

Test bench for throttle flow dividers-adders

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Abstract. The control of modern mobile machinery and technological equipment increasingly relies on the utilization of multi-circuit and branched hydraulic drives. The complexity of technological processes and the demand for precise and consistent executive movements present challenges for hydraulic drive developers. Throttle flow dividers are utilized to synchronize mechanisms powered by a single power source. The article discusses the creation and implementation of a testing platform for throttle dividers and flow dividers-adders, commonly used in various technical systems for regulating liquid or gas flow. It delves into the fundamental principles of throttle flow dividers-adders and details the design and functionality of the developed test bench. The results of experiments conducted to evaluate the bench's operation and measure accuracy are presented, providing insights into its efficacy and reliability for testing throttle flow dividers-adders.

1 Introduction

At present, there is significant progress in the field of mechanical engineering, prompting the need to enhance control capabilities of mobile machinery and technological equipment. This has resulted in an increased utilization of synchronized hydraulic drive systems across a wide range of industries.

The escalating sophistication of technological operations, coupled with the mounting need for precise execution of executive actions and their coherence, presents new obstacles for hydraulic drive developers. Fluctuating external loads and the inherent elasticity of hydraulic systems [1, 2] hinder the coordination of output link movements in intricate multi-circuit hydromechanical systems. Numerous variables impacting the reliability of a hydraulic-mechanical system render it challenging to definitively assess the specific impact of individual components during the initial design phase [3].

In intricate hydraulic systems, the performance of setups where a single hydraulic pump drives multiple separate hydraulic motors stands out. An essential objective in these configurations involves guaranteeing the coordination of output link movements, irrespective of the applied load. Optimal synchronization method selection is crucial for achieving the necessary precision in synchronization. Synchronizing hydraulic systems can be accomplished through a variety of methods aside from direct mechanical linkage of hydraulic motors, which may not always be practical in systems with intricate actuator setups. Other

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prevalent techniques include connecting hydraulic motors or pumps via shafts (referred to as volumetric synchronization), linking hydraulic motor cavities in series, utilizing hydraulic follower systems with distributors and hydrotachometers, and employing hydromechanical or electrohydraulic tracking systems.

A commonly used and effective method in machine hydraulic systems involves employing throttle dividers and flow adders to establish a smooth speed synchronization circuit. This device allows for precise coordination of movements or speeds among multiple hydraulic motors operating under different loads [4, 5].

Utilizing a hydraulic flow splitter involves the division of a single stream of hydraulic fluid into multiple streams, taking into account a specific ratio to ensure synchronized movement of output components despite changes in loads. In contrast, a flow combiner operates similarly to the splitter but in reverse, enabling easy integration into hydraulic systems and cost-effective operation. These flow combiners facilitate speed synchronization across a wide range of outputs from hydraulic motors [6, 7].

2 Material and research methods

In various hydraulic drive scenarios, flow dividers and combiners play a crucial role in optimizing the performance of applications like construction machinery, transportation vehicles, agricultural equipment, metal processing machinery, aeronautical and marine systems, as well as lifting and holding mechanisms. An essential aspect of ensuring precise synchronization is the thorough examination of potential errors during the flow division process in the dividers. The accuracy of flow division errors in both flow dividers and combiners is dictated by the comparison of pressure values in each output hydraulic line during operation [8, 9]. By analyzing the data collected, the primary focus is to determine the maximum flow division discrepancy. It is essential to conduct trials under the most significant pressure variance across the outlets.

Frequently, enhancing the dependability of hydraulic components in a system requires diminishing other factors like weight, size, intricacy, expenses, precision, and more. This can be accomplished by incorporating innovative design strategies. [10, 11].

A comparative analysis of failures of hydraulic drives during operation showed that approximately a third of all cases of failure of hydraulic drives occur in hydraulic regulation and control devices.

Therefore, when producing and designing new flow dividers, they must be checked before installation on equipment, compared with existing ones, and weaknesses and strengths identified. For these purposes, bench tests are carried out [12-14].

In this study, the object is a test bench for flow dividers and flow dividers-adders. Until now, insufficient attention has been paid to the development of test bench designs for checking the reliability of flow dividers. The lack of research and publications in this area clearly indicates that this problem is underestimated among specialists. The issues of choosing the optimal elements and parts for test benches also remain unsolved.

Therefore, when producing and designing new flow dividers, they must be checked before installation on equipment, compared with existing ones, and weaknesses and strengths identified [15, 16]. For these purposes, bench tests are carried out.

Figure 1 shows an experimental bench for testing a flow divider. Two double-acting hydraulic cylinders serve as the working body. This is necessary to simulate the load of a hydraulic cylinder. When moving upward, the liquid enters the lower cavity and exerts pressure to lift the hydraulic cylinder, and the liquid entering from above creates a load simulating work in real conditions.



