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MULTIPURPOSE STAND IN THE FIELD OF HYDROSTATIC DRIVES

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Abstract: The reconfiguration of Romania's industrial production in recent decades, due to the opening of markets, has also had the effect of significantly reducing the national production of hydraulic components and systems. On the other hand, the demand was covered by imported equipment, which requires, after a period of time, repair or performance evaluation. The reduction of staff involved in the design of components and systems has led to a decrease in the volume of knowledge in the field of hydraulic drives, which is trying to be eliminated by training technical staff in the field in universities. Through the collaboration between the Research Institute for Hydraulics and Pneumatics in Bucharest and the Polytechnic University Timisoara, a stand was created that has a double function: it is used both in the process of training students and for testing equipment, on request, in the laboratory of hydraulic machines and systems at the university.
Keywords: test stand, hydraulic components, PLC, data acquisition

INTRODUCTION

Before 1990, the Romanian industry had a significant part of the production of hydraulic components, which were then integrated on a national level in various systems, so as to cover a large part of the demand for equipment with hydraulic actuation in the country, and to be offered for export. The component factories produced almost all types of hydraulic apparatus (pumps of various types, linear and rotary hydraulic motors, distribution and regulation apparatus, auxiliary apparatus). The penetration on the free market of some import components, from more or less famous manufacturers, at competitive prices, caused the demand for components produced in the country to decrease; at the level of 2022, Romania still produces only a few types of hydraulic components in significant quantities, as follows:

- gear pumps, at SC HESPER SA Bucharest
- distribution and regulation equipment, at SC HIDROSIB SA Sibiu
- linear hydraulic motors, at WIPRO Infrastructure Engineering Râmnicu Vâlcea

Some of the hydraulic equipment importers also offer design, execution, commissioning services for systems made with imported equipment. There are also a significant number of companies that deal with the repair of hydraulic equipment, and in particular pumps and motors.

Both for some products that have gone through a maintenance process and for those that have been repaired, a performance evaluation is necessary, which can only be done with specialized equipment, such as stands equipped with modern parameter measurement systems. Under certain conditions, the owner of such a stand can provide training services in the field, especially if he has staff with teaching capabilities. Using a performance stand in a technical university has several social and economic benefits:

- is used to deepen technical skills in the field of hydrostatic drives for students
- provide experimentation reports for equipment of beneficiaries in industry and services (the university is a provider of performance evaluation services)
- can be included by the university in the professional development process of employees from various companies that request training in the field.

In this context, the idea of a multifunctional stand appeared, to be used by the Politehnica University of Timisoara, both for didactic activity with students and to offer services to interested companies (Kheiralla, A.F. et al., 2007; Elshorbagy, K.A. et al., 2018). The services mainly consist of testing repaired pumps and hydraulic motors or new linear hydraulic motors produced by the companies (Achten, P. et al., 2017).

STRUCTURE AND CHARACTERISTICS OF THE EQUIPMENT

The structure of the stand was designed in such a way as to meet the 2 purposes, didactic and economic (Meng, F.H. and Zhang, J.H., 2013; Salah, T. and Kassem, S., 2012). Thus, a complex structure was created, which provides information about several types of devices: pumps, motors, distributors. The stand has a specialized module for testing linear hydraulic motors, a module for rotary hydraulic machines (Grama, L. et al., 2013) and an auxiliary tank equipped with devices that work together with the two testing modules. The scheme of the stand can be found in Figure 1.

The operation of the stand, as well as the acquisition of the experimental data (Chen, F. and Yan, G., 2011) resulting from the test, is managed by an electrical subassembly that has a PLC as its basic component (Grama, L. et al., 2009).

The diagram of the stand contains pumps P1 and P2, driven by electric motors EM1 and EM2, two base plates on which the limiting valves RV1 and RV2 are mounted, as well as directional control valves DCV1 size 6 and DCV2 size 10. With the help of directional control valve DCV1 auxiliary control circuits can be powered. With the help of DCV2, the testing modules for rotary machines and hydraulic devices can be powered. Through a series of ball valves (HBV) it is possible to feed or isolate the different circuits that feed the cylinder test modules, hydraulic pumps/motors or the area for testing distributors, valves, servo valves, flow regulators or throttle valves (Michelson, S. et al., 2012).

