Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

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To cite this article: A V Gruzin *et al* 2021 *J. Phys.: Conf. Ser.* **1901** 012114

Experimental studies of a valveless non spool-type pneumatic percussion mechanism of a hammer

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Abstract. Performing different kinds of activities, both in mining companies and in construction of industrial, housing and civil facilities requires specialized equipment provided with attached active operating elements, for example, pneumatic hammers. The analysis and selection of a schematic diagram of a pneumatic percussion mechanism are performed using known elements-features and structural additional expanding elements-features. This allowed a development of a new design of a valveless non spool-type pneumatic percussion mechanism of a hammer, for which analytical studies of its operating modes using a mathematical model were conducted. Experimental studies were carried out with an experimental sample of a pneumatic percussion mechanism to specify the reliability of parameters for the proposed mathematical model.

1. Introduction

In the process of mining and at construction facilities if drilling and blasting operations are impossible, percussion mechanisms are used for labor-intensive technological operations[1-6], such as:

- crushing and destruction of oversize rock and frozen soils;
- penetration, roof and sides wall scaling of mine workings;
- hole drilling, formation of recesses and holes in rock masses;
- disassembly of a certain structural elements of industrial buildings and engineering structures.

Currently, the Russian Federation as well as countries of the former Soviet Union and beyond have been widely used pneumatic, hydraulic, hydro pneumatic and other percussion mechanisms, unitized with various sizes of basic carrier machines to carry out the above-mentioned work. Pneumatic hammers are preferred due to [7]:

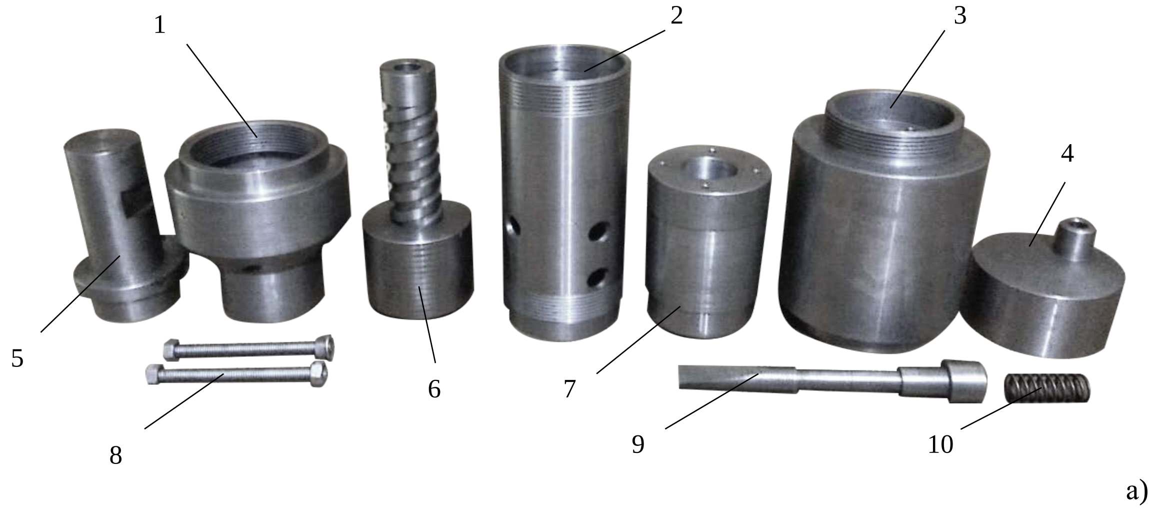
- a reliable operation in hard natural climatic and technological conditions;
- air usage as a working medium to ensure a steady operation and low requirements for thermal operation modes of moving system elements;
- providing required percussion power of machine function elements during various technological operations;
- meeting environmental and safety requirements.

In view of the above, the issues of creating new structures of pneumatic percussion mechanisms (PPM), determining their rational geometric characteristics, providing the required percussion power and minimum air consumption during technological processes at mining enterprises and construction facilities are relevant.

A mathematical model of operation of a valveless non spool-type pneumatic percussion mechanism (VlNsPPM) of the hammer was previously developed in order to find rational parameters of its operation [8, 9]. Experimental studies of working processes of the examined VlNsPPM of a hammer were conducted to estimate correctness of accepted limitations and assumptions in previously performed analytical studies [10-12].

2. Methodology, hardware and software to carry out experimental studies

The design of VlNsPPM of a hammer with elements-features of a combined air distribution with a required percussion power and low air consumption is the subject of the experimental study. Components of VlNsPPM of a hammer and its general view are shown in Fig. 1.



