The Concept of a Modular Integrated Test Stand for Testing Hydraulic Drive and Control Systems

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Abstract. The paper presents proposals for the construction of a stand for testing elements of hydraulic drive systems. The presented solution is an excellent example which can be used to design and build such a system for companies or scientific centers that provides testing services for hydraulic pumps and motors. The article shows the demand of companies in Poland for the construction of test stands, necessary in the technical assessment of new and used elements, used in stationary stands and mobile working machines or vehicles. This approach clearly shows how to increase company's competitiveness and implement a new service. The proposed high power station (up to 350 kW) allows for testing of elements in a wide range of volumetric flow rate (up to 500 dm3 / min) and working under high pressure (up to 50 MPa). The new modular solution enables any integrated configuration of the station, depending on the company's needs.

Introduction

Hydraulic drive elements play one of the key roles in the development and position of domestic and foreign industry. For many years, many industries have used numerous components or comprehensive systems that create the manufacturing technology of a given company, including innovative projects leading to a competitive product. Today, hydraulic drive is widely used, among others in the aviation, mining and machine industries. The transfer of energy using liquids as a working medium, in particular in terms of high forces and moments, is still unmatched and many machines would not be able to function without its use. In each country, including Poland, you can identify companies that manufacture components or comprehensive hydraulic systems, operate stationary and mobile machines and devices, as well as service or regenerate parts. Especially at the production and service stages, it is necessary to have workstations and tools for the correct assessment of the properties and functionality of components, e.g. Bosch-Rexroth, Danfoss, Sun Test Systems, Parker Hannifin or MH Hydraulics. The correct selection of pumps, engines and other elements for hydraulic systems, especially for responsible hydrostatic drive systems and vehicle suspension systems [1], requires a good knowledge of the characteristics of these elements. Such characteristics are plotted on the basis of experimental data of these machines. Depending on the type of desired characteristics, a specialized test stand is configured [2]. A hydraulic motor without a speed reduction gearing can be used to directly drive the running wheels of a low-speed working machine or vehicle. The necessary condition, however, is stable motor operation at very low speed. Therefore, such a motor must have very small leaks in the timing slots. Another desirable feature of hydrostatic drive system components is their low weight. Among the known designs of pumps and hydraulic motors, the lowest weight-to-power ratio is characterized by pumps and satellite motors [3]. In addition, an important feature of mobile machines is the low level of emitted sound [4]. At the same time, manufacturers and research labs are looking for new solutions and applications of hydraulics, including using water as a working medium. In this case, pumps, motors and valves made of traditional steel can be coated with special coatings [5, 6], which will allow, among others, to replace more expensive and more difficult to process stainless steel. Regardless of the working medium, hydraulic systems based on numerous components must be tested for exposure to low and high operating temperatures in accordance with regulations [7]. Based on the above, it can be concluded that it is necessary to build multi-functional stands for testing hydraulic components or systems and verification of simulation tests. The complexity of tests and, in particular, a wide range of power required shapes the design of such solutions that allow for a flexible approach to testing. The implementation of such tasks is facilitated by modular solutions that can be integrated and tailored to your needs.

The proposed test stand is of interest to many industries, not only directly related to the production of power hydraulics [8], but also pressure components in heat transport [9] or chemically aggressive compounds in biotech [10, 11]. It could also be useful for testing protective coatings [12, 13], even in corrosive conditions [14]. The availability of such a research stand can significantly increase the efficiency of management and industrial logistics [15-17], as well as the analytical methods used [18-20] and pipe shaping [21].

Assumptions

When designing the station, it was assumed that the system would be based on an electric motor with a power of 350 [kW] and speed regulated by the inverter within the range of 800 ÷ 2300 [rpm]. The electric motor will supply two independent systems with two hydraulic units with a maximum flow rate of 500 [l / min] and an operating pressure of 50 [MPa], each with a mechanical load system. Control with the use of Load Sensing (LS) systems will be implemented by two triple sets of proportional control signals with maximum operating pressures of 4 [MPa] and 37 [MPa]. In addition, the station will allow for the testing of pumps and motors with variable flow direction and the measurement of such parameters as pressure, temperature, flow rate, rotational speed and load torque. The concept of the layout **-** the modular station for testing hydraulic pumps and motors consists of the following modules: 1.pump power supply module, 2. motor module (load), 3.circuit connection module, 4. LS control module.

