The rational repair and maintenance cycle of the KamAZ car gearbox taking into account the pre-repair operating time

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Abstract. A significant proportion of the costs and downtime for repairs are on transmission units, and especially on the gearbox (GB). Based on the research results presented in the work, up to 76% of all transmission failures fall on the gearbox of a KamAZ 6540 automobile under ordinary operating conditions. The purpose of the study is to justify the repair and maintenance cycle (RMC) of the gearbox of the KamAZ 6540 automobile, taking into account the pre-repair operating time. The proposed methodology for assessing the pre-repair resource allows you to select the resource elements of the gearbox, taking into account the value of their resource and coefficient of variation. The structure of the RMC proposed in the work provides for: the first current repair during running hours - 125940 km; first overhaul during running hours - 251880 km; second current repair during running hours - 377820 km; second overhaul during running hours - 503760 km. Thus, changing the structure of the gearbox REC allows increasing the gearbox resource from 380 to 500 thousand km.

1. Introduction. Automobiles manufactured by the Kama Automobile Plant are widely used in all industries. The KamAZ cars of the sixth series, in a structural respect, differ significantly from their predecessors. Due to the increased load capacity and speed of the car, Stayer bridges with a final drive ratio of 6.88 were used. According to the manufacturer, the resource of the engine and bridges is from 0.5 to 2 million kilometers [1]. In the basic configuration, a ten-speed gearbox is installed on the chassis of the KamAZ 6540 car. In connection with the above, the study of reliability indicators of this gearbox model is relevant. The change in the technical condition of the units during operation is characterized by significant dispersion, which indicates the advisability of using the statistical method to determine the pre-repair operating time.

2. Materials and methods. The current structure of the repair and maintenance cycle (RMC) of units due to current and overhauls is not rational, since it does not take into account the actual changes in the technical condition during operation and rational forms of repair. Improving the structure of the REC is advisable by calculating the rational periodicity of repair work, taking into account changes in the technical condition during operation. With this in mind, the aim of the study is to determine the pre-repair resource of resource elements and the rationale for a rational RMC GB.

In the study of various random processes using statistical analysis of the selective method. It consists in establishing the generalized characteristics of the totality of observation not for everyone, but only for a part of its constituent elements, taken by random selection. The legitimacy of the application of this method is based on the law of large numbers. According to this law, the average value of the attribute, measured in a large number of tests, approaches the mathematical expectation [2,3,4].

When determining the pre-repair time using the statistical method, the selection of the actual pre-repair time should be made from among the machines of a certain age composition, operated in real conditions.

To find the value of the pre-repair operating time of the GB, its mathematical value is determined, which in the case of a normal distribution has the form [5]:

\[
\text{E}(\text{t}) = \mu + \sigma Z
\]

where \( \mu \) is the mean value of the operating time, \( \sigma \) is the standard deviation, and \( Z \) is a standard normal deviate.

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Taking into account formula 1, the value of the pre-repair operating time of GB will be determined from the formula:

\[
\text{(2)}
\]

where \( \sigma_x \) is a quarter of the area under the normal distribution curve and corresponds to the abscissa \( t = \frac{2}{3} \approx 0.67 \) or \( x = \frac{2}{3} \sigma_x \).

Then, by the nomogram, the power distribution indicator \( m \) and the value of the pre-repair operating time corresponding to the segment on the abscissa, which cuts off 75% of the area of the distribution curve of the pre-repair operating time of the gearbox, are determined (Figure 1) [8,9,10].

![Figure 1. Scheme for determining pre-repair running hours graphoanalytical method](image)

3Results and discussion. The observations were carried out for 23 vehicles that were operated in the Ural-Siberian region from 2007 to 2018.

In order to identify the least durable parts of the gearbox, limiting the amount of pre-repair running hours, data on the number and probability of occurrence of failures are analyzed.

The graphs of the distribution density function of the pre-repair resource and the integral failure curve of parts and assembly units are shown in Figures 2-5.

