Ensuring Reliability of Transfer Gearbox

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Abstract: There is a tendency in the world to create and develop intelligent vehicles. Considering that while smart vehicles have not conquered the market and potential customers are only thinking about the degree of trust in them from the point of view of the transportation process safety, the issues of ensuring the reliability of such vehicles are becoming more urgent. One of the trucks main characteristics that ensure their reliability is transmission units. The transfer gearbox of KAMAZ 6522 trucks was chosen as the object of the study. The statistics of the transfer gearbox failures for 2018-2019 were considered. Based on these statistics, the problem area of the unit and mileage the breakdown occurs were determined. The transfer gearbox main faults include the shaft bearings wear, the teeth of the included gears wear; the switching mechanism clamps wear. Bench tests have shown that the countershaft bearing is experiencing overheating due to lubricant lack, which ultimately leads to failure. In most cases, the cause of these faults is the lubrication system malfunction, as a result of which the transmission parts overheating occurs. The relevance of the work is due to the fact that it is necessary to analyze the causes of failures in the transfer gearbox that cause transmission parts overheating and establish dependencies that cause overheating. This will increase the unit reliability and propose methods for improving its operation. Based on the data obtained, it was proposed to increase the holes for the lubricant supply in the seat of the front intermediate bearing of the intermediate shaft by 1.5 mm by changing the milling parameters. At the end of the work, the transfer gearbox is again subjected to life tests. The scientific novelty lies in the establishment of the dependence of the intermediate shaft bearing heating temperature on the operating time by bench tests.

1 INTRODUCTION

The need to increase the efficiency of road transport usage and ensure the implementation of transport work's required volume with minimal costs requires constant work to improve vehicle reliability. It is one of the factors affecting the vehicle competitiveness (Makarova, Pashkevich, Buyvol, Mukhametdinov, 2019). The complexity of the problem lies in the fact that vehicles are operated in different road and climatic conditions with different degrees of their workload and the driver's staff qualifications (Makarova, Khabibullin, Belyaev, 2012). And in the case of autonomous vehicles' creation, high reliability can be ensured with an integrated approach to solving this problem at all stages of the "life cycle" of a car: during its design, manufacture and operation.

A truck with a high cross-country ability, equipped with a complex mechanism for transmitting torque to the axle. Because these vehicles are

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designed for long trips on low-grade road surface and even off-road, they are equipped with several drive axles at once to increase cross-country ability, but this in turn complicates the torque transmission system. A transfer gearbox is used for proper distribution and coordination in the required proportions of torque between the front, rear axle and the engine.

During the vehicle operation, it is worth paying great attention to the transfer gearbox condition and operability. In order to understand whether the transfer gearbox needs repair, it is important to monitor the appearance of the following signs: constantly or regularly there are knocks, noises and other sounds while driving, which warn of problems in normal operating mode; transmissions began to turn off on their own; there are difficulties in gear shifting. The task of predicting the transfer gearbox current state is especially important at the design and operation stage in order to determine the optimal frequency of maintenance and repair.

2 METHODS OF ENSURING THE OF TRANSMISSION UNITS RELIABILITY: A LITERATURE REVIEW

One of the trucks main characteristics that ensure their reliability is transmission units. In keeping with customers' high expectations and requirements to vehices, developing reliable products is critical. In addition, for reasons of competitiveness, it is necessary to know the product future life as accurately as possible (Woll, Jacobs, Feldermann, 2017).

Manufacturers divide the methods of ensuring the automotive equipment reliability into three categories conditionally corresponding stages of the vehicle life cycle: structural reliability; improving reliability in operation; technological reliability assurance.

Monitoring and diagnostics of the vehicle technical condition are very important at the operation stage, as this allows eliminating the causes of possible failures and predicting the vehicle life (Makarova, Shubenkova, Mukhametdinov, Giniyatullin, 2020). Diagnosis is an important component in predicting vehicle reliability (Gritsenko, Shepelev, Zadorozhnaya, Shubenkova, 2020, Tsybunov, Shubenkova, Buyvol, Mukhametdinov, 2018). Studies of equipment with rotating parts (generators, turbines, fans, etc.) for the development of faults that cause vibration are carried out by vibration diagnostics (Sait, Sharaf-Eldeen, 2018, Muszynska, 1995). Failure detection using a vibration signal is considered one of the most important methods applied to rotating parts (Furch, Nguyen, Glos, 2017, Gritsenko, Shepelev, Zadorozhnaya, Almetova, Burzev, 2020). The article (Makarova, Mukhametdinov, Gabsalikhova, Garipov, Pashkevich, Shubenkova, K., 2019) justifies the possibility of improving the trucks reliability by creating an intelligent system and a method for clutch diagnostics by controlling changes in vibration levels.

