Highly efficient hard rock-breaking tool for mining machines

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Abstract. Under consideration is the experience gained in design and manufacture of tools for mining machines meant for operation in uncontrollable conditions. It is shown that equipping the mining machines with disk tools reduces specific consumption of the tools, specific power-input and dusting during breakage of hard rocks.

1. Introduction
Experience of longwall mining equipment operation in off-standard conditions (complex structure coal seams, ore bodies and placers) [1–5] shows that rock destruction consumes much energy and results in high wear of tools [6]. An alternative to series-produced cutting tools can be shearing discs commonly used on various heading and shearing machines [7–9].

The earlier research [10] yields that for shearing discs mounted on shearer drums for breaking hard rocks, the most efficient mode is low-cycle force-impact destruction when stress state is preliminary created and repeatedly used during the passes of the disc tools. Moreover, in this case, it is possible to cut down destruction energy by 15–20 times as compared with the free shearing mode, which allows series-produced cutting machines to be used in extraction of minerals with ultimate compression \( \sigma_c \leq 140 \text{ MPa} \).

2. Bench tests results
As a result of bench tests on breaking of different rock lithotypes by shearing discs, the operating envelope of the tools (cut width \( t_c \) and penetration depth \( h \)), ensuring minimum energy input, is determined, and arrangement recommendations are made of shearing drums, based on which an aggregate equipment concept is developed.

For the analysis of various arrangement layouts of shearing drums and selection of efficient operation modes of shearers with regard to their energy and force performance, a simulation model of load formation on a shearing tool is developed [10, 11]. The source data of the model are the sequence of load impulses formed on separate tools with regard to variable cross-section of chips, the parameters of the impulses are determined in accordance with the experimentally found laws of distribution; the output of the model is a random discrete sequence of instantaneous values of power taken by the shearer motor.

Examination of various possible design layouts of the mounting group from the viewpoint of reliable secured rotation of the shearing disc, especially if arranged on the goaf side of the drum, has resulted in picking out the mounting group embedded in the body disc rolling cutter, it is also found that the critical factors that govern efficiency of the mounting group are the tribotechnical characteristics (roughness of adjoining surfaces, clearance, friction coefficient, etc.). Based on the
analysis of influence exerted by finishing operations on the quality of surface of parts and, eventually, on the joint friction coefficient, technical requirements for the mounting group are formulated.

From the laboratory investigation data, the geometrical parameters of the shearing disc tool such that ensure efficient destruction and sufficient tool strength are determined (Figure 1).

Figure 1. Design of a disc tool with various structure reinforcement insert: (a) conical; (b) mushroom; (c) ellipse.

3. Production tests results
The production tests of prototype shearing discs in cutting coal with dirt bands and partings, metamorphized quartz vein and permafrost placer, as well as in extraction of sulphide ore from thin lodes [13, 14] prove validity of the recommendations used as the framework for shearing disc design and show that:

— destruction energy in coal with fine-graine sandstone partings and hard inclusions makes $H_W = 0.7–1.0 \text{ kWh/m}^3$;
— destruction energy in quartz metasomatites (very brittle rocks) is on average $H_W = 0.85–1.25 \text{ kWh/m}^3$ and maximum 4.5 kWh/m$^3$ in extraordinary operation mode;
— specific energy of destruction of permafrost placer alluvium (viscous rocks) makes on average $H_W = 2.8–3.5 \text{ kWh/m}^3$ and maximum 4.1 kWh/m$^3$;
— specific dust formation halves as compared with rock cutting by series-produced tools;
— specific wear of shearing disc tools totals 8 discs per 1000 m$^3$ of broken rocks;
— TBF of the mounting group is 800–1000 m$^3$ of broken rocks.

Good results obtained in destruction of viscous and strong permafrost placer rocks made the basis for designing the cutting tool for underground kimberlite extraction without blasting. Kimberlite ore of higher strength ($\sigma_c \geq 50 \text{ MPa}$) and viscosity ($\chi \geq 0.14$) [15, 16] can be cut by moon miners advantageous for:

— selective slicing of mineral reserves;
— simultaneity of cutting and haulage operations during displacement of cutting tool on the face;
— high mobility and maintainability in limited reserves bodies;
— infinitely variable control of the cut layer thickness.

The cutting drums of boom miners should be equipped by shearing discs (Figure 2) using the scheme implemented on prototype machine TM-D25 [17].
High wearability of discs, minor dust formation and ability to transfer much more energy to the face as against cutters enable engineering of cutter–shearer drums with shearing discs.

The modeling result of the drum performance with the shearing disc tools in destruction of rocks of various strength and brittleness in Figure 3 prove that the range of application of the shearing discs implemented low-cycle force-impact destruction is much wider than the tangential rotary picks have.

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