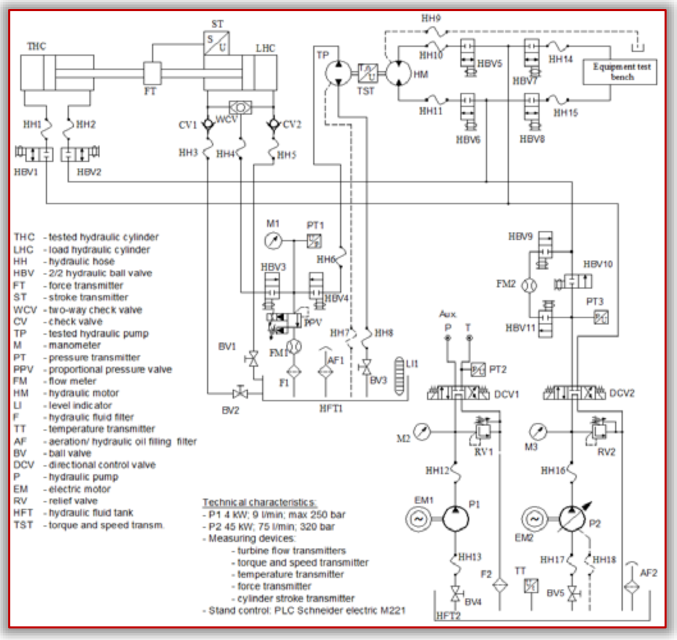

Figure 1. Scheme of the test stand used for hydrostatic drives

This work area is arranged on the cover of the main tank, in the form of a plate that has channels for the mechanical fixation of the test apparatus. The hydraulic circuits are made with hydraulic pipes and a series of HH hoses, to prevent vibrations (Castro, R.M. et al., 2014).

The auxiliary hydraulic fluid tank allows the supply of the tested pump TP or another pump used as a load for a tested hydraulic motor HM and the hydraulic load cylinder LHC, which can perform loads for the tested hydraulic cylinder THC. The load level on linear or rotary hydraulic motors can be adjusted using the PPV proportional valve.

To measure the mechanical and hydraulic parameters, the PT pressure transmitters, the FM flow transmitters, the FT force transmitter, the ST hydraulic cylinder rod position transmitter, the TST torque and speed transmitter and the TT oil temperature transmitter, are used in the stand diagram. For the direct visualization of the regulated pressure at the valves, the M pressure gauges can be used.

THE MAIN CHARACTERISTICS OF THE STAND

If in terms of the didactic nature of the stand, a very high drive power is not required, but for performing of test services the stand must have sufficient power to allow testing a significant part of the existing hydraulic equipment.

The maximum flow rate, and therefore also the pump displacement, is calculated using formula (1), and is a function of the working pressure, but also of the pump type.

$$N = \frac{Q \cdot P}{600 \cdot \eta_t} \, [\mathrm{kW}] \tag{1}$$

where:

Q – pump flow, in l/min

P – outlet pressure

η_t – the total efficiency, which is calculated with the formula:

$$\eta_t = \eta_v \cdot \eta_{mh} \tag{2}$$

For pumps working at pressures of max. 210 bar (gear pumps, vane pumps, e.g.) and have lower efficiencies (0.85), the maximum flow will be:

$$Q_{max} = \frac{N \cdot 600 \cdot \eta_t}{210} \tag{3}$$

resulting in $Q_{max.}$ = 45 • 600 • 0.85 / 210 = 109.3 l/min, where total efficiency η_t was estimated at the value of 0.85, according to Table 1.

For a pump with a higher efficiency (pumps with axial pistons, η_t = 0.92), using formula (2) and considering a higher working pressure of 315 bar, we obtain a maximum flow rate of 78.9 l/min.

Through the variation of the displacement or the drive speed of the pumps, it is possible to carry out tests at pressure and flow superior to those above, under the conditions of maintaining the value of the product P • Q at values that do not lead to exceeding the power of 45 kW (taking into account and the efficiency of rotating machinery, η_t).

The total efficiency can also be appreciated with the help of the Table 1.

