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Study of Mechanical Loosening of Rocks using Highly Powerful Bulldozer: Example of Quarries of Construction Materials

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Abstract: This study provides the results of a study on mechanical loosening using the bulldozers of different capacity. Creation of powerful and super-powerful bulldozers and improvement of the designs of modern rippers over the past 5 years has significantly expanded the scope of mechanical loosening which is now considered as one of highly efficient production processes in open mining. In order to improve the quality of mined raw materials and minimize their losses, the schemes with the involvement of rippers like layered rock excavation and with the creation of intermediate warehouses, etc. are used successfully. In Russia and abroad, progressive manufacturing of rippers is explained by a number of advantages in comparison with the existing methods of loosening. In open-pit mining, the rippers allow to eliminate some of the shortcomings inherent in drilling and blasting such as seismic effect and damaging effect of rock fragments during projection, significantly reduce the cost of loosening by more than 1.5-2 times as well as to improve work safety and capacity.

Key words: Bulldozer, ripper, rock, mineral deposit, seismic velocity, layered excavation

INTRODUCTION

There are two main types of rippers: traction (towing) and bulldozer-attached (back-located). Traction rippers are used when loosening the soil with remnants of tree roots, removing the stumps and loosening the frozen or compacted soil.

The weight of the bulldozer with attachments (Fig. 1) is summed up with a force created by the hydraulic system which provides fast deepening of the working attachment in the soil and the constant depth of loosening. In case of a need to perform other operations, the ripper rack rises, allowing using the carrier vehicle for all purposes (Kovalevskiy and Argimbaev, 2016; Yakubovisky *et al*., 2014; Kholodnyakov and Argimbayev, 2014; Argimbaev and Kholodjakov, 2014; Yakubovisky *et al*., 2015; Argimbaev *et al*., 2015).

Ripper's attachment body is composed of a rack, tip, one or two safety plates designed to protect the bottom of the rack from significant wear and tear (Fig. 2).

In order to ensure cost-effective work in a variety of circumstances, there are two types of tips (axial and penetrating) and of three configurations: long (for abrasive rocks), short (for operation in harsh conditions with increased push loads) and medium (for normal operating conditions). Most tip enclosures

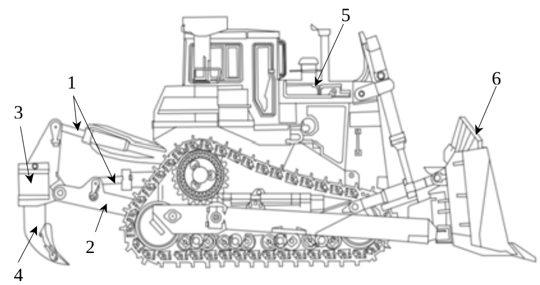

Fig. 1: Principal structural layout of the ripper: 1) Hydraulic system; 2) Frame; 3) Vane; 4) Rack with tip; 5) Bulldozer and 6) Blade

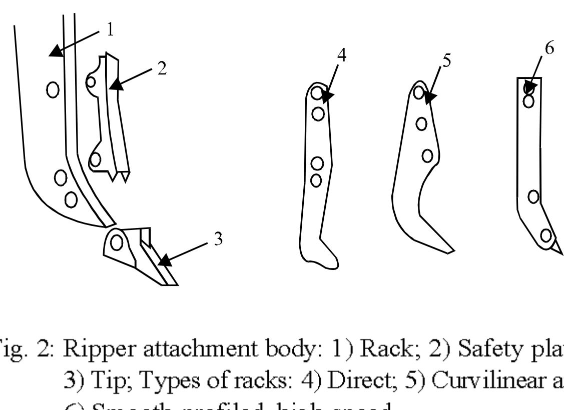

Fig. 2: Ripper attachment body: 1) Rack; 2) Safety plate; 3) Tip; Types of racks: 4) Direct; 5) Curvilinear and 6) Smooth-profiled, high-speed

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Table 1: Recommendations on the use of tips in different conditions

Loosening conditions	Tips used
Two hitch-towed bulldozers	Short
Single-frame and multi-frame	
For extreme operating conditions	Short/medium
Average conditions	Long/medium
Abrasive conditions	Long

have the self-sharpening form, i.e., in case of worn face of tip the edge of the tip doesn't get blunt (Argimbaev and Kholodjakov, 2016; Argimbaev, 2016a; Pikalov *et al*., 2016; Kaerbek and Maya, 2016).

