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WAYS TO UPGRADE THE UTILISATION EFFICIENCY OF OPEN-PIT DUMP TRUCKS

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ABSTRACT

The study of the operational reliability of the mechanical, electrical and hydraulic equipment of open-pit dump trucks was carried out directly in the conditions of Western Kazakhstan. When collecting data on assessing the reliability of machines, the requirements of GOSTs were taken into account. Source data were processed using methods of mathematical statistics and the theory of probability.

Obtaining reliable information is associated with a number of difficulties caused by the specifics of the operation of career equipment. Carrying out of stop-watch readings to obtain sufficient volume of information about the operation of machines requires the great expenses of time and money. That's why we have adopted the system for collecting information that maximizes the use of existing sources of information and ensures the achievement of goals.

PURPOSE OF THE WORK AND THE RESEARCH METHODOLOGY.

The purpose of this work is to increase the efficiency of the use of especially heavy-payload open-pit dump trucks operating in the harsh climatic conditions

of Western Kazakhstan by assessing the level of operational reliability of machines and separate units, analyzing the causes of **Failures [1].**
The system for collecting and processing the data on the reliability of machines should provide:

- obtaining of the comparable and objective data on the reliability of similar machines;
- the ability to summarize the processing results;
- the ability to organize centralized processing of information about the reliability of parts, assemblies and machines as a whole.

For this purpose, the reporting data of mining enterprises were used as initial information: reports of dispatching and mechanical services, books of order, shift protocols, accident reports, information from the production technology department.

All this ensured the receipt of sufficiently complete and accurate data on the failures of open-pit dump truck, their reason, the duration of the period of downtime under repair and the labor content of the repair. In addition, the initial data were: the machine operating time of the equipment and its duration for various periods of operation selected according to the reporting data.

When collecting information on reliability, primary forms, information storage forms and forms of recording the results of quantitative and qualitative reliability analysis were used.

Primary forms take into account unsystematized information about the operation of open-pit dump trucks. Their filling is carried out at the place of operation of the machines.

The journal of primary accounting of information reflects the following information:

- passport information of the car;
- operating conditions and operating modes;
- date and time of starting and stopping the machine;
- the nature of the failure of parts or assemblies;
- running hours from the beginning of operation (in hours or kilometers);
- time to find and repair the failure;
- reason for failure;
- storage forms make it possible to systematize information according to the necessary attribute. For example, the following subsystems were distinguished from an open-pit dump truck as a system: mechanical equipment, electrical equipment, undercarriage, hydraulic equipment, etc.

The main forms of recording the results of a reliability analysis are:

- a list of reliability indicators of machines;
- a list of reliability indicators of machine components;
- a list of types of damage and failure;

- a statement of the labor content and cost of maintenance and repair.

The following values were adopted as specified parameters for assessment of the machines reliability, according to the current methodology and **GOST [2]**:

C_r - readiness coefficient;
W (t) - failure flow parameter, h;
T - mean time to failure, h (t.km);
T_b is the mean repair time, h;
C_{tu} - utilization factor.

The main physical meaning and method of calculating these criteria is as follows:

In the steady state of operation, the availability factor is determined from the expression:

$$C_r = \frac{T}{T + T_r} \quad (1.1)$$

where T is mean time to failure value, h (t.km);
T_b is the mean repair time, h;

The mean recovery time should be understood as the average time of enforced nonscheduled downtime caused by the repair of a forced single failure:

$$T_r = \frac{I}{m} \sum_{i=1}^{n} \tau_i \quad (1.2)$$

Where m is the number of failures;
τ_i is time spent on repair of the 1st failure, h
To determine the mean time to failure value, the following expression can be used:

$$T = \frac{t1 - t2}{m}, \text{ h.} \quad (1.3)$$

where t1 - t2 - machine operating time (running hours) of the truck for a certain period of time, h;
m is the number of failures for the same period of time.

The failure rate parameter is determined from the dependence:

$$\omega(t) = \frac{\sum_{i=1}^{N} n_i(t + \Delta t) - \sum_{i=1}^{N} n_i(t)}{N * \Delta t}, \frac{1}{\text{hour}}, \quad (1.4)$$

where n1 (t) is the number of machine failures during the operation time, h;
N is the number of machines of the same type being monitored;
t is a sufficiently small period of time, h
The utilization factor can be determined from the expression:

$$K = \frac{T_м}{Tм + Tр + Tа} \quad (1.5)$$

where T_m is machine operating time of the equipment for a certain period of time, h;
T_a - the total time of failure downtime of the machine for the same period, h
T_p - time spent on scheduled preventive maintenance, h
In general, the proposed indicators cover both the production work of the machines and reflect their suitability for maintenance and technical repair.
The issues of cold endurance of metal structures of machines are of great importance for the conditions of Western Kazakhstan. In this regard, the calculation of reliability indicators is carried out for the winter and summer periods of operation separately. The months when the monthly average minimum outdoor temperature reaches –20 ° C are taken as the winter **period [3].**

1.2 Status of the issue on the preliminary treatment, maintenance and repair of domestic and foreign open-pit dump trucks.