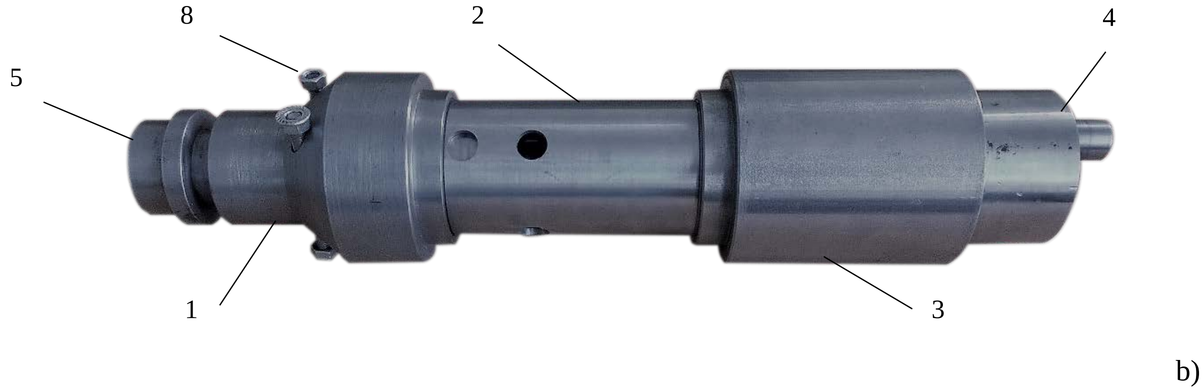


Figure 1. VlNsPPM of a hammer: a) components, b) general view. 1 - idling chamber housing; 2 - cylindrical housing of power stroke chamber; 3 - distribution chamber housing; 4 – supply pressure chamber housing; 5 - shank end; 6 – stepped striker; 7 - sleeve; 8 - pins; 9 - rod; 10 – spring.

The experimental research program was focused on identification of the following parameters in a work process of VlNsPPM of a hammer such as pressures in chambers under working and idle operations, energy and percussion frequency; vibration and noise characteristics. A high-speed digital video camera TMC-6740GE with a Navitar DO-5095 lens was used in the course of experimental study of dynamics (energy and percussion frequency) of the work process of a hammer's VlNsPPM. Technical characteristics of this video camera and its lens provided for 1250 frames/s shooting of the work process and required linear resolution in the field of view about 10^{-4} m [13]. Assistant V3 vibrometer and Testo 815 noise level meter were used to measure vibration and noise characteristics.

3. Technique for results processing of experimental studies of VlNsPPM of a hammer

Special software product Frame Analyzer has been developed to process obtained video frames [14]. Video frames processing consists of two stages: a preparatory stage and a frame processing stage. The preparatory stage includes the determination of parameters for viewing and frames processing of high-speed video recording:

1) a video frame viewing scale is set in order to reduce the effect of pixel discreteness of a screen on data processing results;
2) loading of the first frame of high-speed video recording;
3) performing of sequential numbering of all frames;
4) determining of the scale of exposed image in order to ensure a correct calculation of values obtained during the experiment;
5) setting of a frame exposure rate;
6) setting of the analysis mode of obtained experimental data (constant or discrete mode).

A constant analysis mode allows sequentially observation of the dynamics of one selected point, defining its motion and speed by successive clicks on each analyzed frame. A discrete mode allows observation of the dynamics of different points on each two consecutive frames. Statistical processing of the results of experimental studies was carried out using Direct repeated measurements software product [15].

4. Comparative analysis of integrated study results

Recording of operating process parameters in chambers of hammer's VlNsPPM was carried out in series of eight measurements for various pressures in the network (0.4; 0,5; 0.6 and 0.7 MPa) after the mechanism began operating in a steady mode.

Processing of obtained video frames made it possible to get data about the speed change of a hammer's VlNsPPM shank end when it is stricken with a stepped striker, taking into account the impact coefficient between them. Option settings of the pneumatic hammer were carried out according to the preliminary calculation of VlNsPPM using the Program for calculating barodynamic characteristics of the pneumatic percussion mechanism [16]. Air pressure supplied from p_o network, rebound coefficients of striker k_y and casing $k_к$ from the tool; flow coefficients of intake throttles of chambers of working μ_p and idle μ_x strokes and exhaust air discharge channels $\mu_{в1}$, $\mu_{в2}$ are initial data for preliminary calculation. Values of flow coefficients μ_i are calculated according to dependencies given in a reference book [17], and rebound coefficients are calculated according to recommendations [18]. As a result of experiments, flow coefficient values μ_i, rebound coefficients k_y, $k_к$, as well as air pressure p_0 in a prechamber were refined and used to perform a repeated specified calculation on a computer. Flow coefficient values were specified according to the method of identification by pressure diagrams.

