Preparation and carrying out of tests to assess the operation modes of a medium-duty cargo vehicle transmission

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Abstract. This article discusses the achievements of Nizhny Novgorod State Technical University n.a. R.E. Alekseev specialists in the field of medium-duty truck Gazon Next testing in order to determine the engine operation modes and mechanical transmission in conditions close to operational. The latest achievements of measuring technologies for assessing the car performance properties are shown. The experimental characteristics obtained are necessary for the mechanical transmission robotic kit development.

1. Introduction

One of the important trends in the modern mechanical transmissions development is the increasing use of clutch and gearshift automated control. Almost all well-known companies, for example, ZF, Volvo, Mercedes-Benz, Scania, Renault, Eaton, etc. install regular or at the customer’s request automatic transmission control [1]. The use of automated control, among other things, provides a reduction in the gear shift time (for trucks in 1,5-2 times) and, accordingly, improving the car acceleration qualities and increasing the car efficiency due to the automatic optimal selection of the switching moment. The automatic control system must produce a gear shift based on a given law of gear shift automatic control [2], which is called a combination of gear torque constraints (both from lower to higher gears, and vice versa) from the main factors, such as the car speed and the engine load. It is determined by the fuel control pedal position. Thus for successful functioning of the system in its operation algorithm it should be established, that at every turn before transmissions switching the optimum time which should be allotted to actuators work in given conditions of movement is determined. This value will determine the magnitude of the power change on the leading wheels before and after the gear shift [3].

At the present stage of transport equipment development there is a rapid change of models at mobile machines modification processes intensification, increase in number of new developments that provides cars with higher consumer quality and competitiveness in the market. Car transmissions control automating is an important task. This helps to increase the engine and transmission service life, to improve pass ability and comfort due to a smoother change in torque on the drive wheels, starting and acceleration, to increase the transport operations productivity [1].

The automatic control system must produce a gear shift based on a given law of automatic control called combination of gear torque constraints (both from lower to higher gears, and vice versa) from the main factors, such as the car speed and the engine load determined by the position of the fuel supply control pedal [2].
2. Preparing to testing

In order to obtain the dependencies (the process of starting, switching to higher and lower gear, stopping) of the transmission control law, the specialists of the Nizhny Novgorod State Technical University developed and installed a measuring complex (figure 1) on the test object (medium-duty truck GAZON Next) according to the evaluation of the mechanical transmission operation modes in conditions close to operational.

![Measuring unit schematic diagram](figure1)

The presented measuring device allows to record such dynamic parameters as:
- Vehicle linear speed (km/h);
- Longitudinal and lateral acceleration (g);
- Yaw, pitch, roll speed (°/s);
- Crankshaft speed (rpm);
- Input and output shafts gearbox revolutions (rpm);
- Accelerator pedal position (%);
- The fact of pressing the brake pedal (0/1);
- Clutch pedal position (mm);
- Actual engine torque (Nm);
- Friction torque in the engine (Nm);
- Driver torque request (Nm);
- Torque on the propeller shaft (Nm);
- Forces in the gear shift cables (N);
- Fluid pressure in the clutch hydraulic drive (MPa);
- ABS, ASR functions triggering.
Torque measurement, especially on rotating shafts of mobile devices, is a complex technical task. For its solving a significant number of devices with different operating principles have been developed in the world. In some cases, the torque determination, and accordingly, the object power, is carried out by indirect indicators. For example, in cars the torque can be determined by fuel supply, exhaust temperature and other indications. This approach does not allow a high degree of certainty to determine the power requirement. Precise torque measurement is carried out using systems that determine the shaft torque deformation of [4].

In this regard, NSTU experts decided to apply the torque measuring method on the shaft deformation using a strain gauge bridge. In this case, the resistance strain gauges are glued to the shaft at an angle of 45° to the rotation axis, electrically connected to the bridge circuit. The use of this scheme increases the sensitivity, improves the resulting characteristics linearity and significantly reduces the temperature effect on the output signal. In addition, the advantage of the bridge is that it measures only the change, not the total resistance [4]. The main difficulty in using this method in relation to rotating elements is to transfer the measured readings to the recording equipment. Modern electronics development allows using a digital radio channel to make data transfer as simple as possible.

