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Apparatus for controlling the amount of undissolved gas in the hydraulic fluid

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Abstract. This paper considers an ultrasonic method for controlling the amount of undissolved gas in hydraulic systems for any size of gas bubbles and a varying size-consist. Also, the main reasons for the appearance of undissolved gas in the hydraulic fluid take into account. The paper is of great importance because known methods for measuring the amount of undissolved gas require complex testing benches consisting of a large number of elements. The proposed apparatus will simplify the control of the amount of undissolved gas in the hydraulic fluid used in the hydraulic drive while maintaining the accuracy of the measurement.

1. Introduction

Mineral oils used as the hydraulic fluid of most hydraulic systems may contain a certain amount of gas-air component in the undissolved state in addition to the necessarily present dissolved gases.

The amount of undissolved gas in the hydraulic fluid depends on many parameters: pressure, temperature, flow velocity, physical fluid properties, the number of impurities, design features of the hydraulic system and its operating modes. There are gas bubbles in the leak paths of the surfaces of the elements of the hydraulic system. Thus, their material and the undulation of their surface have an impact on the amount of gas content.

The reason for the appearance of undissolved gas in the hydraulic fluid may be the following. The first is suction into the air system due to a hydraulic system malfunction (the leaky connection of the elements) or poor-quality maintenance and operation such as refueling, an unacceptable decrease in the liquid level in the hydraulic tank. The second is a phase transition of a part of the dissolved gas into an undissolved state in the areas of pressure-drop loss below the saturation pressure of the liquid. The third is the process of gas diffusion from the liquid into micropores on the surfaces of the hydraulic elements due to capillary phenomena. The places of possible air leakage are often the lines of suction and discharge of liquid. Air can enter into the fluid through the pump flanges and inlet screen at the suction section. The air intake is possible along the planes of the connectors of the housing parts and the shaft seal in displacement, vane, and other pumps that soak the hydraulic fluid through the channels of the housing. Air can enter the hydraulic system through the cylinder rod seals, if the instantaneous fluid demand exceeds the pump flow during the operation, for example, when the load-lowering is quick. Intense saturation of the fluid by dispersed air can occur when deepening in the hydraulic tank of the suction, drain or drainage pipelines is not enough. Air can also enter the hydraulic system through the connection points of the elements, where either the passage area (throttles, valves) or the direction of fluid flow (hydraulic fittings) changes dramatically [6, 7, 8].



The sum of the volumes of the liquid component V_l and the gas one V_g define the mixture volume V_{mix}

$$V_{mix} = V_l + V_g. \quad (1)$$

The sum of increments of the volumes of the liquid component dV_l and the gas one dV_g interprets the infinitesimal increment of the mixture volume

$$dV_{mix} = dV_l + dV_g. \quad (2)$$

Expressing parameters included in the formula (2) is more convenient for practical use in terms of the value of the parameters under atmospheric pressure p_0 . When the pressure changes from p_0 to p , papers [1, 2, 3] consider occurring the process of gas-phase compression by polytrope

$$V_g = V_{g,0} \left(\frac{p_0}{p} \right)^{\frac{1}{n}}, \quad (3)$$

where $V_{g,0}$ – the volume of gas under atmospheric pressure p_0 ; n – polytropic exponent.

When the pressure changes from p_0 to p , the dependence of the bulk elastic modulus of the hydraulic fluid on the pressure becomes linear [4, 5]

$$B_l = B_{l,0} + Ap, \quad (4)$$

where $B_{l,0}$ – the bulk elastic modulus of the hydraulic fluid under atmospheric pressure p_0 ; A – coefficient that depends on the type of liquid and temperature.

The approximate formula is used to define the volume of the liquid component

$$V_l = V_{l,0} - V_{l,0} \frac{p - p_0}{B_{l,med}}, \quad (5)$$

where $V_{l,0}$ – the volume of liquid under atmospheric pressure p_0 ; $B_{l,med}$ – mean value of the bulk modulus of the hydraulic fluid in the pressure interval p_0 to p .

The formation of undissolved gas in a fluid due to phase transitions in areas of pressure drop occurs in these areas in all hydraulic systems below the saturation point of the solution. It happens even in cases where this drop is insignificant.

2. Description and operating principle of apparatus

The apparatus permits to measure the amount of undissolved gas using an ultrasonic parameter. The ultrasonic method for determining the concentration of undissolved gas in a fluid consists of generating an ultrasonic wave, examining the medium under research, registering the waves transmitted through it, and then comparing the signals.

