ISSN 1454 - 8003
Proceedings of 2019 International Conference on Hydraulics and Pneumatics - HERVEX
November 13-15, Băile Govora, Romania

ELECTROHYDRAULIC CONTROL DEVICES

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Abstract: *The article refers to the history of the theoretical and practical development, in Romania, of a sub-domain of great interest in the automation process, which is based on the hydraulic elements. The grouping of these equipments in the category of electro-hydraulic control devices was due to the fact that they are hydraulic, that they are adjustable, and the control is electronic. Specifically, these are electro-hydraulic servovalves and proportional electro-hydraulic directional valves.*

Keywords: *Servovalve, proportional valve, controller, PID controller*

1. Introduction

This material tries to remind the specialists in Romania that the field has been approached seriously and with theoretical [1, 2], but also industrial achievements, from 1965-1968 by some research units but also by some precision mechanics factories as well as by a specialized factory in production of hydraulic equipment. Sometime later, after 1974, the research, design and manufacturing activities of these equipments were intensively developed by the hydraulics team from the Institute of Machine Building led by PhD eng. Marin Virgil [3]. About the same period, only theoretical preoccupations began at University Politehnica of Bucharest at the Department of Automation (S. Florea, I. Dumitrache and Ilie Catana). At a certain time, the works from the aviation research units were also of great interest; those were projects carried out by several researchers including Ion Ionescu and C. Mares; also the servosystems and even servovalve achievements of the AEROTEH Bucharest factory were important.

2. Electrohydraulic servovalves

The first servovalves were developed at the level of experimental model and prototype by the engineers Mihai Popescu and Sergiu Medar who also called upon the team of precision engineering from the hydraulics factory in Ramnicu Valcea led by the foreman Popa. During this period, the SV60 servovalve was developed; it unfortunately also had some elements from the MOOG valves and did not exceed the maximum working frequency of 30Hz. About the same time, Prof. Patrut, together with the young specialists David and Tonciu, as well as with two precision engineering foremen, developed the first models of larger flow valves needed for applications with servo cylinders required for a seismic platform. Unfortunately, these achievements, although interesting and quite close to the international level, remained at the stage of experimental or functional models. The first industrial results in the country were obtained after passing the issue from the Institute for Machine-Tools to the Institute of Machine Building, team of proportional hydraulics. Here, engineers among which we mention Petrin Drumea, Mihai Stefan, Ioan Balan and Ion Moldoveanu, created a family of sevovalves, the SD series, sizes 60, 150 and 240 which recorded working frequency of 60Hz. During this period intense work was carried out in collaboration with the Institute of Physics in Iasi which, through the team of PhD. Chiriac, managed to solve the problem of the components made of permalloy, a material with high magnetic permeability qualities. One of the interesting industrial achievements was the servovalve pilot (SV00) developed at Electrotimis in Timisoara, used mainly in spark erosion machines (EDM) of their own manufacture. The same type of servovalve was also developed at IEH Ramnicu Valcea for general purpose industrial applications.