In the torque study on the medium-duty truck GAZON Next driveshaft, it was decided to use the multi-channel telemetric system KMT MT32-ENC8, which includes:

1. Signal handler module from the strain gauge bridge MT32-STG (3 pieces);
2. Control module-collector on the SPI-bus MT32-ENC8;
3. High-frequency transmitter MT32-Tx-320kbit;
4. Stand-alone power module with a lithium battery CR-P2.
5. MT32-DEC8 radio decoder;

The telemetry kit mounted on the drive shaft as well as the glued strain gauge sensors are shown in figure 2.

![Figure 2](image)

Figure 2. Strain gauges and telemetry installation on the propeller shaft to measure torque
1- Torque strain gauges glued onto the shaft; 2- Control assembly module MT32-ENC8; 3- High-frequency transmitter MT32-Tx-320 kbit; 4- Signal handler module from the strain gauge bridge MT32-STG.

Before installing the measuring drive shaft on the testing vehicle, readings obtained from strain gauges were calibrated on the torque physical amount.
In automated mechanical transmission, the selection and switching process is provided by electric motors with a gear part. In this regard, for the selection and calculation of optimal in size and parameters actuators, it was necessary to experimentally determine the forces arising in the drive. For this purpose, measuring ropes were made, calibrated and installed on the test vehicle (figure 3).

![Diagram of measuring ropes installation](image)

**Figure 3.** Installation and calibration of measuring ropes

a) Measuring strain gauge ropes calibration; b) Installing ropes in the drive
In addition to the standard sensors, external sensors were installed: a gyroscope to determine accelerations and rotational speeds along 3 axes (figure 4a), a linear movement sensor for the clutch pedal (figure 4b), a pressure sensor in the clutch hydraulic drive (figure 4c), speed sensor of input gearbox rotation (figure 4d).

![Image](76x507 to 286x665)

![Image](311x448 to 473x665)

![Image](76x271 to 286x429)

![Image](326x249 to 503x429)

**Figure 4.** Installation of additional sensors

a) Gyroscope IMU05;  b) Linear clutch pedal sensor;  c) Pressure sensor in the clutch hydraulic actuator;  d) Input shaft rotation speed sensor

The TMR-200 dynamic data acquisition system was used to record in time the torque values measured and transmitted by the telemetry kit, the tensile forces arising in the transmission cables as well as signals from additional sensors (figure 5). It consists of following blocks:

- TMR-211 control;
- TMR-281 indication;
- Deformation measurement (full bridge circuit) TMR-221 (necessary for recording the measured values with a telemetry kit and the linear displacement sensor readings);
- deformation measurement 1G2G4G TMR-222 (tensile forces measurement in the cables and pressure in the hydraulic drive);
- CAN / Voice / GPS TMR-251 (communication via user CAN-bus with Racelogic Vbox3i);
- TMR-253 digital input-output (decoding the signal from the rotational speeds frequency sensors of the gearbox input and output shafts).

**Figure 5.** Dynamic data acquisition system TMR-200
1- Display unit TMR-281; 2- Control unit TMR-211; 3- CAN / Voice / GPS TMR-251; 4- Deformation measurement unit 1G2G4G TMR-222; 5- Digital input-output unit TMR-253; 6- Deformation measurement unit TMR-221.

**Figure 6.** Installation of recording equipment in the vehicle cabin
1-Multifunctional speed meter Racelogic VBOX 3i 100HZ; 2- CAN-bus; 3- Vbox control display; 4- Timestamp trigger; 5- Getac PC; 6- TMR-200 dynamic data acquisition system; 7- MT32-DEC8 radio decoder; 8- Displacement sensors power unit.
3. Testing

The vehicle tests were carried out at various loads (gross weight, 50% of maximum, curb) in the following driving modes:

- Pull away at maximum fuel supply (with 1 gear, with 2 gear);
- Pull away with partial engine characteristics (from 1 and 2 gear);
- Acceleration with maximum fuel supply (gear changes analysis 1-3-4-5-5-6);
- Acceleration with partial engine performance;
- Braking by the “engine” from the maximum speed (gearshift analysis 6-5-4-3-2-1);
- Movement in the trunk-line and urban cycles (GOST 20306-90);

Figure 7 presents examples of the experimental graphs obtained - the process of pulling away (figure 7a), switching from lowered to a higher gear (figure 7b, figure 7c).

![Figure 7. Experimental schedule of the process of starting and switching gears at maximum fuel supply](image-url)
4. Conclusion

Subsequently, these experimental dependencies will be used in the force and kinematic calculations of actuators for the gearshift drive and clutch control as well as in the embedded software development of the automated mechanical transmission electronic unit.

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