

Determination of variables for air distribution system with elastic valve for down-the-hole pneumatic hammer

AYu Primychkin^{*}, AS Kondratenko and VV Timonin

Chinakal Institute of Mining, Siberian Branch, Russian Academy of Sciences,
Novosibirsk, Russia

E-mail: ^{*}808@nn.ru

Abstract. The air distribution system of down-the-hole pneumatic hammer 105 mm in diameter is updated to enhance drilling efficiency. The design model of the down-the-hole pneumatic hammer is constructed in ITI SimulationX environment. The basic variables of the air distribution system with an elastic valve are determined so that to ensure increased impact energy at the limited pre-impact velocity and the same machine size.

The modified design of a pneumatic hammer with a diameter of 105 mm is intended to enhance efficiency of drilling [1]. Such diameter machines are used in underground blast hole drilling with rock drill model NKR-100. The most widely employed currently is pneumatic hammer model P105PM designed at the Institute of Mining, SB RAS, based on air hammer M48 and manufactured by many plants, including Stary Oskol Machine Shop.

The new modification of a pneumatic hammer is based on the layout of PP105-EN hammer [3], with an air distribution system equipped with an elastic valve, oriented by PP105-K hammer designed by V. Gaun [4]. The present R&D was aimed to increase blow energy of an air hammer at the limited pre-blow velocity and the preserved dimensions of the machine. The earlier research has shown that pneumatic hammers with elastic valves exhibit higher capacity as against valveless machines of the same sizes. Figure 1 shows the layout of PP105-EN hammer. An elastic ring-shaped valve (ERV) is installed in an adapting pipe 1 to control inlet of compressed air from the main line to the power stroke chamber B. Also from the adapting pipe, compressed air is fed to a central pipe 2 for bottom hole purge. The side holes 3 in the central pipe perform continuous feed of a cell C to supply the back stroke chamber A or the power stroke chamber B depending on the position of the striking part 6. ERV closure takes place when the power stroke chamber drops due to the opening of the exhaust channels 4 made in the walls of the housing 9.

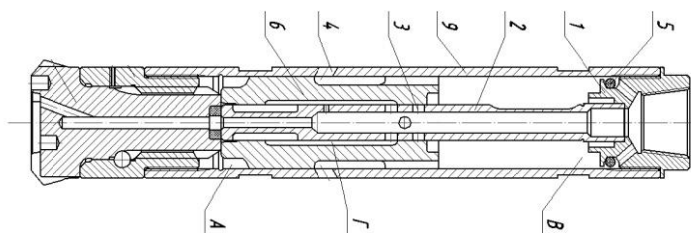


Figure 1. Down-the-hole pneumatic hammer PP105-EN (legend is explained in the text).

The feature of the elastic valve is that it is round. Such valve prevents from variation in the valve passage pressure p^* [5]. According to the research findings [6], it is possible to vary the average pressure above the valve and to adjust ERV actuation pressure by placing a rectangular cross-section valve with a face on the side of the air flow exit.

The given study task was to determine rational sizes of chambers, areas of channels, dimension and weight of striking part, positions of distributing edges of the striking part and, certainly, parameters of ERV with a view to ensuing maximum possible energy and capacity of hammering.

A quick and economical way of development of air distribution systems for pneumatic percussive machines is the computer-aided modeling. This method allows experimentation without manufacture of a full-scale sample of the machine.

The down-the-hole pneumatic hammer PP105-EN with an elastic valve installed in the system of air distribution was modeled in ITI SimulationX. The model included the key parameters of the machine: volumes of the working chambers, areas of channels, times of opening and closure of the channels, weight and areas of the striking part on the sides of the power stroke and back stroke chambers. Also, the model contained the earlier modeled elastic valve [7], that described the operating cycle of the valve, namely, control of the flow area of the passage feeding the power stroke chamber depending on the valve pressure difference. The model of the valve accounted for the valve stiffness, pre-tension, maximum travel, elasticity of the valve material and the length of the face (if present).

This model of a pneumatic hammer enables variation of any design parameters of an air distribution system and allows controlling the associated change in the energy characteristics of the hammer: A —blow energy; v —blow frequency; W —impact capacity; u —pre-blow velocity of the hammer head; q —compressed air flow rate, and others.

The ITI SimulationX model of the down-the-hole pneumatic hammer PP105-EN is depicted in Figure 2. The elastic valve is represented by a throttle 2 controlled by a function block 4. In the model, the valve actuation pressure was calculated using a simplified option as this is sufficient for a design calculation and there is no need to make detailed description of the valve travel [5].

