Mechatronic Systems Embedded into the Electrohydraulic Control Equipment for Industrial Applications

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Abstract: *Electrohydraulic control equipment manufacturers keep pace with technological evolution and incorporate in these devices the latest technologies. Thus it was switched from analogue technology to digital and from analog control signals to the data communication protocols (e.g. Profibus, CANopen). The latest models of such equipment contain microprocessors and sensors and can be parameterized using software provided by manufacturers. Installation and maintenance of such equipment is recommended to be performed by qualified personnel only. These devices are used in various equipment for industries such as mechanical processing, metallurgy, construction, etc.. These allow interfacing with automation systems based on industrial computers or PLCs. The article presents the description and characteristics of such equipment.*

Keywords: *servohydraulics, mechatronic system, proportional control, characteristic curves*

1. Introduction

Modern machinery have reached a very high degree of automation today.These require besides computerized management system some controlpartsfor subsystems or working bodies [1]. The hydraulic control equipment must be reliable,to ensure accuracy, good dynamics and to can be interfaced with the computerizedmanagement system.

A mechatronic system can be defined as a technical system consisting of mechanical components, electronics and intelligent software necessary for control of movements for obtaining certain functions.

The modern hydraulic control equipments incorporates besides the mechanical part, electro mechanical converters, sensors and electronic modules driven with microprocessors.These equipments are manufactured in variants with data communication (e.g Profibus) that can be connected easily with the process computer [2]. Industrial applications include the machine tools with numerical control, injection machines, turbines control and control of precise movement in centers of simulationand for car components tests. Electrical feedback for position of such equipment enables higher gains control loops, improving the dynamics and eliminating errors caused by hysteresis and temperature variations

2. Types of electrohydraulic control equipment which embed mechatronic systems

A classic servovalve for controlling a hydraulic motor is shown in Figure 1. This servovalve with two stages with mechanical feedback is a model produced by Moog. This is a valve whose spool is positioned proportionally to the amount of input electrical signal and internal movement of the spool is accomplished using hydraulic fluid under pressure.This model does not have embedded sensors and electronics.

Block diagram of a mechatronic system of an hydraulic control equipment can be seen in Figure 2.

The modern electro hydraulic control equipment (proportional directional valves or servo valves) have incorporated such a system. They have an actuator that moves a mechanical element which is a distribution spool, a position sensor and an electronic module that processes the signal from the positionsensor based on a control loop with PID controller and allows giving external commands to the device and monitoring of realized value (actual value).

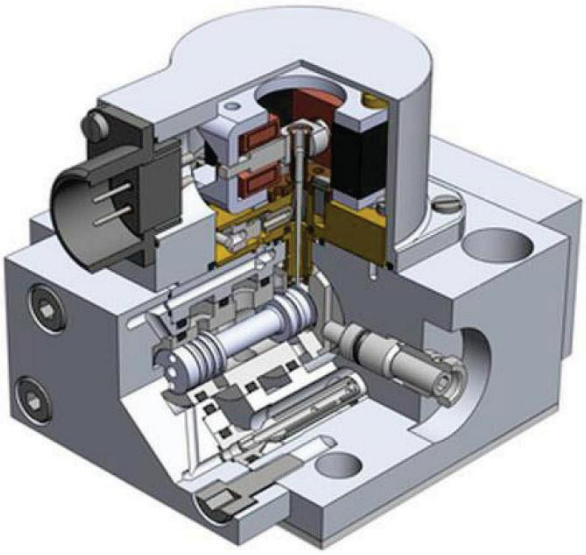


Fig. 1. Servovalve without electronics

Mechanical element is interconnected with the hydraulic subsystem that controls a drive system (e.g. hydraulic motor).

