8 Tendencies in development and the outlook for the future

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The, as yet very young, secondary control technology with its complex closed loop control is as yet unknown in many hydraulic circles and, not only on these grounds, is very slow to be introduced in new developments in spite of its many advantages.

Previous applications lie mainly in special purpose machines and short run production machines. The limitation of these drives to "one-offs" is naturally a disadvantageous for the costing side, as everything must be made individually to suit the particular application. The aim must be to get secondary controls accepted in high volume production machines.

8.1 Tendencies in development

The quality of control in a system under secondary control depends mainly on *(see chapter 3)*:

a) The dynamics of the positioning system of the secondary unit.

b) The quality of the drive of the monitoring system

c) The power density of any hydraulic accumulators in the system.

ALL areas of difficulty must become the target areas for future development.

In order to improve the dynamic response of the positioning controls of the secondary units, only swashplate axial piston units can be employed together with increased positioning powers.

Further development of closed loop control systems must aim towards:

d) Improved quality of closed loop control including the matching of system parameters to variable parameters of the machine system being controlled (varying masses, system specifications etc.).

e) The inclusion of secondary control as "one of the family" within the area of conventional drive concepts.

The work on problem **d)** leads to the development of adaptive digital control technology, which compared with analogue control technology requires new, as yet unfamiliar, control strategies (array regulators and management strategies). This is necessary, as the conventional PID controls are too time sensitive. Naturally, these new developments are transferable to other drive technologies.

The ease of use of digital closed loop control elements and the continuing drop in price levels makes the hardware ever more competitive and powerful. Thus, combined with a standardized macro-structure for closed loop software, a unified hardware system will become available. The matching of the system to individual needs then only requires to be made via the standardized software the basic structure of which will make the necessary modular elements available to the user as required.

Such a digital controller will assume further functions in addition to its controlling function, such as diagnostics, monitoring functions, requirement specific priority controls, emergency closed loop control functions, on-off algorithms, collective load measurement, diary functions etc.

Problem **e)** poses a problem for the whole of the control system. The incorporation of, for example, an application orientated hydraulic system such as load sensing requires an extension to the load sensing control system (e. g. an overwrite flow sensing) which can operate:

- with various actuators (cylinders or motors)
- in various control systems (throttling or secondary control)
- under varying operating conditions (pushing, pulling, pre-filling or returning power)
- under conditions of varying priority (sometimes changing during an operation).

This concept must be designed on a modular system basis:

1) into which a number of components, which are already available, can be integrated (load sensing valves, secondary drives, pump control systems, etc.).

2) or which alternatively contains a purely hydraulic or electronic (adaptive digital) control.

The overwrite flow sensing system is a solution of this type for the near future *(Fig. 65)*. This illustrates five different types of actuator systems (throttling with pressure compensators either as meter-in or meter-out controls and also secondary controls), the power supply to which is supplied by individual pumps (cascade system) "as required" (the overwrite flow sensing system).

