Application of mathematical data processing to determine the actual technical state of the motor-wheel belaz gear box

A V Kudrevatykh, A S Furman, A S Ascheulov, A S Ashcheulova and O S Karnadud
Federal State Budgetary Educational Institution of Higher Education “T.F. Gorbachev Kuzbass State Technical University”, Vesennya St, 28, Kemerovo, Kemerovo region, Russia

E-mail ascheulovas@kuzstu.ru

Abstract. Continuous plant operation is provided with machinery and equipment, which is in technically serviceable condition. Timely diagnostics of the actual technical condition of equipment and units components will allow avoiding unforeseen failures and making unscheduled maintenance or repair works. Thus, this technological operation will allow keeping the used equipment in work condition. Among the promising methods for diagnosing the actual technical condition of gearboxes of motor-wheels of open-pit dump trucks BELAZ, vibration, noise measurement and thermal methods are marked. However, it is necessary to apply mathematical methods of processing and modeling of wear processes for more accurate processing of the obtained parameters. Thus, not only the continuous operation of equipment is achieved by means of set of methods, but also the productivity of the coal mining complex increases by means of increasing the equipment resource.

Mining dump trucks are becoming more and more popular in open pit mining enterprises. This tendency of the popularity of this type of transport is associated with its high reliability, flexibility of route changes, adaptability to various climatic conditions, low capital intensity. In addition to these main advantages, mining dump trucks have a number of other positive aspects such as high flexibility and mobility; small size compared to other types of transport, autonomy. Thus, the share of transportation using road transport reaches 75% at Kuzbass open-pit coal mining enterprises and this number continues to grow [1, 2, 3].

The annual increase of coal mining amount leads to high complexity and the necessity to buy additional units of equipment, which lead to increase of costs related to the maintenance and repair works of the current mining equipment complex [4, 5, 6]. Reducing this indicator is possible in various ways, but the most effective is to increase the reliability and durability of units and mechanisms of the used equipment.

The main difficulty faced by enterprises to improve reliability and durability of equipment is the ability to predict the technical condition of components and units. This situation is due to the little information about the state of the mechanism under study, which arrives in real time. Thus, the actual objective is to develop and implement methods to identify and expect actual equipment technical condition. This can be achieved by introducing a diagnostic process into routine maintenance [7, 8, 9].
Currently, there are a large number of methods for repair-in-place diagnostics of motor-wheel gearboxes of mining dump trucks. Each has both positive and negative qualities. The method of physical and chemical analysis of the used oil shows the actual technical state of the gearbox of the motor-wheel, while the composition of metal impurities can say with great certainty which gearbox part has started to have increased wear [10, 11, 12]. Main disadvantage of this methodology is the presence of physical and chemical laboratory for analysis at the company, or the signing of an additional agreement with a third party. The absence of this drawback makes the following three methods more optimal.

Vibroacoustic diagnostics includes two methods that complement each other. When carrying out diagnostics in this way, the level of noise and vibration is measured. These two indicators are the consequence of each other. During the operation of a working gearbox, vibration and noise will be present, only their level can be called minimal. Noise and vibration will increase in case of failure or the beginning of increased wear. Failure is understood as a breakdown of gears or cutting off one or more teeth on them. Therefore, in any case impact forces appear, which are the reason for the increase in noise and vibration. At the same time, the measurements taken can be saved in the form of reference and subsequent diagrams and measurements can be compared with diagrams. This must be done, since it is difficult for a person to catch small changes in the level of noise and vibration, and it is possible to indicate accurately the changes taking place from the diagrams. Figure 1 shows the method and place of fixing the «Diamekh 2000» device on the wheel rim for measuring the vibration level in the gearbox of the BELAZ motor-wheel.

Figure 1. The method of fixing the device «Diamekh 2000» to the wheel rim.

Figure 2 shows two diagrams of measuring the vibration level in the gearbox of the motor-wheel. The upper graph is taken from a working gearbox, and the lower one is taken from a gearbox with a defect. Therefore, when analysing the graphs, it can be seen that at 63 Hz frequency, there is a slight increase in vibration on a gearbox with a defect. However, this method does not allow identifying the cause of the noise, it informs only about the changes that have begun in the gearbox compared to the serviceable one.
The noise level in the gearbox was measured using the «Assistant SI V1» device simultaneously with the vibration measurement. It was installed on the wheel rim like the «Diamech 2000» device in figure 1. Figure 3 shows two diagrams for noise measurements, in the upper graph the noise figure is 93 dB and it is the “starting point”, since the signal was removed on a working gearbox. There is an increase in noise up to 105 dB at the lower one, increased vibration is observed at this very moment. Thus, it confirms the assumption made above that vibration and noise are interrelated and the appearance of one of the indicators is accompanied by the appearance of the second one. Also, as in repair-in-place diagnostics using the vibration measurement method, noise measurement informs only about the presence of a malfunction or the beginning of an imminent failure, but does not indicate the cause of the noise.
The third method of repair-in-place diagnostics of BELAZ motor-wheel gearboxes is temperature analysis using a thermal imager camera. In this case, there is no need to install any sensors on a mining dump truck, it is enough to be near it, but this is also a disadvantage, since for each measurement it is necessary to go to the open-pit to take measurements, when using the previous methods it is possible to make measurements in distance. As it is known, during the operation of the oil, metal impurities accumulate in it; it can be concluded based on used oils about the actual technical condition of the gearbox; when the oil is clogged with various deposits and wear products, its physical and chemical properties, including viscosity, are violated. In this regard, in places of wear, various particles "stick", which in turn increases the friction force, and as a result, the temperature of both the oil itself and the entire unit increases locally. The main advantage of the temperature analysis is in the determination of local overheating, which makes it possible to determine the probable faulty part of the gearbox.

