Results of modeling the operation of the hydraulic pump in the Matlab-Simulink application and testing on the diagnostic bench

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Abstract. The article provides information on the design of the original stand for diagnostic tests of hydraulic equipment and lubrication systems of various transport and self-propelled vehicles. The scientific novelty of the work is the concept of a mobile diagnostic stand with extended testing capabilities at various drive shaft speeds. As an example of the functional capabilities of the stand, the test results of the NSh-32 pump of the fourth class of the company "Hydrosila" are presented. No publicly available data on the characteristics of the investigated hydraulic pump was found. Based on the test results, a comparative analysis and discussion of the performance of this sample with a pump of the previous class was carried out. Additionally, data on the capabilities of the measuring complex for measuring the parameters of an internal combustion engine, in which the hydraulic pump under consideration can operate, is presented.

1. Introduction
The research aimed at improving the technical service system for transport and self-propelled vehicles through the creation of diagnostic equipment is relevant. More and more complex types of mathematical analysis are being added to the existing diagnostics system [1] and methods are being introduced that were not previously used for hydraulic systems [2]. There is a serial test equipment that allows you to check the performance of hydraulic and lubrication systems of units transmitting torque [3, 4, 5]. As a rule, when diagnosing these systems, a comprehensive assessment of their performance indicators is not carried out [6, 7], imitation of the load on the unit is not provided [5], in addition, such equipment is stationary, uses an electric drive. A three-phase electrical network is required for operation. To solve the above problems, it is proposed to use a unit with a hydraulic system as diagnostic equipment. General view and hydraulic diagram of the unit are shown in Figure 1. Principle of unit operation. The hydraulic oil from the tank (1) is cleaned in a full-flow filter (3), then enters the hydraulic pump (9) mounted on the tested unit. By changing the fuel supply of the internal combustion engine and the position of the adjustable throttle (7), the characteristic speed and load modes of operation of the tested unit are established. Rotation speed is controlled by standard or portable tachometers, the oil pressure is measured by a pressure gauge (6) on the unit dashboard. After setting the characteristic operating mode by switching the on / off valve control knob (8), the oil
Flow is directed to the positive displacement flow meter (4), the readings of which are necessary for calculating the load parameters. After passing through the flow meter, the oil returns to the unit tank. To prevent pipe leaks, a block with an adjustable safety valve (5) is installed in front of the adjustable choke. During the tests, the following operating parameters are monitored:
- pressure in the high-pressure line;
- oil temperature in the hydraulic tank;
- oil consumption over time;
- shaft rotation frequency (option). The use of the developed unit with a hydraulic drive makes it possible to realize the following advantages:
- smaller weight and size parameters;
- mobility, since the developed installation is located on the chassis;
- ensuring smooth control of the rotation speed;
- the ability to check both engines and gearboxes in connection with the relatively low speeds of the hydraulic pump, as well as diagnose the parameters of the operation of hydraulic pumps at different modes of shaft rotation speed.

![Image](image.png)

**Figure 1.** Scheme of the stand:
a) hydraulic scheme of the stand; b) model view illustration.

### 2. Materials and Methods

The hydraulic pump NSh-32 manufactured by the company "Gidrosila" [4] was selected as the object of diagnostics. The choice of the model is due to its widespread use in transport and self-propelled vehicles. Due to the lack of data on the parameters of the fourth generation pumps, a numerical mathematical modeling of the operation of the NSh-32 pump of the MASTER series of the fourth generation was carried out. The simulation of the operation of the hydraulic pump was carried out...
using the engineering calculation program of the Matlab-Simulink application (Figure 2). To check the adequacy of the simulation on the designed stand, a series of tests of the specified pump was carried out and the values obtained were evaluated with the parameters of the NSh-32M pump of the third generation (Figure 3). The following constants were used in the simulation and testing: the kinematic viscosity of the VMGZ hydraulic oil $0.75 \cdot 10^{-4} \text{ m}^2/\text{s}$, the mechanical efficiency of the pump 0.95. The rotational speed of the drive shaft is $25 \text{ s}^{-1}$ (1500 rpm).

![Figure 2](image)

**Figure 2.** Designed circuit in the Simulink production environment.

3. Results

Based on the results of numerical modeling in the Matlab - Simulink application, a dynamic change in various physical indicators, for example, the pressure and flow of hydraulic oil, at selected points of the designed circuit was obtained. Based on the test results of the selected pump brand on the bench, the characteristic was obtained in the steady-state operation mode (Figure 3). It was found that for a fourth-class hydraulic pump the maximum value of the volumetric efficiency is 0.86 and is achieved in the range of 12.5 ... 14 MPa. For comparison, the same pump model of the third class achieves a volumetric efficiency of 0.88 at a pressure in the range of 10 ... 12 MPa.

4. Discussion

The simulated work processes of the designed stand in the Matlab-Simulink application cannot be evaluated based on the test results of the hydraulic pump on the proposed stand, since the installed measuring devices do not allow evaluating the dynamic change in the recorded values. However, the data obtained during the tests make it possible to evaluate the performance of hydraulic pumps at a steady-state pump shaft speed, as well as to additionally carry out tests at other speed modes, if necessary.

In the near future, it is planned to conduct research on the operating modes of the NSh-32 hydraulic pump installed on the D-144 engine. Research will include the measurement of pressure parameters, volumetric flow rate of hydraulic fluid at a given engine speed. The use of an internal combustion engine as a drive for a hydraulic pump will make it possible to investigate the indicated parameters at wider ranges of rotation frequencies. It will also be possible to evaluate engine performance such as power, torque, hourly fuel consumption and specific effective fuel consumption.
5. Conclusion
The simulation showed the limited capabilities of the application used. In subsequent studies of the hydraulic pump, the rotational speeds of the drive shaft will be varied in order to build a multi-parameter characteristic. Additionally, the use of a pump as a loading element will allow simulating the load on the units in order to diagnose the parameters of the lubrication system.

At the moment, an experimental measuring complex installed on the engine can measure the pressure and temperature of the oil in the engine lubrication system. If necessary, it is possible to realize the measurement of the volumetric flow rate of the oil pump.

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