# Energy-saving compression valve of the rock drill

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**Abstract.** The relevance of the research is due to the necessity to create pneumatic rock drills with low air consumption. The article analyzes the reasons for low efficiency of percussive machines. The authors state that applying a single distribution body in the percussive mechanism does not allow carrying out a low-energy operating cycle of the mechanism. Using the studied device as an example, it is substantiated that applying a compression valve with two distribution bodies separately operating the working chambers makes it possible to significantly reduce the airflow. The authors describe the construction of a core drill percussive mechanism and the operation of a compression valve. It is shown that in the new percussive mechanism working chambers are cut off the circuit by the time when exhaust windows are opened by the piston and air is not supplied into the cylinder up to 20% of the cycle time. The air flow rate of the new mechanism was 3.8 $m^3$/min. In comparison with the drill PK-75, the overall noise level of the new machine is lower by 8-10 dB, while the percussive mechanism efficiency is 2.3 times higher.

## 1. Introduction

Percussive mechanisms of pneumatic rock drills have high compressed air flow, low efficiency and high exhaust noise level [1], which leads to significant energy costs, decrease in productivity and restrictions concerning the usage of powerful machines if there is central supply of devices with compressed air, as well as deterioration of hygiene and sanitary working conditions. Therefore, creating highly efficient and energy-saving percussive mechanisms is an urgent problem when drilling equipment is designed.

The main reasons for high air consumption are: considerable leakage of compressed air into the atmosphere from pneumatic circuits through the cylinder when an exhaust window is opened by a piston, and faulty process operating cycle in chambers. The longest airflow takes place through a reverse chamber. These leaks are specific characteristics of a valve and a slide-valve; their duration can reach up to 32% of the operating cycle time. For instance, in the core drill PK-75, the direct airflow from a circuit into the atmosphere takes 23% of the cycle duration. The proportion of such leakages is significantly larger since the speed of the air supplied into the cylinder increases during the exhaust which intensifies the noise level of air exhaust to a greater extent.

Properties of machines are considerably determined by the structure of a compression valve. A single distribution body (DB) [2-7] is used in most types of percussive machines. Its functions are accomplished by a slide-valve, a piston and, most commonly, a valve. As DB has two reversals within an operation cycle, it is impossible to fully cut off the working chambers from the circuit before an exhaust window is opened and to realize an energy-saving operating cycle. The search for chambers cutoff from the circuit leads to premature air inlet into working chambers and, as a result, there is a loss in energy parameters and other indicators.

The increase in the percussive mechanism efficiency is associated with the working chambers cutoff from the circuit before opening an exhaust window and the improvement of process operating cycle. Applying a compression valve with two DBs separately controlling the air inlet into working chambers opens the greatest opportunities in achieving maximum efficiency.

This paper describes the construction and the working principle of a new compression valve with two self-sustainable valve DBs which separately operate working chambers. It also outlines the main results of the prototype test of the core drill percussive mechanism which was performed in the drilling laboratory of the Research and Design Institute (NIPIrudmash) and under industrial conditions at the mine.

## 2. Materials and Methods

The study of percussive mechanism was carried out in the laboratory of Tomsk Polytechnic University at the stand with a hydraulic feeder by a short stem with a cross bit on a concrete block and granite. Air pressure in the distribution box and working chambers, command channels and the inlet channel of the reverse chamber was registered by strain gauge pressure sensors. Immediate air temperature in working chambers was measured by resistance sensors. An inductive sensor was used to record the piston motions. Contact sensors were applied to record valve reversal. Strain-measuring amplifiers TA-5, the loop oscillograph N-115, resistance and shunt bridge R-155 were used to record signals from the sensors. Airflow rate was measured by the differential pressure flowmeter which consisted of a restriction orifice and the differential manometer DT-50. Determining the characteristics of the impact unit operation was fulfilled according to pressure diagrams on the computer or a track curve of the piston.

The mechanism was tested in the drilling laboratory of the Research and Design Institute (NIPIrudmash) at the stand with a screw feeder while drilling granite with a hardness of 10–12 (according to the scale of the professor M.M. Protodiyakonov) by a cross bit 65 mm in diameter.

The tests of the new and the commercial impact units applied in the drill PK-75 were performed at the mine on a rod-piston feeder with the use of the same rotary head. The drill was operated by remote control. Water-flush drilling was performed in rocks with a hardness coefficient of 14 16 at the same feeding force. The phonometer Sh-63-1 was used.