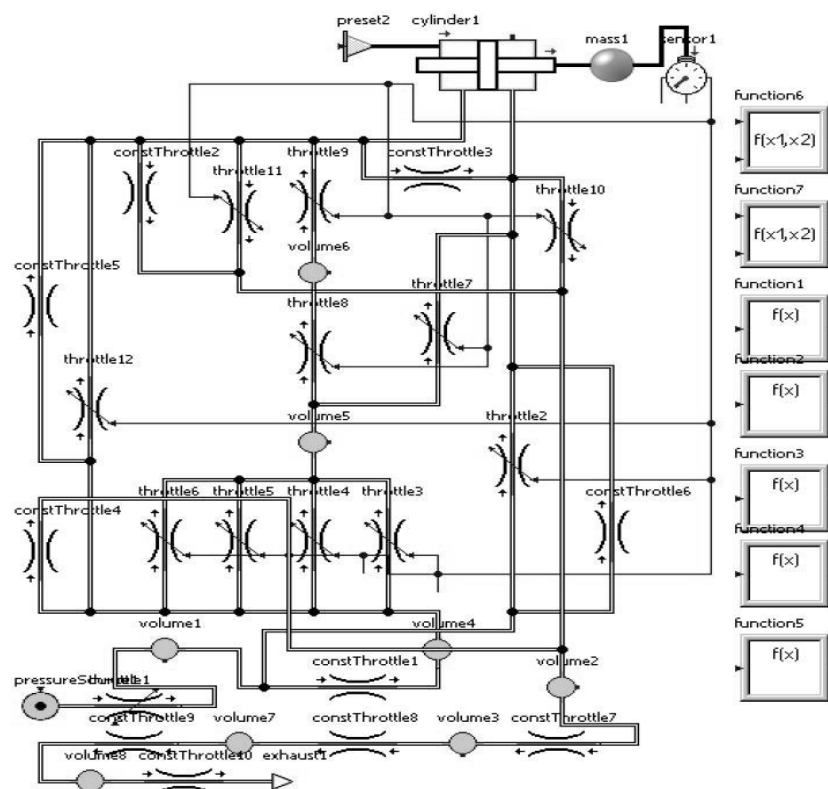


Figure 2. Pneumatic hammer PP105-EN model in ITI SimulationX.

The modeling involved various combinations of the variables of the air distribution system. The back stroke chamber volume (vol0A) was varied from 0.1 to 0.279 l, and the power stroke chamber volume (vol0B)—from 0.05 to 0.12 l. The striking part weight m was ranged between 4.08 and 4.62 kg, the elastic valve capacity (throttle2) was varied from 36 to 48 l/(bar·s), the edge of the exhaust hole (throttle10) was displaced by 0 to 26 mm (relative to the forward position of the hammer head), the pipe edge (throttle7) was shifted by 70–130 mm. The main feed line pressure was assumed 0.5 or 0.6 MPa. The maximum pre-blow velocity was limited to 9 m/s [8]. The overall calculation variants totaled 33.

After the calculations, we selected design variables to ensure the highest blow performance of the percussion machine at the minimized flow rate of compressed air. The plots of the operational cycle of the pneumatic hammer with the selected variables are given in Figure 3.

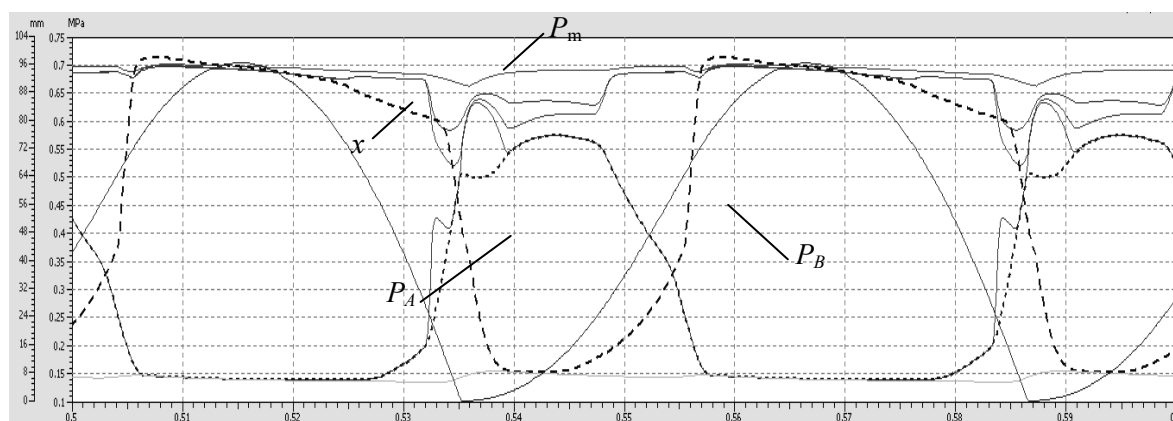


Figure 3. Operational cycle of pneumatic hammer with the rationally adjusted air distribution system: x —striking part travel; p_A —pressure in the back strike chamber A; p_B —pressure in the back strike chamber B; P_m —pressure in the main line.

