Improvement of air distribution in DTH air hammer

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Abstract. Advancement trends in DTH air hammer engineering are described, and the modern design requirements are presented. The schematic of DTH air hammer to comply with the current standards is given. Reliability of the machine with three-stage hammering unit is discussed. The process of bottomhole cleaning in this DTH air hammer operation is described. The capacities of an elastic valve arrangement at the largest stage of the hammering unit are determined. The theoretical and full-scale test data of the proposed DTH air hammer design are presented.

1. Introduction
The long-term practice of using DTH air hammers proves their high capacity and endurance. For example, the penetration rate in hard rocks is increased to 800 mm/min and the endurance exceeds 8000 running meters. Such advance in the foreign countries became possible owing to using a higher pressure source (2.0–2.5 MPa). Russia chose the way of modifying and improving the machine design. Open pit mining in Russia is commonly carried out using high pressure drills of foreign manufacture, and it is of the current concern to have a domestic air hammer to operate at increased pressures, air hammers enjoy increasingly wider application in geological exploration and in casing-while-drilling. Engineering of new air hammers should take into account the specificity of mining and of manufacture of these machines. The foreign-manufacture DTH air hammers have no valving and perforating to exhaust spent air to bottom-hole, and feature high productivity and long service life. The energy source is high—pressure compressed air, which governs the high capacity of the air hammers, due to the high impact energy. These air hammers are made of high-quality materials and using advanced manufacture technologies.

2. DTH air hammer layout and test results
The Institute of Mining offered a new DTH air hammer layout to meet the current challenges (Figure 1) [1]. The cross-section area of the cylinder cavity is utilized better and more effectively, which enables increasing the machine performance.

This layout is advantages for the elimination of internal channels in the piston, which increases the piston strength, makes it possible to manufacture DTH air hammers of smaller diameter and to elevate the energy source pressure. In this layout, the cavity between the piston and the bit is the cavity of atmospheric pressure and needs no air-tight packing, which allows minimizing the number of mounting surfaces in the structure of the bit. Furthermore, the requirements for the precision and cleanness of the mounting surfaces are decreased, and the manufacture cost of the drilling tool is reduced thereby. It is possible to design adaptable axle boxes of various type bits, which allows using
special-purpose and series-produced bits of different designs, which pushes the application limits of DTH air hammers.

![DTH air hammer diagram](image)

**Figure 1.** DTH air hammer diagram: 1—housing; 2—piston; 3—air-distribution case; 4—ring-shaped cavity of power stroke chamber; 5—frontal power stroke chamber; 6—constant-pressure idle stroke chamber; 7—recess; 8—bit.

In this diagram, the piston has three steps with the seating surfaces (Figure 2). For the reliability of free travel of the piston, without galling of the seating surface, there is a sleeve with an O-ring, with a certain freedom of radial displacement.

![Layout of DTH air hammer P165](image)

**Figure 2.** Layout of DTH air hammer P165: 1—bit; 2—recess; 3—piston; 4—housing; 5—ring-shaped cavity of power stroke chamber; 6—split sleeve; 7—O-ring; 8—stopper; 9—constant-pressure idle stroke chamber; 10—air-distribution case; 11—frontal cavity of power stoker chamber; 12—adapter.

Compressed air, via channels in adapter 12 and air-distribution case 10, enters constant-pressure idle stroke chamber 9. Position of piston 3 governs periodic air admission in the cavities of the power stroke chambers (cavities 5 and 11) via idle stroke chamber 9 and periodic exhaust from these cavities through recess 2 in housing 4 and the channel in bit 1 to the bottom-hole. In draining of the power stroke chamber, the force applied to piston 3 from the side of idle stroke chamber 9 becomes prevailing and implements the idle stroke. In to-and-fro motion, piston 3 hits bit 1 at the end of each duty cycle. Sleeve 6 embraces the smallest middle step of piston 3 via sufficiently dense but movable fit H8/e7. The contact between sleeve 6 and air-distribution case 10 with seating fit H9/c8 with a larger clearance to ensure certain displacement of split sleeve 6 in the radial direction when piston 3 moves. The air bleed from idle stroke chamber 9 to cavity 5 is prevented by O-ring 7. Stopper 8 prevents squeezing of sleeve 6 to cavity 5. Such design ensures reliable operation of the air hammer.

Drilling operations included bottom-hole scavenging and removal of drill fines from the hole, which influences the efficiency of drilling. In case of pore scavenging of the bottom-hole, regrinding takes place, which consumes much energy unproductively. Scavenging uses compressed air or mud fluid [2, 3].

Piston travel in most DTH air hammers is executed via controllable chambers of idle and power stoke, which exhaust spent air in turn to the bottom-hole. It is more efficient in scavenging, when spent air is exhausted from the power stoke chamber at the end of a duty cycle and in the beginning of
the next duty cycle. The exhaust from the idle stroke chamber in the middle of a cycle is less effective. In the proposed layout, all air exhaust takes place in the most useful period, right before and after the piston hits the bit.

The pressure increase is not a single possibility to improve operation of DTH air hammers. It is possible that the air distribution system design permits the simplest shapes of critical impacting parts, which can enhance endurance of these parts. Another way is to further increase capacity of DTH air hammers and to expand the range of drilling diameters.