## 3. Results and Discussion

In Tomsk Polytechnic University a percussive mechanism construction (figure 1) with a new compression valve has been designed as applied to the core drill PK-75 with independent rotation of the drill and a piston 120mm in diameter, and its samples have been investigated. Some results of research and development of the operating processes in this percussive mechanism are outlined in the works [8-10].

Let us describe the mechanism operating principle.

The chamber ***o*** communicates with the atmosphere through the command channel ***c*** and the piston 2 groove through the exhaust window ***g***. The valve 4 and the pushrod 5 are in the upper position. Compressed air inflows through the channel ***d*** into the cylinder reverse chamber 1, the piston 2 moves upwards. The valve 6 and the pushrod 7 are in the down position. During further motion, the piston opens the command channel ***c*** compressed air is supplied from the reverse chamber into the chamber ***o***. The sum of forces acting on the upper faces of the pushrod 5 and the valve 4 is greater than the force under the valve. The valve 4 and the pusher 5 are reversed to the down position and the air inlet into the cylinder stops until the exhaust window ***в*** starts opening by the piston. Then the piston closes the exhaust window ***e*** and compresses air in the direct chamber. The air supplied through the command channel ***f*** into the chamber ***p*** enables a steady down position of the valve 6. Then the chamber ***p*** communicates with the atmosphere through the channel ***f***, through the piston groove and the exhaust window ***e***. The valve 6 and the pushrod 7 move upwards, and compressed air flows into the direct chamber. After that, the piston holds the upper operating position and starts direct motion (in figure 1 – down).

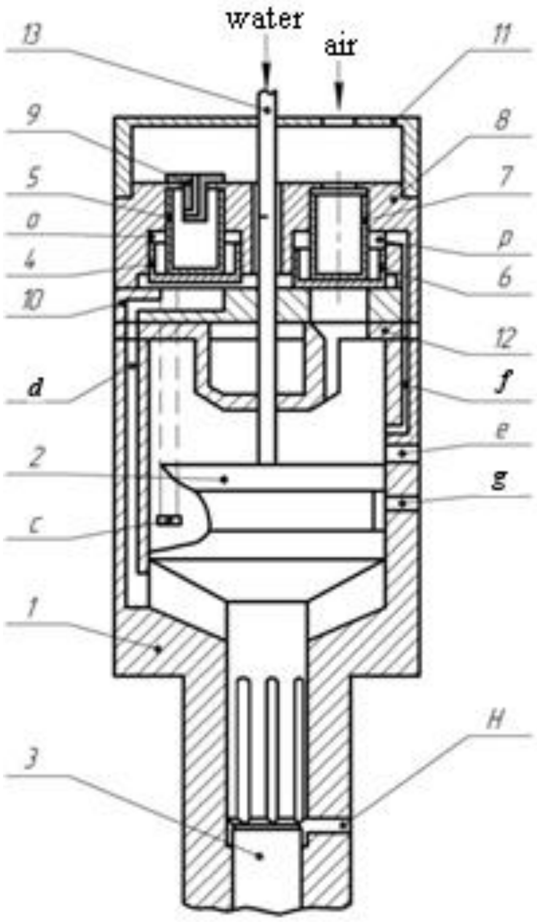


**Figure 1.** The scheme of the percussive mechanism.

A percussive mechanism comprises:
1 – cylinder with exhaust windows ***e*** and ***g***;
2 – piston; 3 – drill rod;
4, 5 – valve and pushrod of the reverse chamber;
6, 7 – valve and pushrod of the direct chamber;
8 – distribution box; 9 – throttle; 10 – valve body;
11 – cover; 12 – cylinder cover;
13 –flushing out supply tube;
***o***, ***p*** – chambers above valves;
***c, f*** – command channels of the direct and reverse chambers, respectively; ***d*** – inlet channel of the reverse chamber;
H – outlet.

Under air pressure, the piston moves forward and after a while it opens the command channel ***f***, compressed air flows from the direct chamber into the chamber ***p***. The valve 6 and the pushrod 7 move as far as they can go to the valve body 10, i.e. direct chamber is cut off from the circuit. Remaining air flows out into the atmosphere when the exhaust window ***e*** is opened by the piston. The piston compresses air in the reverse chamber, air flows through the channel ***d*** under the piston and into the chamber ***o*** above the valve 4. The valve 4 and the pushrod 5 are in the down position. At further motion of the piston, the chamber ***o*** and the command channel ***c*** are connected with the atmosphere through the piston groove and the exhaust window. The valve 4 and the pushrod 5 move upwards, then the piston strokes the jackrod 3. Next operating cycle of the mechanism begins under rebound impulse and compressed air pressure.