The modules should be connected by means of additional hydraulic pipes and/or hoses taking into account the required pressure values and volumetric flow rate, which are set by the producer of the tested element. During testing, the appropriate duty cycle should be adopted. Control and monitoring of work parameters are carried out using a control and measuring system, the construction and principle of operation of which is omitted.

Pump module (power supply)

The power module (Fig. 1) performs the function of a pump drive with the elements necessary to connect the hydraulic suction lines with the connections p1T, p2T, p3T and leak lines p1R, p2R, p3R (if required). The module allows you to connect on one drive shaft a maximum of three sectional pumps set with a maximum power of 350 [kW] and a rotational speed in the range from 800 to 2300 [rpm], controlled by an inverter. The electric motor (8) acting as a drive allows for transferring a nominal driving torque of 2300 [Nm]. In addition, the module contains elements for controlling and measuring the pump operating parameters, such as pressure on the suction lines p1T, p2T, p3T; rotational speed e.g. and torque Mp (3); volumetric flow rate on the leakage lines Q1R, Q2R, Q3R (4 and 5); pressure p1 and oil temperature T1 and volumetric flow rate Q1 to 120 [l / min] (6). For these pumps, there is also the use of an overflow valve up to 50 [MPa] (9) and a relief for the system by means of an adjustable throttle valve (12). The above elements should also be used in tests of supplementary pumps in installations with variable flow pumps.

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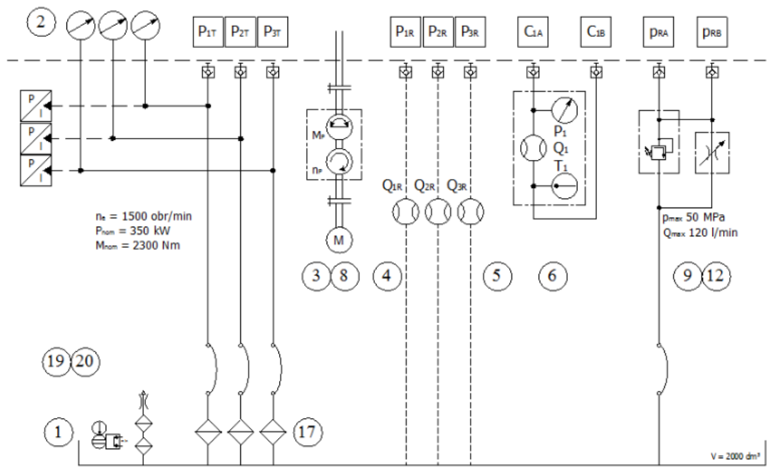

Fig. 1. Schema of the stand system power module.

Module of the hydrostatic motor load

The load module (Fig.2) performs the function of continuing the hydraulic line from the supply module and its load with maximum pressure, thanks to the use of the HM mechanical brake (13).

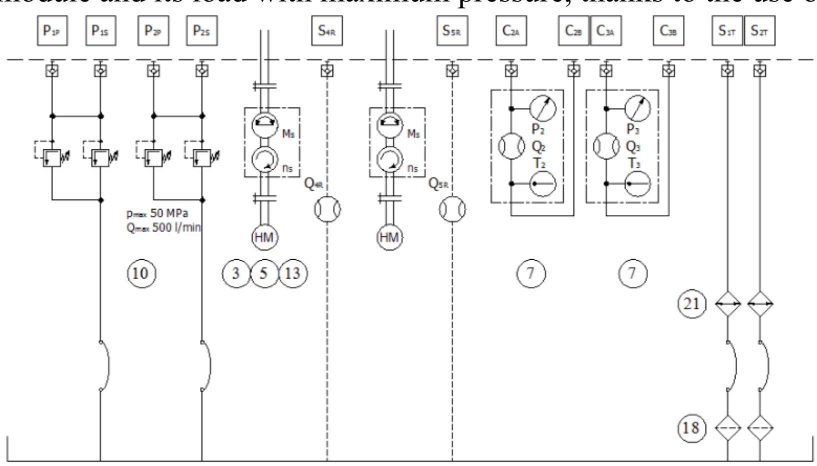

Fig. 2. Diagram of the load system.