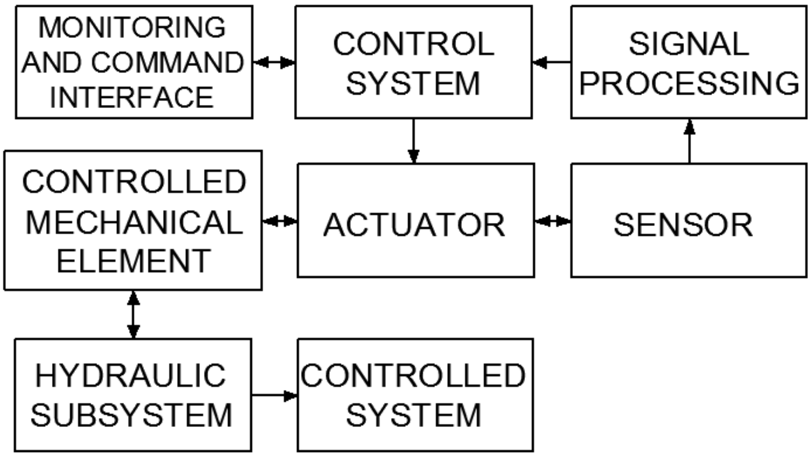


Fig. 2. Block diagram of a hydraulic control equipment

2.1 Proportional directional valve with two internal control loops

In Figure 3 there is a piloted proportional directional valve with two control loops one for control of movement for the pilot spool and one for main spool of valve.After receiving the command signal, the pilot send pressurized oil in one room from the ends of the main spool of the directional valve in the direction P→A or P→B.Stroke of the spool, implicitly flow, depend of the pressure acting on the surface from the end of the spool. Hydraulic pressure produced by the pilot with the proportional solenoid can be achived with a pressure reducing valve or pressure relief valve.
Without command signal the main spool is maintained centered by two coilsprings located at its ends. With the help of an electronic controller the spool position is maintained precisely according to the control signal [3].The electronics ensure good repeatability, accuracy and reduced hysteresis. The directional valve dynamics is influenced by the control system with proportional electromagnet.

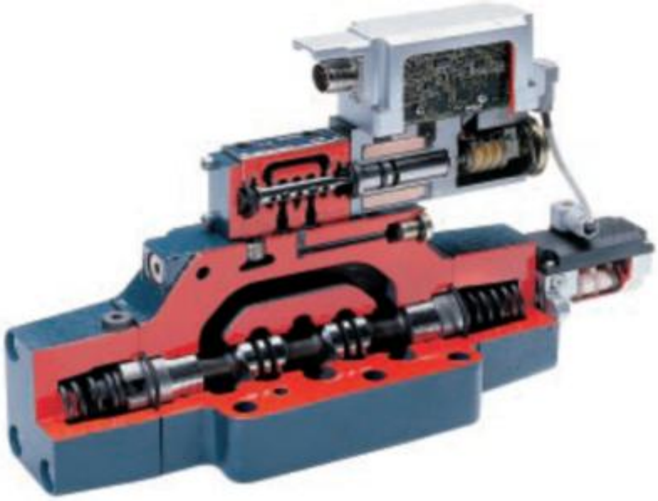


Fig. 3. Proportional directional valve with two LVDT’s

2.2 Proportional directional valve with pilot with proportional solenoids

A high response piloted proportional directional valve having proportional pilot with proportional solenoids is the one in Figure 4 [4]. It has a pilot with two proportional solenoids and a loop position control only for the main spool. The transducer for moving the main spool for hydraulic fluid distribution is housed alongside with the circuit board into a case.

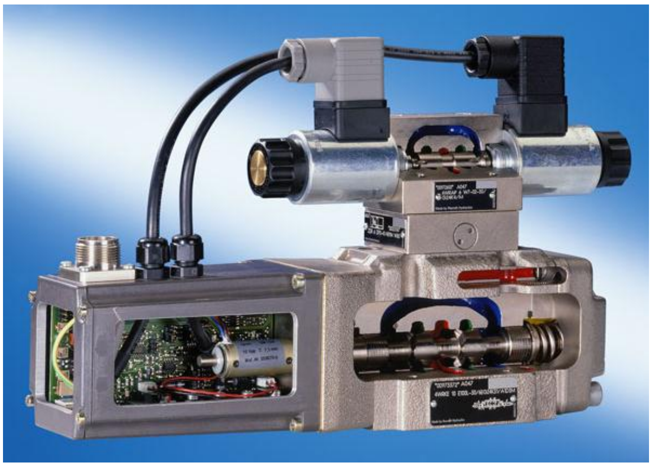
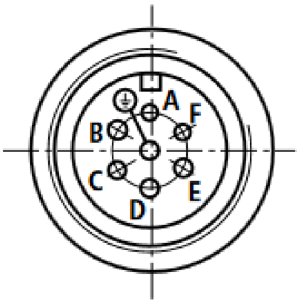


Fig. 4. Piloted proportional directional valve

In Figure 5 can be seen allocation of pins from electric connector of such equipment.



Pin	Allocation
A	24 V
B	0 V
C	Ref. for actual value
D	Command value
E	Ref. for com. value
F	Actual value

Fig. 5. Valve connector and pins

Between the D-E pins of directional valve can give command signal in ±10 V domain and between pins C-F can be read the signal value of the realized position of the spool also in the range of ± 10V.There are versions with 0 ... 10 mA or 4 ... 20 mAsignal, and other with digital communication options EtherCAT, Profinet, etc.

2.3 Proportional directional valve direct commandedwith linear force motor

In Figure 6 there is another type of directional valve with direct drive linear motor [5] with permanent magnets.The actuator with mobile coil has better linearity than proportional solenoid one.
At this directional valve, linear motor is located on one side and the electronics and the stroke transducer on the other side. Centering springs for spool are incorporated in linear force motor with permanent magnet.These directional valves have high dynamics and accuracy and are preferred for accuracy in positioning axes and hydraulic pressure control and speed. These directional valves reach frequency response of real servovalves. Electronics are made with microcontroller and have the possibiliity to be parameterized using a dedicated software.