Working processes in chambers of experimental model of VlNsPPM with p_o=0.6 MPa, k_y=0.2 and $k_к$=0.1 are represented by oscillogram of pressure change in chambers of working and idle operation modes p_i=p(t) (Fig. 2).

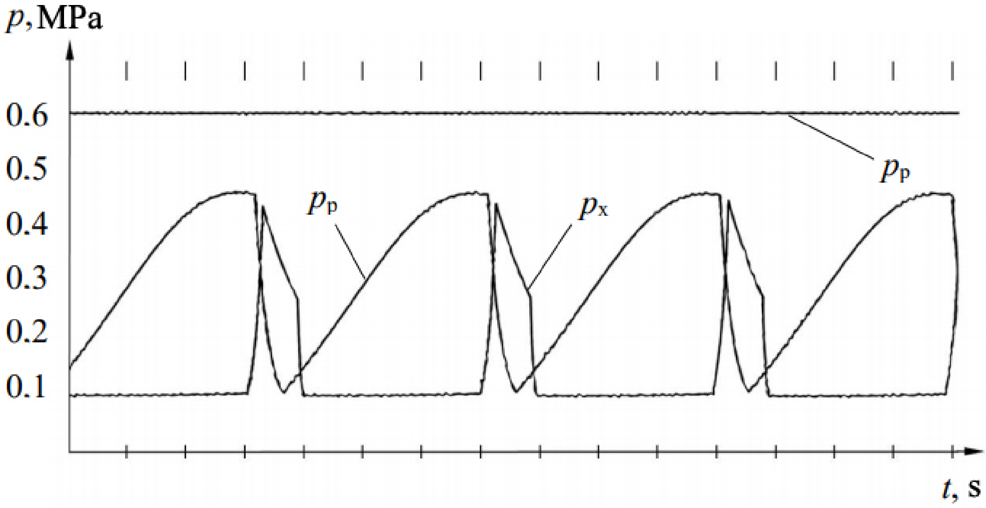
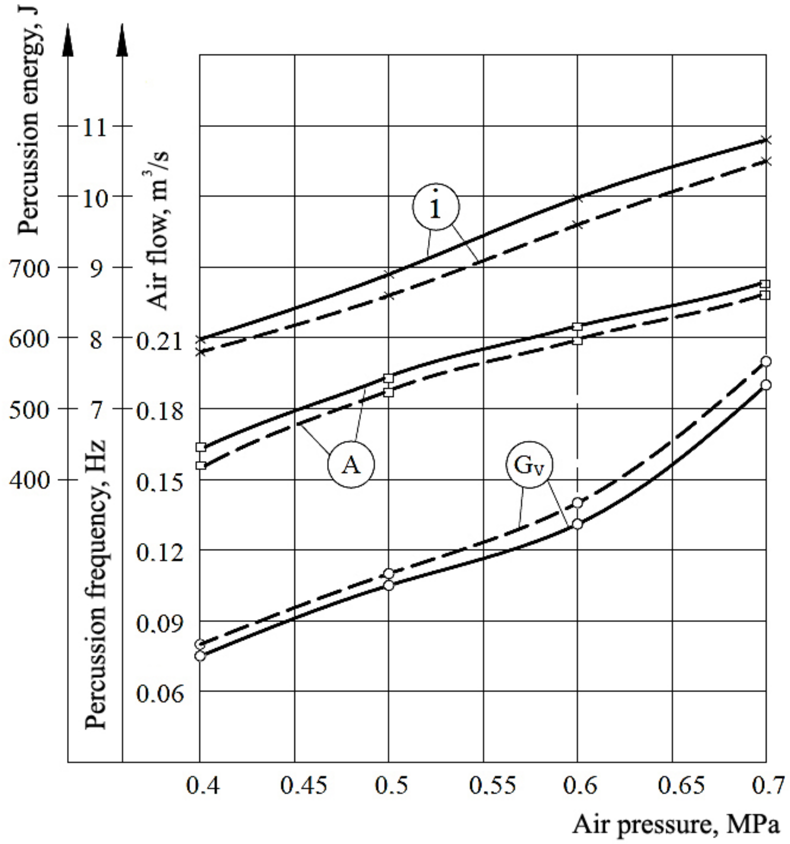


Figure 2. Oscillogram of working processes in chambers of working and idle operation modes of hammer's VlNsPPM.

