

## TECHNOLOGY AND COMPUTERIZED STAND FOR PROOFING REVERSIBLE HYDROSTATIC PUMPS

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**Abstract:** *The paper presents complex issues that involves the development of a technology and a computerized testing stand for reversible hydrostatic pumps and highlights the multitude of parameters to be measured and monitored in their probation. Using specially developed software, the computer system control and monitoring, data processing manages the operation and purchased on a modern instrumentations, proper application and provide documents that show the results of tests performed.*

**Keywords:** *Computerized stand, hydraulic pumps, closed hydraulic circuit, verification of hydrostatic pumps, stand for testing, experimental verification.*

### 1. Introduction

Reversible hydrostatic rotary pumps (also called "closed loop") are complex high-tech products, used in a wide range of applications, of which only exemplify their use to achieve hydrostatic transmissions of mobile machinery.

In order for verification of technical characteristics and periodic certification or after repair, the pumps must be checked after specific methodology and using specialized test stands.

A modern test system requires the existence of information technology in its structure. In addition experimental test systems should include in their composition sensors and high precision transducers, knowing that usually one transducer must be more precise with an order of magnitude than the precision of the size checked.

### 2. Tests and checks on hydrostatic reversible pumps

Reversible hydrostatic pumps are subject to two categories of evidence: type and batch. Samples and checks content is presented in Table 1.

TABLE 1

| Item No. | Checks, tests                   | Of type | Batch |
|----------|---------------------------------|---------|-------|
| 1        | Exterior aspect                 | x       | x     |
| 2        | The size of principal parts     | x       | -     |
| 3        | Principal parts materials       | x       | -     |
| 4        | Connection size and gauging     | x       | -     |
| 5        | Mass                            | x       | -     |
| 6        | Geometric volume "in charge"    | x       | x     |
| 7        | Geometric volume "without load" | x       | x     |
| 8        | Maximum pressure                | x       | -     |
| 9        | Nominal pressure                | x       | x     |

|    |                                   |   |   |
|----|-----------------------------------|---|---|
| 10 | Minimum pressure                  | x | x |
| 11 | Maximum speed                     | x | - |
| 12 | Rated speed                       | x | x |
| 13 | Minimum speed                     | x | - |
| 14 | Flow "in charge"                  | x | x |
| 15 | Flow "without load"               | x | x |
| 16 | Flow pulsations                   | x | - |
| 17 | Strong flow losses                | x | x |
| 18 | Power at the pump shaft           | x | - |
| 19 | Noise level                       | x | - |
| 20 | Outside the air tightness         | x | x |
| 21 | Operation at extreme temperatures | x | - |
| 22 | Lifespan (endurance)              | x | - |

### 3. Technology for testing reversible hydrostatic pumps

Testing technology for reversible hydrostatic pumps presented in this paper concerns only samples that are essential for assessing the quality of these products. [1]

For making attempts with research character, such as for example samples for checking functioning in dynamic conditions, procedures may be supplemented by:

- Elements of measuring physical quantities of mechanical nature (including hydraulic) and convert them into electrical nature sizes;
- Specialized equipment in the IT (information technology) for signal processing from the testing process;
- Testing instructions adapted to the special accuracy and the particular nature of the tests.

#### 3.1. General principles

Testing technology of hydrostatic rotary machines will include:

- Hydraulic scheme of proof;
- Structure (composition) scheme of hydraulic test equipment;
- Instructions regarding the development of tests;
- Indications concerning the expression of results verifications;
- Other information necessary for carrying out the tests.

In the category were included run-checks, although it is not a test in itself, but an operating system product that can be equated with commissioning. [2]

By running product aims to operate at nominal parameters by anointing primary work surfaces in relative motion and be slack their efforts so they can take maximum contact.

The realization depends on correct running-in of the product and the mean proper functioning.

It is advisable to make the running-in test stand because it allows precise adjustment of product and functional parameters of the working fluid. [3]

#### 3.2. Measurement parameters

For measuring the parameters presented in paragraph 2 is used, besides conventional measurement devices and modern equipment where operations are performed using measurement transducers that offer the possibility of automation and introducing of information technology in the process of testing. In this way it performs automatic adjustment of the imposed parameters and automatic recording of the measured parameters. [4]

##### ● Pressure measurement

Pressure transducers most commonly used at equipping test stands for reversible hydrostatic pumps are:

- With elastic sensitive elements (curved tube, diaphragm, bellows, etc.);

- With piezoelectric elements.