Let us consider typically occurring moments during the compression valve operating (figure 2).

The indicative points on the diagram of air pressure in the reverse chamber correspond to: **a** – piston forward position; **c** – start of opening the command channel ***c***; **e** – opening the exhaust window ***g*** (figure 1). Points **d** and **l** on the line 1 correspond to the time of valve 4 seating and lifting from the valve body seat 10. On the diagram of the air pressure in the direct chamber, points **i** and **j** stand for the time of opening the command channel ***f*** and the exhaust window ***e*** (figure 1) during the piston direct motion, respectively. The start of the valve 6 lifting and seating on the valve body 10 (figure 1) is observed on the line 2 at the moments referring to points **g** and **k**. The air pressure diagram $P_1$ up to point **b** shows intensive air inlet into the chamber after the valve lifting from the seat. Point **f** corresponds to air cutoff in the cylinder. Up to that moment, drop in pressure is observed temporarily, i.e. increase in air consumption due to opening the command channel. On the whole, the air pressure curve $P_1$ reflects the change in immediate airflow and the percussive mechanism operating process.

The valve operating diagrams 1 and 2 demonstrate that compressed air is not supplied into the cylinder in periods of time from point **d** to point **g** and from point **k** to point **l**. The moments of air inlet and cutoff in working chambers do not coincide. This all enables to accomplish the necessary process cycle in working chambers and reduce inefficient air consumption.

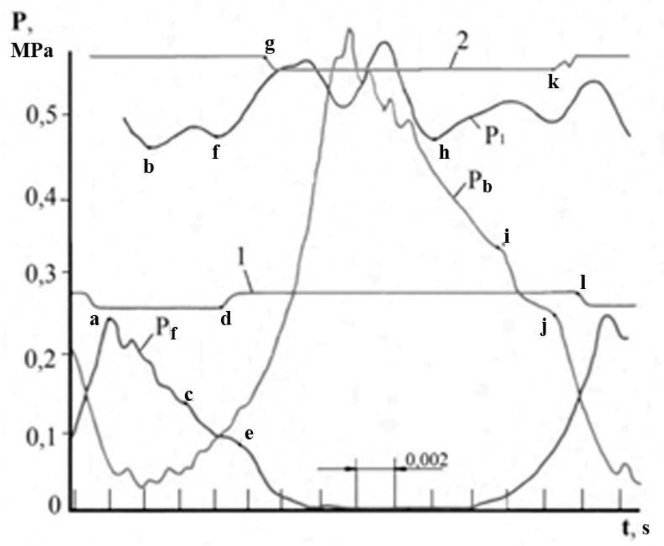


**Figure 2.** Oscillograph of the percussive mechanism operating processes: 1 and 2 – valve reversals of reverse and direct chambers, respectively; $P_b$, $P_f$ и $P_1$ – air pressure in the direct and reverse chambers, pre-valve chamber of the percussive mechanism, respectively.

## 4. Conclusions

High efficiency of the mechanism is achieved owing to implementing two autonomous DBs with inverse connection with the piston through the command channels and coordinated characteristics of elements in distribution and operation units. Unlike the extensively used machines with two DB reversals where the air inlet into the cylinder is continuous, the new device has four DB reversals within an operating cycle which allows performing an energy-saving operating cycle.

The features of the energy-saving operating cycle in the designed mechanism are: the working chambers are cut off from the circuit before the exhaust window is opened by the piston, air is not supplied into the cylinder up to 20% of the operating cycle time, the values of thermodynamic processes are less than 1.4, the internal energy of compressed air is used, maximum air pressure in the direct chamber is higher than that of the circuit, distribution phases in chambers are asymmetrical.

The laboratory and industrial tests of the drill have shown that it possesses higher technical and economic indicators in comparison with the core drill PK-75. The comparative tests of drills have shown that the new machine develops drilling speed 20-25% higher and has overall noise level lower by 8-10 dB. Its percussive mechanism has the efficiency 2,3 times higher, airflow rate being 3,8m$^3$/min.

The results of the conducted research have proved a possibility to create energy-saving constructions of impact machines that significantly surpass their known industrial counterparts in efficiency.

Implementing drills with the new percussive mechanism will enable to reduce energy consumption, increase productivity and improve hygiene and sanitary working conditions.

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