Journal of Engineering and Applied Sciences 14 (19): 7154-7158, 2019
ISSN: 1816-949X

A Review of Mining and Loading Equipment Currently used for Open Pit Mining

Dmitry Nikolaevich Ligotsky
Saint-Petersburg Mining University, 21 Line V.O., 2, 199106 St. Petersburg, Russia Federation
ligozkij@rambler.ru

Abstract: The study contains data review based on application of major mining and loading equipment in open pit operations. Examples of manufacturing and use of modern unmanned equipment were reviewed. Trends for increasing hydraulic excavators in entire fleet of mechanical shovels operated in open pits were identified. Russian manufacturers of open pit excavators cannot compete with global manufacturers of backhoe hydraulic excavators. Majority of hydraulic excavators operated in the open pits and quarries are made by four largest manufacturers: Liebherr (Germany), Komatsu Ltd. (Japan), Caterpillar Inc. (USA), Hitachi Group (Japan). This study becomes even more relevant as the Russian Government is prioritizing import phase-out, large-scale manufacturing and application of domestic backhoe excavators.

Key words: Haul truck, front-end loader, rope excavator, hydraulic excavator, mineral deposit, USA

INTRODUCTION

Open pit mining is the method for solid mineral extraction that prevails in the international mining industry and the Russian Federation as well. More than 70% of solid minerals, almost 100% of construction materials, 70% of coal and 80-90% of ferrous and non-ferrous ores in the Russian Federation are mined with open pits and coal strip mines (Loginov, 2015).

Open pit mining is currently evolving in a specific direction that involves operation of more advanced equipment with bigger linear dimensions which eventually results in a larger scale of mining parameters.

Extraction and loading works are among the main features of open pit operations. Single-bucket excavator with a mechanical shovel is the one most frequently seen in open pits for rock excavation. Excavators with a mechanical shovel are used in mining and geological conditions where continuous mining equipment is not efficient. By their working tool design, excavators are divided into two types front and backhoe shovel (Ligotsky and Mironova, 2018).

As worldwide trends show, mining companies tend to reduce the number of rack crowded shovels in favor of powerful hydraulic excavators with front and backhoe shovel as their design is improving at a higher rates.

As a rule, single-bucket excavators with mechanical shovel designed for open pit mining of solid mineral deposits have a similar design, tracked undercarriage, they are divided into mining and stripping types and are equipped with power or diesel drive. Stripping excavators were designed mostly during the Soviet period. This type of equipment has large dimensions and long operating tools for rehandling operations and backfilling the mined-out areas (Argimbaev and Yakubovskiy, 2014).

The number of automotive vehicles is continuously increasing for open pit mining purposes. In open pits of USA, Canada and South America, more than 85% of rock materials are hauled by dump trucks in Australia, this number is almost 99%. The number of automotive vehicles operated at open pits exceeds 75% in Russia and CIS countries. Rapid improvement of mining equipment tends to increase bucket capacity consequently, triggering improvement of hauling fleet. It is worth noting that combination of mining and conveying equipment (excavator-haul truck) is modified based on the well-known dependency where improvement of one set of units improves the other one (Kaerbek and Maya, 2016).

Over the last years, mining companies have been targeting to maximize efficiency of mining costs and minimize human labor in extraction of solid minerals. Theories related to use of robotic, unmanned vehicles to provide the safety of employees became more popular. Relevancy of this agenda ramps up when it comes to operations in severe environmental, climatic and ground conditions (Gavrishev *et al*., 2016).

The world has seen some practical examples of unmanned equipment. Komatsu Innovative Autonomous Haulage Vehicle (IAHV) with a load capacity of 230 tons (Fig. 1) was presented by Komatsu Ltd. (Japan) at Las Vegas Exhibition in 2016.