The most common kind of transport in quarrying [4] is automobile. About 60% of the rock mass in the quarries of the CIS and more than 85% in foreign quarries are transported by means of automobile transport. In the near future, with the increase in the volume of open-cast mining, the freight turnover of mining transport will increase even more. Despite the fact that road transport is relatively expensive and labor-intensive, the undeniable advantages and a wide range of applications allow to consider it the most universal and progressive means of transport in open cast mining. The main advantages of automotive rolling stock: high maneuverability and mobility are manifested especially well in difficult operating conditions.
The application of dump trucks as mining transport determines the necessity for a production process chain of the following plan:

- preparatory work (preparation for starting and starting the engine, every shift maintenance, refueling, etc.);
- maintenance;
- current repairs;
- storage of serviceable cars outside working time.

All these processes are carried out in the truck fleet. As a rule, overhauls of cars and the most complex components and assemblies are carried out at the car repair enterprises.

Increasing in the productivity of open-pit dump trucks is an important task, especially now, when open-pit mining uses powerful expensive vehicles [5]. Increasing the efficiency of using dump trucks is possible with the following activities:
- the creation of a production and technical facilities that provide for the maintenance and repair of the heavy dump trucks prior to the arrival of automobiles in quarries;

- the use of loading mechanisms with the bucket with a capacity corresponding to the dump truck body capacity;
- selection of a rational operation of dump trucks;
- equipping the quarries with an ensemble of auxiliary machines, and the mechanisms for maintaining and repairing of the roads;
- ensuring the construction of main roads assigned for the quarry project during the first years of the quarry operation, strict observance of allowable slopes during the construction of the internal quarry roads, in accordance with the technical characteristics of dump trucks operated in the quarry;
- creation of entrances to excavators and unloading places on dumps in a state that ensures comprehensive use of speed capabilities of dump trucks and traffic safety;
- creation of the reserve of tires and replacing them on the line without returning of the dump trucks to the garage;
- organization of refueling of the cars directly in the quarry;
- performing of the simple repair of dump trucks at the places of malfunctions using the mobile workshop trucks;
- the introduction of modern methods of diagnostics of physical situation, improvement of the maintenance and repair quality;
- rational organization of the management of the physical situation and age structure of the vehicle fleet and timely decommissioning of worn-out cars;
- improvement of existing standards for spare parts for dump trucks and their differentiation by climatic zones and difficulties in operating conditions of vehicles.

Development of standards for maintenance and repair of dump trucks BelAZ-540A and BelAZ-548A

Operational reliability of especially heavy payload dump trucks

To analyze the operation of machines over the past period, reporting information on the operation of equipment was used. In general, data on the reliability assessment of machines for the period from January 2017 to December 2019 were collected and processed. Reliability analysis was carried out for the entire fleet of open-pit dump trucks using an averaged vehicle. Such averaging is quite legitimate, since dump trucks were operated under identical **conditions [6].**

Data describing the operation of the vehicles were processed and averaged over the entire observation period, as well as separately for the winter and summer periods. This permitted to determine the influence of weather and climate conditions on the operation of the equipment. The selection of the parameters for assessing the reliability of machines was carried out according to the methodology above.

In order to establish the nature of the distribution of the reliability level between the main components and assemblies of open-pit dump trucks and identify the least reliable of them, the average the mean time to failure value for the main components and parts of the machines is calculated. The calculation results are presented in the form of a diagram (Fig. 1.1, 1.2), where the running hours were calculated both in running hours and in kilometers. The diagrams show the average the mean time to failure value for the least reliable components in ascending order. The data allows to compare the reliability of individual components, identify the least reliable of them.

