Automated calculation and analysis of impacts generated in mining machine by anvil blocks of complex geometry

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Abstract. One of the most efficient ways of improving percussion-action machines is selecting the shape of an anvil block such that to generate impact adequate to penetration resistance of rocks. From this viewpoint, the authors present a numerical-analysis algorithm and implementation to determine and analyze impacts generated by a complex-geometry anvil blocks. Application of the automated calculation is illustrated in terms of impacts generated in down-the-hole hammers.

Improvement of percussive mining machines means increasing their capacity, extending their life, reducing energy intake and enhancing ergonomic characteristics. All other things equal, the objective can be reached by means of higher supply or by effectivization of accumulated energy conversion to rock fracture energy. The both trends require finding and evaluating methods and means capable to generate elastic deformation waves of efficient form to ensure energy transmission at minimum loss.

Under longitudinal impact on a waveguide-tool, the action effect depends on the weight, pre-impact velocity and shape of a striking tool. Elastic wave generated in a rod under impact is governed both by the energy, i.e. impulse area, and the law of change in the impulse amplitude along the impulse length. This law as a physical fact of influence exerted by the striking body shape on the impact fracture effect was officially put forward by Aleksandrov in 1964 as Discovery No. 13 [1]. On that ground [2–4], selecting efficient shapes of anvil blocks is the most valid approach to enhancing energy transmission coefficient in design of percussion systems.

For the comparison of application of different shape anvil blocks, it is necessary to know conditions and laws of formation of impulses in the waveguide–tool. The problem of determining impulses generated by anvil blocks of different shapes is solved using the grapho-analytical method [5–7] making framework for a numerical algorithm of an authors computer program [8].

The source data for calculating an impact include such parameters of a percussion system as: pre-impact anvil block velocity $V_0$, m/s; anvil block weight $m$, kg; anvil block length $l$, mm; shape of the anvil block; reduced diameter $d_0$ (mm) or cross-section area $S_0$ (mm$^2$) of the waveguide-tool; density $\rho$ and elasticity modulus $E$ of material anvil block is made of, and sound speed $a$ in the material. The calculation results are the law of change in the magnitude of the impulse along its length, amplitude, efficient duration, amplification factor $F_{\text{max}}/F_0$ and energy of the first two waves. The developed numerical-analysis algorithm is shown in Figure 1.
In practical engineering of percussion machines, the striking body—anvil block—is made as a body of rotation with cavities, cuts and holes of different shape and size. Figures 2a and 2b show anvil blocks of DTH hammers PP110EN and PP10NK, respectively, designed at the Institute of Mining, SB RAS [9–12].

**Figure 1. Impact analysis algorithm.**
Prior to calculating an impulse generated by an anvil block of a complex geometrical shape, it is necessary to determine its reduced form, i.e. to represent an anvil block as a body of rotation in order to find cross-section areas $S_i$ of all cylinder stages into which the anvil block is divided according to the grapho-analytical method (Figure 1). The problem can be solved using T-Flex CAD or KOMPAS 3D which allows three-dimensional modeling and geometrical analysis of an anvil block (Figure 3) [13].

The information on the reduced form of an anvil block allows determining and analyzing the generated impulse depending on functional purpose of the machine the anvil block is used in.

When the anvil block strikes a waveguide-tool, the form of the impulse should conform in time with the penetration resistance of rocks. The force required to penetrate a rock-breaking tool in rocks is low in the beginning of penetration and should grow while the tool penetrates deeper since the tool and rock contact area enlarges as the tool penetration depth grows. Accordingly, the amplitude of the impulse should increase.

The analysis of the impulses generated by the anvil blocks of DTH hammers 110EN and 110NK makes it possible to draw the conclusion that their geometrical design should be changed so that to ensure such shape of the anvil block that the area of its cross section intensively enlarges. In this case, the amplitude of an impulse will increase with time as the impulse travels, which will ensure efficient blow energy transmission to a waveguide-tool and, then, to rocks as the form of the impulse conforms with the force required to break rocks.
Figure 4. Impulses generated by anvil blocks: (a) PP110EN and (b) PP110NK.

References
[1] Aleksandrov EV 1964 USSR Discovery No. 13 Byull. Izobret. No 7 p 1
[2] Zhukov IA and Molchanov VV m2014 Rational designing two-stage anvil blocks of impact mechanisms Advanced Materials Research Vol 1040 pp 699–702 DOI: 10.4028/www.scientific.net/AMR.1040.699
[3] Zhukov IA, Zakharova EV and Andreeva YaA 2014 Development of the anvil blocks forms of impact machines as composition of different materials AIP Conference Proceedings Vol 1623 pp 663–666 DOI: 10.1063/1.4899032

[4] Zhukov IA and Dvornikov LT 2015 New Constructive Solutions of Anvil Blocks of Percussion Mining Machines North Charlestone: CreateSpace

[5] Ivanov KI, Latyshev VA and Andreev VD 1987 Drilling Equipment in Mineral Mining Moscow: Nedra (in Russian)

[6] Zhukov IA and Dvornikov LT 2009 Analysis of shapes of anvil blocks in percussion systems using grapho-analytical method Vestn. Komp. Inform. Tekhnol. No 1 pp 15–19

[7] Zhukov IA, Timofeev EG and Molchanov VV 2015 Modeling longitudinal oscillation of composite anvil blocks in percussion systems Nauch. Obozren. No 5 pp 90–93

[8] Timofeev EG, Zhukov IA and Molchanov VV 2017 RF Certificate PVM No 2017613900 Multi-State Anvil Block Impact (in Russian)

[9] Lipin AA, Belousov AV and Timonin VV 2009 RF Patent No 5185 Down-the-hole hammer Byull. Izobret. No 21

[10] Lipin AA and Zabolotskaya NN 2012 RF Patent No 2463431 DTH hammer Byull. Izobret. No 28

[11] Timonin VV 2015 Down-the-hole hammers in underground mineral mining Gorn. Oborud. Elektromekh. No 2(111) pp 13–17

[12] Smolyanitsky BN, Repin AA, Danilov BB et al 2013 Enhancing Efficiency and Durability of Impulse-Generating Machines for Long-Hole Drilling in Rocks Novosibirsk: IGD SO RAN (in Russian)

[13] Zhukov IA 2016 Automation of determining reduced forms of anvil blocks in percussion mechanisms Avomatiz. Proektir. Mashinostr. No 4 pp 50–54