Physical modeling of ring-shaped elastic valve operation in hydraulic percussion mechanism

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Abstract. The paper proves usability of elastic lock-and-control valves in hydraulic percussion mechanisms. The requirements imposed on positive-displacement impact machines for rock drilling are substantiated. The dedicated test bench for determination of actuation conditions of the elastic valve is described. The experimentation procedure, sequence and data are presented.

1. Introduction
Positive-displacement hydraulic percussion mechanisms enjoy wide application in mining and in construction. They operate on machines with active working attachments and are intended to improve their efficiency in cutting frozen soil, in breaking pavements, in soil compaction, trenchless pipeline laying, etc. The review of different distribution systems shows that inclusion of an elastic lock-and-control valve is an efficient solution in terms of performance standards. Such valve simplifies the design and manufacturability of hydraulic hammers. Furthermore, it becomes possible to adjust the key capacity factors—the frequency and energy of blows.

Design of a hydraulic hammer is mostly governed by its distribution system. Classification of distribution assemblies of valveless hydraulic hammering machines is shown in Figure 1 [1].

![Figure 1. Classification of distribution assemblies in hydraulic hammer without valve spools.](image-url)
The use of the ring-shape elastic valve simplifies designs of hydraulic hammers [1]. However, reliable operation of hydraulic hammers in unfavorable conditions requires handling the problem connected with increasing clearances in friction pairs of hydraulic percussion mechanism [2]. The studies aimed to develop elastic lock-and-control elements instead of valve spools have been implemented at the Siberian State Automobile and Highway University in Omsk, Russia [1, 4–6].

The operation of a distribution assembly with an elastic lock-and-control element is shown schematically in Figure 2. When the elastic element is in the lock position under the action of fluid pressure (Figure 2a), in control cell 2, hydraulic lines 5 and 6 are shut off. Piston of the hydraulic percussion mechanism performs idle stroke (gets cocked).

In the open position of elastic element in Figure 2b, control cell 2 is connected to the outlet via hydraulic line 3. The pressure drops in control cell 2, elastic element 4 deforms, and hydraulic lines 5 and 6 connect with each other. The piston makes the power stroke [1].

![Figure 2. Distribution assembly with flat lock-and-control element: 1—body; 2—control cell; 3—hydraulic line of control cell; 4—elastic lock-and-control; 5—outlet hydraulic line; 6—inlet hydraulic line.](image)

Operation of a ring-shape elastic valve in hydraulic hammers Typhoon proves its usability as a lock-and-control element in hydraulic percussion mechanisms [3]. The Institute of Mining has experimentally tested this applicability on a physical model. The tests were aimed to determine the actuation condition of the ring-shape elastic valve in the fluid distribution systems of hydraulic percussion mechanisms.

![Figure 3. Test bench: 1—anvil; 2—piston, 3—high-pressure manual pump; 4—hydropneumatic accumulator (25 MPa); 5—arresters, 6—adjustment screw; 7—channel bar; 8—T-joint; 9—mouth; 10—manometer (10 MPa); 11—elastic valve.](image)

To this effect, a test bench was designed (Figure 3). The test bench is fixated on channel beam 7. Piston 2 and organic glass anvil 1 are clamped between two arresters 2. The left-hand arrester has
adjustment screw 6 to control displacement of the anvil relative to the piston. The required pressure in the system is generated using manual pump 3 and measured by manometer 10 meant for a pressure of 10 MPa. The pressure fluctuations are adjusted using hydro-pneumatic accumulator set in the pressure line. Oil is fed in the system via mouth 9.

The piston has elastic valve 11 which deforms under the action of the hydraulic fluid pressure and seals the idle-stroke chamber along the whole travel.

The tests used the step-wise and cone-wise chambers. The elastic valves were made of rubber and polyurethane and had outward diameters of 37–39 mm.

2. Experimental procedure

The experiment included:
1. Generation of working pressure from 1 to 5 MPa in the system;
2. Determination of the valve deformation in the lock position, $\Delta$;
3. Check of the valve seal capacity in the range of the valve displacements;
4. Determination of the opening pressure of the elastic valve.

![Figure 4. Curves $\Delta=f(P)$ in tests of elastic valves: 1—rubber valve; 2—polyurethane valve.](image)

The working pressure was changed from 1 to 5 MPa. Then, the valve deformation (contraction) $\Delta$, such that the working chamber is sealed, was determined: it ranged as 0.4–1.7 mm in all tests. Sealing of the elastic valve was checked at the constant initial pressure during its displacement in the working range of displacements. The opening pressure of the elastic valve was determined with smooth decrease in the pressure from the initial value to the valve opening. The opening pressure was 0.5–0.8 MPa in all tests.

For the rubber and polyurethane valves, the contraction–pressure curves $\Delta=f(P)$ were plotted (Figure 4). It is seen that for the stiffer polyurethane valve, the contraction proportionally depends on the pressure value. The gentle curve allows suggestion that the percussion mechanism is serviceable within a wide pressure range at different geometry of the valve.

In case of the softer rubber valve, the curve is initially nonlinear. This initial section can be of interest most probably in case of pneumatic percussion machines. Hydraulic mechanisms operate at higher pressures. The manual pump used in the tests was unable to generate higher pressures. However, it is highly probable that the curve $\Delta=f(P)$ preserves the revealed gentle linearity under higher pressures. This simplifies the research into the use of the test valve in hydraulic percussion machines.
3. Conclusions
1. The authors have proved usability of a ring-shaped elastic valve in design of a positive-displacement hydraulic percussion mechanism.
2. The test data on actuation conditions of the elastic valve are applicable in design of positive-displacement hydraulic percussion mechanisms.

References
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