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Research Of Operational Reliability Of Automatic Transmissions

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Abstract. This article is devoted to the review of existing designs of automatic gearbox (AG). Based on the analysis, three types of AG systems are identified, which are installed in modern designs of cars and trucks, as well as in buses. The article presents the main advantages and disadvantages of various types of AG. The regularities of the distribution of the failure density depending on the mileage of city buses are shown. Based on the analytical review, it was found that the failure densities of various types of AG are in good agreement with the logarithmic-normal distribution and the Weibull-Gnedenko distribution law.

Key words: Automatic, manual transmission, reliability, torque converter, hydromechanical transmission, viscosity, oil oxidation, friction force, additives, boundary layer.

Introduction.

Most new cars of different brands are equipped with an automatic transmission They are the most popular, or even the basic version of the transmission on many models of cars, both passenger cars and trucks. Due to the widespread use of automatic transmissions of various types, the issue of their operational reliability is becoming more and more urgent.

The automatic transmission assumes the capabilities of the engine and selects the transmission depending on a set of input data, such as the number of revolutions of the crankshaft, speed and throttle position, to maintain the best application of torque.

The actions usually performed by the clutch and manual transmission are performed automatically, using a torque converter, which allows very small, controlled slippage between the engine and the transmission of the car. Hydraulic valves control the activation of various gears at the request of the driver (the position of the gas pedal), or operating with preset responses to the current operating conditions of the engine and the speed of the car.

There are three main types of modern automatic transmissions: hydro-mechanical planetary-type automatic transmission, variator transmission and robotic gearbox. When the load on the driving wheels increases, the lock is automatically turned off.

Each type of automatic transmissions has advantages and disadvantages that affect their operational reliability. There is no clear answer to the question of which type of automatic transmission is more reliable in operation. Currently, researchers [1-3] have collected a sufficient amount of information about failures of such transmissions, on the basis of which statistical reliability indicators can be justified.

A planetary-type hydromechanical automatic transmission consists of the following main components: a torque converter, a planetary series, a control and control system. The box of front-wheel drive cars additionally contains a main gear and a differential inside the case.

Research analysis.

The absence of rigid coupling in the torque converter has its advantages and disadvantages. Advantages: the torque changes smoothly and continuously, torsional vibrations and jerks transmitted from the engine to the transmission are damped. Disadvantages: low efficiency, since part of the energy is lost when mixing the oil (working fluid) and is spent on the drive of the automatic transmission pump, which ultimately leads to an increase in fuel consumption. To eliminate this drawback, a lock mode is used in the torque converter. When the driving mode is steady on higher gears, the mechanical locking of the pump and turbine wheels of the torque converter is automatically activated. That is, it begins to perform the function of a normal "dry" clutch. At the same time, a rigid connection of the engine with the driving wheels is

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provided, as in a mechanical transmission. On some automatic transmissions, the activation of the lock mode is also provided for lower gears. Movement with blocking is the most economical automatic transmission mode in terms of fuel consumption.

Due to the turbulent movement of the working fluid, it is significantly heated. Therefore, the design of the automatic transmission provides a cooling system with a radiator, which is either built into the radiator of the engine, or installed separately.

The planetary gear is a mechanical gearbox consisting of several satellite gears rotating around a central gear. Gear shifting is carried out by the control system, which on early models was completely hydraulic, and on modern ones, electronics came to the aid of hydraulics.

A feature of the variator transmission is that there are infinitely many possible modes when driving a car. Therefore, the optimal operation of the engine can be ensured if the number of stages in the gearbox is infinite. The CVT is the only type of transmission that exists today that allows you to continuously change the gear ratio between the engine and transmission. Due to the constant operation of the engine in the zone of optimal rotation frequencies, high efficiency is achieved, reduced exhaust gas toxicity and better acceleration dynamics of cars with variators.

The variators are light in weight, simple in design and reliable enough. The main disadvantage of variators is that they are frictional, work due to friction, not gearing, and therefore can transmit a limited torque of 350-400n • m. When the torque is exceeded, the working surfaces begin to slip and wear out intensively. Therefore, they cannot be used in conjunction with powerful engines.

The robotic gearbox occupies an intermediate position between the automatic transmission and the manual transmission. The robotic box is an ordinary manual transmission controlled by an electronic control unit using servos. The clutch is controlled by the same automation. The main problem of robotic control units has become the high complexity of the control mechanisms, as well as the double clutch of DSG boxes and, as a result, their relatively low operational reliability. Also, it is necessary to note the low maintainability of DSG transmissions, where, in case of failure, the elements or the entire gearbox are replaced.

Thus, taking into account the technical features and design complexity of various types of automatic transmissions of cars, reliability becomes one of the most important issues of their technical operation.

To analyze the reliability of transmissions, data on failures of automatic transmissions of different types of passenger cars were collected [1].

All processes occurring in the interfaces of mechanisms, in machines (car), are random. This is due to the fact that the external conditions in which the cars operate: temperature, dynamic loads, etc., change randomly, and for the car, the irregularities on the surface of the road on which the car is moving alternate randomly, randomly repeated interference in the way of movement.

In addition, the strength characteristics of the material itself: the ultimate strength, yield strength, hardness of which the machine parts are made of are not constant values, but change randomly. Thus, when studying any process on a car, we are dealing with random variables, processes [3].

The results of operational tests of various types of automatic transmission of passenger cars under operating conditions, obtained by the researchers of the work [4].

