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Integrable Positioning and Velocity Sensors for Mobile Hydraulics

In recent years the use of electrically or electronically activated proportional valves in mobile hydraulics has grown significantly, and has initiated an accelerated trend towards the implementation of controllable hydraulic drives in agricultural machines. Hydraulic actuators with integrated sensors, which make it possible to utilise electronic control systems, are a good example of this. In this paper the integrated determination of current position and hydraulic cylinder speed through sensors is presented, through which partially automated functions, like electro-hydraulic parallel lifting systems for an agricultural front-end loader can be achieved.

Many years of development in the field of industrial automation technology have lead to the production of many analogue and incremental position measuring systems of a high technical level. The sensors utilised here are connected to the controlling system by means of a real time compatible bus-system and supply the required information with regard to position, velocity and acceleration of the respective drive in temporal coordination with the controlling device. This technology, which finds wide utilisation for stationary applications, is becoming increasingly interesting for controlled movements in mobile machines [1].

The necessity to carry out sensitive movements at low and also high working speeds with mobile machines, such as excavators, loaders etc., is increasing [2]. For example, a tractor with front-end-loader is to speedily extract feed from a clamp silo and during the loading of heavy weight palettes also be able to be positioned with great precision. The loads on the whole tractor are considerable, so that vibration dampening measures would be desirable.

Single loop position regulating circuits offer no satisfactory results, because neither control of movement velocity, nor of acceleration is possible. A more suitable control system utilising the velocity signal was constructed at the ILF.

Requirements for the mobile hydraulics

Should the control of hydraulic cylinder drives, which are often used in mobile machines, be realised in a similar way to the industrial systems, then the existing measuring technology for industrial applications offers itself for initial utilisation. The position measuring technology, developed for industrial requirements, can, for several reasons, not be adapted for mobile utilisation.

- An analogue signal transmission without screened signal line is usually used for mobile machines.
- There are high requirements against process conditioned external environmental influences (water, dust, electric and magnetic fields, vibration, fluctuating voltage).
- Additional elements attached to the outside of the cylinder must be avoided (robustness against mechanical influences, for example stones flying around in the working area of the machine).
- It must be possible to turn the cylinder piston rod within specific limits (tolerance and elasticity of the mechanical driving elements).

In addition, the functional gain caused by the sensor to the driving system must outweigh the additional costs, otherwise no willingness can be expected by the final user for any additional investment.

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This research programme is being carried out in cooperation with the companies MTS Sensor Technologie GmbH & Co, KG (MTS) and CLAAS Industrietechnik GmbH (CIT).