The article (He, Shao, Wang, Lin, Cheng, Yang, 2020) presents a new approach called multi-wavelet auto-encoder of deep transfer for transmission faults intelligent diagnostics with a small amount of training samples. The new type of multi-pulse autoencoder is designed to study important features of the transmission collected vibration signals.

Improving the truck transmission units reliability and durability has been considered in a number of works (Vasilev, Grigorev, Mardashov, 2019, Wang, Wu, 2016, Bartholdt, Grundler, Bollmann, Bertsche, 2018). Failures early detection and diagnostics allows for the correct planning of shutdowns to prevent catastrophic failures and therefore leads to safer operation and higher cost savings (Liang, Zuo, Feng, 2018).

In work (Oliveira, Martins, Seabra, Seyfert, Igartua, 2006), transfer gearbox tests were carried out to assess wear depending on the oil used. The paper (Choi, Yang, Hwang, Son, On, Kim, 2010) examines the distribution of the time of the J79 engine transfer gearbox failure using the probability method, which is one of the most convenient methods of reliability analysis.

Transfer gearbox main faults include: the shaft bearings wear, the teeth of the included gears wear; the switching mechanism clamps wear. In most cases, the cause of these faults is lubrication system malfunction, as a result of which overheating of the transmission parts occurs. The relevance of the work is due to the fact that it is necessary to analyze the causes of failures in the transfer gearbox that cause transmission parts overheating and establish dependencies that cause overheating, which will increase the reliability of the unit and propose methods for improving its operation.

3 RESULTS AND DISCUSSION

According to the data obtained from the complaint acts, a number of the transfer gearbox faults were revealed (Figure 1). Based on these data, statistics of the most frequent failures were compiled, among which the intermediate shaft bearing is the clear leader. The statistics of the main faults and their dependence on the mileage are shown in Figure 2.

These diagrams show that bearing failure occurs on a mileage from 2,000 to 30,000 km. This is due to the fact that these bearings overheat excessively, the lubricating fluid does not flow in the required volume, there is no lubrication and heat dissipation, which ultimately leads to heating, and subsequently to the bearing destruction.

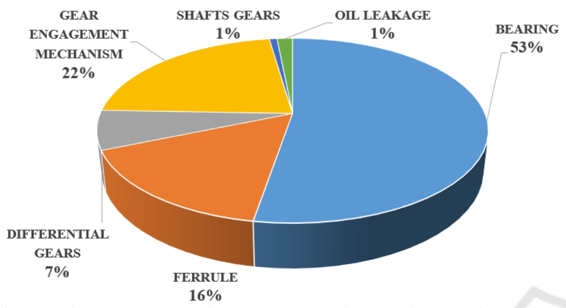

Figure 1: Transfer gearbox failure statistics for 2019.

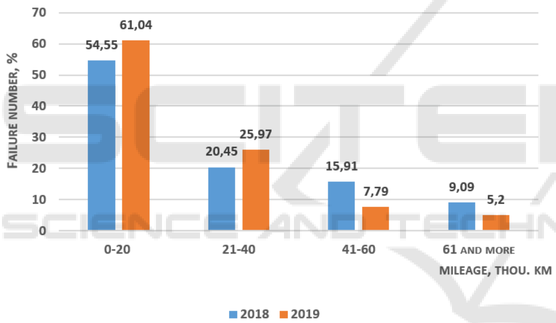

Figure 2: Failure statistics of the front bearing of the transfer gearbox intermediate shaft for 2018-2019.

To determine the critical degree, bench tests for durability are required. The tests were carried out in bench conditions, in a design and research bureau in compliance with the requirements for ensuring normal climatic conditions for testing products in accordance with GOST (GOST 15150-69), namely:

- ambient temperature - (25 ± 10) ° C;
- relative air humidity - (45-80)%;
- atmospheric pressure - (84 - 106.7) kPa.

Tests to determine the resource of an experimental transfer gearbox during flexural life tests were carried out on a stand with a closed power circuit "MTS"

The operating time till failure of any of its component parts was taken as an estimated parameter for the transfer gearbox durability.

Criteria for failure of the transfer gearbox: breakage of the gear teeth; fatigue chipping of the gear teeth or bearing defects resulting in clearly audible knocking.

During the tests, clear knocks were noticed in the transfer gearbox, which characterizes the rollers' defect. From the beginning of the tests, the temperature was measured every hour using a thermal imager on which the overheating zones are clearly expressed, and the temperature after 9 hours was 132 ° C (Figure 3).

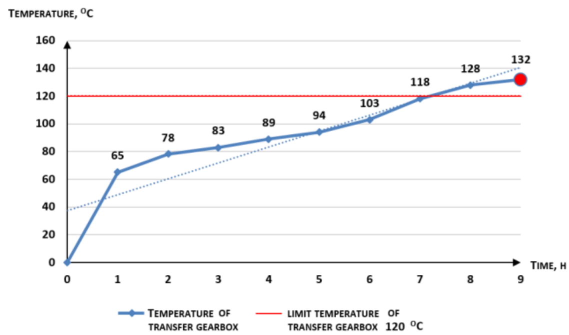

Figure 3: Heating curve for the intermediate shaft bearing zone.