№	Name of performance test indicators	Hydro-mechanical automatic transmission of planetary type	Variator automatic transmission	Robotic transmission
1.	Sample size N, units	80	52	63
2.	Number of intervals "n"	5	5	5
3.	Interval step h, thousand km	82,8	41,4	56,8
4.	Minimum mileage before failure	36,0	46,0	16,0
5.	Lmin, thousand km	450,0	253,0	190,0
6.	The average value of the mileage to failure L, thousand	148,815	144,723	108,330

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	km			
7.	The standard deviation to failure σ, thousand km	76,05	44,95	61,255
8.	Variance D, thousand km^2	5783,545	2020,749	3852,161
9.	Coefficient of variation V	0,51	0,31	0,565
10.	Scale parameter "a"	-	160,358	121,97
11.	Shape parameter "b"	-	3,6	1,85
12.	Laws of distribution of random variables that obey the failures of test objects	Logarithmically normal distribution law	The law of distribution of the Weibull-Gnedenko Research Institute	The law of distribution of the Weibull-Gnedenko Research Institute
13.	Hypothesis testing criteria	Pearson	Pearson	Pearson
14.	Number of failures in intervals:			
	the first interval	33	7	16
	second interval	31	10	24
	third interval	11	20	13
	fourth interval	4	12	8
	fifth interval	1	3	2

When analyzing random processes with an increase in the number of experiments, the accuracy of the test results increases when the number of experiments tends to infinity, the parameters of the experimental data coincide with the true parameters of the process being studied. However, with an increase in the volume of tests (sample size), the material, labor costs and duration of tests increase. In this regard, it is necessary to determine the minimum amount of tests, being set by the error of test results acceptable for practice.

In order to obtain objective information about the operational reliability of the automatic transmission, the authors of the work [4] conducted operational tests. Hydro-mechanical planetary-type automatic transmissions (80 units), variator automatic transmissions (52 units) and robotic gearboxes (63 units) were subjected to the experiment. The samples were formed on the basis of primary documents reflecting the appeals of car owners with automatic transmission failures to the service center. The peculiarity of the primary information was that it was collected directly from operation. The collected information was processed using methods of mathematical statistics and hypothesis testing according to the Pearson criterion.

The table data show the following main calculation parameters for the above three types of automatic transmission (respectively):

interval step h-82.8 (1st type), 41.4 (2nd type) and 56.8 (3rd type) thousand km; minimum mileage to failure Lmin-36.0; 46.0; 16.0 thousand.km; maximum mileage before failure Lmax-450,0; 253,0; 190.0 thousand km; average mileage before failure L -148,81; 144,72; 108,33 thousand km; standard deviation σ-76.05; 44.95; 61.25 thousand km;

the coefficient of variation V is 0.51; 0.31; 0.565.

The results obtained indicate the laws of distribution of random variables (failures):

- for a planetary-type hydro-mechanical automatic transmission, a logarithmically normal distribution law (V=0.51) took place;

- for variator automatic transmission–the distribution of failures obeyed Weibull's law (V=0.31);

- for a robotic gearbox, the distribution of failures also obeyed the Weibull distribution law (V=0.565).

Knowledge of the laws of the distribution of failures and average mileage values allow you to calculate the required number of spare parts of the automatic transmission for the future period. In addition, it is possible to determine the gamma-percent resource and the optimal frequency of maintenance of the automatic transmission, to plot the probability curves of uptime and failures.

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As a result of the tests and processing of primary information, the following expressions were obtained for the theoretical determination of the failure density depending on mileage [4].

- hydro-mechanical automatic transmission of planetary type

$$f(L)=\frac{1}{L\cdot 190.63}\times \exp\left[-\frac{(\ln L-148.815)^2}{11567.205}\right];$$

- variator transmission (variator)

$$f(L)=0.023\times\left(\frac{L}{160.358}\right)^{2.6}\times\exp\left[-\left(\frac{L}{160.358}\right)^{1.6}\right];$$

- robotic transmission

$$f(L)=0.015\times\left(\frac{L}{121.97}\right)^{0.85}\times\exp\left[-\left(\frac{L}{121.97}\right)^{1.85}\right]$$

The resulting equations describe with sufficient accuracy the density of the distribution of failures depending on the mileage of the car. Thus, automatic transmission failures of various types were subject to certain laws of mathematical statistics.

Conclusions.

Based on the performed analytical review, the following conclusions can be drawn:

- currently, hydro-mechanical planetary-type automatic transmissions have a relatively large average resource, the value of which is $\bar{L}$=148,815 thousand km, with a variation range of values from L_{min}=36,0 thousand km to L_{max} =450,0 thousand km;

- the minimum average resource has robotic gearboxes $\bar{L}$=108,33 thousand km, with a variation range of values from L_{min}=16.0 thousand km to L_{max}= 190,0 thousand km;

- variator automatic transmissions have a relatively average resource of $\bar{L}$=144,723 thousand km, with a variation range of values from L_{min} = 46,0 thousand km to L_{max}= 253,0 thousand km. It should be noted that variator automatic transmissions cannot transmit large torques, i.e. no more than 400 n·m;

- knowledge of the laws of the distribution of failures and average mileage values allows you to calculate the required number of spare parts of the automatic transmission for the future period of operation;

-based on the established distribution law, it is possible to determine the gamma percent resource, which is necessary to determine the warranty mileage of the automatic transmission, by the manufacturer;

-having the laws of failure distribution of automatic transmission systems, it is possible to determine the optimal frequency of their maintenance, and it is also possible to construct curves of uptime and failure probabilities (both experimental and theoretical curves).

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