Efficiency of a particular tip depends on both the loosened material and the model of the loosening bulldozer. Very dense materials require the use of "penetration" tips. Materials, whose loosening involves great push loads, require the use of "axia" tips (Argimbayev *et al*., 2016; Argimbaev, 2016b). Table 1 summarizes recommendations on how to use the tips.

MATERIALS AND METHODS

The cost of loosening is to be compared with other methods of material fragmentation as a rule with drilling and blasting based on cost per ton of banked ground. Therefore, there is a need for accurate evaluation of loosening performance to determine unit costs while loosening (Kaerbek and Ivanova, 2016; Argimbaev *et al*., 2014; Bukhman *et al*., 1966). There are three common methods of evaluation of loosening performance:

- Recording of time of loosening
- Measurement of the cross-sectional area and subsequent recording of the time spent for loosening
- Measurement of the time of loosening at a certain distance (the least accurate, however, useful in terms of timing by the method of evaluation of the scope of work)

According to the mine engineering conditions, the limestone-dolomitic deposits of the Tula Oblast (Russia), the preliminary calculation of performance and unit cost of rock loosening was done using the blastless method.

The following conditions were taken as initial data: a bulldozer with the capacity of 538 kW (ripper with one rack), 910 mm distance between passages, average speed when loosening 1.6 km/h (taking into account slippages and stops). Loosening area with the length of 91 m (1 passage). For every passage, the bulldozer requires 0.25 min to lift up, turn and lift down the ripper. Deepening is 610 mm. Seismic velocity of the limestone is 1,830 m/sec (requires measurements for a particular deposit). All time is spent on loosening (without other towing or bulldozing works).

The most common and effective method of evaluation of loosening capacity of the array is a method of seismic survey based on registration of elastic wave propagation velocity depending on physical and mechanical properties and condition of the array of rocks which allows to select equipment depending on the power of bulldozers and select performance depending on the elastic wave propagation velocity in an array of rocks (Argimbaev, 2016c; Argimbayev, 2016).

RESULTS AND DISCUSSION

During the studies, we can calculate the time spent on one passage, that is, 3.66 m. If the operator works 45 min/h on average it is possible to make 12 passages.

Then, the loosened volume per passage will amount to 49 m^3 and performance will amount to 604 m^3/h. It is an empirical fact that the result obtained via this method is approximately 10-20% higher than the actual performance which can be expected. Therefore, the actual performance will amount to 483-543 m^3/h.

For bulldozer with the capacity of 538 kW, engaged only by loosening, depreciation and operating costs will amount to87dol./h including the operator's salary in the amount of 30 dol./h.

The cost of loosening will be within the range of 0.16-0.18 dol/m^3. In case of a need to loosen heavy ground, depreciation and operating costs for the bulldozer will increase. To assess the costs of hard rock loosening, these costs of loosening of heavy ground should be increased by at least 30-40%.

Further, based on the results of field tests conducted with a variety of materials taken from various deposits, the charts of ripper operating efficiency calculated by the seismic wave velocity have been developed (Fig. 3-7).

Given the huge variation of properties in various materials, even among rocks in the same category, these charts should be considered as just one indicator of loosening capacity as well as performance determination by values of seismic velocity, power of bulldozer and ripper type (Fig. 8).

Therefore, during the evaluation of technological capability in rack loosening, the following factors are to be taken into account:

Deepening of teeth: this is especially true for homogeneous materials such as clay or fine-grained limestone and tightly cemented formations (conglomerates, some drift clay and limestone deposits containing rocky fragments).

Low seismic velocities in sedimentary rocks may be a sign of probable loosening capacity. However,

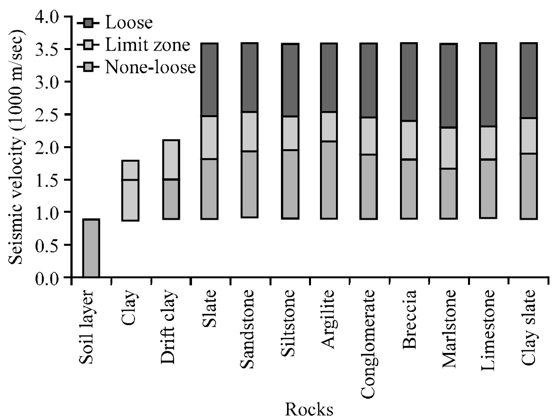

Fig. 3: Evaluation of rock breaking by the seismic wave velocity using single-frame or multi-frame controlled parallelogram ripper and a bulldozer with the capacity of 228 kW and weight of 38.4 tons

