MECHANIZATION AND AUTOMATION OF MINING

STUDY OF LOADING BUCKET PENETRATION INTO A ROCK STOCKPILE

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One of the most labor-consuming and difficult processes of underground mining of economic minerals is loading of a rock mass separated at the faces of extraction and preparatory workings. This process is particularly labor consuming and complicated in mining hard, large-lump, and highly abrasive rocks which are difficult to crush and are typical for underground mining in ferrous and nonferrous metallurgy [1]. The relative cost of loading under these conditions is up to 30% of the total cost of the ore and specific labor costs are 20-25% of the total labor costs for mining 1 ton of ore [2].

In the mining industry for loading rocks and economic minerals there is extensive use of different types of loading machines of periodic and continuous operation [3]. For all loading machines there are typically significant (in magnitude) resistances which arise on introducing the excavating part into a stockpile of material, and in order to overcome them it is necessary to enlarge the chains of the machine, the power driving them, and to increase the strength of individual components and assemblies. A considerable part of the power of loading machine engines is expanded in this loading process.

With high penetration resistance for a loading machine bucket it is introduced to a small depth into a stockpile and poorly filled with rock. Under practical conditions the filling factor for a bucket is at the level of 0.5-0.6, and it rarely reaches 0.7-0.8. This leads to a reduction in loading productivity.

A reduction in the penetration resistance is accomplished mainly as a result of improving the geometric shape of the excavating part, selection of its movement trajectory into a layer of rock, automation of the scooping process, crushing of rock into smaller lumps, etc. However, these paths are almost currently exhausted and cannot give a marked reduction in the penetration resistance.

In view of this with the aim of improving the effectiveness of loading large-lump rock masses from a stockpile use of a pulsed technique is suggested for activating the excavating part of loading machines.

Studies carried out at IGD SO RAN established [2] that with vibration of the excavating parts the penetration resistance may be reduced by a factor of four to five which is mainly achieved as a result of a reduction in the internal and external friction of the rock being loaded. Studies have also established that ahead of the edges of the excavating part during penetration a core of compacted rock forms which is a group of rock lumps moving together with the leading edge of the excavating part into a layer of rock creating with movement increasing resistance. The most effective way of overcoming the core of the compacted zone is an impact load facilitating not only separation of lumps adjacent to each other, but also breaking them.

Recently in the IGD SO RAN considerable experience has been accumulated both in the field of studying breaking of hard materials by impact activators, loading processes, and transporting of rock mass using vibration, and also in creating pulse techniques: impact devices and vibrators which are used extensively in various branches of the national economy.

On the basis of a series of impact devices buckets have been created with activated operation for excavators of the construction and quarry classes [4]. In developing active excavator parts of loading machines it is possible to use a number of successful and already proven structural solutions.

With the aim of determining the main possibility of using activation of the working edge of a bucket of a loading machine in order to improve the effectiveness of loading of a large-lump rock mass from a stockpile formed during extraction experimental studies were carried out for the process of introducing an active loading bucket into a rock stockpile.
Experimental studies were performed on a physical model simulating the process of introducing a bucket and consisting (Fig. 1) of a box-type frame 1, a bunker for the rock mass 2, a loading bucket 3, a pneumatic striker 4, and a hydraulic jack 5.

The box-shaped bucket consists of side walls 6 and a bottom 7 whose leading edge is fitted with interchangeable teeth 8, and rear connecting bolts with a tool 9 of a pneumatic striker 4. The body of the pneumatic striker 10 is fastened in steadyrests 11, and the rear part of the body is flexibly connected with the rod 12 of the hydraulic jack 5. The cylinder of the hydraulic jack is fastened by means of a pin to a bracket 13 with is rigidly secured to the frame 1. The bucket moves along the frame in guides 14. The travel of the hydraulic jack is 0.6 m, the bucket length is 0.6 m, and its width is 0.33 m.

A pneumatic pile driver P125-1K built by the drilling laboratory of IGD SO RAN with an energy for a single impact of 240 J and an impact frequency of 15.8 Hz with air pressure in the supply line of 0.5 MPa was used as a shock pulse exciter.

The vibration pulses are excited by a ‘Napor 01-02’ pneumatic vibrator built by the drilling laboratory of the IGD SO RAN with a vibration frequency of 83 Hz at an air pressure of 0.5 MPa and a static moment (disbalance) of 0.006 kgm. The pneumatic vibrator is fastened between the bucket and the pneumatic striker which in this case serves as an intermediate member transmitting an axial force from the hydraulic jack. Compressed air to the pneumatic exciter is fed from the supply-line by means of hoses with an internal diameter of 16 mm.

Granite rubble with a size fraction of 10-30, 30-60, and 60-90 mm was used as the rock mass.

In accordance with the stated aim during experiments a correlation relationship Pf(L) was determined, i.e., penetration resistance on distance travelled by the bucket during penetration into the stockpile for three varieties of it (static, impact, and vibration). The following parameters were considered in the studies.

Constants: 1) bucket shape and dimensions, 2) rubble stockpile height, 3) physicomechanical properties of the rubble, 4) bucket movement rate.

Variables: 1) fractional composition of the rubble, 2) form of bucket cutting edge (solid edge, edge fitted with teeth), 3) number of teeth in the cutting edge.

In performing experiments the following values were measured:
1) P, the resistance to penetration of the bucket into the stockpile, kN;
2) L, the distance travelled by the bucket on introducing it into the stockpile (amount of penetration), m;
3) compressed air pressure in the supply line, MPa;
4) time of bucket penetration, sec.

Measurement of penetration resistance and compressed air pressure in the supply line was accomplished by means of standard pressure gages DSI-2.5 with a natural frequency of 200 Hz and a set of equipment including a mirror-galvanometer oscillograph K008, a recorder N071.1, a matching equipment unit, and an oscillographic galvanometer. Force on the hydraulic jack rod was determined as a product of the piston area by pressure in the piston cavity recorded on an oscillogram.

Friction forces in compacting the hydraulic jack and within the guides of bucket movement were considered in determining the bucket penetration resistance. For this separate records were made of the force for free rod movement and the force of free movement of the bucket within the guides.

For each of the three fractions present in the rubble comprehensive bucket testing was carried out: static penetration, and penetration with additional excitation in the bucket of impact and vibration pulses.

The sequence of carrying out experiments was as follows. The bunker was filled with rubble of a certain fraction to the maximum possible level (0.8 m). The initial position of the bucket was recorded by a reference point. The valve for compressed air supply was opened (in the case of performing an experiment with dynamic penetration). By successive switching the measuring equipment and hydraulic jack of the experimental unit were set into operation. Under the action of forces applied to the bucket it penetrated the stockpile of rock mass either up to complete advance of the hydraulic jack (with dynamic penetration) or up to an arresting device arising on reaching the maximum force in the hydraulic jack (about 0.8 kN) which was observed with static penetration into rubble with a fraction of 60-90 mm. After reaching maximum penetration the measuring equipment was switched off and the amount of bucket burying was recorded by reference mark. After this reverse travel for the hydraulic jack was switched on and the bucket was withdrawn from the rubble to the original position.

In treating the results of measurement oscillograms were taken as a basis in which marks for the start and finish of bucket penetration were applied. Further treatment of an oscillogram was carried out in sections corresponding to a relatively constant bucket penetration regime.