In April 2013, BELAZ JSC and VIST Group announced their new product BelAZ unmanned haul truck with a load capacity of 130 tons. In February, 2018, VIST

Fig. 1: Komatsu IAHV unmanned haul truck

Fig. 2: BelAZ unmanned haul truck

Robotics from Russia, a subsidiary of VIST Group, tested an unmanned BelAZ haul truck in Morocco (Fig. 2) (Pikalov *et al*., 2016).

Introduction of robotic technology will significantly affect the growth of open-pit mining, use of this equipment will improve safety and eliminate the human factor, especially, in severe mining conditions. However, these projects are currently at the pilot stage with prototypes commissioned only and none of this equipment went into serial manufacturing (Burmistrov *et al*., 2017).

MATERIALS AND METHODS

Review of the trend in using mining and loading equipment in open pit operations shows an increase in the number of powerful hydraulic mining excavators with front and backhoe shovel in the overall fleet of mechanical shovels. During this study, deliveries of mining and loading equipment to the Russian market were reviewed based on the data available from public media and specialized literature.

Fig. 3: Le Tourneau L-2350 front end loader

As practical experience shows, front-end single-bucket wheeled loaders may also be used for mining operations in open pits.

This equipment is used mostly in auxiliary works, however, it can be also used in the production process as well. Front-end single-bucket loaders are used in quarries during extraction of construction materials, backfilling mined-out areas, at transshipment and bedding stockyards and sometimes for recovery of properly blasted and crushed minerals.

Table 1 contains the data on main manufacturers of heavy front-end loaders. Le Tourneau is the only manufacturer of front-end loaders in the world that installs modern electric drives on all models. Each wheel has an electric drive completely independent from the others, this is the only system available on the market of front-end loaders with independent drives for all 4 wheels.

Le Tourneau L-2350 is the largest loader used nowadays (Fig. 3). Single-bucket front-end loaders can be efficiently used together with other types of mining equipment due to their versatility, high mobility and maneuverability as they can do loading and auxiliary works and clean handling sites.

Main shortages limiting wide use of front-end loaders in quarries are the low operating parameters of their work equipment that limit the height of mined benches and low traction with the surface. Traction is negatively affected by variations in the properties of surface ground (moistening, ice and thawing). Single-bucket front-end loaders have insufficient tearing force along the face entire height. Tearing force is mostly efficient in the face lower part due to specific digging geometry of the loader (Argimbaev and Kholodjakov, 2013).

Table 1: Basic parameters and specifications of heavy loaders

Manufacturers	Models	Bucket capacity (m^3)	Digging height (m)	Dumping height (m)	Digging depth (m)	Weight (t)
Le Tourneau	L-2350	40.52	13.3	7.3	0.25	262.20
Caterpillar	994K	24.50	11.7	8.8	0.23	240.02
Komatsu	WA1200-3	20.00	11.9	6.3	0.29	205.20

Fig. 4: Rope excavators with front shovel: a) Caterpillar; b) P&H; c) TYHI; d) IZ-KARTEX and e) Uralmashplant

RESULTS AND DISCUSSION

Opportunities for production of mining machinery in Russia were largely affected by the transition period of 1992-2000. This period saw significant decrease in mining scope which resulted in an excess of mining and loading equipment in the mining companies. Decline in production of machinery in the Russian engineering industry was obvious. Due to this recession in the mining equipment engineering, no excavator with a bucket capacity of exceeding 15 m^3 was manufactured in Russia until 2010. Most of the large companies mining the solid mineral deposits were designed to use excavators with a maximum bucket capacity of 15 m^3.

This period saw a rapid growth of mining equipment production in other countries. New models of mining equipment were engineered and went into serial production in USA, Japan and Germany. Wide range of standard sizes of actively engineered equipment was put into serial production-hydraulic excavators with front and backhoe shovels.

USA, Russia and China are the only manufacturers of rope excavators with rack crowded shovel. Figure 4 shows major manufacturers: Caterpillar Inc.; Komatsu Mining Corp (P&H); Taiyuan Heavy Industry Co., Ltd. (TYHI); IZ-KARTEX LLC and Uralmashzavod (UZTM).