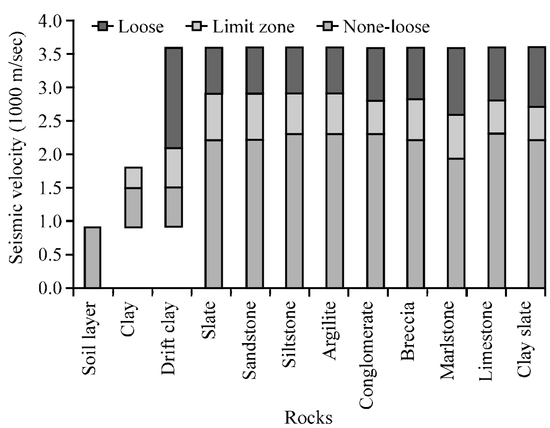

Fig. 4: Evaluation of rock breaking by the seismic wave velocity using single-frame or multi-frame controlled parallelogram ripper and a bulldozer with the capacity of 302 kW and weight of 48.8 tons

if the fractures and joints of seams hamper the deepening of teeth, loosening of thismaterial could be inefficient.

Preliminary blasting can create enough destruction, facilitating the deepening of teeth, particularly in limestone, conglomerates and some other rocks; however, during the analysis of blasting in the harder rocks it is required to carefully calculate the economic efficiency.

Loosening for scraper loading can require quite a different technique than in the case when the same material shall be loaded by the bulldozer. Cross loosening requires another approach (Fig. 7 and 8).

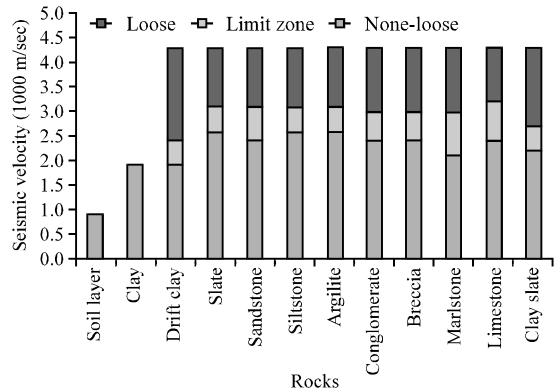

Fig. 5: Evaluation of rock breaking by the seismic wave velocity using single-frame or multi-frame controlled parallelogram ripper and a bulldozer with the capacity of 447 kW and weight of 70.2 tons

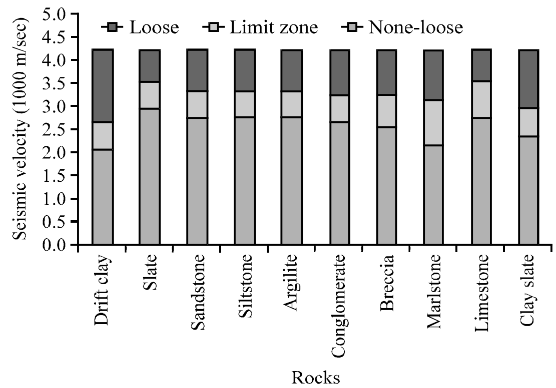

Fig. 6: Evaluation of rock breaking by the seismic wave velocity using single-frame or multi-frame controlled parallelogram ripper and a bulldozer with the capacity of 634 kW and weight of 104.5 tons

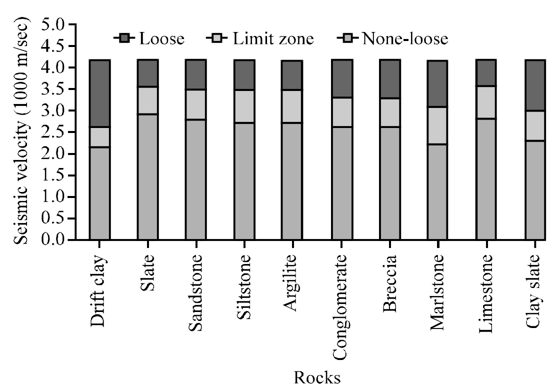

Fig. 7: Evaluation of rock breaking by the seismic wave velocity using single-frame or multi-frame controlled parallelogram ripper and a bulldozer with the capacity of 634 kW and weight of 104.2 tons