Table 1. Efficiency of hydraulic pumps (Internet source: Casey, B., 2011)

Pump type	Overall Efficiency %
External gear	85
Internal gear	90
Vane	85
Radial piston	90
Bent axis piston	92
Axial piston	91

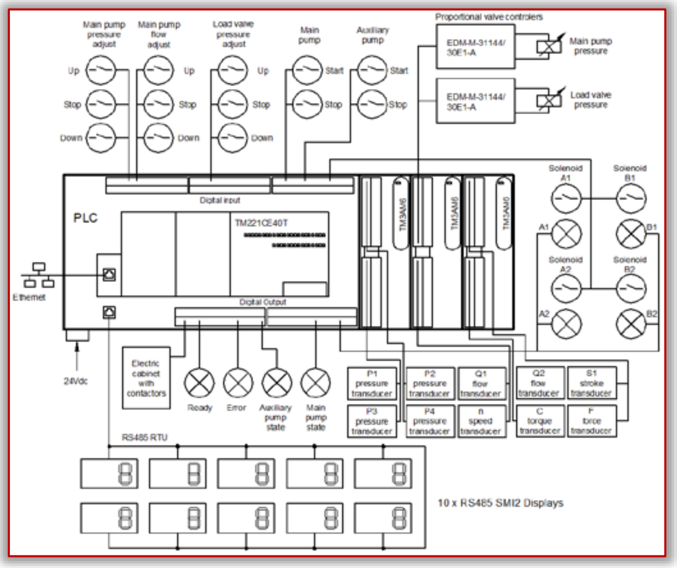

Figure 2. Block diagram of the operating console equipped with PLC

The control panel of the stand (Figure 2) is made with a programmable logic controller M221 from Schneider Electric (Figure 3). It has 24 digital inputs, 16 transistor source outputs, 2 analog inputs, a serial line port, Ethernet port, 24

Vdc power supply. To connect the transmitters and the controllers for the proportional valves to the PLC, three TM3AM6 modules were attached, which have 4 voltage or current inputs and 2 voltage or current outputs.

Stand commands are made by push buttons, with visual confirmations by means of indicator lights. To adjust the pressure and the flow rate, digital Up/Down buttons were implemented with the help of PLC. The on or off status of the pumps, stand ready or certain error codes can be visualized with the help of indicator lights. The solenoids from the 4/3 directional valves also have luminous confirmations in the control buttons. To view the adjusted values for the flow rate and pressure from the main pump and to display the values read by the transmitters, on the panel are displays with RS485 communication type SMI2 produced by Akytec.

Figure 3. PLC Schneider Electric M221 with analog input/output modules and the proportional controllers located in the electrical cabinet

Characteristics of the transmitters:

≡ Pressure: 250 bar and 400 bar ;
≡ Flow: 120 l/min and 60 l/min turbine flow transmitters;
≡ Torque and speed: 500 Nm and 360 pulses/rot;
≡ Temperature: 0…100 °C Pt 100 temperature transmitter;
≡ Force: 10000 kgf;
≡ Linear displacement: 0…1200 mm.

OBTAINING EXPERIMENTAL DATA

The results of the tests carried out on the stand, both laboratory works for students and tests of different hydraulic equipment made for various companies can be recorded graphically with the help of a PC application (Figure 4).

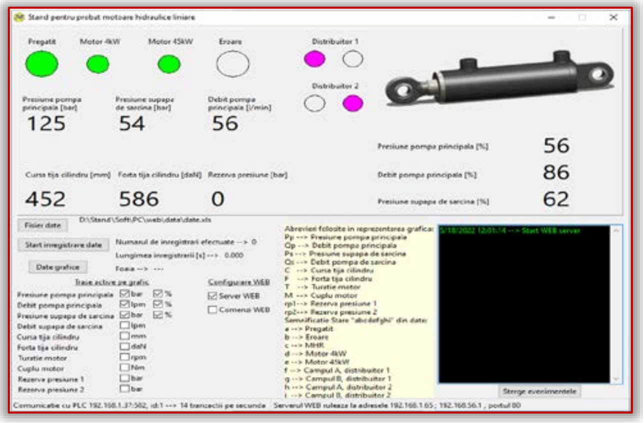

Figure 4. The main panel of the PC application

In Table 2 it can be seen the addresses assigned for the parameters used by the test stand. From address 23, information can be obtained about the solenoids of the hydraulic directional valves that are activated, the testing module that is active, the electric motors that are in operation, stand ready and various error signals.

The operator can select which parameters to be recorded depending on the tests performed. The recorded diagrams can be exported to the Clipboard and are automatically saved in a Microsoft Excel file, the file name containing the current date and time.