It was decided to design auxiliary valves mountable in air hammers without slide valving system of air distribution. Auxiliary valves allow boosting the air hammer power toward increased competitiveness and wider applicability of the machines. An auxiliary valve system should keep the basic design unviolated, should be simple, and should preserve the advantages of the slide valving-free machines, such as easy actuation and weak sensitivity to the cross-section sizes of feed lines.

The unloading elastic valve can make it possible to extend the travel length of the piston, which can enhance the unit impact energy and enlarge the critical section areas of the piston [4, 5].

The proposed layout of DTH air hammer have an atmospheric piston cavity in-between the piston and the bit, which enables mounting the unloading valve directly on the piston as in DTH air hammer model P110FGMU in Figure 3 [6].

Elastic ring 5 placed in a circular groove at the head of piston 4 with a clearance at its larger diameter side acts as an unloading valve. When piston 5 in its idle stoke, the compressed air in the frontal and ring chambers of power stroke after exhaust cut-off and the bleed air entered in the chambers via gaps of movable fits of the piston flows through the clearance mentioned above to the channels at the end of the piston and out to atmosphere. The piston areas on the side of the frontal and ring chambers of power stroke is a few times larger than on the side of the idle stroke chamber, and the compressed air in the frontal and ring power-stroke chambers essentially decelerates the piston when in idle stroke and limits its travel. The air exhaust from the frontal and ring power-stroke chambers after the exhaust cut-off through elastic valve 5 enables decreasing counter-pressure and, as a consequence, reducing the piston movement resistance while the piston travel when in idle stroke gets elongated. In the power stoke piston 4 is subjected to the compressed air pressure on the side of the frontal and ring chambers of power stoke at the higher value of the stroke, which increases the unit impact energy and the whole capacity of the machine.

![Figure 3](image)

Figure 3. Diagram of DTH air hammer model P110GM with elastic valve arranged on piston: 1—bit; 2—axle-box; 3—housing; 4—piston; 5—elastic valve; 6—half-rings; 7—stopper; 8—case; 9—adapter.

The shape of the groove and the presence of the large-diameter side surface enables periodic exhaust of air from the power stroke chambers using two parts only—the piston and the elastic ring, without participation of the other components of the design, which makes this system independent. The effect of the valve on the air hammer performance is determined from taking and interpreting pressure diagrams (Figure 4) [7].

It is evident from the diagrams that the pressure in the power stoke chamber before the compressed-air inlet is higher by 0.1 MPa in the variant with the valve than without it. Furthermore,
the piston travel resistance in the idle stroke is reduced, which enables the longer travel from 82 to 92 mm and the higher impact energy by 20%. Using the proposed layout, the models of DTH air hammers are designed, with different diameters and wide range of compressed air pressure—PV170M and PV130 for drilling holes with diameters of 165–170 and 134–152 mm, respectively. The working air pressure is 1.2–2.0 MPa. The pistons for these machines were manufactured at the Novosibirsk State Technical University. These DTH air hammers are intend for drilling in strong and medium-strength rocks using domestic manufacture drills URB-2A2 and foreign drills ROC L6 and ROC L8. The prototype DTH air hammers were tested at a full scale.

![Figure 4. Diagrams of pressure in chambers of DTH air hammer P110GMU: (a) without valve; (b) with elastic valve on piston.](image)

Prototype PV170M was tested in full-scale conditions at Siberian Mining Company. During the test period, the air hammer model drilled holes more than 600 m in total length at the constant efficiency and penetration rate of 400 mm/min. Then, the air hammer was sent to Vostok JSC for exploration drilling, and was equipped with a core receiver adapter. Drilling was carried out using drill SBU-2RT at compressed air pressure of 1.0 MPa. Exploration drilling was intended to strike placer gold in different rocks with gravel and boulders at a depth of 5–20 m. Based on the test results, Vostok ordered manufacturing of 8 DTH air hammers forwarded to mines in Khakassia (Lake Shira).

Prototype PV130 was tested in operation on Sweden drill Roc L8 at compressed air pressure of 2.1 MPa. The test drilling length amounts to 870 running meters. The penetration rate is 600 mm/mi, which equals the penetration rate of the foreign-manufacture machines in the same conditions. The test proved efficiency of DTH air hammer models PV170M and PV130 in operation with high-pressure drills of the foreign and domestic manufacture. As per the order of Vostok, two air hammers P165 were manufactured at Spetsgidravlika.

High-rate coal mining in fully mechanized longwalls requires reduction of concentrate of methane in mine air. This is achieved by means of pre-mine drainage and full-blast ventilation of roadways and
mined-out voids. The best pre-mine drainage technique is drilling of long drainage holes from delineating headings around an extraction panel. For this purpose, the small-size DTH air hammer model ASH43 was manufactured.

The small-diameter DTH air hammers are used in straight hole drilling [8, 9]. It is promising do design larger diameter air hammers using the proposed layout for railroad pole drilling from railway platforms in the permafrost areas [10–12].

3. Conclusions
The diagram and layout of a DTH air hammer proposed in this paper enables efficient engineering of various diameter machines for wide range of working pressures. The tests of the DTH air hammers designed by this layout have proved high capacity and reliability of the machines. The layout can be the basis for the further improvement of air distribution using auxiliary valving systems with elastic valves.

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