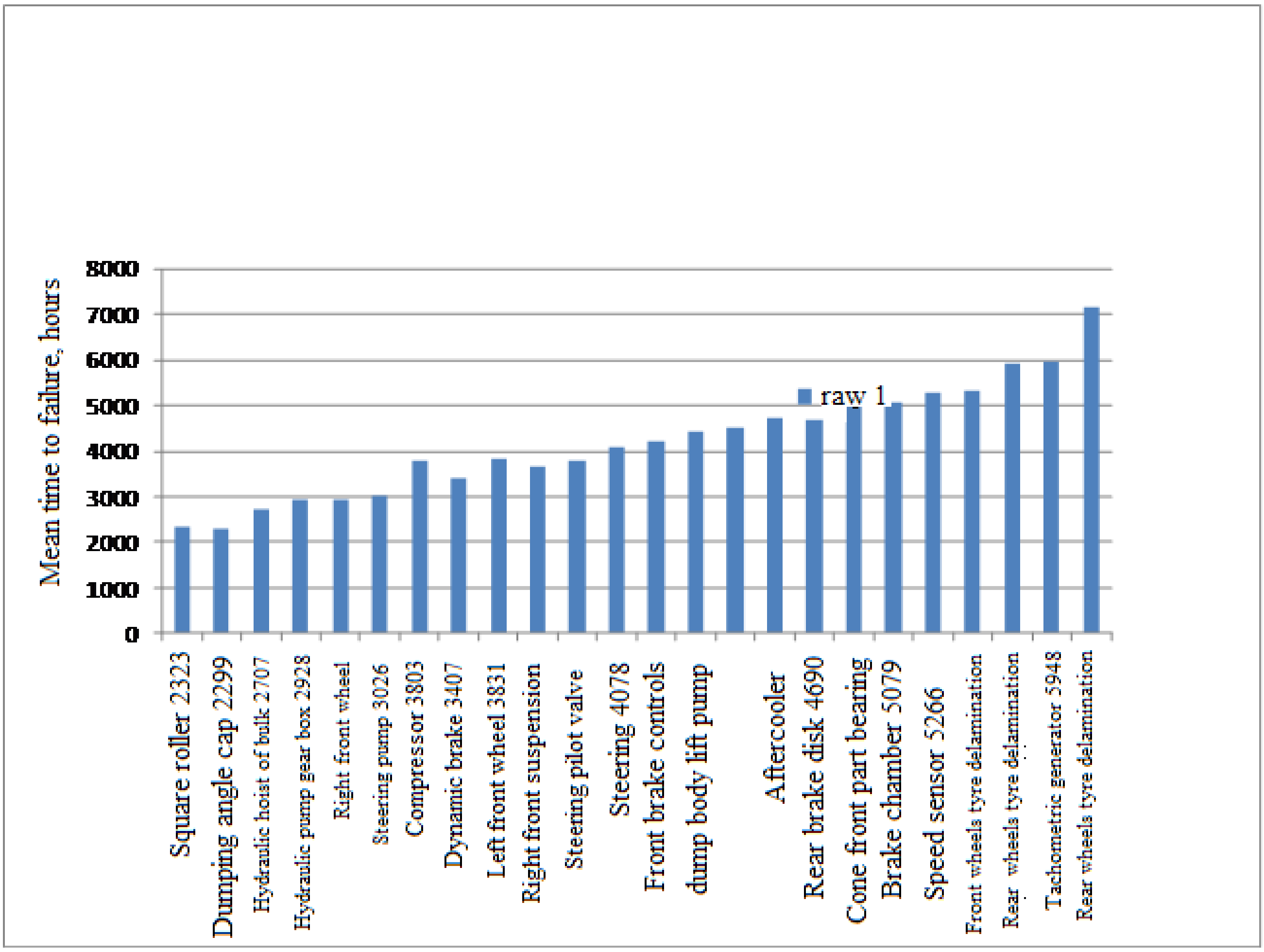


Fig. 1.1. The diagram of the mean time to failure of the main components and assemblies of BelAZ-540A and BelAZ-548A dump trucks