In addition, the module allows for the use of elements necessary to connect hydraulic filtered (18) drain lines with the use of S1T, S2T connections and internal leaks with the use of S4R, S5R connections and leaks lines S4R, S5R (if required). The stand allows you to connect two motors at the same time, while the total power of both systems may not exceed the input power of 350 [kW]. In addition, the module contains elements for controlling and measuring motor operating parameters, such as rotational speed ns and torque Ms (3); volumetric flow rate on the leakage lines Q4R, Q5R; pressure p2, p3, oil temperature T2, T3 and volumetric flow rate on supply lines Q2, Q3 up to 500 [l / min] (7). For the used motors, it is also possible to use adjustable overflow valves up to the pressure of 50 [MPa] (10).

Closed circuit connection module

In the case of testing units operating in a closed system, both pumps and motors, the elements shown in Fig. 3 are necessary for use.

The non-return valve block (11) mounted on the plate (14) is used to connect the supplementary pump, and the non-return valve block (11) mounted on the plate (16) protects the motor against overload due to braking. The overflow valve block (10) mounted on the plate (15) protects the supply pump connected to the supply module. All components can operate at a pressure of 50 [MPa] and a maximum flow of 500 [l / min].

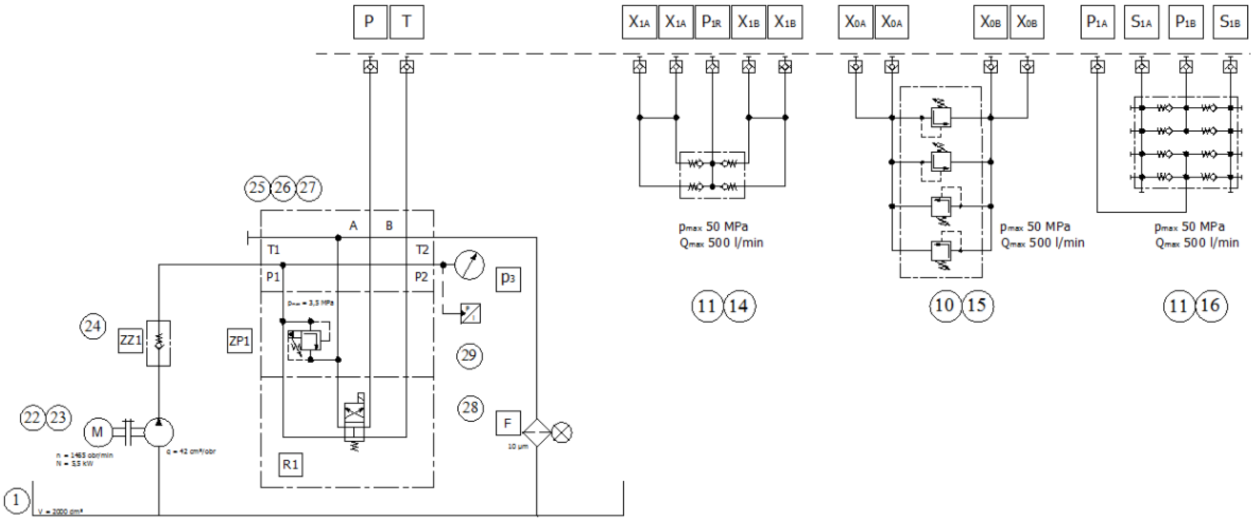

Fig. 3. Elements of additional connections for the closed system.

Hydraulic power pack based on a gear pump with constant unit volume of 42 [cm3] (23) and an electric motor with the power of 5.5 [kW] (22) allows for generating a control signal with a maximum pressure of 3.5 [MPa] for elements that require its use.

Load Sensing (LS) control module

The LS control system (Fig. 4.) plays the role of an additional system enabling the control signal to be supplied to pumps and motors with variable operating parameters, whose main parameters are the following: volume flow rate Qmax (10 [l / min]); 3 control signals pmax1 (37 [MPa]); 3 control signals pmax2 (4 [MPa]); supply pressure p (20 [MPa]).

The proportional valves 4/3 from R3 to R8 used allow for the adoption of control in accordance with the required duty cycle or load of the components tested. Pressure sensors pLS1 ÷ pLS6 allow for reading the current setting or save it in the control and measurement system.