● Flow Measurement

Reversible rotary pumps circulating flow is measured by direct or indirect methods:

- Transducers used to measure by direct methods are the type with fixed volume measuring chamber (graduated beaker) and is suitable especially for the drainage pump flows;

- Transducers used to measure flow by indirect methods are: the ratchet driven by jet, turbine, mass (with production forces Coriolis) with decreasing flow section (diaphragm, nozzle, bellows), swirl jet (type Vortex) with inarticulate dipping and without elastic reaction (flowmeter), but immersion articulated (flip).

● Measuring of the rotation speed

The main types of speed transducers used in hydraulics are DC or AC tachogenerators and speed transducers with photoelectric elements, inductive or magnetic.

● Power Measurement

Determination of reversible hydrostatic pump energetic characteristics requires measurements of torque and effective powers.

Because the pump always work coupled with another driving unit, power consumption at the pump shaft can be measured in two ways:

- Directly, with instruments and transducers for electrical power if the pump is driven with electric motor with known parameters (including yield);

- Indirectly, by measuring the torque drive using torsionmetric couplings interspersed between the spindle motor and pump shaft; in the same time is measured the drive speed also.

● Other sizes involved in the process of testing the reversible hydrostatic pumps - length, time, strength, temperature, density, viscosity, etc. - can be directly measured with callipers, stopwatch etc., or indirectly with transducers of various types.

3.3. Sampling scheme and layout

Hydrostatic testing scheme of reversible pumps is shown in Fig.1, and structure (component) scheme in Table 2.

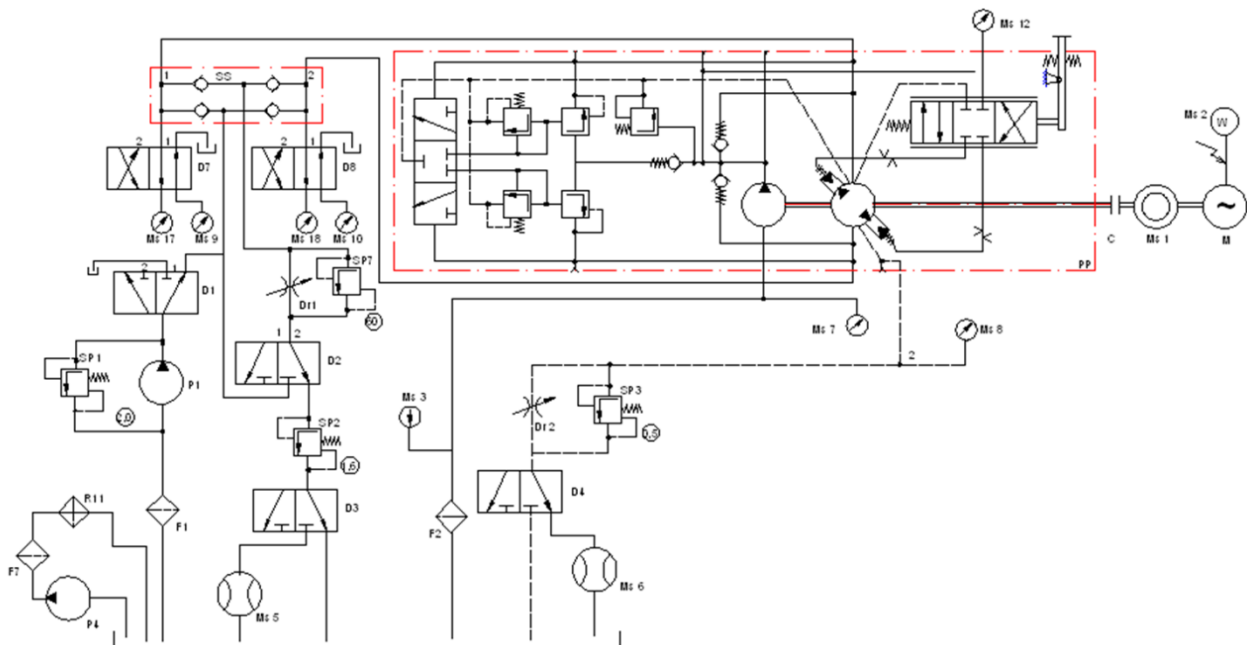


Fig.1. Hydraulic testing diagram for reversible pumps.