Fig. 1. General view of the test bench for testing choke flow dividers/adders

The bench consists of a test flow divider DP, a hydraulic distributor P1 with mechanical control from a cam mechanism K, a pressure hydraulic valve – KP; distributors with electromagnetic control – P2 and P3; test bench KI-4815, which provides pump drive – N, stabilization of the temperature of the working fluid, determination of fluid flow in the drain line during the operating cycle and its cleaning. In the experimental bench, the appropriate pressure level is provided by throttle loading using a throttle DR and electromagnetic controlled distributors P2 and P3. The inlet pressure level is periodically monitored by a pressure gauge MN.

All control is carried out by automation, which is located on top in a metal box shown in Figure 2. The control is very simple, there is a main toggle switch, which has three positions – movement of hydraulic cylinders up, down and off. There are also two more on the right and left to turn on the load supply to each hydraulic cylinder separately.



Fig. 2. Bench control panel

There are 3 pressure gauges installed on the bench as demonstrative instruments. One of them, located on the left, shows the pressure in front of the hydraulic cylinders that the pump creates. The other two show the pressure of the created load in each hydraulic cylinder.

The main element of this entire installation is the pump shown in Figure 3, which creates the necessary pressure and speed of fluid movement. It is capable of pumping liquid at a speed of 63 liters per minute and creating a pressure of 15.0 MPa. This pump is connected to a 30 kilowatt electric motor.

Metal tubes go from the hydraulic cylinders to the pump, which are connected to high-pressure hoses and subsequently a throttle flow divider is connected to them. This is done for convenience in changing dividers after testing.

Hydraulic fluid is used as the working fluid. Its main volume is filled in the tank under the pump, about 85 liters. There is also a reserve tank under the bench, which is used to drain remaining oil when replacing dividers. After it is filled, it overflows and into the main tank it is about 20 liters.

The throttle divider test bench thus performs an important function. It helps to evaluate such characteristics as functional parameters, design features, and, in principle, the operability and safety of the divider. Also, at the bench you can visually compare different samples, choosing the most suitable one for yourself and only then installing it in the equipment. Another important aspect of using this bench is checking batches of throttle dividers that are produced in production for defects.

3 Results and discussion

Experiments carried out with membrane-type flow dividers on this test bench revealed that they demonstrate high accuracy in steady-state conditions. However, under variable load, the synchronized system is significantly affected by its volumetric stiffness [17, 18].

In addition, it should be noted that with large differences in the loads on the working parts of the synchronized system, it is impossible to unambiguously judge its accuracy of operation, relying only on the division error indicators of the throttle flow divider. In this case, the volumetric rigidity of its hydraulic system has an important influence on the operation of the system, even in stationary operating modes.

It can be noted that the use of membrane-type throttle flow dividers ensures high accuracy of operation of synchronous hydromechanical systems of general purpose, the synchronization error of which does not exceed 3%.

The bench's design comprises two essential systems: the power supply system and the measuring system. In the power system, components such as a reservoir, hydraulic pump, safety valve, and filter are included. An electric motor drives the hydraulic pump consistently, while the safety valve regulates the fluid pressure at the hydraulic pump's discharge point.

The working fluid is supplied from the hydraulic pump to the input of the divider, where it is divided into two streams. After passing through two throttle bodies, the working fluid is drained into the tank through a filter.

The measuring system of the bench is equipped with flow meters and pressure gauges, which allows not only to measure, but also to record all parameters of the input and output circuits of the divider during its testing.

Increasing the level of automation of the test process control system will improve the designed version of the bench. The use of cable sensors will allow you to accurately determine the position and speed of synchronized hydraulic drives, and installing a controller will allow you to program the test cycle with the possibility of adjustment.

The test bench uses the NAR 63/20 pump – this is an axial piston pump, which is usually used for tasks that require high pressure and high fluid flow rates. A photo of the placement of the NAR 63/20 pump on the bench is shown in Figure 3.



Fig. 3. Pump NAR 63/20 on a bench for testing throttle flow dividers/adders

To ensure the load of the tested hydraulic devices, two double-acting hydraulic cylinders are used (Figure 4).



Fig. 4. Double-acting hydraulic cylinders on a test bench for testing throttle flow dividers/adders

The flow divider-adders are connected to the bench using high-pressure hoses, which makes it possible to test flow dividers-adders of various sizes and locations of inlet and outlet fittings. The connected flow divider-adder is shown in Figure 5.



Fig. 5. Flow divider-adder

The developed test bench for choke flow dividers-adders is an effective and reliable tool for testing the operation of these devices. The experimental results showed that the bench allows for accurate and reliable measurements of flow parameters and assessment of the operation of choke dividers-adders. Further use of this bench will improve the quality of tests and increase the reliability of technical systems that use throttle flow dividers/adders. In

general, the bench meets the requirements of modern science and technology and can be recommended for use in engineering practice.

The need to create throttle flow dividers has become evident due to the common application of multi-motor hydraulic systems in diverse sectors, including industrial and mobile equipment. These systems necessitate the synchronized functioning of actuators, underscoring the importance of designing up-to-date and effective throttle dividers that can guarantee the harmonious operation of all system elements.

Depending on the operating characteristics and functionality requirements, various technical solutions are used, such as complex structures with adjustable volumetric hydraulic machines and throttle flow dividers. In situations where time synchronization of mechanisms is required, the most optimal option is to use throttle flow dividers.

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