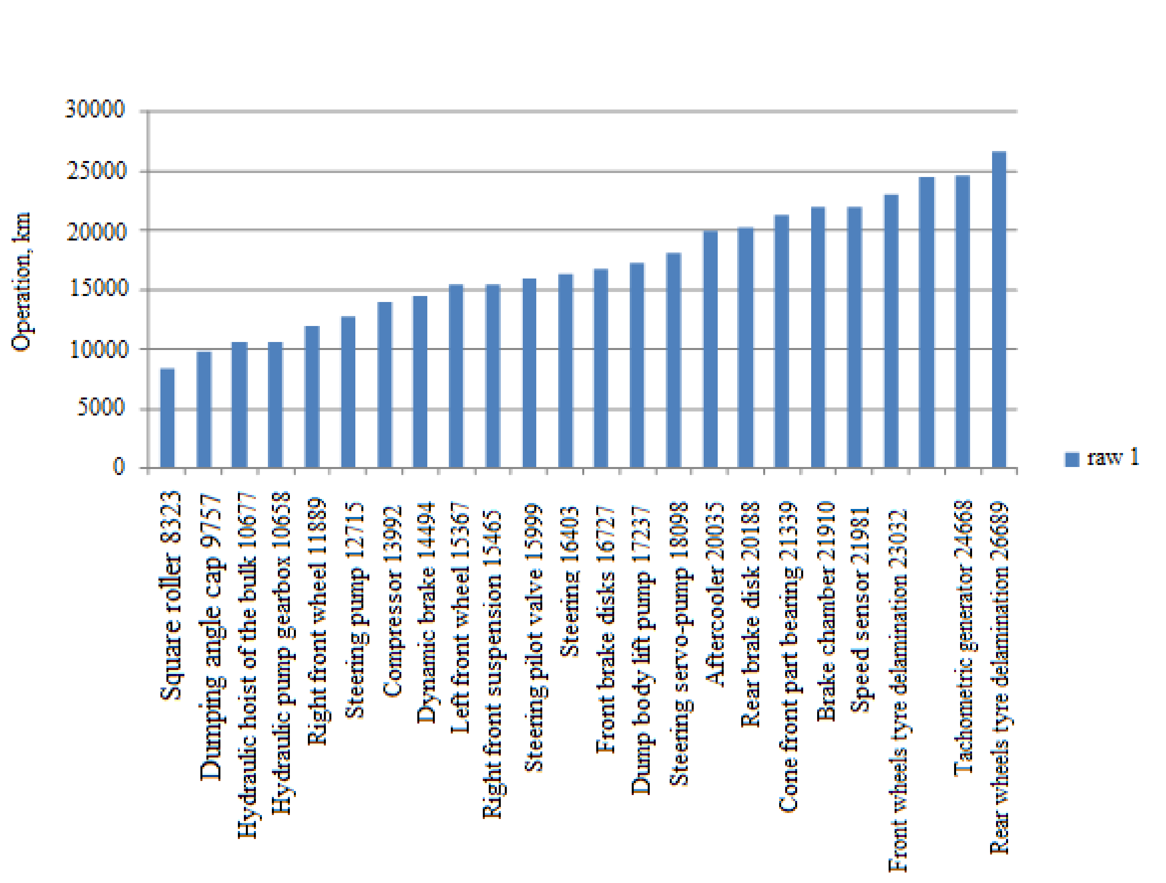


Fig. 1.2. The diagram of the mean time to failure of the main components and assemblies of BelAZ-540A and BelAZ-548A dump trucks

The data presented (Fig. 1.1, 1.2) characterize the significant spread in values of the mean time to failures and repair time between separate machine components. The square roller, the bulk lift valve, a main pump drive gearbox are the least reliable in which the average interval between successive failures is 2223, 2299 and 2928 running hours, respectively. The wheel disks, a steering pump, a compressor, a dynamic brake, the front-wheel suspension are characterized by the low level of reliability, in which the uninterrupted operation of does not exceed 3660 running hours.

In order to analyze the maintainability of dump trucks, the average repair time and the labour content of repair were calculated, the calculation results are presented in the diagram (Fig. 1.3) The analysis of the diagram shows that the greatest amount of repair time falls on the following components: the rear and the front tires and the cone front part bearing (18, 24 and 64 hours, respectively). The maximum values of labor content also fall on these components (respectively 48, 72 and 168 work hours). All this indicates not only to an insufficient level of maintainability of the above specified components, but also to a low level of their reliability.

Based on the calculated data, distribution diagrams are constructed between the individual types of machinery equipment. The diagram is based on the average values of the assessed failure rate (Fig. 1.4). The following subsystems stood out from the dump truck as a system: electrical equipment, hydraulic equipment, undercarriage, suspension, engine, mechanical part, pneumatic equipment and auxiliary equipment. At the same time, failures of the following units and parts were relegated to the failures of the dump truck subsystems:

1. Electrical equipment:
Cables, brushes, traction electric motor, exciter, tachogenerator, heaters, contacts, contactors, stabilitron tube, etc.

2. Hydraulic equipment:
Glands, hose collapse and delamination, swelling of cumulatives, hydraulic cylinders, pumps, valves, valve cores, steering pilot valve, pressure regulator, etc.

3. Undercarriage:
Wheel disks, tires, semi-axles, breakage of a rear hub, gear system of a motorized wheel, side tire bead, breakage of an axle shaft of wheel-hub of front suspension, etc.

4. Suspension:
The square roller, suspension pins, in-frame mounting seat of the suspension ring, front suspension caliper, shock absorbing plates, front suspension plate, cone front part bearing, suspension arrester, etc.

5. Engine:
Starters, turbocharger, fan belts, cooling system pipes, antifreeze and fuel leaks, heat exchangers, regulator, etc.

6. The mechanical part:
Pump drive gearbox, mounting brackets of engine-bearing bed, main frame and bulk, bearings, gears, etc.

7. Pneumatic equipment:
Compressor, valves, hoses, compressor belts, brake chambers, air leak, etc.

8. Auxiliary equipment:
Grease pump, grease hoses, cab heater, adjustment of cab heating, etc.

The diagram data shows the highest value of the assessed failure

rates occurs at the undercarriage components of the car and hydraulic equipment

(23.3% and 24% respectively). It should be noted that the total

value of the number of failures in running equipment and suspension elements,

makes up more than 1/3 of the total number of failures on the dump truck **[7].**

In order to establish the influence of climatic factors on the operational reliability of vehicles the separate calculation of assessed failure rate for all types of dump truck equipment was carried out taking into account the winter and summer periods of operation.