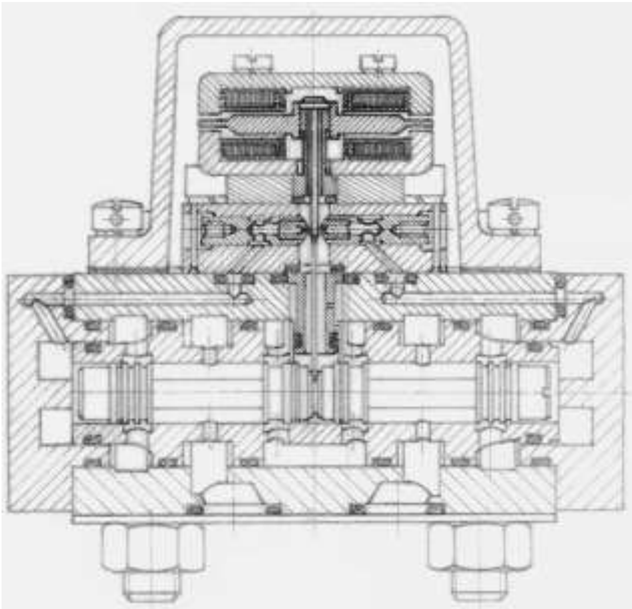


Fig. 1. SD60 hydraulic servovalve

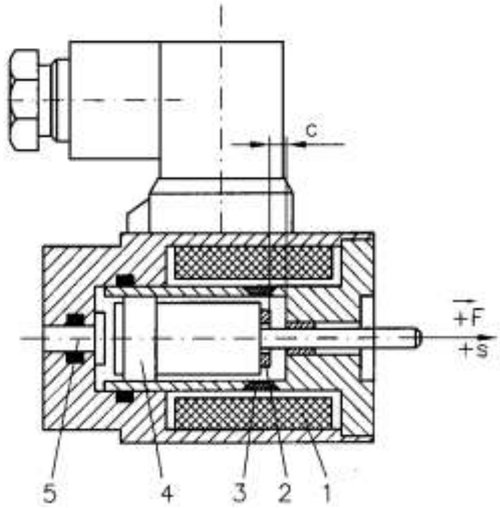
3. Electrohydraulic proportional valves

Proportional hydraulic devices appeared in the 60-70s, many years after the servovalves, due to two important economic factors. The first factor was that the price of the valves was extremely high; thus the entire hydraulic automation system became prohibitive. The second factor was that the number of hydraulic applications with the dynamics offered by servovalves was at most 20% of the total industrial hydraulic automation installations, the rest requiring much lower performance, and consequently the luxury of using servovalves was difficult to sustain. The solution of proportional hydraulic equipment was quickly found, and in this way the transition to industrial manufacturing was made at a rapid pace. The general solution is that in which the standard directional control valves, existing in manufacturing, for which there were standard technologies, have undergone small changes, especially in the control part, and have been transformed into proportional directional control valves, or proportional hydraulic valves [4]. Thus, by replacing manual or electrical controls with proportional force or stroke electromagnets, proportional hydraulic devices were obtained. Initially the team from ICTCM led by Dipl. Eng. Petrin Drumea, which also included the engineers Mihai Stefan and Ioan Balan, as well as the electronics team, led by Dipl. Eng. Mircea Comes, achieved the first force proportional electromagnet with which both directional control valves and hydraulic valves were equipped [5]. Proportional hydraulic equipment with proportional force electromagnets was introduced in series production at the hydraulics factory in Ramnicu Valcea where the proportional hydraulics group was quickly created within the servovalve team led by the foreman Popa [6, 7]. An important step in the direction of improving the manufacturing was taken with carrying out the first serious projects on an electromagnet, by Dipl. Eng. Mircea Comes, and making a manufacturing technology, by the foreman Ion Oprea, by which the axial alignment of the component elements was achieved [8, 9].

The force proportional electromagnet is an electrical device which develops, at the level of a central translation axis, an axial force proportional to the value of the electric current with which it is supplied.

A typical constructive solution of force proportional electromagnet is shown in figure 2.
The device consists of a magnetic circuit provided with a coil which is the magnetic field source. The magnetic circuit consists of a series of fixed cores and a plunger - mobile magnetic core which can move axially under the action of a magnetic field.

The axial displacement of the mobile core and implicitly of the translation axis is relatively small (usually between 1 ... 2 mm); on the other hand, the developed force is relatively important. In general, work is performed with electromagnets that develop a maximum force (at the maximum supply current of the coil) of the order of 8 daN. Characteristic force curve as a function of axial displacement, at constant supply current, F=f(c) for i_c =ct is shown in figure 3.



1 – coil; 2 – diamagnetic spacer; 3 – diamagnetic coil; 4 – plunger; 5 – plunger manual release piston

Fig. 2. Force proportional electromagnet

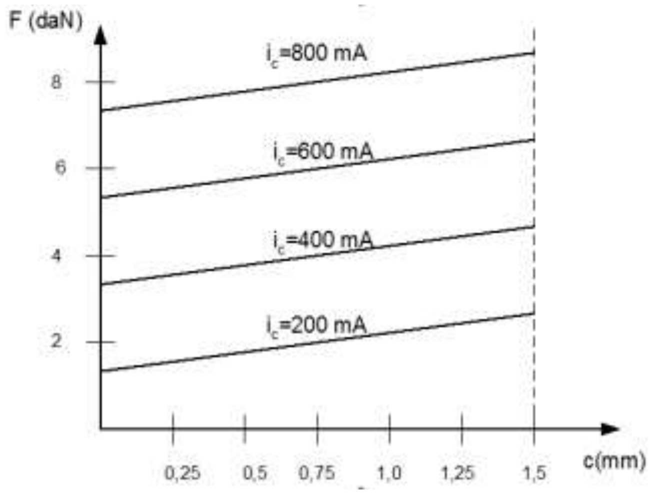


Fig. 3. The characteristic F =f (c), for i_c = ct of the force proportional electromagnet

The proportional hydraulic directional control valve performs its function through a translation slide valve, receiving control pressures at both ends, and from the difference in these pressure values a force of translation occurs. This force is balanced by the antagonistic force of an elastic system consisting of springs, after covering a displacement. Thus, proportionality is established between the displacement of the slide valve and the difference of the control pressures, implicitly the drive current of the actuator. By the construction of the device body, this movement of the slide valve causes progressive variations of the flow sections towards consumers. As one can see on the symbol, the device is provided with four hydraulic ports, namely:

- P - pressurized fluid supply port
- A,B - ports for hydraulic consumers
- T- return port
- The function of the device is to select the direction of flow to one consumer or the other and determine the flow rate to the selected consumer.