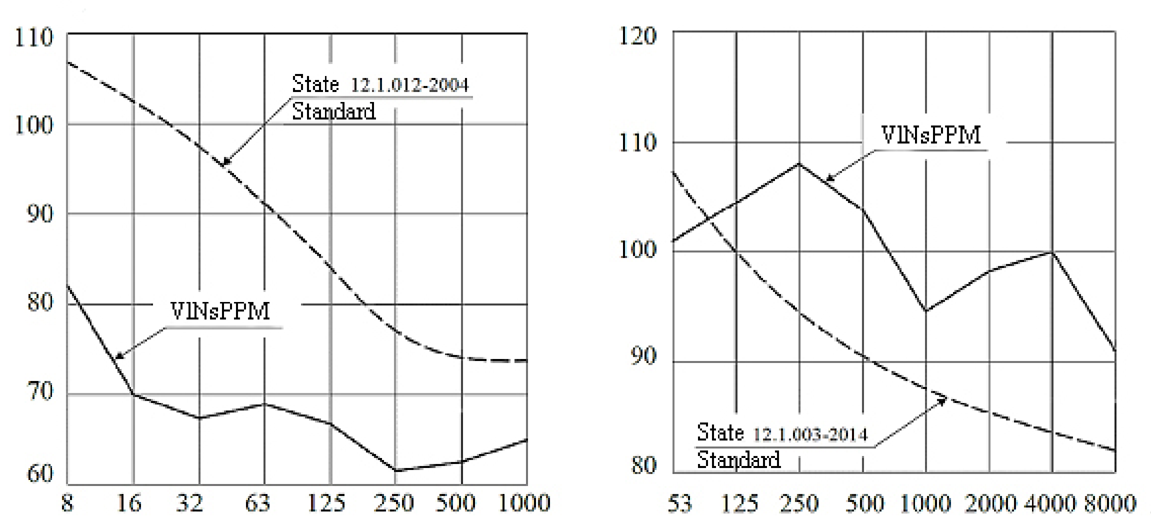
As the study of oscillograms shows, the nature of the change in air pressure in VlNsPPM chambers of a hammer at steady operation modes indicates the stability of operating cycles for each of the modes. The results of experimental studies are presented with a dashed line, the results obtained by means of a mathematical model are given with a solid line in fig. 3.



A – percussion energy; i – percussion frequency; G_v – air flow

Figure 3. Research results of parameters of hammer's VlNsPPM.

The measurement of vibration and noise characteristics of percussion pneumatic hammer with VlNsPPM was conducted on a bench with a press force on the housing Fp = (2250…2400) N (fig. 4).



a) b)

a) vibration; b) noise

Figure 4. Characteristics of VlNsPPM of a hammer.

Vibration characteristics of a percussion pneumatic machine with VlNsPPM do not exceed standard values in all range of frequency change (Fig. 4 a) [19]. At the same time, noise characteristics of VlNsPPM almost in all frequency range slightly exceed standard values (Fig. 4 b) [20].

The analysis of numerical and experimental data of energy characteristics shows their disagreement within acceptable limits. Maximum difference in absolute values of air pressure in VlNsPPM chambers of a hammer does not exceed 2.5% for the working stroke chamber, and disagreement for the idling chamber does not exceed 3%. The disagreement in percussion energy values does not exceed 3.84%, in percussion frequency it does not exceed 3.96%, and the disagreement in air flow rate is 6.87%, which is within the range of possible error of measurement results and their processing, performed by means of mathematical statistics methods.

5. Conclusion

A sample of hammer's VlNsPPM containing combined air distribution facility at inlets to working and idle operation mode chambers was manufactured for experimental studies. The air distribution facility was constructed in a form of overlapping calibrated channels controlling air flow. A procedure to conduct complex research using modern information technology, hardware and software was developed. Experimental studies of VlNsPPM of a hammer were performed for network pressure 0.4; 0.5; 0.6 and 0.7 MPa. Data on percussion energy, percussion frequency, air flow rate and the effect of design parameters of VlNsPPM were obtained. For this design of VlNsPPM of a hammer, the percussion energy of experimental model varied from 413.8 to 669 J, the percussion frequency changed from 7.8 to 10.5 Hz, the air flow altered from 0.08 to 0.20 m^3/s if the network pressure changed from 0.4 to 0.7 MPa. The results of the studies showed a disagreement between experimental data and numerical simulation data on percussion energy up to 3.84%, on percussion frequency up to 3.96%, on air flow up to 6.87%, which is within the error level of instruments and measurement processing.