Rope excavators with front mechanical shovels for open pit mining have a robust design that reduces maintenance costs and enables repair of the excavator in the bench. A peculiar operational feature for this equipment is 15-20 years of service life while the maximum service life of hydraulic excavators is 10 years. However, world history has seen much longer application of hydraulic excavators: they were successfully operated at the Drummond open pit iron ore mine in Colombia and at the Chuquicamata open pit copper mine in Chile for up to 20-25 years (Rafkatovich and Mironova, 2018).

Assessment of trends in using excavators in open pits shows that increasing the number of powerful hydraulic mining excavators with front and backhoe shovel in the overall fleet of mechanical shovels. During this study, deliveries of hydraulic excavators to the Russian market were reviewed based on the data available from public media and specialized literature.

Currently, the "excavator-haul truck" combination with backhoe hydraulic excavators having a bucket

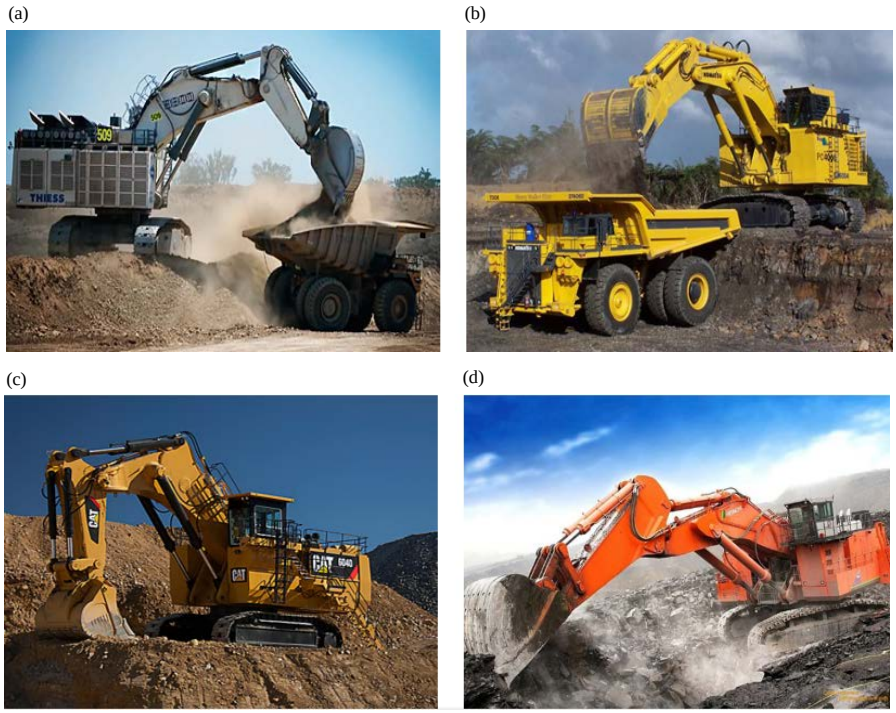

Fig. 5: Serial manufacturers of backhoe hydraulic excavators for open pit application are: a) Liebherr; b) Komatsu; c) Caterpillar and d) Hitachi

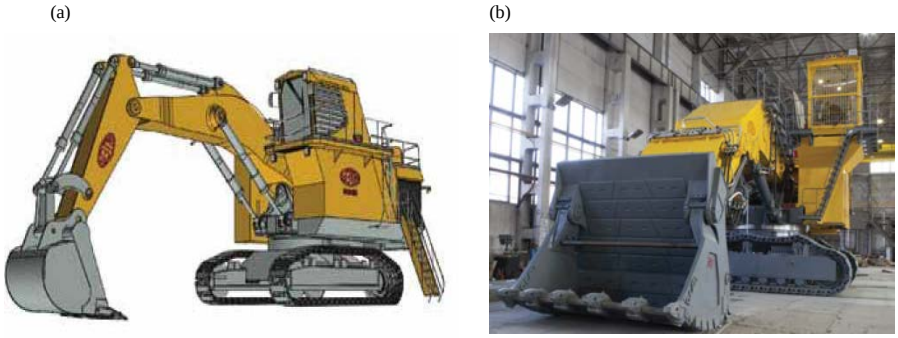

Fig. 6: Project of UGE-300, Russian hydraulic excavator: a) UGE-300 with backhoe shovel and b) UGE-300 prototype with front shovel

