rig is furthermore equipped with various sensors, like pressure, volume flow and temperature sensors, speed and position sensors at the consumers and the individual pressure compensators.

The step response of the new system with alternating and hybrid pump control respectively in comparison with the well known hm load sensing system is shown in **figure 2**. This measurement was carried out with the front end loader as consumer. At the time of 0 s the directional control valve was opened stepwise from 0 to 35 %. Before the step incitation, the system operated in stand-by and was therefore controlled in both cases with the hm volume flow controller that is as hm load sensing system. The figure shows the behaviour of the consumer by means of the cylinder velocity.

Fig. 2

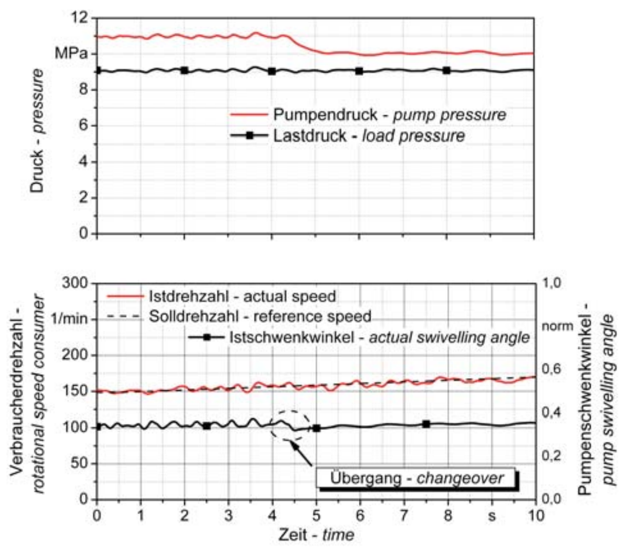


Comparison of step responses

The step response of the hydraulic-mechanic load-sensing is characterized by a typical high overshoot with a slow decrease of the oscillation subsequently. Although both systems control the LS pressure margin, in difference to the hydraulic-mechanic system, there is no such overshoot of the pump swivel angle and pump pressure respectively, therefore the dynamic behaviour is much smoother. This is due to the fact that the electro-hydraulic system works mainly as a flow demand system. The pressure margin controller controls merely small deviations and has only a minor effect in case of high step incitation.

In order to control the system behaviour in case of alternating pump control from hm to ep control, it is reasonable to choose the system incitation as small as possible. This is achieved by controlling the opening of the directional control valve with marginal, constant gradient. **Figure 3** depicts the system behaviour in such a case, in which an oil motor was used as rotational consumer. At the time of 4,5 s the flow demand of the valve exceeds the upper limit for the operating range of the hm load sensing system. Hence, the epc gets active and the system control changes from the hm to the ep controller. As a consequence, the pump swivelling angle is reduced such, that the pressure margin between the pump and the load pressure is reduced. Through this, the hm controller closes its pump pressure connection and gets inactive. While the changeover can be observed by regarding the pump swivelling angle (highlighted in **figure 3**) there is hardly any disturbance in the course of the consumer velocity visible.

Fig. 3



System behaviour during controller changeover

The energetic behaviour of the new system is characterized by the course of the pump and the load pressure. While the load pressure is not affected, the pump pressure decreases after the alternation of the pump controller about 1 MPa. Regarding the shown operating range in **figure 3**, this leads to an increase of the system efficiency of approximately 10%.

Conclusions

At the Institute of Agricultural Machinery and Fluid Power an enhanced, electro-hydraulic Load-Sensing system was developed. In this contribution the simple set-up of the system with only one additional pressure difference sensor, which is suitable for mobile use, was shown. The idea of the heterodyne flow demand feed forward and pressure difference control with a followup control application of the hydraulic-mechanic and the electro-hydraulic flow controller was presented. With the help of measurement plots the improvement of the dynamic and energetic behaviour on the one hand and the smooth controller transition on the other hand was exemplified.

Literature

[1] Fedde, T.: Elektrohydraulische Bedarfstromsysteme am Beispiel eines Traktors. Dissertation. TU Braunschweig, 2008

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