The calculation results are presented in the diagram **(Fig. 1.4).**
The data of the diagram show that the assessed failure rate of such subsystems as the mechanical part, pneumatic equipment, auxiliary equipment and undercarriage increases during the winter period of operation **(Fig. 1.4. C, F, H, I).**

The assessed failure rate of the electrical equipment hydraulic equipment and suspension elements increases significantly during the summer period of operation (Fig. 1.4. A. B. D).

The increase in the number of failures of mechanical equipment of dump trucks in the winter period is associated with an increase in the number of brittle fractures of the metal structures of the vehicles and a change in the paste-forming properties of steels at low and negative ambient temperatures.

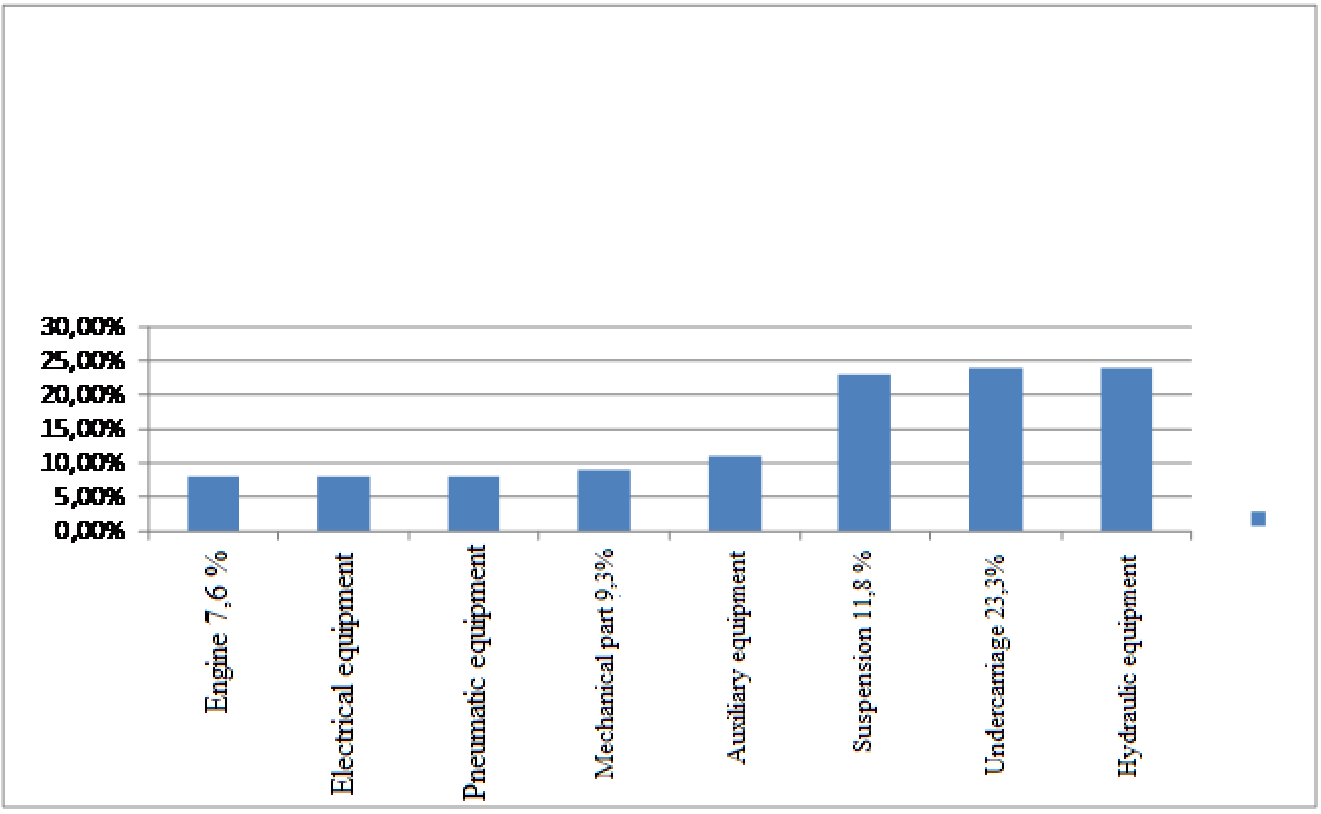


Fig. 1.3. The assessed failure rate Distribution Diagram
between subsystems of dump trucks BelAZ-540A and BelAZ-548A

The reason for the decrease in the reliability level of the nodes of electrical equipment of cars in the summer period should be considered Apparently, the deterioration in the cooling conditions of electrical equipment, which causes overheating of individual components and assemblies, a decrease in the dielectric insulation strength and, as a result, the failure of the assembly.