Depending on how the flow is, two categories of proportional directional control valves can be distinguished:

- Proportional directional control valves with progressive variation of the flow section (throttling). The flow varies proportionally with the control current in the situation when a constant pressure drop is maintained on the flow section through the device.
- Proportional directional control valves with embedded pressure regulator. The flow varies proportionally with the control current, for pressure drops on the flow section which may vary within relatively wide limits.

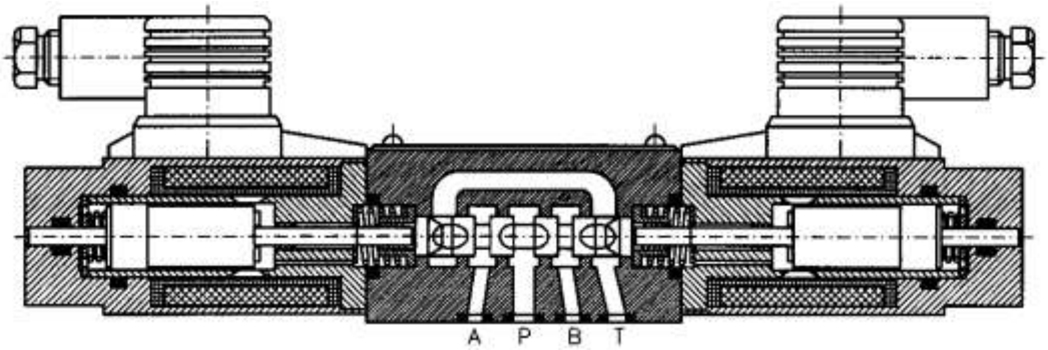


Fig. 4. Single stage proportional directional valve

4. Electronic control units

In the first years of interest of the Romanian specialists in the field the development of electronic control blocks was performed by hand, without a clear conception, and most of the time they were imported from the countries where there is already a mass production of this type of equipment. The first arranging of the subdomain and the transition to manufacture typification has been carried out by the Dipl. Eng. Mircea Comes, within the specialized group led by Dipl. Eng. Petrin Drumea. In time, the team has increased by hiring the engineers Adrian Grozea, Marian Blejan, Marian Neacsu and S. Smarandache. In 1981-1989, the electronic control blocks were standardized both for proportional equipment and for servovalves [10].

Servocontroller for electrohydraulic proportional valves

This servocontroller was designed to have a small printed circuit board that can be easily adjustable and can be used in as many applications. The diagram of fig. 5 is good for automatic control modules, intended for control of positioning systems, which use proportional hydraulic elements. It contains the following blocks: error amplifier, electronic PID controller, polarity separator for control with signal ± 10 V and a dual final power stage in switching mode for electromagnets A and B. In fig. 6 one can see the servocontroller assembly made on a printed circuit board which was mounted in an enclosure.

Servocontroller for servovalves

Servocontrollers for servovalves control have a structure similar to the servocontrollers for proportional elements. In this sense they contain the error amplifier and the PID type controller. Because the valves are equipped with bipolar electromechanical converters, the polarity separator block is no longer needed. Also, since the torque motor coils are usually connected in series or in parallel, a single output stage is required to generate the required servovalve current. Servovalves require a relatively low control current, up to 50mA on the coil, i.e. maximum 100mA. Therefore, the current voltage conversion stage does not need to be of the PWM type, the dissipated energy is much lower than in the case of proportional elements. Based on these considerations, the diagram of a servocontroller (fig. 7) for the control of electro-hydraulic servovalves has been developed.