TABLE 2

| Symbol   | Name and explanations  |
|--|------------------------|
| PP   | Tested pumps           |
| F <sub>1</sub> , F <sub>2</sub> , F <sub>3</sub> | Filters 10 micrometres |

|                            |                                  |
|----------------------------|----------------------------------|
| $K_n$                      | Coupling                         |
| M                          | Drive motor                      |
| $M_{S1}$                   | Tachometer                       |
| $M_{S2}$                   | Power Meter                      |
| $M_{S3}$                   | Oil temperature measurement unit |
| $M_{S5}, M_{S6}$           | Flow Meter                       |
| $M_{S7}$                   | Pressure gauge - 100 ... 300 kPa |
| $M_{S8}$                   | Pressure gauge 0 ... 600 kPa     |
| $M_{S9}, M_{S10}, M_{S11}$ | Pressure gauges 0 ... 2.5 MPa    |
| $M_{S17}, M_{S18}$         | Pressure gauges 0 ... 60 MPa     |
| $P_1$                      | Pumping aggregate 16 MPa         |
| $P_4$                      | Coolant pump and oil filter      |
| R                          | Oil cooler and heater            |
| $SP_1, SP_2, SP_3$         | Pressure valves 16 MPa           |
| $SP_7$                     | 40 MPa pressure valve            |
| Dr1                        | Throttle 40 MPa                  |
| Dr2                        | Throttle 16 MPa                  |
| SS                         | Check valve                      |
| $D_1, D_2, D_3, D_4$       | Distributors 16 MPa              |
| $D_7, D_8$                 | Distributors 40 MPa              |

### 3.4. Testing methodology

Testing methodology presented below refers to reversible hydrostatic pumps, fitted with adjustable servo-controlled mechanism that is commonly used in applications such as "hydrostatic transmission". [5]

Apparatus which realise refresh functions, safety and clearing required in a closed hydraulic circuit (it involves switching valve, non-return valve and pressure valves) are tested separately. On bench testing for pumps can only made adjustment of pressure safety valves of the working circuit and the auxiliary circuit.

#### A. Checks carried out outside the testing stand

- external visual inspection;
- checking of dimensions and outline;
- verification of the mass (weight).

#### B. Checks carried out on the testing stand

##### ● Testing conditions

- the testing bench should not introduce radial or axial forces at level of drive shaft ;
- drainage pipe shall be so located that the proven pump to be permanently filled with oil;
- the testing bench has a device for continuous regulation and with retaining of the mechanic servo-control lever.

##### ● Stand Function

- discharge pressure is adjusted by Dr 1 throttle;
- drainage pressure is regulated with Dr2 throttle;
- the pump flow will be measured with the flowmeter  $M_{S5}$ , by switching the distributor  $D_3$  to position 2;
- the drainage flow will be measured with the flowmeter  $M_{S6}$ , by switching the distributor  $D_4$  to position 2.

##### ● The running-in and checking external seal

Because tested pumps are reversible pumps, will take care that the  $D_7$  and  $D_8$  distributors to be switched in such a way that the high pressure will be at measuring apparatus  $M_{S17}$  and  $M_{S18}$ .

Adjusted parameters and their values are presented in table 3.

TABLE 3

| Sense of displacer | The pressure at the connector A $p_a$ [MPa] | The pressure at the connector B $p_b$ [MPa] | The pressure of the drainage $p_{dr}$ [kPa] | Time $t$ [min] | Obs.                     |
|--------------------|---|---|---|----------------|--------------------------|
| A $\rightarrow$ B  | $p_{min}$                                   | $1/3 \times p_{nom}$                        | max   | $t_1$          |                          |
|                    |   | $2/3 \times p_{nom}$                        | max   | $t_2$          |                          |
| B $\rightarrow$ A  | $1/3 \times p_{nom}$                        | $p_{min}$                                   | max   | $t_3$          |                          |
|                    | $p_{nom}$                                   |   | max   | $t_4$          | Check external tightness |

- Zero setting
  - during "zero" position adjustment of the pump, servo-command should not be operated;
  - setting is done with testing bench in closed circuit (distributor D2 switched to field 1 and distributor D1 to field 2), by progressive closing of the throttle DR1 and correction of the pump's swing gear downwards the pressure difference measured with the pressure gauges MS17 and MS18.
- Swinging (tipping) time
  - measuring the time in which the capacity of the pump increases from  $V_g = 0$  at  $V_g = \max$ . is made with the testing bench in closed circuit mode and Dr1 throttle valve closed completely;
  - a swinging command is done to the maximum displacement and measures the time to achieve maximum power drive, read on the device MS2. Measurement is made for both driving directions of the pump.
- Functional control
 

For the functional control will make the following checks:

  - verification of the maximum displacement at idle;
  - verification of the maximum displacement in full charge;
  - internal flow loss;
  - drive power in charge.

These checks will be made for both direction of rotation of the pump.

Adjusted parameters and their values are presented in table 4.