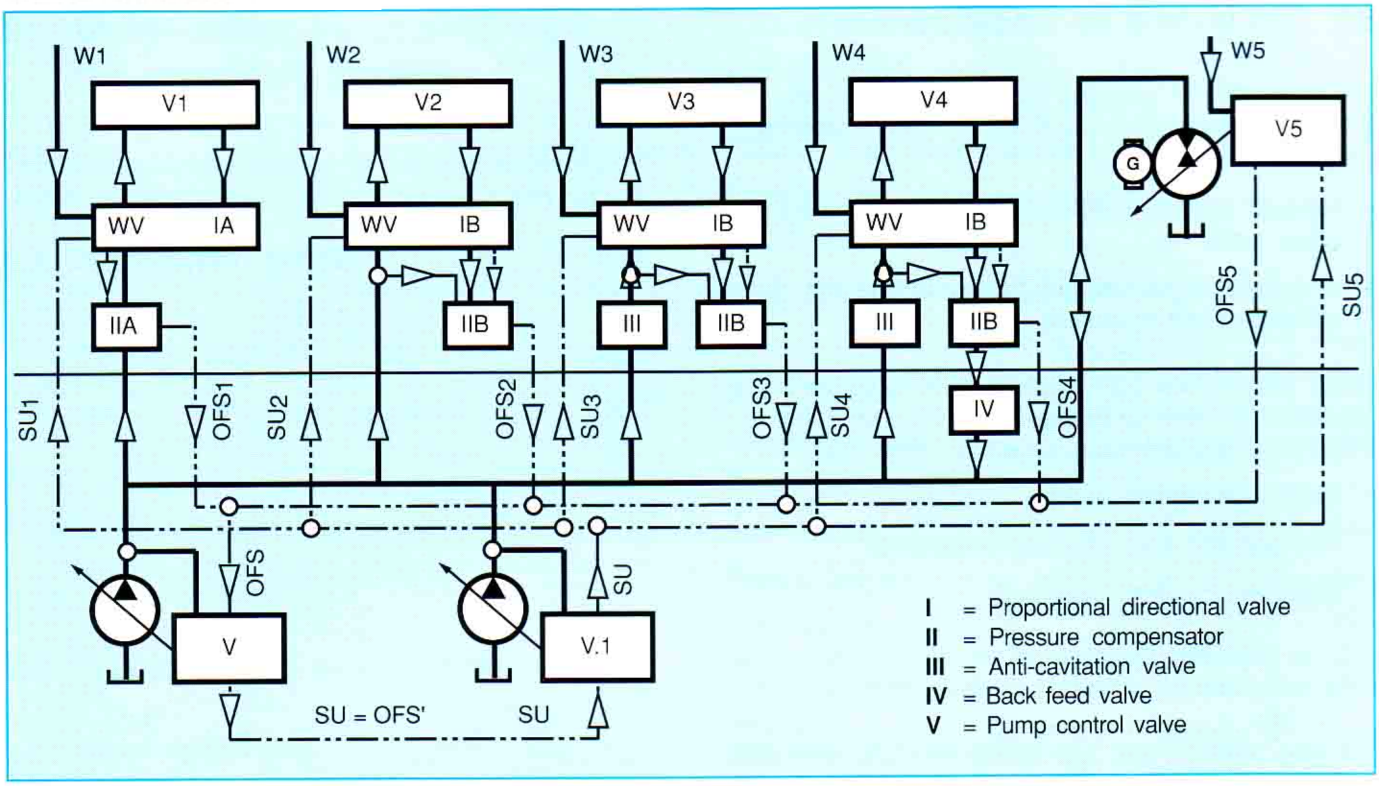

Fig. 65: *Overwrite flow sensing system variations*

The four throttle controlled actuators, V1 to V4 are controlled by proportional valves with load sensing signals as meter-in controls (1A), or as flow sensing meter-out controls (1B). Actuator V1 has pressure compensator (IIA) in the feed line. Actuators V2 to V4 have compensators in the return line (IIB). By arranging the pressure compensator in the return line, the feed line can include a pre-fill function (III) as in V3 and V4.

With heavy over-running loads and high counterbalance pressures(V4) it becomes necessary to incorporate a valve to return power to the system (IV) from the return line.

A unit under secondary control (V5) is also connected to the same common system.

All of the units return an overwrite flow sensing signal back to the pump controls (V and V1) if they are receiving too little flow, thus causing the pump(s) to swivel out. If no such signal occurs, the pumps swivel back towards zero until one of the five actuators sends an overwrite flow sensing signal. In the case of the throttling controls (V1 to V4), the overwrite flow sensing signals are generated at the pressure compensators (IIA and IIB). In the secondary control system, it is generated by the swivel angle ($\alpha_{max.}$).

When pump control (V) has swivelled fully out, and an overwrite flow sensing signal is still present, it sends a low flow signal to the downstream controller (V.1). The second pump then swivels out until the first pump is once more below its maximum and the low flow signal disappears.

If, with both pumps at maximum, and there is still insufficient flow, control (V.1) sends a low flow signal to the individual actuators V1 to V5 under a predetermined priority sequence to cause these to reduce their requirements until the second pump is once more within its control range.

In the case of the throttle controlled actuators V1 to V4, the low flow signal operates directly upon the controls of the proportional valves.

In the secondary control, the signal operates on the command speed level and **NOT on the swivel angle !**

Pressure, power limiting and priority controls are all integrated within the pump controls (V and V.1)

All the devices use here, with the exception of the flow return valves and anti-cavitation valves, are standard valves with only small changes in the signal lines.

All hydraulic signalling (overwrite flow sensing and low flow sensing) can be achieved by means of low pressure warning switches. The system structure shown in *figure 65* can be connected directly into a closed loop digital control system.

The presently available hydraulic accumulator systems are, referred to their capacity, both too heavy and too expensive. Especially for secondary control, the application of " constant pressure accumulators" (accumulators with a condensing gas as the storage medium) would be particularly advantageous. The gains made in the developments in this specific area would be particularly desirable.

8.2 The outlook for the future

If it is possible to integrate secondary controls into requirement orientated hydraulic closed loop control systems, this would lead to:

- reduced system costs based around the existing power units
- a division of the control costs between the drive systems driven in parallel.

Within this reduced cost structure, new applications are possible which were previously too expensive. The main areas to be targeted would be in the mobile field :

- Cranes and mobile cranes
- Wheeled and track mounted excavators
- Container handling machines.

In these machines, the rotational and linear drives do not place extra-ordinary demands on the control accuracy.

The new control closed loop control structure must also not be forgotten as it will offer additional advantages such as system diagnostics, emergency control functions, requirement orientated priority structures, component monitoring, collective load measurement etc.