Summary

The article presents a design of building a modular/integrated test stand for pumps and hydraulic motors with high performance parameters - pressure 50 [MPa] and volume flow rate 500 [l / min]. The proposed hydraulic stand is characterized by a modular construction, which allows for its free configuration, depending on the user's needs regarding the size of the tested elements and the method or algorithm of their control.

The presented hydraulic diagrams show a detailed structure, the analysis of which allows further development of the concept of connecting pumps and motors working in both directions. A set of valve blocks enables the connection of open and closed systems, and the multi-section Load Sensing control module allows for comprehensive simulation of work cycles at variable load settings. Numerous measurement signals of the main hydraulic and mechanical parameters allow for the creation of a history of tests and analysis of results, e.g. determining the efficiency of pumps or engines or the technical condition of the tested component. Extensive connection sets and a 350 [kW] electric motor allow for testing a set of several hydraulic components at the same time. This work is an excellent benchmark for designing or building similar hydraulic stations. The company that implements the proposed solution will use niches on the market in the aspect of technical tests of high-pressure power hydraulics.

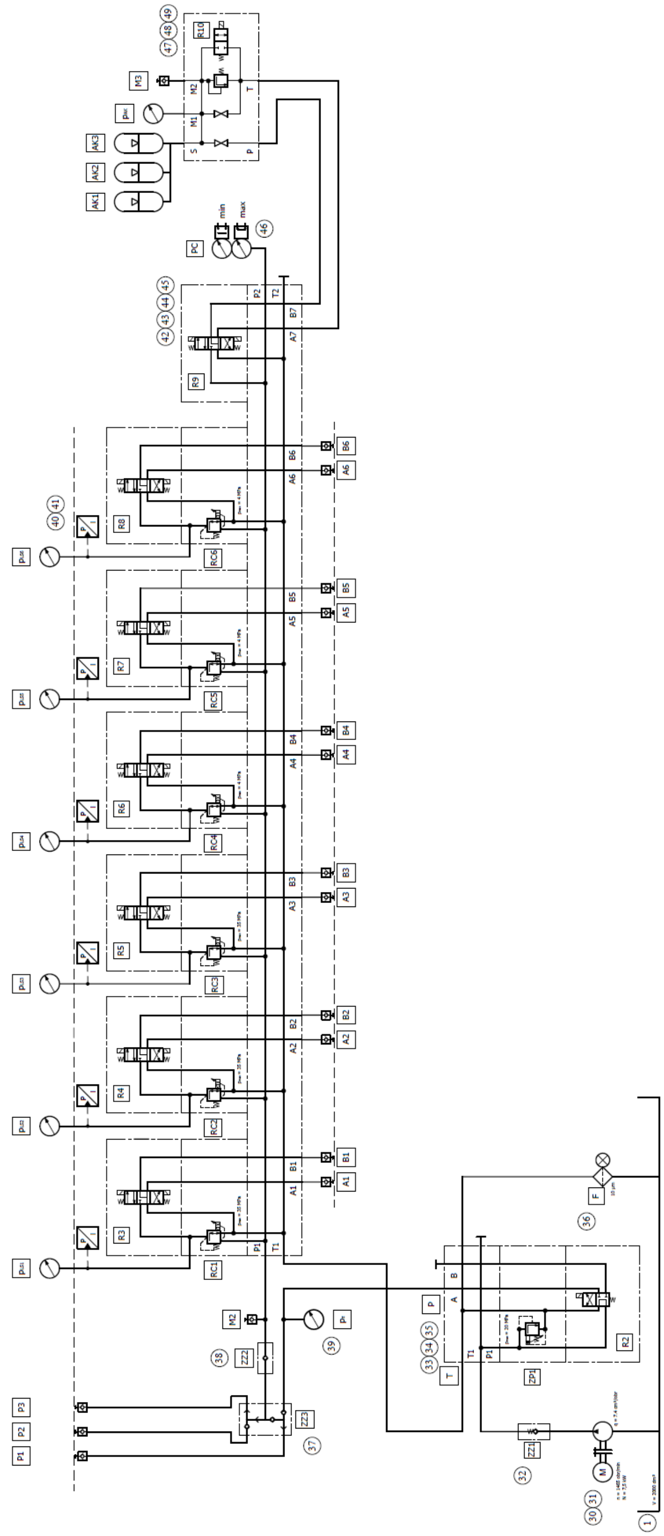

Fig.4. Schema of the LS control module.

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