Dispersed composition varying, the acoustic wave is pulsed at a frequency exceeding the resonant frequency of the smallest bubbles to provide the possibility of measuring the concentration under any size of the gas bubble. Then step is finding the average statistical value of acoustic signals that have traveled different distances in a fluid with gas bubbles. The change in the damping coefficient uses to tell about the concentration of undissolved gas in the liquid.

The damping of acoustic energy in a gas-liquid mixture connects with the loss mechanism: viscous losses, geometric scattering losses, heat, and resonance losses.

Figure 1 shows the testing bench used to measure the amount of undissolved gas in a fluid at different temperature conditions under different pressures [9, 10].

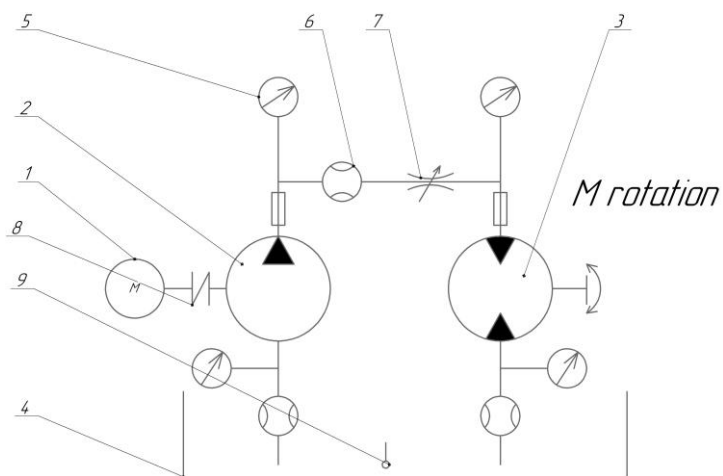


Figure 1. Testing bench for determining the amount of undissolved gas in a moving fluid: 1 - engine; 2 - pump; 3 - motor; 4 - tank; 5 - pressure sensors; 6 - flow meter; 7 - adjustable throttle; 8 - coupling; 9 - thermometer; 10 - ultrasonic sensors fixation.

The fluid flows from the tank 4 through the suction pipe and enters the pump 2. The engine 1 is the drive of pump 2. Then the fluid flows through the clutch 8, the discharge line, and it enters the motor 3. After that, it leaks through the drainpipe to the tank. There are highly sensitive pressure sensors 5 in the suction and discharge lines, before entering the motor and on the drain line to control the pressure at different points of the hydraulic system. Flowmeters 6 installed on the suction, discharge, and drain pipelines use to fix the amount of fluid passing through these pipelines per unit time. It permits to change the pressure in the discharge line for an experiment on different operating modes of the hydraulic system by step adjustable throttle 7. Ultrasonic fixation sensors use to record the amount of undissolved gas. They also record changes in the ultrasonic wave as it passed through the fluid. Records from ultrasonic sensors show on a computer monitor and make using special software. Figure 2 shows the elements of the testing bench.

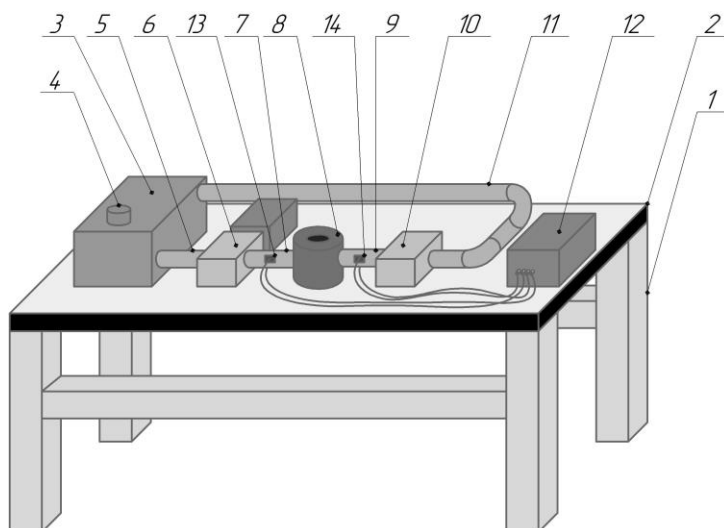


Figure 2. Testing bench for monitoring undissolved gas in the hydraulic fluid: 1 - table legs; 2 - countertop; 3 - tank; 4 - filler neck; 5 - a suction pipe; 6 - pump; 7 - discharge pipe; 8 - step shutter; 9 - pipeline in front of the hydraulic motor; 10 - hydraulic motor; 11 - a drain pipe; 12 - device for ultrasonic fixation; 13, 14 - ultrasonic sensors.