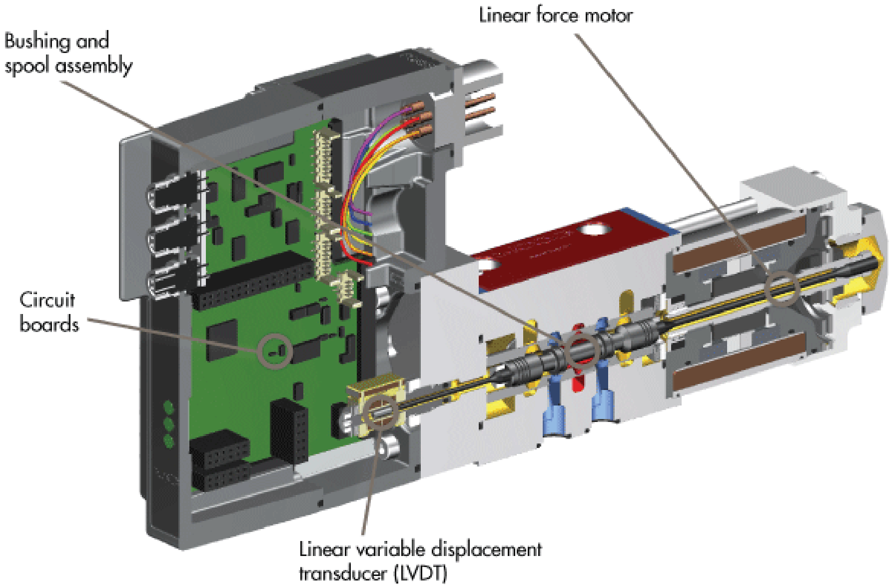


Fig. 6. Proportional directional valve with linear motor with permanent magnets

Table 1: Hysteresis by type of valve

	Direct operated			**Two-stage**	
Valve actuation	Open loop proportional solenoid	Closed loop Proportional solenoid	Voice coil linear motor	Hydraulic with mechanical feedback	Hydraulic with electrical feedback
Hysteresis	5 %	2 %	0,2 %	2 %	0,2 %

2.4 3 stage servovalve with on board electronics

The Servo valves are built also within 3 stage block. Such a servovalve is found in Figure 7[6]. To achieve a centre of the main spool it uses coil springs located in the side covers. Attached to the right cover there is a box containing the electronic control and transducer of LVDT type for the position of the spool. This servo valve has implemented a "fail safe" function. Between pilot body and main body it lies an on-off valvewith electric command to bring the main tray in a safe position depending on the version at voltage supply cutting. Anotherversion can bring to the center the spool where all hydraulic ports are closed with over laps. Another version can bring A→T after cut off of pilot pressure. These valves are suitable for the position, velocity, pressure and force control.

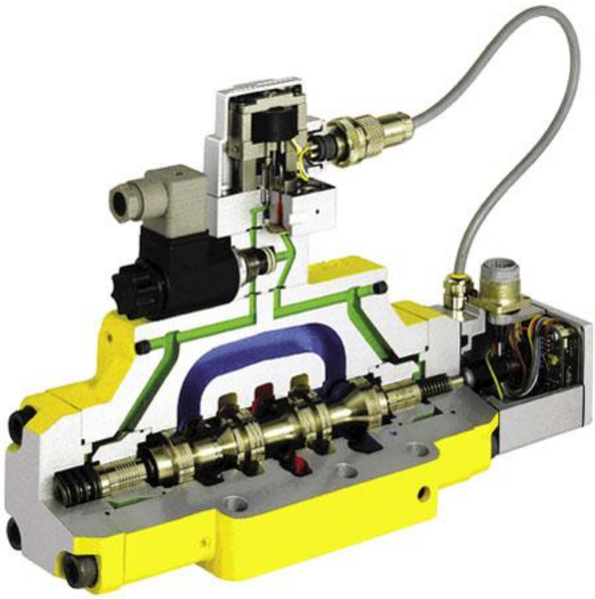


Fig. 7. 3 Stage servovalve

In fig. 8 can be seen a block diagram of the electronics incorporated in the body of the servo valve.