Figure 4 shows images from the «Testo 870» thermal imager camera, when measuring the temperature of the BELAZ motor-wheel reducer. In the left photo, the temperature indicator at the hottest point is 37.9 °C. This measurement was made on a serviceable mining dump truck. The second photo shows a thermal diagram from the gearbox, which shows a defect. This is the same gearbox as in previous studies. Thus, there is little temperature rise of 5o C, which indicates the presence of defects or the gearbox elements. As it was mentioned above, temperature analysis allows to localize the location of the defect, but not to determine the faulty part accurately, that is, it can detect the presence, but not a specific malfunction.

Figure 4. Increase in the temperature of the motor-wheel during the operation of a mining dump truck.
Reliability and durability are one of the main indicators of the productivity of coal mining enterprises. Increase in these parameters will allow not only to reduce the cost of repairs and maintenance, but also to reduce the downtime of equipment during routine repair works. The most effective way to increase the performance reliability is to introduce the technological operations of repair-in-place diagnosis of components and units of coal mining complex. Thus, for determining the actual technical condition of gearbox motor-wheel BELAZ, several different techniques are used. However, each of them individually does not give a complete picture of the integrity of the gearbox itself and the serviceability of its elements. Therefore, it is necessary to use them in combination, whereby it is possible to predict the state of the gearbox and its remaining resources with a high probability. Moreover, it is not necessary to carry out all operations at once, it is enough to use one technique to detect a defect, and if it is present, carry out further diagnostics until the cause of the malfunction of the investigated unit is revealed.

References
[1] Dadonov M, Kulpin A, Ostanin O and Suleimenov E 2019 Distribution of static normal reactions to wheels of open-pit dump trucks depending on the longitudinal and cross sections of the open-pit road *E3S Web of Conferences International Innovative Mining Symposium* 105 03009
[2] Kosolapov A and Krysin S 2017 The raising influence of information technologies on professional training in the sphere of automated driving when transporting mined rock *E3S Web of Conferences* 21 03012
[3] Zhironkin S A, Barysheva G A, Khoreshok A A, Tyulenev M A and Hellmer M C 2016 Economic and technological role of Kuzbass industry in the implementation of national energy strategy of Russian Federation *Innovative Technologies in Engineering* 142 012127
[4] Stenin D and Stenina N 2017 Dependence of reliability and resource of the elements of the design of quarry automatics with the degrees of their downloads *E3S Web of Conferences* 23 03002
[5] Stenin D V, Kulpin A G, Kultayev E E, Kulpina E E and Borovtsov V A 2016 Influence of service conditions of quarry dump trucks on the thermal state large-size tires *Coal in the 21st Century: Mining Processing and Safety* 116-9
[6] Stenin D V, Stenina N A and Bakanov A A 2016 Evaluation of the open pit vehicles loading influence on the reliability of motor-wheel reducers *Coal in the 21st Century: Mining Processing and Safety* 256-60
[7] Panachev I A, Biryukov A V, Shalamanov V A and Vinidiktov A V 2019 The relationship of particle size distribution and energy consumption of crushing in various technologies for the development of coal seams *Bulletin of KuzSTU* 6 51-5
[8] Voronov Yu E, Kosolapov A V, Voronov A Yu and Romashko V G 2019 Complex assessment of the technical level of mechanical equipment in open pits *Mining equipment and electromechnanics* 4 26-33
[9] Furman A S and Buyalich G D 2017 Investigation of the transport process of dump trucks *Mining Equipment and electromechnanics* 5 40-2
[10] Kudrevatykh A V, Ascheulov A S and Ascheulova A S 2019 Method for determining the actual technical condition of the rotary gearbox of quarry excavators *Bulletin of KuzSTU* 3 24-9
[11] Kudrevatykh A, Ashcheulov A, Ashcheulova A, Karnadud O and Rattmann L 2019 Actual technical condition assessment of a motor-wheel gear of a dump truck belaz based on the operating oil parameters *E3S Web of Conferences IVth International Innovative Mining Symposium* 105 03021
[12] Kudrevatykh A V, Ashcheulov A S and Ashcheulova A S 2019 Actual technical condition assessment of mine excavators’ slewing gear based on the operating oil parameters *IOP Conf. Series: Materials Science and Engineering* 537 032033