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An Adaptive Hydraulic System for Tractors

The Load-Sensing system has established itself as a standard hydraulic system in medium-sized and large tractors. Increasing demands for higher capacity, consumption and work quality require new solutions for the hydraulic system. An electro-hydraulic Flow-Demand system is discussed in this paper, which makes it possible to adapt hydraulic system characteristics to the specific process conditions through electronically actuated proportional valves and an electrically adjustable variable displacements pump.

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Keywords

Mobile hydraulics, electro-hydraulics, flow-demand control

More than 70% of the current tractor models in the power bracket above 74 kW are equipped with load sensing systems [1]. As compared with constant pressure- and constant flow systems, so-called closed-center load sensing (LS) is characterized by relatively good utilization of diesel engine power under all conditions of operation. For tractors, the good operating behaviour and small power loss of the LS system during stand-by operation is very important because the percentage of time without noticeable power output is relatively large there.

The current trend towards the optimization of processes in agricultural machinery leads to the increasing use of auto-mated drives, for which the hydraulic system of tractors with electronically con-trolled proportional valves provides good conditions. Here, the system-related disadvantages of the load sensing system become obvious as significant shortcomings.

1. Dynamic behaviour
Load sensing systems are based on the load-dependent control of the pump pressure. This principle leads to a load-dependent system capable of oscillations with weak damping and limited acceleration capacity.

2. Efficiency
The constant LS system pressure difference of 2 MPa is responsible for significant power losses in constant volume flows. If a consumer works permanently, these system-related power losses cause relevant additional fuel consumption of the tractor and could lead to overheating of the oil and to forced breaks for oil cooling.

Electro-hydraulic flow-demand system

As compared with a conventional LS system, the direct adjustment of the pump displacement based on electronic control signals to the directional control valves improves the system significantly (*Fig. 1*). In contrast to the LS system, load pressure does not exert a direct influence on pump displacement. This circuit principle based on flow-demand control does not require the measurement of pump- or load-pressure. The necessary pump rpm signal is generally available as a CAN message of current engine speed in modern tractors. The flow-de-

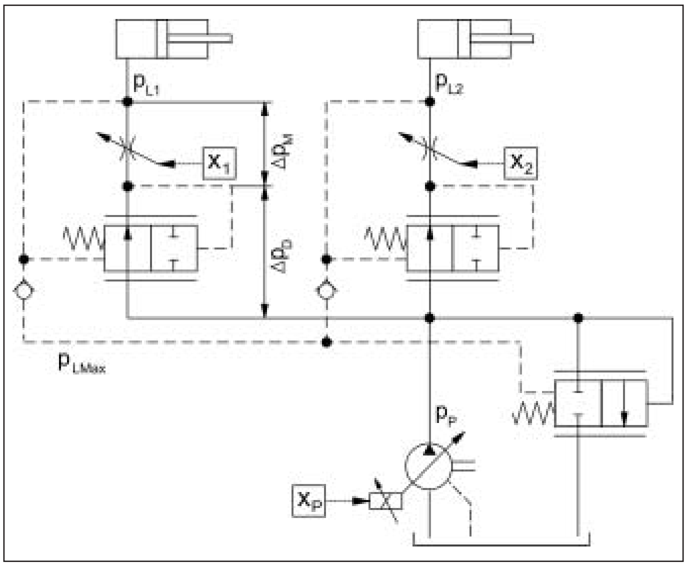

Fig. 1: Electro-hydraulic flow-demand system

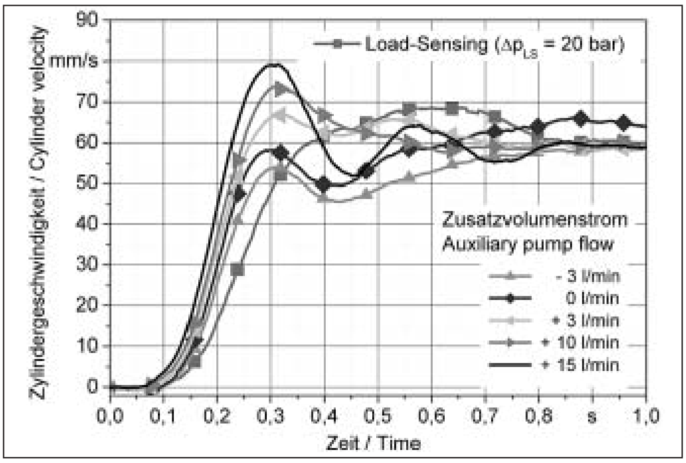

Fig. 2: Dynamic behaviour

mand system enables the volume flow generated by the pump and the valve volume flows to be adapted independently. If the consumer volume flows are small, pump pressure needs to be monitored additionally, because the hysteresis of the components makes it impossible to precisely adapt the delivery of the variable displacement pump to the valve opening. In the circuit realized here, this task is taken over by a bypass pressure balance in accordance with the principle of open-center load sensing, which allows an auxiliary pump flow to be diverted.