TABLE 4

| Sense of displacement | The pressure at the connection A - $p_a$ [MPa] | The pressure at the connection B - $p_b$ [MPa] | Drain pressure $p_{dr}$ [kPa] | Measured parameters   |
|-----------------------|--|--|-------------------------------|---|
| A $\rightarrow$ B     | $p_{min}$                                      | $p_{min}$                                      | < max                         | $n_{an}$ – drive speed<br>$Q_{vg\ max}^{p\ min}$ – maximum flow at low pressure   |
|                       |  | $p_{nom}$                                      |                               | $Q_{vg\ max}^{p\ n}$ – maximum flow at rated pressure<br>$Q_{dr}$ – the flow lost by drainage<br>$P_{an}$ – maximum drive power<br>$n_{an}$ – drive speed |
| B $\rightarrow$ A     | $p_{min}$                                      | $p_{min}$                                      | < max                         | $n_{an}; Q_{vg\ max}^{p\ min}$  |
|                       | $p_{nom}$                                      |  |                               | $n_{an}; Q_{vg\ max}^{p\ min}; P_{an}; Q_{dr}$  |

The parameters derived are:

- geometric volume without load 
$$V_g^{p_{min}} = \frac{Q_{V_g^{max}}^{p_{min}}}{n_{an}}$$

- geometric volume with load 
$$V_g^{p_{nom}} = \frac{Q_{V_g^{max}}^{p_{nom}}}{n_{an}}$$

- loss of displacement 
$$\Delta V_g = V_g^{p_{nom}} - V_g^{p_{min}}$$

● Adjusting pressure valves

The adjustment of the pressure regulating valves of the reversible pump is done when the throttle Dr1 is closed to maximum displacement  $V_g = \max$  and speed  $n = n_{nom}$ , and the adjustment of the pressure valve fitted on the auxiliary pump (refresh pump) is made when  $V_g = 0$  and  $n = n_{nom}$ .

- maintaining  $V_g = \max$  will do for a few seconds (5...10 sec.). A higher duration of operation at  $V_{g_{max}}$  with throttle Dr 1 closed leads to overheating the pump because the oil in the circuit no longer passes through the cooler;

- between two switches to  $V_{g_{max}}$ , the pump must operate a while (30 ... 60 sec.) in "zero" position, for cooling.

#### 4. Computerized testing bench for testing reversible hydrostatic pumps

##### 4.1. The constructive and functional principles

Testing bench proposed by the authors for testing the reversible hydrostatic pumps is based on the following principles:

- allows testing reversible hydrostatic pumps most widespread in the field of hydraulics;
- is built starting from a model that can be fitted with various interchangeable mechanical, hydraulic or electronic attachments, allowing to perform complete tests for the reversible hydrostatic pump;
- allows further developments and implementation of information technology.

Commands, settings and record for the measured parameters is carried out as follows:

- for batch tests: commands, settings and recording parameters is performed in automatic mode;
- for type and periodic test: the distribution taps' command and the adjustment of parameters are manually done, and recording parameters obtained on tests are automatically.
- the test of endurance: adjustment of parameters of the sample is done manually, and adjusted parameters are checked and adapted periodically. In this sample does not use automatic control loops.

##### 4.2. Block diagram of computerized stand

Block diagram of the stand used for testing reversible hydrostatic pumps is shown in Fig. 2.

The stand has two tuning loops through which it controls automatically the following parameters:

- pressure on the discharge side of the pump;
- oil temperature;

Cooling fluid work is done with cooling equipment dipped in the oil.

##### 4.3. The computer system for control and monitoring of parameters

The computer system for control and monitoring of parameters has the role to control the command elements and to monitor sensors from the stand. [6] The system configures and monitors the stand in order to achieve type and batch tests for hydrostatic pumps, reversible. Database management subsystem provides management of the acquired data during sampling and generates tests result.

Functional, the computer control and monitoring system of parameters consists of an electrical force subsystem, monitoring and control subsystem, and the subsystem of data bases. [7]

Constructive, the system consists of electric and automation panel, operator control panel, transducers and electro-hydraulic command elements located on the stand, PC as well as electrical wiring of the stand.