After the necessary calculations, the function of the distribution density of the pre-repair resource and the integral failure curve of the gearbox of the KamAZ 6540 automobile were obtained:

\[
\text{(3)}
\]

\[
\text{(4)}
\]
\[ f(T) = 0.77 \cdot 10^{-3} \cdot \left( \frac{T - 113200}{52330} \right)^{0.8} \cdot e^{-\left( \frac{T-113200}{52300} \right)^{1.8}} \]

\[ F(T) = 1 - e^{-\left( \frac{T-113200}{52300} \right)^{1.8}} \]

Tcp – average operating time;
Td – allowable operating time;
F(T) - integral failure curve of parts and assembly units;
f(T) - distribution density function of the pre-repair resource

Figure 2. Graphs of the distribution density function of the pre-repair resource and the integral curve of the gear 5 gear failure

\[ f(T) = 1.3 \cdot 10^{-3} \cdot \left( \frac{T - 98919}{40860} \right)^{0.8} \cdot e^{-\left( \frac{T-98919}{40860} \right)^{1.8}} \]

\[ F(T) = 1 - e^{-\left( \frac{T-98919}{40860} \right)^{1.8}} \]

Figure 3. Graphs of the distribution density function of the pre-repair resource and the integral gear failure curve of the 4th gear gear

\[ f(T) = 1.4 \cdot 10^{-3} \cdot \left( \frac{T - 158220}{78000} \right)^{0.7} \cdot e^{-\left( \frac{T-158220}{78000} \right)^{1.7}} \]

\[ F(T) = 1 - e^{-\left( \frac{T-158220}{78000} \right)^{1.8}} \]

Figure 4. Graphs of the distribution density function of the pre-repair resource and the integral failure curve of the rear driven shaft ball bearing
\[ f(T) = 1.4 \cdot 10^{-3} \cdot \left( \frac{T - 187700}{86310} \right)^{0.7} \cdot e^{-\left( \frac{T - 187700}{86310} \right)^{1.7}} \]

\[ F(T) = 1 - e^{-\left( \frac{T - 158220}{86310} \right)^{1.8}} \]

Figure 5. Graphs of the distribution density function of the pre-repair resource and the integral front roller bearing failure curve

Function graphs are demonstrated in Figure 6.

Figure 6. Graphs of the distribution density function of the pre-repair resource and the integral curve of the KamAZ 6540 gearbox failure

To enlarge the KP's repair life in the repair and maintenance cycle, it is necessary to provide for the replacement of a number of unreliable parts and assembly units, in particular: gears 5 gears, gears 4 gears, ball bearing of the rear driven shaft, front roller bearing.

The resource after overhaul of the control box is within 25-72% of the pre-repair resource. The resource of the GB significantly depends on the serial number of the repair. Differentiation by the repair number showed the following dynamics of the GB resource: after the 1st repair - 72%, 2 - 50%, 3 - 32%, 4 - 28% of the pre-repair. This is due to the mutual influence of transmission units, leading to an increase in dynamic loads in the transmission during operation. With more repairs, the service life of the control unit is reduced by 20% and the cost of repairs increases by 25%. From such a statement, it becomes obvious that a change in the gearbox RMC in the conditions of a repair enterprise is justified.

At present, the RMC structure has been formed, consisting of three overhauls and elimination of failures during the operation of the gearbox. As practice shows, such a RMC structure, after the third overhaul, leads to decommissioning of the unit due to its low after-repair resource.

It was recommended that the Kama Automobile Plant carry out overhaul of the gearbox while the vehicle was running for about 300,000 km, however, as our studies show, the actual average pre-repair running time is 125940 km. In the conditions of the repair enterprise, as a rule, without considering the reasons and conditions for the occurrence of a failure, overhaul of the control gear is carried out.
The proposed RMC structure provides for:
- the first current repair during running hours - 125940 km;
- first overhaul during running hours - 251880 km;
- second running repair during running hours - 377820 km;
- second overhaul during running hours - 503760 km.

Maintenance work No. 1 and No. 2 includes the replacement of low-resource parts and assembly units.

Thus, studies of the present work show that the inclusion of two current repairs in the structure of the RMC significantly increases the overhaul and overhaul life of the gearbox.

The transmission RMC for the proposed structure, taking into account the second overhaul, will be 503,760 km.

4 Conclusions.
1. Studies have shown that the average pre-repair running time of the gearbox of the KamAZ 6540 is 182,260 km.
2. The rational scheme of the repair and maintenance cycle of the KamAZ vehicle gearbox was proposed and recommended.

Acknowledgments
The authors are grateful to Professor Egorov AV and Associate Professor Zubova EV for the assistance in writing the article.

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