References

[1] Abramenkov D E, Melnikova A S, Dedov A S, Popov N A, Gruzin A V and Abramenkov E A 2012 *Classification of features and schematic diagrams of pneumatic percussion mechanisms of construction mounted hammers* (News of higher educational. Construction)

1(637) pp 92–101
[2] Abramenkov D E, Abramenkov E A, Gruzin A V, Krutikov E I, Popova A S and Popov D A 2012 *Schematic diagrams of valveless pneumatic percussion mechanisms with a coaxial air pipeline chamber and their physical and mathematical description* (News of higher educational institutions. Construction) **6(642)** pp 60–68
[3] Hartman H L and Mutmansky J M 2002 *Introductory Mining Engineering 2nd Edition* (Hoboken, USA: John Wiley & Sons, Inc.)
[4] Hustrulid W A and Bullock R L 2001 Underground Mining Methods: Engineering Fundamentals and International Case Studies (Littleton, USA: Society for Mining, Metallurgy and Exploration, Inc.)
[5] Allen E and Iano J 2019 *Fundamentals of Building Construction: Materials and Methods*, 7th Edition (Hoboken, USA: John Wiley & Sons, Inc.)
[6] Rutherford C 2018 *Building Maintenance & Construction: Tools and Maintenance Tasks* (Interactive) (Kahului, Hawaii, USA: University of Hawaii Maui College and the Construction Technology)
[7] Gruzin A V, Kulikov A V, Abramenkov D E and Abramenkov E A 2012 *Schematic diagram of a throttle no slide pneumatic percussion mechanism and its physical and mathematical description* News of higher educational institutions. Construction **10 (646)** pp 81–87
[8] Abramenkov D E, Abramenkov E A, Bukatova O A, Gruzin A V, Kulikov A V and Malyshev M S 2016 *Pneumatic percussion mechanism* Pat. of the Russian Federation No. 2015118484/03: appl. 18.05.2015: publ. 20.07.2016 IPC E21B 1/30 (2006.01), E21B 1/38 (2006.01), E21C 37/24 (2006.01)
[9] Gruzin A V 2019 *Proc. of the 2nd Int. Sci. Conf.* (Kursk: South-West. state university) pp 112–118
[10] Schenk H 1978 *Theories of Engineering Experimentation* (New York, USA: McGraw-Hill Companies)
[11] Doebelin E O 1995 Engineering Experimentation: Planning, Execution, Reporting (New York: McGraw-Hill Companies)
[12] Juristo N, Moreno A M 2001 *Basics of Software Engineering Experimentation* (New York, USA: Springer Science+Business Media)
[13] Gruzin A V and Gruzin V V 2007 *Justification of parameters and building of a test bench to study a percussion effect of a stamp on a soil* International scientific journal Current problems of our time **1(14)** pp 297–302
[14] Gruzin A V, Gruzin V V and Kucherenko M V 2014 *Image processing method* Pat. of the Russian Federation No. 2013100628/08: appl. 09.01.2013: publ. 10.12.2014 IPC G06T 7/20 (2006.01), G06K 9/36 (2006.01), E21C 37/24 (2006.01)
[15] Gruzin A V 2020 *Processing of direct repeated measurements according to State Standard R 8.736-2011* Certificate of state registration of computer programs 2020612660, Russian Federation No. 2020611785: appl. 25.02.2020: publ. (reg.) 28.02.2020
[16] Gruzin A V, Gruzin A V and Gildebrandt M I 2017 *Program for calculating of barodynamic characteristics of a pneumatic percussion mechanism* Certificate of state registration of computer programs 2017616753, Russian Federation No. 2017610282: appl. 10.01.2017: publ. (reg.) 13.06.2017
[17] Idelchik I E 2012 *Handbook on Hydraulic Resistances* (Moscow: Book on Demand) p 466
[18] Yesin N N 1965 *Method of research and refinement of pneumatic hammers* (Novosibirsk: Institute of Mining, Siberian Branch, Russian Academy of Sciences USSR) p 76
[19] State Standard 12.1.012 - 2004. Labor safety standards system. Vibration safety. General requirements: nat. standard of the Russian Federation: off. ed.: conf. and put into effect by order of Federal agency on technical regulation and metrology on Dec. 12, 2007 No. of 362-st: intr. for the first time: date of intr. 2008-07-01 / developed by OAO Research Center for Control and Diagnostics of Technical Systems. - M.: Standardinform, 2010 p 15
[20] State Standard 12.1.003 - 2014. Labor Safety Standards System (LSSS). Noise. General Safety Requirements (Reprint): nat. standard of the Russian Federation: off. ed.: conf. and put into

effect by order of Federal agency on technical regulation and metrology on Dec. 29, 2014 No. of 2146-st: intr. for the first time : date of intr. 2015-11-01 developed by OAO Research Center for Control and Diagnostics of Technical Systems. M.: Standardinform, 2019 p 24