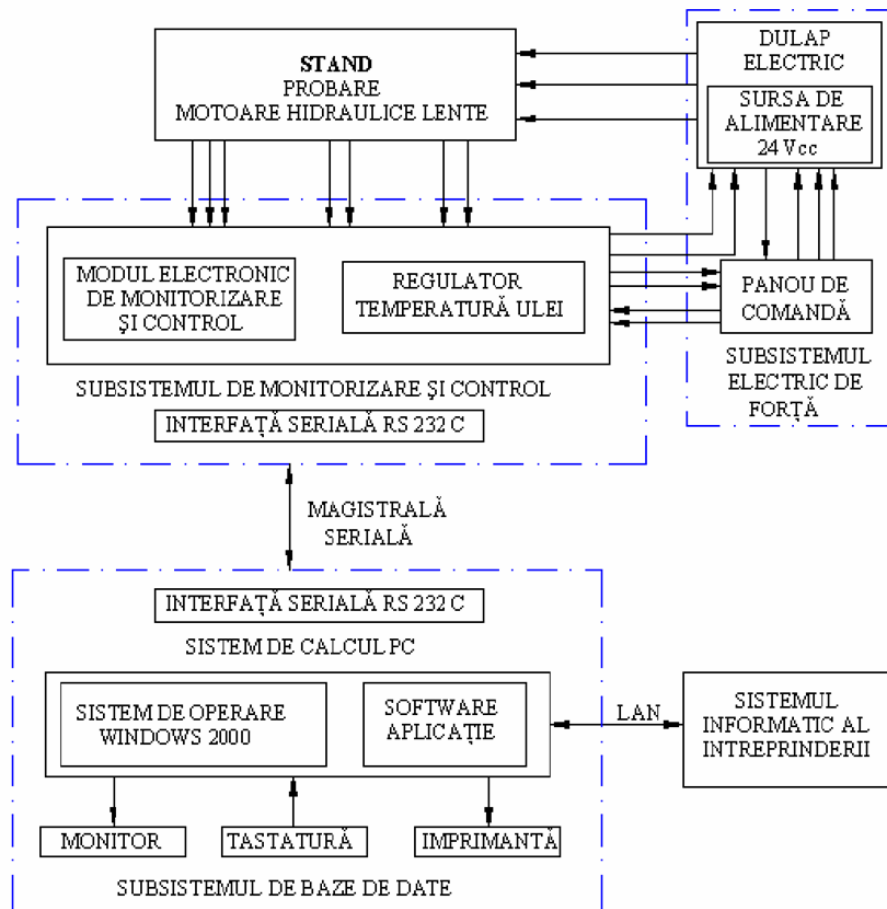


Fig. 2. Block diagram of reversible hydrostatic pump test stand

#### 4.3.1. The electrical force subsystem

This subsystem is designed to command the power elements placed on the stand. From the construction point of view, this subsystem is arranged in the electrical cabinet of the stand and in the front panel of the stand.

This subsystem ensures command for the following elements:

- the electric motor to drive the proved pumps - M;
- the electric motor to activate pump aggregate of 16 MPa - P1;
- the electric motor for hydraulic cooling and filtration pump - P4;

The subsystem provides both overcurrent protection for electric motors, as well as specific interlocking booth operation.

This subsystem contains a 24 V DC power supply source too, stabilized voltage for transducers and electronic modules of the stand as well as for the signalling elements and command buttons placed on the automation cabinet and the closet panel.

Implementation of the logic of operation of the electrical subsystem of force is made with a PLC.

#### 4.3.2. Monitoring and Control Subsystem

This subsystem contains the electronic module for monitoring and control, the temperature regulator, transducers and sensors arranged on the stand and electro-hydraulic command elements..

Electronic module for monitoring and control, mounted in the electrical closet, manages sensors and transducers the electro-hydraulic elements of execution, as well as communication with PC.

Electronic module controls the pressure adjustment loop on the discharge circuit of the tested pump through the proportional throttle Dr1 and pressure transducers MS17 and MS18.

Transducers used in the adjustment loop module are coupled with the electronic module on separate inputs, in order to ensure rapid acquisition, necessary to regulate, of the parameters from the process. Transducers and sensors used for monitoring are connected via serial lines. A second serial communication allows to the module to interface with the PC computer that manages the database and program testing.

Temperature controller controls the oil temperature adjustment by the heating resistors and the cooling aggregate based on information received from the system of measurement of the temperature of the oil. Transducers and sensors disposed on the stand may have interface modules to adjust the output signal of the electronic monitoring and control module.

#### 4.3.3. The database system

The application software that runs on your PC manages your database with the results of tests, implements testing program and provides communication with electronic monitoring and control module. Another function is that of the database server to integrate data acquisition system and computer control in the system of the enterprise, providing access for the various compartments (the quality service, sales service, technical service, etc.), to the information obtained during the tests.

## 5. Conclusion

The technology proposed for testing stand for reversible hydrostatic pumps represents a modern solution that:

- allows tests and verifications which are essential for quality certification of the reversible hydrostatic pumps;
- allows completion special items in order to carry out research activities;
- allows control, adjustments and recording parameters manually, as well as automatic control and monitoring using the informatic system.

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