One of the main reasons for the sharp decrease in the level of reliability of the suspension elements of dump trucks in the summer is unsatisfying road conditions.

Among the components of the undercarriage, tires have the low level of reliability; that's why a separate calculation of reliability indicators for the rear and front tires was carried out to compare the tire performance. The calculation results are presented in the diagram (Fig. 1.5). The analysis shows. That the tire mileage of BelAZ-540A and BelAZ-548A dump trucks in Western Kazakhstan does not exceed 27.000 km, making for the rear outer, inner and front wheels 26.859km, 21.981 km and 23092 km respectively. It should be noted that the tire mileage does not reach the one guaranteed by the manufacturer.

The analysis of the reliability of the steering system of the BelAZ-540A and BelAZ-548A dump trucks (Fig. 1.6) shows that the servo valve and steering pump have a low level of reliability, which have an operating time of 3783 and 3020 running hours respectively. The same diagram (Fig. 1.6) shows the labour content and repair time of the steering system elements, allowing to judge the maintainability of the system.

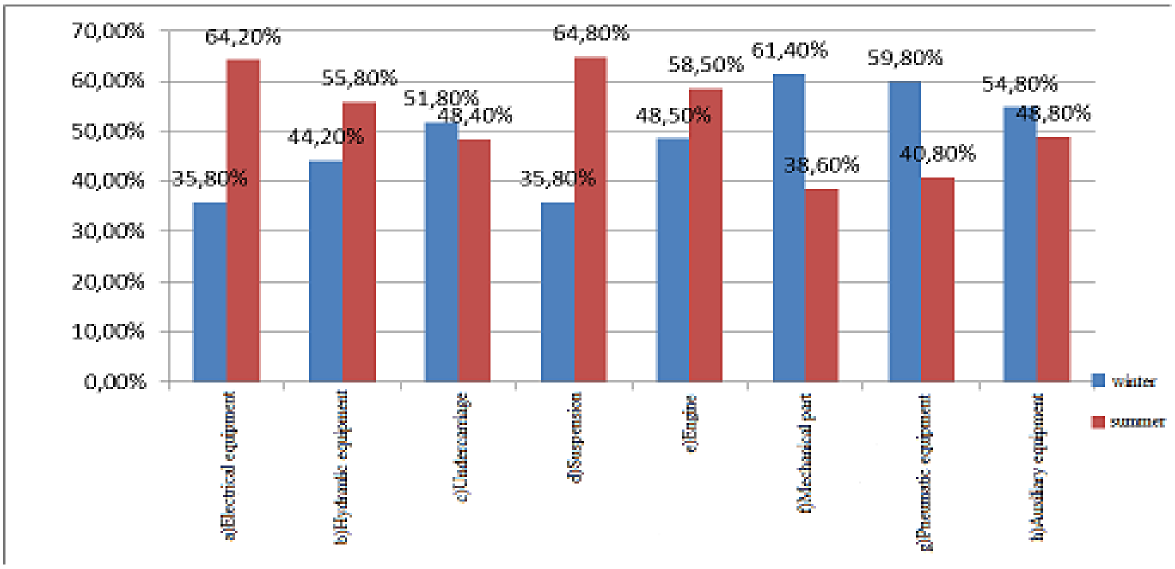
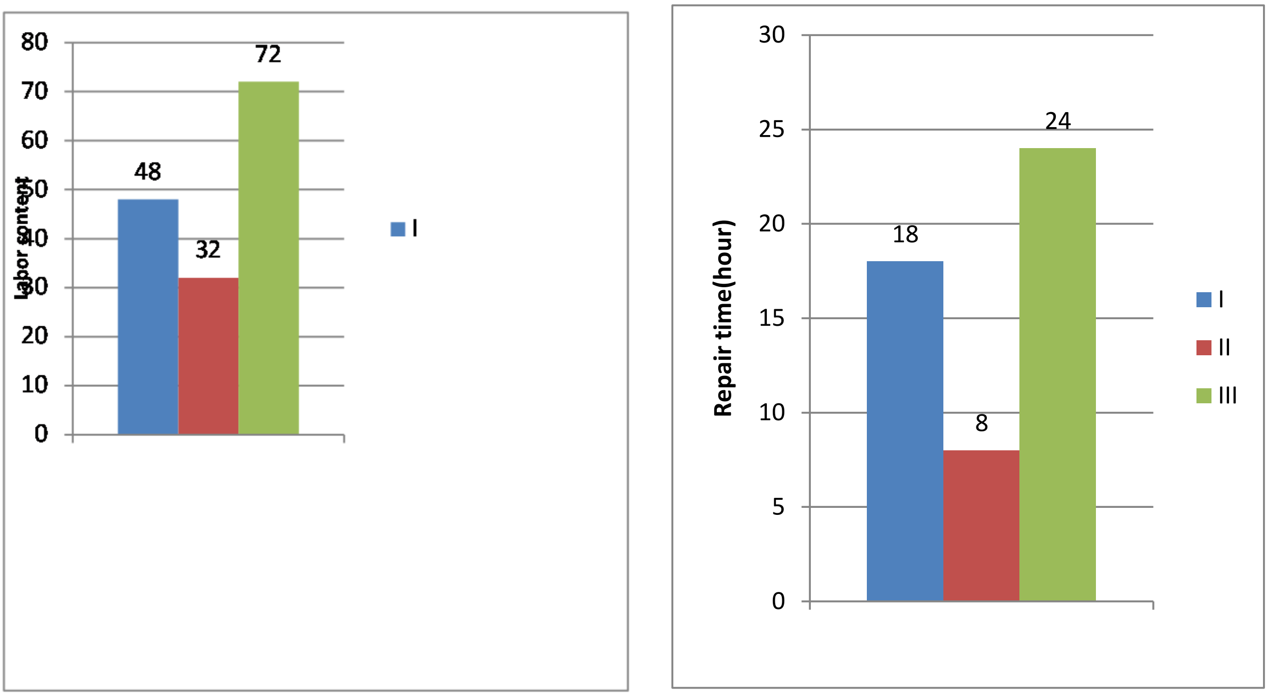
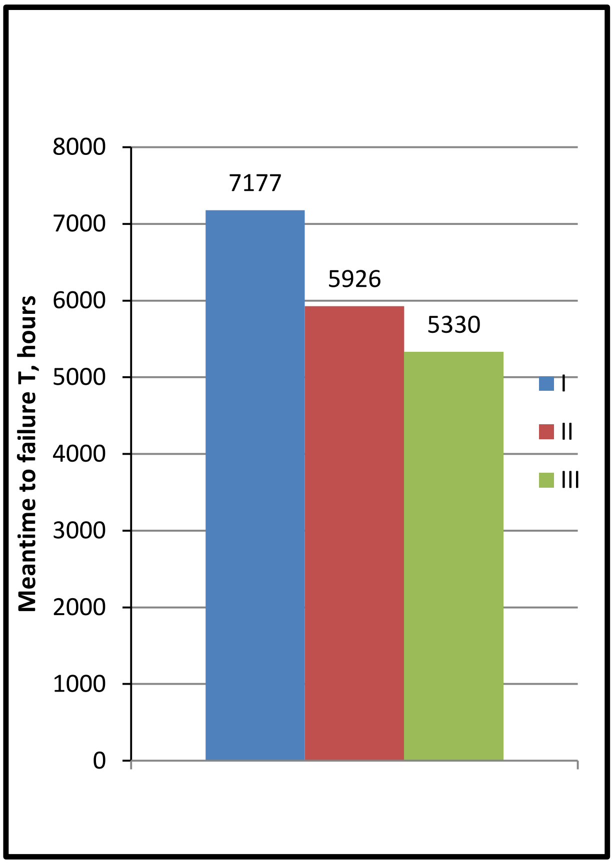