Keywords
Mechatronics, mobile hydraulics, sensors

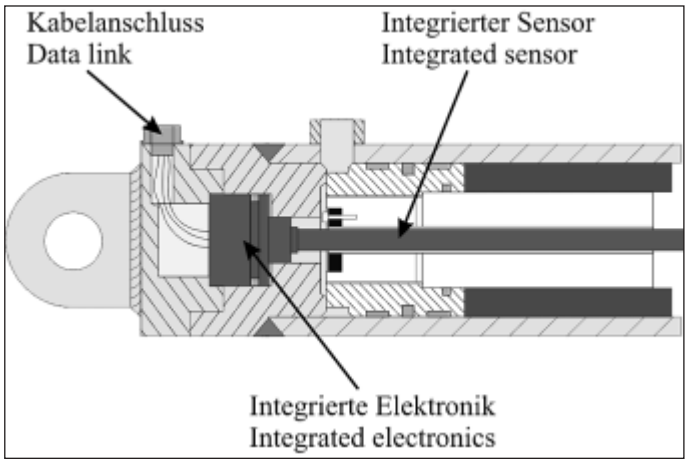

Fig. 1: Integrated position sensor

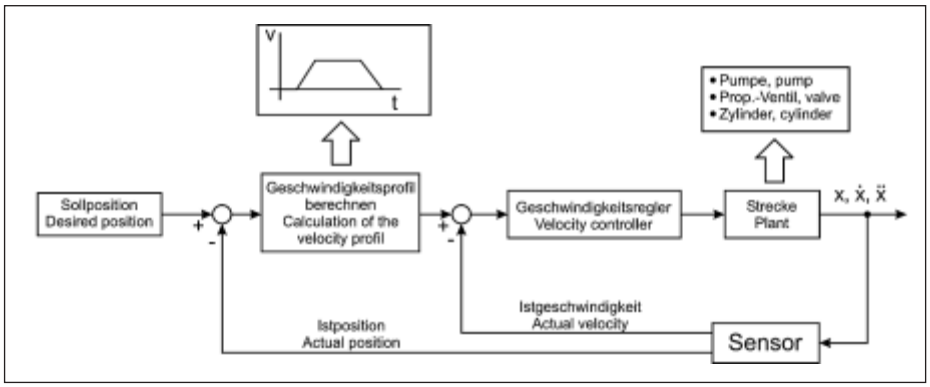

Fig. 2: Cascaded position and velocity control system

Integral position sensor with velocity evaluation

The itemised requirements for a position measurement on hydraulic cylinders can only be practically fulfilled with an integral distance measuring system. Signals giving the relevant velocity are a prerequisite for the mentioned high quality control systems, regardless as to whether they are gleaned by an additional sensor, by a sensor integrated or extern differentiation of the position values in the control device. In the method realised, the integration of the differentiation process in the sensor housing results in a high quality signal of the velocity signal, due to the favourable screening and short signal cable, which enables a simple analogue transmission of the signals gained. With the cooperation of a sensor manufacturer and a cylinder manufacturer, relevant sensor prototypes were integrated in a differentiation cylinder for an agricultural front-end-loader (*Fig. 1*).

Electrohydraulic parallel guide

In this project the electro-hydraulic parallel guide for a frontend-loader was realised as a practical utilisation. A constant pressure system with two electrically adjustable proportional valves can be utilised as a hydraulic system. Two separate cascaded closed loop velocity controls, the basic structure of which is shown in *Figure 2*, were coupled to realise a parallel guide. The desired value can be loaded by means of a joystick, but also by a numeric input. A nominal movement profile is calculated from the numerical reference value while the joystick signal can be converted directly as reference velocity for the cylinders. In this case the reference angle of the attachment can be changed by means of the second proportional axis of the joystick.

The functioning of the coupling relies on the synchronisation of velocity of the cylinder, in the sense of a parallel guide, being predetermined with the aid of a velocity map, which is created by the kinematics of the front-end-loader. This velocity map for a parallel guide is preset for all angles of the attachment. Characteristic maps for further movement sequences are also possible.

Should there be a deviation of the attachment from the preset angle, then a superordinated control takes care of a slowing down of the leading cylinder pair of the front-end-loader, so that the preset angle can be complied with.

Figure 3 shows a lifting and lowering cycle of a parallel guide with a constant pressure system and the usual mobile compatible proportional valves. It is obvious that by using conventional controllers a work cycle with a deviation angle of the attachment of less than 3° is possible. An interesting question is the quality of the control when using the usual tractor load-sensing-system. This question is being investigated on a newly installed tractor hydraulics testing rig at the ILF.

Outlook

The possibilities for user specific automated functions in the field of mobile hydraulics are on the increase. This brings new challenges to the sensor technology, which will increasingly become the focus for sensor manufacturers [3]. Integrable positioning sensors are a good example here. Should the manufacturers and users of machines succeed in putting the extended functions into practice, then a wide variety of new automation possibilities in mobile hydraulics and particularly in the field of agricultural technology are attainable.

Literature

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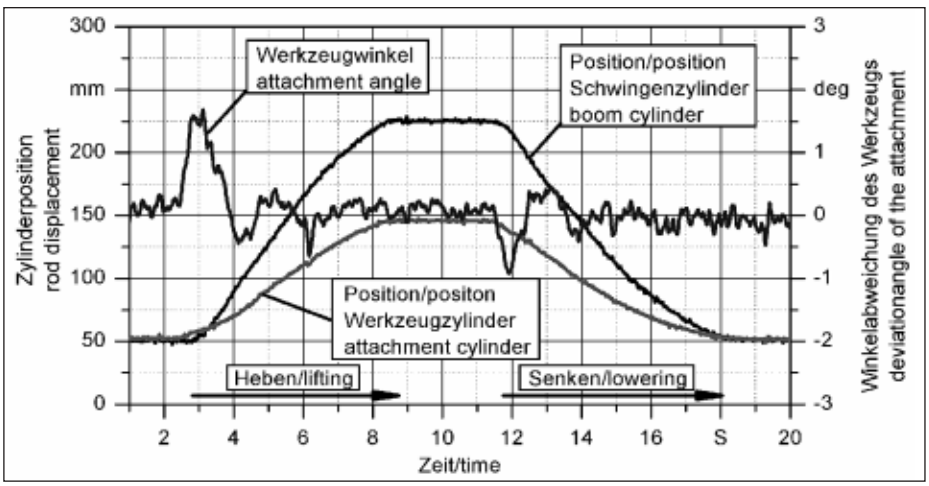

Fig. 3: Lifting and lowering cycle with electro hydraulic parallel lift