The stand test application also contains a Web server that can be activated to view the stand parameters on mobile devices through a web browser. The operator can also activate the Web command function so that commands can be given for the 2 directional hydraulic valves or the flow and pressure values of the main pump and the pressure of load valve can be changed. To record the diagrams, the application uses the parameter values transmitted by the programmable logic controller through the Modbus TCP/IP protocol in the local network. Parameters such as main pump pressure and flow rate, hydraulic cylinder stroke, hydraulic motor speed etc. they are identified with the help of numerical addresses (memory words in the PLC).

Table 2. Allocation of Modbus registers for the parameters monitored by the analog inputs of the PLC

Memory word	Adress	Symbol
1	%MW10	PMPPRES
2	%MW11	PMPFLOW
3	%MW12	VALVPRES
4	%MW13	STROKE
5	%MW14	FORCE
6	%MW15	FLOW1
7	%MW16	FLOW2
8	%MW17	TORQUE
9	%MW18	PRESS1
10	%MW19	PRESS2
11	%MW20	PRESS3
12	%MW21	PRESS4
13	%MW22	SPEED
14	%MW23	STATE

Figure 5 shows a fragment of the ladder diagram used to acquire data using the programmable logic controller.

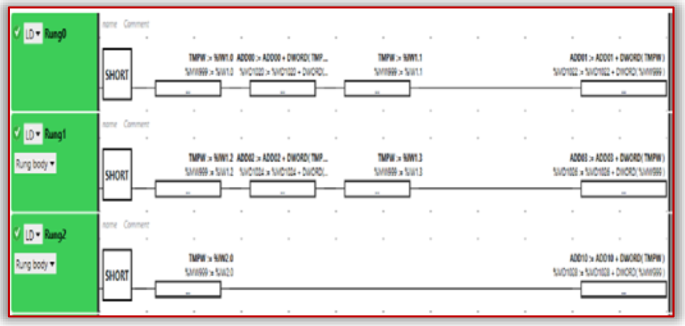

Figure 5. Ladder diagram for data acquisition from stand transmitters

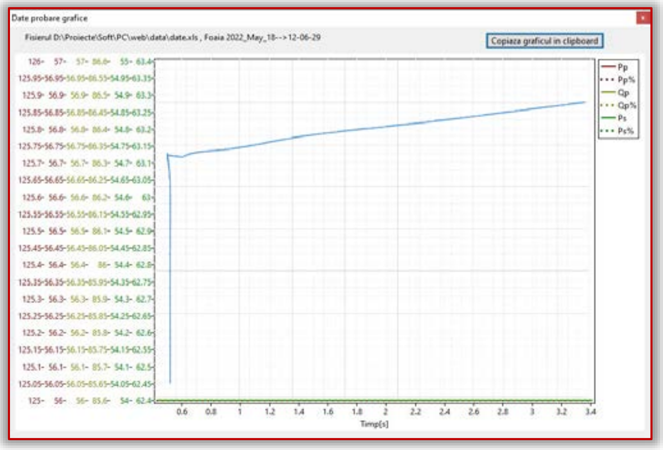

Figure 6. Graphic display of the PC application

Figure 6 shows the application window in which different graphs can be drawn for the different parameters of interest depending on the testing carried out. The recorded graphics can be selected from the main panel of the application. The graphs are displayed superimposed, each plot having a corresponding color and scale. The parameter plots in the graph can be identified with the help of a legend displayed next to the graph.

CONCLUSIONS

The stand allows the realization of laboratory works with students as well as the testing of hydraulic equipment for companies.

The modules of the stand allows the testing of different types of hydraulic devices; thus, with the help of linear hydraulic motors and rotary hydraulic motors subassemblies, linear hydraulic motors (hydraulic cylinders), pumps and rotary hydraulic motors can be tested, and to the fixing plate on the main hydraulic fluid tank, can be tested devices from the category of hydraulic regulation and control equipment: directional valves, servo valves, pressure valves, throttle valves , flow regulators etc.

The stand is modern and is equipped with measuring equipment, transmitters and software application for data acquisition and storage.

The operating parameters of the test stand are transmitted via Modbus TCP / IP protocol in the LAN network.

The monitoring of the operating parameters of the stand can be done, by the students, by a web browser through a web server that can be activated from main software application.

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