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System Analysis of the Influence of External Factors on the Load of a Truck Transmission

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Abstract

The paper describes the authors' approach to solving problems related to ensuring reliable and trouble-free operation of truck transmissions. A systematic analysis of a set of factors that determine the load of transmission units in various driving conditions on the basis of the theoretical studies is proposed. The importance of taking into account the influence of the external environment and the supporting surface when assessing the performance of cardan drives and driving axles is shown. The description of a sequential approach to road research of automobile transmissions is given. Based on the results of road tests of driving axles, it was concluded that it is necessary to take into account temperature gradients in the critical zones of the main gear. A method for optimizing the driving axle working processes using the objective function of loading is proposed. The conclusion is made about the rationality of on-board temperature control of transmission units. It was found that the use of on-board temperature control systems makes it possible to increase the level of reliability and timely identify the state of transmission units prior to failure.

Key words: truck, transmission, cardan drive, drive axle, final drive, operating temperature, target function

I. INTRODUCTION

The main task of any owner of a vehicle intended for cargo transportation is timely delivery of cargo, without leaving the line, that is, the maximum vehicle release rate. The task of the service specializing in the technical operation of a vehicle is to ensure the highest possible technical readiness coefficient, that is, the constant readiness of the vehicle to carry cargo [1].

Over the past decades, the efficiency of the vehicles released by the factory, their power, economic and environmental performance, reliability and durability have grown significantly. Despite this, the experience of operating the vehicle fleet shows that a significant proportion of vehicles are operated with malfunctions, which lead to a decrease in their performance [2]. Therefore, the term "readiness" of a vehicle for cargo transportation also implies maintaining the vehicle in such a state when the efficiency parameters provided by the manufacturer are in optimal condition, otherwise the vehicle's potential is not fully realized, which leads not only to an increase in the cost of fuel and lubricants, but also increases the delivery time of the goods.

To keep the vehicle in good technical condition, the following performance strategies are provided:

1. Event-base - work is performed to restore performance after something has happened;
2. Routine maintenance - a set of tests is carried out by the manufacturer, based on which certain time intervals are established; it is necessary to perform maintenance or repair work after them;
3. Condition-based maintenance - an assessment of the condition of an individual unit or unit is carried out; based on this assessment, a forecast is made when it is necessary to perform maintenance and repair work.

The goal of any commercial enterprise, including an enterprise engaged in road transport, is to make a profit. Therefore, when choosing an approach to planning repair and maintenance work, it is necessary to choose the most cost-effective methods. Let's consider these methods. The first method is the simplest, since we carry out any work only when we are sure that the vehicle is inoperative. However, it is the most expensive at the same time. For example, if we talk about an engine, the costs of eliminating failures are on average 8-10 times higher than the costs of their prevention [3, 4]. The second method is the most popular approach today. It gives a much higher level of vehicle availability, but is still quite expensive. This is due to the fact that often most of the vehicles at the time of work are in such a condition that these works are not required yet, since manufacturers set the time for all works so that the majority of vehicles do not fail by the time when all maintenance and repair works are scheduled. The third method is the most high-tech and cost-effective. It is with this approach that we can achieve the best economic indicators.

II. METHODS

The study of the performance and reliability of the transmission units of a truck cannot be reliable without taking into account the influence of the road surface and the environment. This is due to significant differences in operating conditions in the climatic zones of the Russian Federation [7]. For example, changes in atmospheric pressure and air temperature should be taken into account in order to obtain reliable information about the mode of operation in elevated and mountainous regions.

This paper provides data from a study of transmissions of KAMAZ vehicles, which are designed for trouble-free operation in the air temperature range of -45 ... + 40 ° C for regions and countries with a temperate climate, relative humidity up to 75% and dust content up to 1 g / m3 [8].

In the course of the research it was established that the operational state of a vehicle is an element of the natural-technical system "driver (repairman) - transmission - support surface - environment". An assessment of the weights of the inter-element relationships of this system was carried out; this made it possible to make changes in the generally accepted calculation methods.

The efficiency and durability of the transmission in difficult road conditions are determined by a set of measures to establish and maintain a rational range of temperatures for parts and transmission oil. For example, when a vehicle is moving, overheating of transmission oil and parts can occur; dust, wear particles and other contaminants can enter the lubricating layer. Due to the listed phenomena, it becomes necessary to take into account changes in loads under the influence of various factors [9, 10].

To reduce costs, which noticeably increase as we approach the stages of operation and maintenance of automotive components and systems, it is necessary to take into account the entire complex of interactions between the driver, the environment, the power unit and chassis units when developing promising designs [11]. In this case, the research should be based on the methodology of the mutual influence of significant external and internal factors which have an effect on the vehicle and included in the system "driver - vehicle - road - environment" [12, 13].