Acceleration behaviour

If a consumer is accelerated to a higher speed, an auxiliary pump flow can be used to bridge the time delay in the widening of the angle of the variable displacement pump, which results in greater consumer dynamics as compared with classic load sensing (*Fig. 2*). The consumer shows an extended acceleration phase, which can be controlled by the volume of the auxiliary pump flow. Greater auxiliary pump-flows result in a relevant bypass volume flow, which leads to LS-typical oscillating behaviour. As compared with classic load sensing, however, system behaviour is more efficient because pump pressure is controlled by the bypass directly at the directional control valve block, which requires small hydraulic capacities and smaller time constants.

System efficiency

If the volume flow of the variable displacement pump is reduced in proportion to the valve opening or if the opening of the valve under the greatest load pressure is increased, the under-supply results in a relative opening of the individual pressure balance. The bypass closes, which results in a reduced pressure drop at the directional control valve. Consequently, pump pressure falls to the greatest load pressure plus the remaining pressure losses at the individual directional control valve. This allows a pressure difference of approximately 0.5 MPa at the directional control valve to be reached, which means a considerable reduction of power losses as compared with classic load sensing, where they are 2 MPa. *Figure 3* shows a measurement of the power losses at the directional control valve in the case of an average load on the hydraulic system. Since the component efficiency of the pump and the engine remain untouched, the examination of the power flows at the directional control valve is sufficient for assessing the system efficiency. The diagram shows the hydraulic power supplied to the consumers and diverted via the bypass in relation to the hydraulic power delivered by the pump, which was determined by measuring the individual pressures and volume flows. The volume flow losses to the pilot control units are examined in this method.

This measurement proves that system efficiency at this load can be increased by approximately 10% as compared with classic load sensing. Especially in the medium load range, which is typical of mobile hydraulics, a significant increase in efficiency of about 10% can be achieved as compared with load sensing, where pressure losses are 2 MPa. During automated movements, such as the electro-hydraulic parallel motion of a front loader [2], greater dynamics can provide better quality of motion control. In this case, reduced hydraulic efficiency seems acceptable because such drives are turned on only for a relatively brief time.

Continuous adaptation of the system properties of the hydraulic system enables processes in agricultural machines to be operated with a compromise of optimal efficiency and necessary system dynamics.

Future prospects

The project showed an impressive improvement in the efficiency of hydraulic systems with pressure- and volume-flow adaptation in an open circuit. The presented flow-demand system allows the system properties to be flexibly adapted to the individual tasks of the hydraulic system.

The development of electro-hydraulically controlled variable displacement pumps for an open circuit is the key to the introduction of such hydraulic systems. The quality of delivery adjustment determines the achievable efficiency of the flow-demand system. Due to growing fuel costs, users are expected to show greater interest in such intelligent drive systems.

Literature

Books are indicated by •

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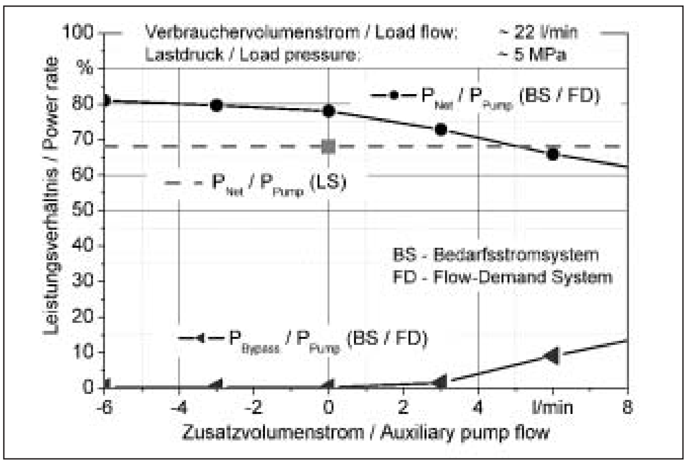

Fig. 3: Measured efficiencies at the valve