Fig. 1.4. Assessed Failure Rate Distribution Diagram
BelAZ-540A and BelAZ-548A dump trucks by periods of operation





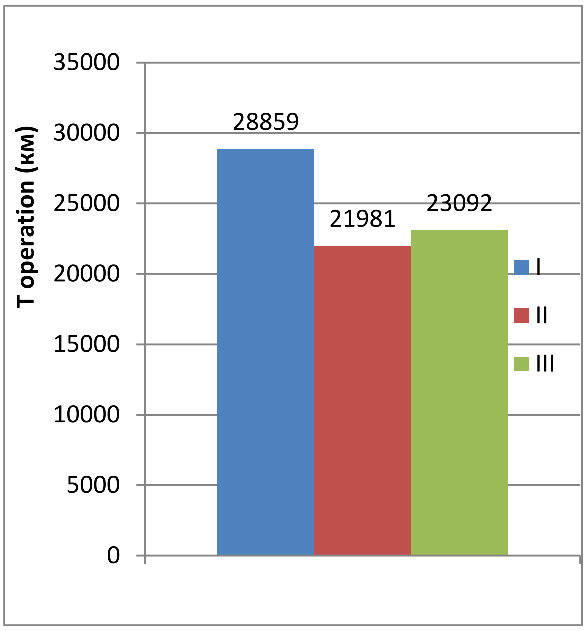


Fig. 1.5. Tires reliability.
I - Delamination of the rear outer wheels tires.
II - Delamination of back internal wheels tires.
III - Delamination of front wheels tires.