III. RESULTS AND DISCUSSION

Road tests of driving axles and cardan drives of trucks were carried out under normal operating conditions in order to perform a reliable assessment of the influence of systemic factors [17]. The task was to obtain information about the processes of heating and cooling the transmission units at an ambient temperature of 20 ... 25 ° C and a minimum wind speed (0 ... 2 m / s).

During the road tests, a number of necessary indicators were taken into account:

1. Technical parameters of the vehicle (maximum torque, effective engine power, number of gears and gear ratios of the gearbox, type and gear ratio of the main drive, availability of differential lock).

2. Technical conditions for the wheel drive operation (volume and type of gear oil to be poured, type of grease, residual mileage or degree of wear and tear of parts, presence (absence) of noise and knocking during operation of units, presence (absence) of oil leakage, temperature state of units before testing, the distribution of mileage on the route by gears, the average value of the crankshaft speed when driving in top gear conditions).

3. Road testing conditions (route length, road surface type and average adhesion coefficient, elevation difference on the route and average slope value, presence of surface defects and support obstacles, overcoming areas with low adhesion coefficient and probable wheel slip).

4. Weather and climatic conditions of the tests (ambient air temperature at the beginning and during the tests, wind speed and direction at the beginning and during the tests, the presence (absence) of precipitation on the unit surfaces, the occurrence of a bulldozer effect on snow-covered areas).

According to the research carried out by the authors, the greatest interest is not only the unit temperature, but also the temperature distribution, which makes it possible to establish possible critical zones of heating or cooling. Therefore, temperature gradients should be monitored at specific locations corresponding to the placement of bearing units and gearing.

The data of road tests confirmed the correctness of the theoretical provisions of heat exchange between the transmission units and the environment, and made it possible to clarify the mathematical model created for the working processes of the truck's main gear (Fig. 1).

The presence of critical zones in the main transmission and the drive axle beam subjected to significant temperature gradients, and, as a consequence, being in unsatisfactory lubrication conditions during long-term operation, was confirmed.

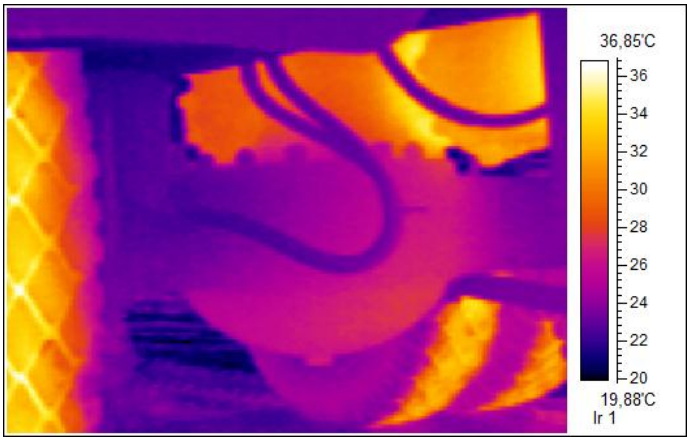

Figure 1. Thermal map of the intermediate axle in the KAMAZ vehicle

The temperatures were determined in the critical zones described in [4]. It was found that significant temperature

gradients appear in the longitudinal and cross sections during long-term operation of a drive axle. The final temperature value used in the calculations was corrected by the value specified by the state of the environment (temperature and air mobility) for the corresponding critical zone.

IV. SUMMARY

During the tests, a significant relationship was established between a number of parameters in the driving axle working processes. It is concluded that it is necessary to control the presence of the relationship between certain indicators, which can indicate with a high degree of reliability a malfunction of the unit. For example, noise in the final drive can be associated with both broken teeth and bearing wear, with different oil heating levels.

An optimization model should be applied to assess the reliability of the final drive and other units. It is proposed to calculate the objective function for the above criteria of work processes [18]. The weighting coefficients of the corresponding indicators are found empirically according to the statistics of malfunctions and vehicle failures in the given climatic conditions. The heat balance of the unit is determined in accordance with the classical heat transfer theory for the known physical properties of materials from which parts are made, transmission oil and atmospheric air [20].

The objective function taking into account the weight of the influence of system factors allows us to determine the feasibility of adjusting the temperature regimes of transmission units:

$$U_t = \sum_{i=1}^{n} (\alpha_i R_i),$$

Where α_i are the weight coefficients of system factors; R_i - the system factor value for the given loading and climatic conditions.

V. CONCLUSIONS

The carried out theoretical and experimental studies of the working processes in the transmission units of a truck allow us to draw the following conclusions:

1. The technical condition of drive axle units and the probability of their failure-free operation vary significantly during operation in certain climatic conditions. With the resulting negative impact of a number of factors, unit failure is possible. In such a situation, timely information from the on-board complex about a deviation in the operation of the drive axle will help to avoid breakdowns and eliminate the malfunction in advance.

2. The use of on-board control systems to monitor the current parameters of the technical condition of transmissions is necessary, since this reduces the likelihood of intensive wear and failure of units.

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