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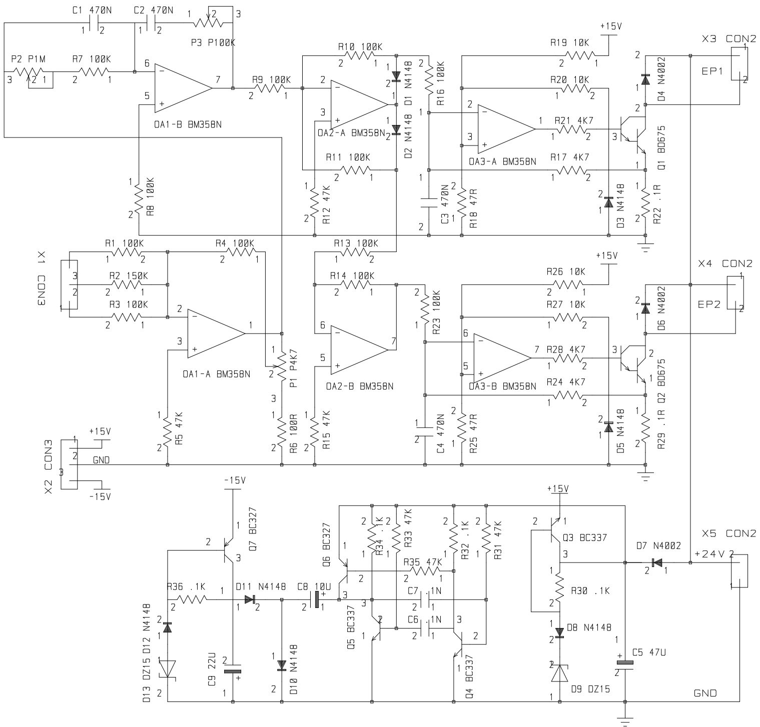

Fig. 5. PID controller diagram for proportional elements

Fig. 6. Mode of manufacturing for the controller for proportional elements

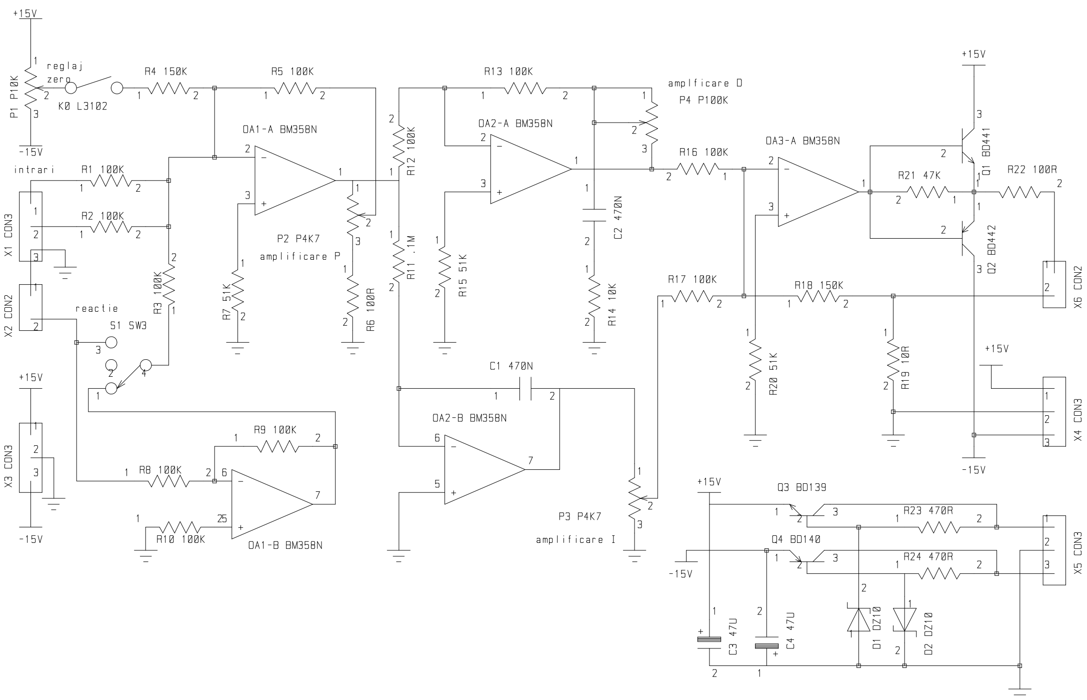

Fig. 7. Electronic diagram of servovalve controller

5. Conclusions

The field of electro-hydraulic control equipment has been approached at the same time with many of the industrially advanced countries. Unfortunately, the poor facilities of the hydraulics factories and the lack of specific materials, sometimes even special ones, prevented the realization of an intense manufacture.

Given the novelty of the field, the number of specialists using these equipments was quite small and as a result the demand for the industry for such products was kept low, so the size of the manufacture remained at the order of tens of pieces per year.

In the last 30 years, this sub-domain has also been abandoned, as is the case with most of the fields in the area of hydraulic drives.

Acknowledgments

This work was done under the scientific Programme NUCLEU 2019, Contract PN 19-18.01.01, Stage 21/2019.

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