A portable apparatus for controlling the amount of undissolved gas simplifies the testing bench for determining it in a moving fluid. Figure 3 shows the hydraulic circuit of the proposed apparatus.

It consists of a hydraulic tank 1 having the test fluid. This fluid flows through the manifold and the distributor 2. Then pump 5 sucks it up, and the fluid fills the hydraulic system. After filling the hydraulic system of the test fluid, the distributor closes, the pressure increases in the hydraulic system

using the hand pump 5. When the required pressure is reached in the hydraulic system, ultrasonic sensor 4 measures the amount of undissolved gas.

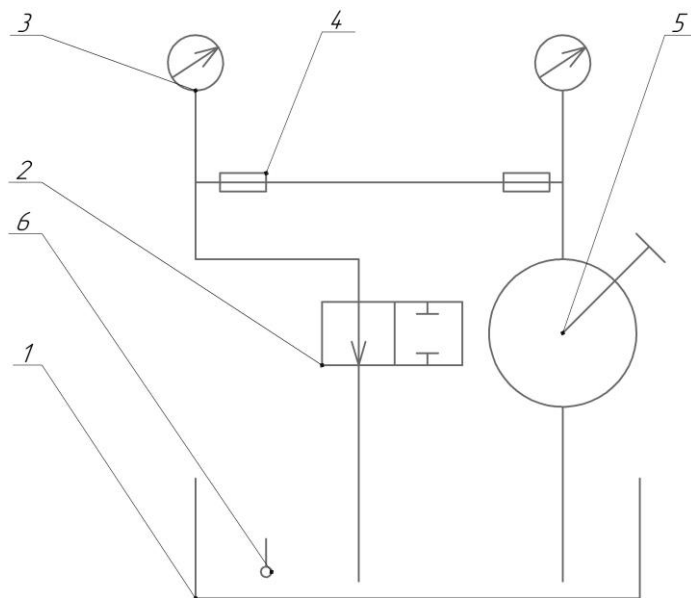


Figure 3. Apparatus for determining the amount of undissolved gas: 1 - tank; 2 - the distributor; 3 - pressure gauge; 4 - ultrasonic sensor; 5 - manual pump; 6 - thermometer.

Comparing the measurement accuracy of the proposed apparatus with the testing bench shown in figure 2 are below.

Figure 4 shows a scan of the result of measuring the amount of undissolved gas on a testing bench (figure 2) under a pressure of 5 MPa and the insoluble gas content of 3%.



Figure 4. The results obtained by the testing bench.

Figure 5 shows a scan of the result of measuring the amount of undissolved gas under a pressure of 5 MPa and the insoluble gas content of 3% using the proposed device.



Figure 5. The results obtained by the proposed apparatus.

A comparison of the results obtained on the portable apparatus with the results obtained at the testing bench permits to conclude that the discrepancies are small and to control undissolved gas in the working fluid of the hydraulic drive of self-propelled vehicles can use the proposed apparatus.

The advantage of the proposed control apparatus is in its mobility and overall dimensions. This device does not require power from the network to rotate the electric motor. The self-contained power supply charges the ultrasonic sensor. All measurements can be in field conditions.

3. Conclusion

The conducted experimental research confirms the reliability of mathematical models and the obtained theoretical results. At the same time, that leads to the development of the testing bench. The measurements carrying out for different pressures (1, 3, 5, 10, 15 MPa) give the picture fitted to the expected results. The results of measuring the gas content in mineral oil carrying out on a portable device accord with the results obtained on the testing bench. They differ no more than 13%.

North exploration company, that is a branch OJSC «Krasnoyarskgeologiya», introduces the proposed method. The implementation act confirms that.

These results can be useful for the design of hydraulic drives and their operation. This decision ensures more stable dynamic characteristics and increase service life. The parameters of the working fluid, depending on the gas content and determining characteristics of the hydraulic drives, can get in the category of controlled factors.

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