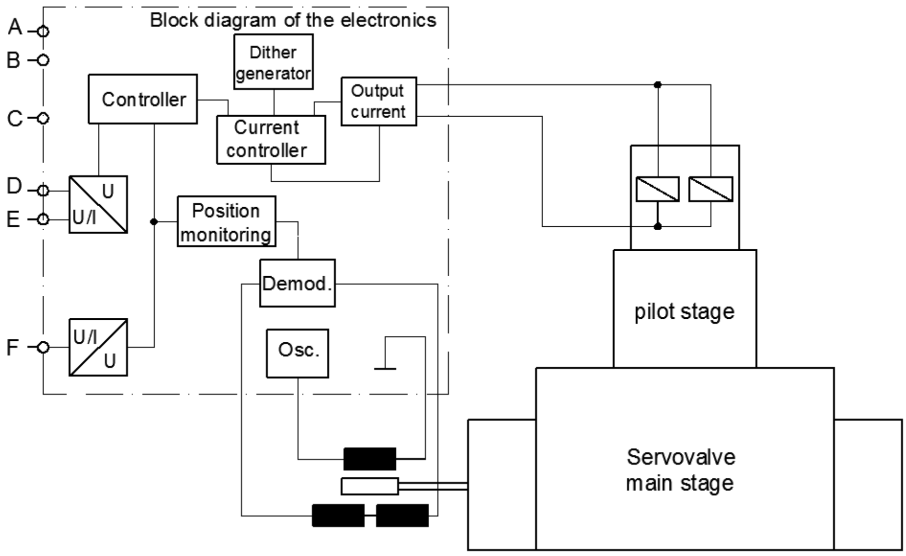


Fig. 8. Block diagram of the electronics of the servo valve

Testing this equipment is made by qualified personnel using specialized test stands. Characteristic curve of such equipment can be drawn in the laboratory using an application developed in LabVIEW. Such an application was used to obtain the characteristics of Figure 9. In figure 9 A was drawn a diagram for a classic servo valve without integrated electronics by recording flow values using a flow transducer. B chart in Figure 9 was obtained by recording the signal "actual value" provided to terminal F of a servo valve with integrated electronics. Comparing the two charts can see the difference between linearity and hysteresis of the two servo valves. The diagram of equipment with internal control loop (B) is linear and has a very low hysteresis.

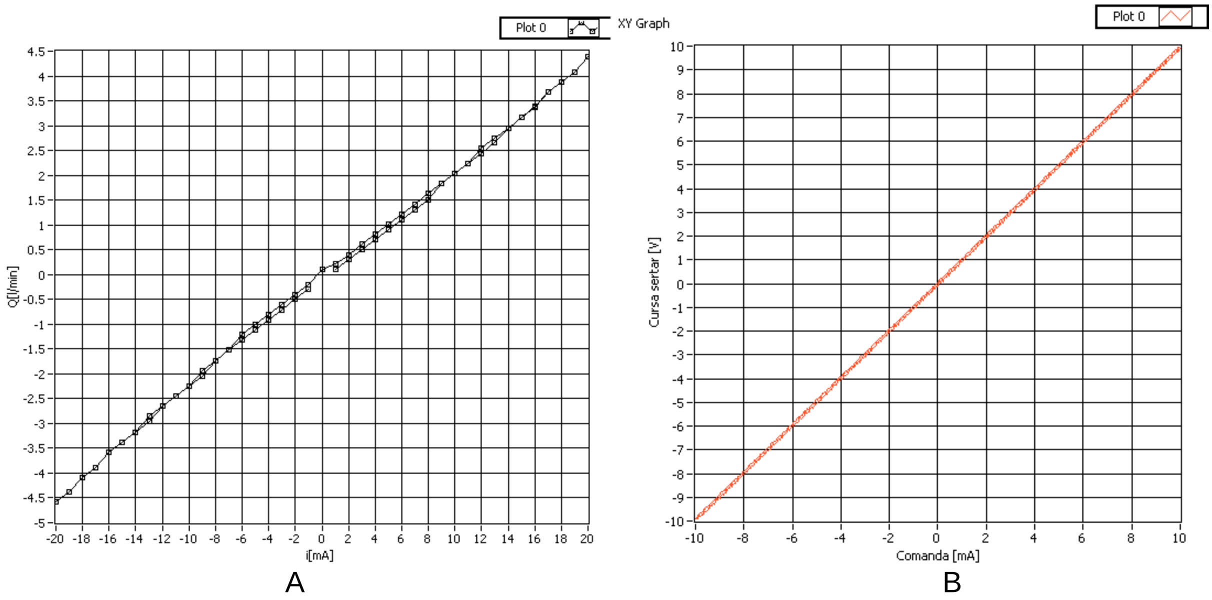


Fig. 9. Valves characteristic curves

3. Conclusions

Such equipment's include microcontrollers, sensors and high precision mechanical components. These devices can be used in industrial machinery for regulating the position, pressure, speed and force control.

Compared to classic proportional servo equipment, equipment with electric positioning system allows higher control loops, improving the dynamics and eliminating errors caused by hysteresis.

Maintenance of this equipment must be carried by specialized personnel or specialized companies, otherwise it may exist the risk of irreparable damage.

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