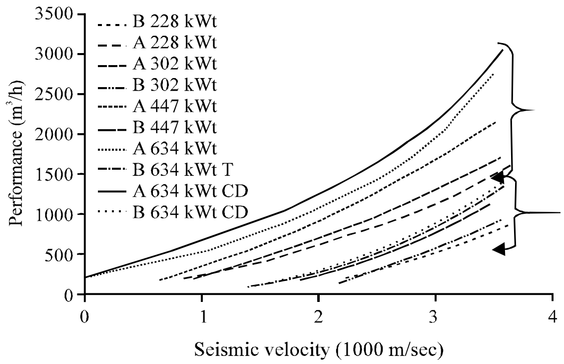

Fig. 8: Performance of bulldozers with various capacities with single-frame ripper of parallelogram type A ideal operational conditions, B adverse operational conditions

CONCLUSION

Number of used racks, length and thickness of the rack, teeth angle, direction, position of flapper valve everything shall be adjusted in accordance with the operation conditions. The successful loosening may depend on whether the operator finds the proper combination of the parameters for these conditions.

REFERENCES

Argimbaev, K.R. and H.A. Kholodjakov, 2015. Erection methods and constructions of primary tailing dike. Intl. J. Ecol. Develop., 30: 47-54.

Argimbaev, K.R., 2016a. Monitoring of the industrial process impact on the environment in an open pit. Int. J. Ecol. Dev., 31: 23-28.

Argimbaev, K.R., 2016b. Simulation of a geomechanical monitoring algorithm for open-pit mining. Res. J. Appl. Sci., 11: 811-815.

Argimbaev, K.R., 2016c. Simulation of rock mass stress-strain behavior using the method of equivalent materials during ore deposit open-pit mining. Res. J. Appl. Sci., 11: 894-899.

Argimbaev, K.R., H.A. Kholodjakov and M.M. Yakubovskiy, 2014. Selections of safety relay units for high-voltage electromotor while developing technogenic deposits. World Appl. Sci. J., 30: 730-732.

Argimbaev, K.R., H.A. Kholodjakov, 2016. Development of numerical models for rock mass stress-strain behavior forecasting during ore deposit open-pit mining. Res. J. Appl. Sci., 11: 281-286.

Argimbaev, K.R., M.M. Yakubovskiy and M.A. Ivanova, 2015. Design justification of drainage and anti filter facilities of the tailings at various methods of their constructions. Intl. J. Ecol. Develop., 30: 76-85.

Argimbayev, K.R., 2016d. Assessment of the stress-strain state of the foliated cutoff mass. Intl. J. Ecol. Dev., 31: 68-77.

Argimbayev, K.R., M.O. Bovdui and K.V. Mironova, 2016. Prospects for exploitation of tailing dumps. Int. J. Ecol. Dev., 31: 117-124.

Bukhman, I., P.G. Simakov, A.S. Argimbaev and S.V. Beliaev, 1966. Removal of dust from the air of an excavator operator's cabin. Gigiena Sanitariia, 31: 96-108.

Kaerbek, R.A. and B.O. Maya, 2016. The experience of the introduction of mobile crushing and screening complexes on a deposit of building materials. Res. J. Appl. Sci., 11: 300-303.

Kaerbek, R.A. and M.A. Ivanova, 2016. Calculation coefficient of strength decrease of the rock mass fragments in the shotpile. Res. J. Appl. Sci., 11: 245-250.

Kholodjakov, H.A. and K.R. Argimbaev, 2014. Waste storage feasibility of concentrating mill in overburden dumps. World Appl. Sci. J., 30: 738-740.

Kholodnyakov, G.A. and K.R. Argimbayev, 2014. The choice and substantiation of the technological parameters of tailing formation in an overburden dump body. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 2: 50-57.

Kovalevskiy, V.N. and K.R. Argimbaev, 2016. Experimental research of explosive jet penetration in rocks. Min. J., 12: 19-23.

Pikalov, V.A., A.V. Sokolovsky, V.N. Vasilets and K.V. Burmistrov, 2016. Substantiation of efficient parameters for hybrid open pit-underground mining of coal. Gornyi Zhurnal, 1: 67-72.

Yakubovskiy, M.M., K.R. Argimbaev and M.A. Ivanova, 2014. Investigation of the quarry transfer points influence on reduction of mining operations. World Appl. Sci. J., 30: 1401-1403.

Yakubovskiy, M.M., K.R. Argimbaev and M.A. Ivanova, 2015. Constructions investigation of ore transfer points within mining limits while developing the deep pit. Intl. J. Ecol. Dev., 30: 83-87.