capacity of 4-15 m^3 are widely used in the open pit coal mines. These units reduce coal losses due to their digging geometry and travelling trajectory of their buckets. Backhoe hydraulic excavators for open pit application are used in the Russian coal, iron ore, construction, polymetallic and gold mining companies. Same trend is applicable for the mining companies in Ukraine, Kazakhstan, Uzbekistan and other countries.

Serial manufacturing of hydraulic excavators for open pit operations started in the end of 1960. Powerful hydraulic excavators (with a bucket capacity of 5-42 m^3) produced by four largest companies are widely used in quarries and coal mines: Liebherr (Germany), Komatsu Ltd. (Japan), Caterpillar Inc. (USA), Hitachi Group (Japan) (Fig. 5 and 6).

One of the prioritized state-run programs for import phase-out includes studies, engineering, serial production and commissioning of domestic hydraulic excavators having front and backhoe shovels in order to compete with models made in other countries.

In 2016, Uralmashzavod PJSC (UZTM) completed the design of UGE-300, a Russian backhoe hydraulic excavator with a bucket capacity of 16 m^3 (Fig. 6a).

Table 2: Technical specifications of UGE-300, front shovel

Operational weight (t)	Bucket capacity (m^3)	Digging radius (m)	Bucket raise height (m)	Dumping height (m)	Digging depth (m)
300	16	14	15.9	11.2	2.6

UGE-300 is planned to be assembled and delivered to the Berezovskiy Mine owned by Stroyservice Coal Mining Company in 2018. In 2018, the prototype of UGE-300 hydraulic front shovel has been assembled (Fig. 6b). Table 2 for basic technical specifications.

Backhoe hydraulic excavators and rope excavators with front shovel have their own strengths and weaknesses, however, appropriate use of mining equipment may provide higher productivity of the open pit excavating fleet.

CONCLUSION

Rope shovels will never be completely replaced by the hydraulic excavators on the market, however, they have gained their own niche in industry.

REFERENCES

Argimbaev, K.R. and H.A. Kholodjakov, 2013. Determining the safe working height of an power shovel for the development of iron-bearing tailing dumps. World Appl. Sci. J., 27: 1087-1090.

Argimbaev, K.R. and M.M. Yakubovskiy, 2014. Economic substantiation of a quarry usage and an overburden dumps, considering the disposal of industrial waste in them. World Appl. Sci. J., 29: 1621-1625.

Burmistrov, K.V., N.A. Osintsev and A.N. Shakshakpaev, 2017. Selection of open-pit dump trucks during quarry reconstruction. Procedia Eng., 206: 1696-1702.

Gavrishev, S.E., K.V. Burmistrov, S.N. Kornilov and N.G. Tomilina, 2016. Evaluation of transportation flow charts with open-pit hoisting systems in open pit/underground mining. Gornyi Zh., 5: 41-47.

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.

Ligotsky, D.N. and K.V. Mironova, 2018. Perspective technology of open-pit mining of limestone and dolomite. J. Eng. Appl. Sci., 13: 1613-1616.

Loginov, E.V., 2015. Improving the efficient of mining in the deposit of broken stone. Sci. Rep. Resour., 1: 183-185.

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.

Rafkatovich, A.K. and K.V. Mironova, 2018. Methods for the reduction of loss and optimization processes open pit mining operations when mining man-made deposits formed by sections.J. Eng. Appl. Sci., 13: 1624-1631