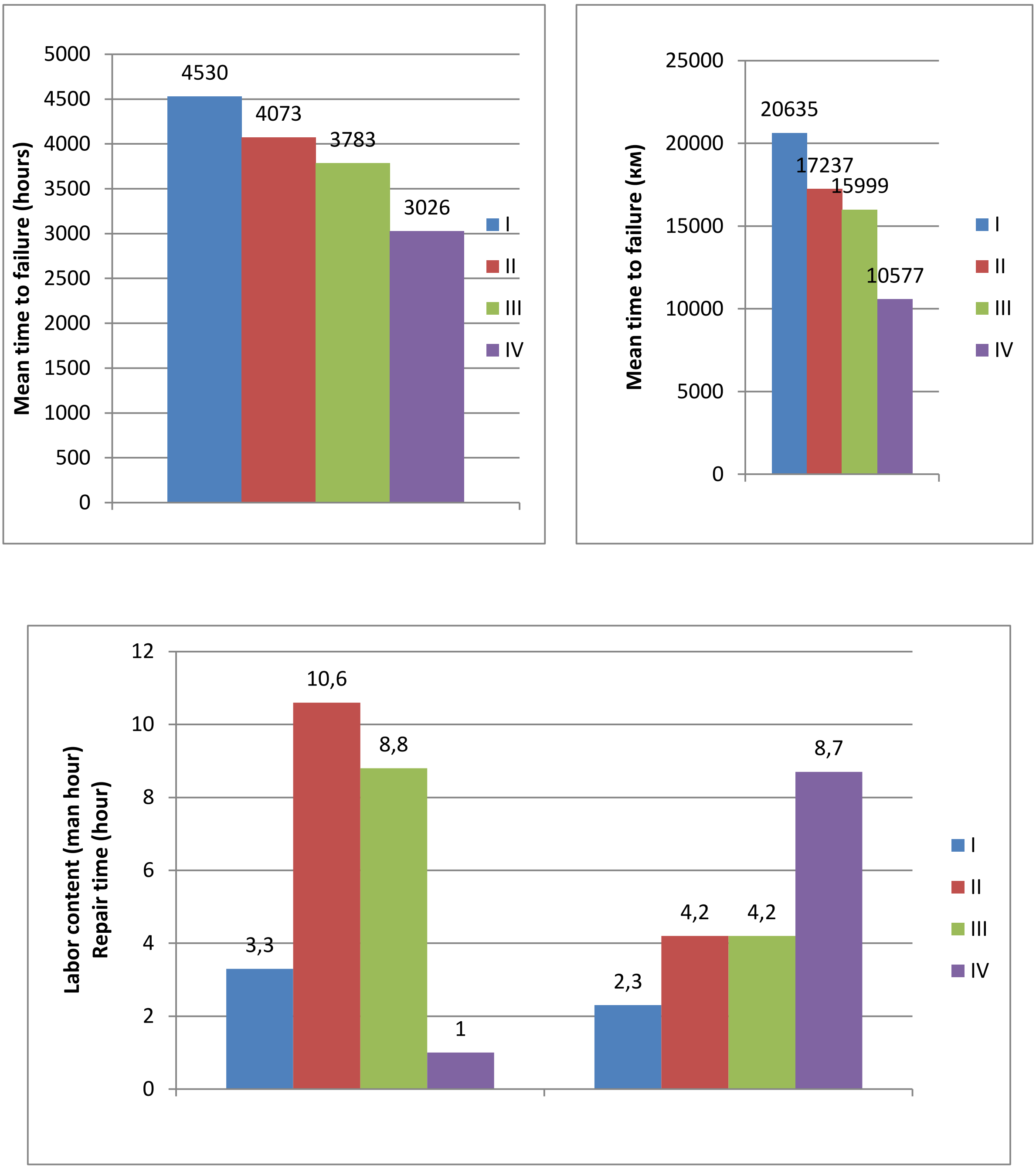


Fig. 1.6. Reliability of the steering system.
I - Steering servo pump.
II - Steering.
III - Steering servo valve.
IV - Steering pump.

The data on the operational reliability analysis should be considered preliminary, since they are obtained on the basis of a short period of monitoring the operation of BelAZ-540A and BelAZ-548A dump trucks and the low intensity of their operation.

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CONCLUSION

1. The methodology has been developed for collecting and processing primary information for assessing the performance of open-pit especially heavy-payload dump trucks.
2. The indicators characterizing the reliability level of BelAZ-540A and BelAZ-548A dump trucks in the conditions of Western Kazakhstan are obtained.
3. It has been established that the reliability level of BelAZ-540A and BelAZ-548A dump trucks depends on the climatic conditions, the least reliable components and assemblies of vehicles are determined.

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