In a durability test, an intense rise in temperature was noticed within 9 hours, which subsequently led to the transfer gearbox failure. After a lengthy test, the transfer gearbox was disassembled. During disassembly, the following results were made: the intermediate shaft bearing was destroyed, the bearing rollers were severely deformed, and a crack was also found in the transfer gearbox cover. The bearing destruction occurred due to the spare part overheating, as a result of which the transfer gearbox failed.

Figure 4 shows the result of the tests carried out, which clearly shows that in the first case, the test was interrupted, due to the transfer gearbox failure at 9 hours of testing, having completed 24% of the total number of cycles:

9 hours = 24% = 67 200 cycles.

In the second case, the test is completed:
37,2 hours = 100% = 280 000 cycles.

Based on the data obtained, the transfer gearbox durability is increased by 4 times.

The test results before and after the changes are shown in Table 1.

Table 1: Comparative characteristics of data after testing.

Test data	Test time, hour	Number of cycles, rpm	Limit temperature, ° c
Before enlarging the housing port	9	67 200	132
After enlarging the housing port	37,2	280 000	113

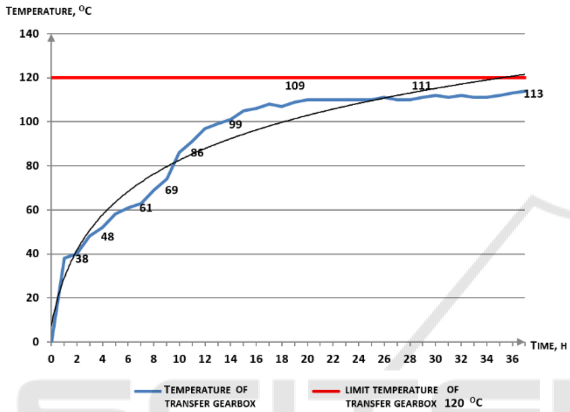

Figure 4: The graph of the temperature change of the transfer gearbox intermediate shaft bearing

Upon completion of tests in this mode with a load of 3.4 V on the transfer gearbox input shaft, the thermal imager showed the highest temperature of 113 ° C in the studied area of the front intermediate bearing. The overheating test can be considered satisfactory since the next test mode is to shift the transfer gearbox down. In low gear, the shaft speed and load (load in low gear is 2.7 V) is lower than in high. Considering these modes, this study on the overheating of the intermediate shaft front bearing area is satisfactory, since at the lowest gear the temperature will decline.

Figure 5 shows the test results before and after changing the crankcase bore in the form of a comparative graph of the transfer gearbox temperatures in the area of the intermediate shaft bearing.

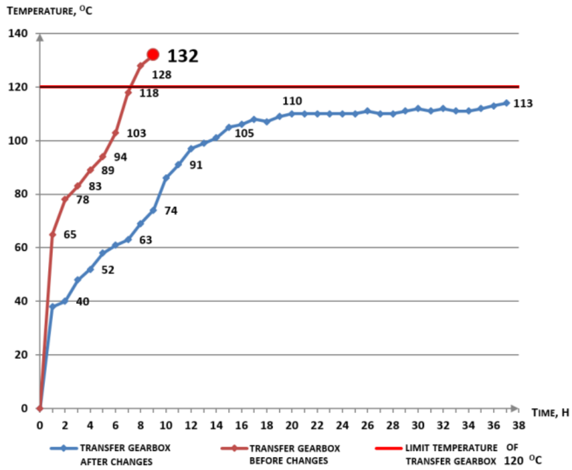

Figure 5: Heating of the intermediate shaft bearing area before and after improving the transfer gearbox housing

4 CONCLUSIONS

As a result of a study of the truck transfer gearbox operation, it was found that the heating of the intermediate shaft bearing at a certain operating time exceeds the maximum permissible values, which negatively affects the lubrication system. The lubricating fluid does not flow in the required volume, there is no lubrication and heat dissipation, which ultimately leads to heating, and subsequently to the bearing destruction.

In order to eliminate this defect, work to improve the design of the transfer gearbox housing was carried out. To increase the hole for the lubricant supply in the seat of the intermediate shaft front intermediate bearing by 1.5 mm was taken as the main measure. Bench tests were carried out to evaluate the proposed activities. As a result, it was revealed that a change in the diameter of the hole in the intermediate shaft front intermediate bearing socket for supplying grease increased the throughput of the lubricating fluid, which in turn allowed keeping the temperature within the normal range, and thereby increasing the durability of the transfer gearbox by 4 times.

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