The rational design of the air distribution system involved such finalized variables as: back stroke chamber volume (vol0A)—0.279 l; power stroke chamber volume (vol0B)—0.05 l; striking part weight m —4.42 kg; capacity of the elastic valve (throttle2)—48 l/(bar·s); position of the exhaust hole edge (throttle10)—0 mm (relative to the forward position of the hammer head); position of the edge on the pipe (throttle7)—70 mm. The main feed line pressure was 0.6 MPa.

With the rationally set air distribution system, the pneumatic hammer performance is: blow energy $A = 162$ J; blow frequency $\nu = 19.5$ s⁻¹, impact capacity $W = 3.2$ kW; air flow rate $q = 0.036$ m³/(kW·s); pre-blow velocity $u = 8.6$ m/s. As compared with the series production air hammer P105-PM, the new design hammer has the higher blow energy by 40%, the increased impact capacity by 18%, the lower air flow rate by 20% and the reduced blow frequency by 19%.

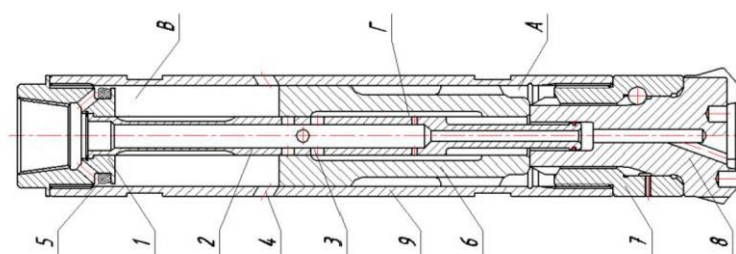


Figure 4. Modernized down-the-hole pneumatic hammer PP105-1KT. Description is in the text.

On the ground of the computer modeling results, the layout of the pneumatic hammer PP1-5-EN was modified: the central pipe 2 was elongated; the valve 6 was re-shaped and the elastic valve 5 of rectangular cross-section and with a face was included in the layout. The modernized pneumatic

hammer is intended for drilling holes with a diameter of 105 mm. The modified layout is shown in Figure 4. The mode of operation of this hammer is the same as with PP105-EN (refer to Figure 1).

Comparing the performance of the series production machines and the modernized pneumatic hammer design, the latter exhibits the considerable increment in the blow energy and capacity at the low air flow rate.

The new-design pneumatic hammer was trialed at a commercial scale in Gubkin Mine, KMAruda, between 12 and 18 June 2016.

Drilling using rock drills NKR-100MPa was carried out in quartzite with a low content of metals, with the strength up to 200 MPa. Drilling of blast holes was oriented top downward. Compressed air pressure in the main line of the pneumatic hammer was 0.7 MPa.

The commercial trials showed that penetration rate is 1.5–2 times higher with the modernized pneumatic hammer than with the series production hammer P105-PM.

References

- [1] Eremenko VA, Karpov VN, Timonin VV, Barnov NG and Shakhtorin IO 2015 Basic trends in development of drilling equipment for ore mining with block caving method *Journal of Mining Science* Vol 51 No 6 pp 1113–1125
- [2] Esin NN 1976 *Down-the-Hole Pneumatic Percussion Machines for Hole Drilling* Novosibirsk: Nauka (in Russian)
- [3] Timonin VV 2015 Downhole air hammers for underground mining *Gorn. Oborud. Elektromekh.* No 2 pp 13–17
- [4] Gaun VA 1981 Author's Certificate No. 848615 Pneumatic percussive device *Byull. Izobret.* No 27
- [5] Petreev AM and Primychkin AYU 2015 Influence of air distribution system on energy efficiency of pneumatic percussion unit of circular impact machine *Journal of Mining Science* Vol 51 No 3 pp 562–567
- [6] Petreev AM and Primychkin AYU 2016 Ring-type elastic valve operation in air hammer drive *Journal of Mining Science* Vol 52 No 1 pp 135–145
- [7] Petreev AM, Voronstov DS and Primychkin AYU 2010 Ring-shaped elastic valves in the air percussion machines *Journal of Mining Science* Vol 46 No 4 pp 416–424
- [8] Serpeninov BN and Nikonova IP 1976 *Transmission of Axial Impact in Hammer Head–Rod–Rock System as Regards Some Percussive Machines: Report* Novosibirsk: IGD SO RAN (in Russian)