Research of the gear changing process for a medium-tonnage cargo vehicle

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Abstract. One of the promising innovation vectors in the automotive industry is the automation of mechanical manual transmissions, which allows starting, maneuvering and changing gears in an automatic operation mode of the power unit, which ensures a reduction in the total time of the switching process, as well as enhances dynamic qualities and fuel economy of the vehicle. This article deals with the approach of scientists of Nizhny Novgorod State Technical University in the implementation of the project to automate the process of shifting gears of a GAZ medium-tonnage truck.

1. Introduction
At the present stage of developing transport technology, there is a rapid change of manufactured models with the intensification of processes for modifying mobile cars, an increase in the number of new developments, which provides vehicles with higher consumer qualities and competitiveness in sales markets. Automating management of car transmissions is an important task. This contributes to an increase in the service life of the engine and transmission, increased maneuverability and comfort due to a smoother torque change on the drive wheels, starting and acceleration, and increases productivity of transport work [1].

Works on automation of management of mechanical transmissions (AMT), as an innovative direction in the development of the global automotive industry, with serial production started around the end of the 90s of the last century. One of the steady trends in the global automotive industry is equipping power trains of trucks, buses and road trains with automated manual transmissions (KP). Being an integral part of modern mechatronic systems, actuators (MI) make it easier for a driver to control the gear shift, provide a reduction in the total time of the shift process, which contributes to improving the dynamic qualities and fuel economy of the vehicle [2].

However, due to a number of unresolved design and technological issues, imperfections of the control program (software), AMT systems of the first generation have not received a worthy application among consumers. Nevertheless, AMT systems have a number of indisputable advantages over other automatic transmission systems. AMT transmissions have double functionality of the transmission control method - manual and automatic, while they are simpler and more reliable, determine the reduction of fuel consumption and toxicity of exhaust gases. According to the world's leading automotive industry companies such as Hofer (Germany), Ricardo UK (UK), AMT transmissions, with more advanced actuators based on electromechanical and electro-hydraulic drives, as well as transmission control software of the highest level, should have a high potential for using in budget and middle class cars [2].

The study of the automated mechatronic control system of the power unit (AMCUSA) is being carried out, because the development of a promising, reliable AMCUSA for the automotive industry
remains to be an unsolved problem. Leading car manufacturing concerns and specialized US and European companies such as Eaton (Auto / Ultra Shift and Ultra Shift Plus transmissions), ZF (AS-Tronic), Volvo (Geartronic, I-shift), Scania (Opticruise), Mercedes (Telligent Gearshift Automated) [3], they are working hard, to create and improve the new generation AMSUSA with a modular structure of automation systems for trucks, buses and road trains [4].

Taking into consideration the promise of mechatronic systems, experts of Nizhny Novgorod State Technical University, with the support of the United Engineering Center GAZ, the Gorky Automobile Plant, have begun to develop a robotization kit for the mechanical transmission of the Medonnazh cargo vehicle Gazon Next. Studies were carried out with the financial support of the Ministry of Education and Science of the Russian Federation under the project, contract No. 02.G25.31.0270 of May 29, 2017 (Resolution of the Government of the Russian Federation of April 9, 2010 No. 218). The experimental research conducted with the use of measurement equipment of the NNSTU Centre of collective use of “Transport Systems”.

When debugging an automated mechatronic control system of a power unit (AMCUSA), one of the most labor-intensive steps is to automate the process of starting off. The driver, acting on the accelerator pedal, sets the course of the starting process. There is no mechanical connection between the pedal and the fuel feed controls. The selection and activation of the gear with which the breakaway is performed, the control of the torque characteristic and the engine speed of the internal combustion engine and the process of closing the dry friction clutch are implemented by a microprocessor system using the appropriate pneumatic, hydraulic or electric actuators [4].

The implementation of a simple, at first glance, algorithm is associated with great technical difficulties, ranging from calculating and agreeing on the characteristics of various levels of the executive part of the system and ending with the choice of the strategy for controlling the friction clutch and engine in the process of starting. The main problem is that the mechatronic system must ensure the operation of the clutch in all modes without energy and dynamic overloads of transmission elements. Moreover, the smoothness of the transition process, estimated by the oscillations of the derivative of the longitudinal acceleration of the vehicle, should be at a sufficiently high level [4].

In this regard, considering complexity of creating a vehicle’s dynamic model transmission control system, as well as the limited computational resources of existing microcontrollers when performing arithmetic operations on floating-point numbers, it was decided to focus on developing the so-called “statistical” model with calibrated tables corresponding to those or other vehicle modifications and modes of its movement.

2. Preparing to testing

The basic principle of building a “statistic” model is to obtain a sufficient array of experimental data characterizing the control system. In this regard, NNSTU specialists were assigned the task of conducting experimental studies in order to obtain data describing the process of starting, shifting gears, as well as assessing the influence of driving conditions on fuel efficiency.

The developed measurement setup (figure 1) allows recording such parameters as:
- linear speed of the vehicle (km / h);
- longitudinal and transverse accelerations (g);
- speed of yaw, pitch, roll (° / s);
- crankshaft speed (rpm);
- the speed of the input and output shafts of the gearbox (r / min);
- accelerator carcass position (%);
- the fact of pressing the brake pedal (0/1);
- position of the clutch pedal (mm);
- current engine torque (N · m);
- the moment of friction in the engine (N · m);
- the requested torque driver (N · m);
- the moment developed on the driveshaft (N · m);
- efforts in the shift cables (N);
- fluid pressure in the hydraulic clutch (MPa);
- instant fuel consumption (l/h);
- total fuel consumption (l);
- operation of the functions ABS, ASR.

Figure 1. Schematic diagram of the measurement setup: 1 – Multi-functional Racelogic VBOX 3i 100HZ speed meter; 2 – Dynamic data acquisition system TMR–200; 3 – GPS / Glonass antenna; 4 – IMU04 gyroscope; 5 – Kistler DFL Flow–meter; 6 – YaMZ engine control unit; 7 – Telemetry kit mounted on the propeller shaft; 8 – pressure sensor; 9 – cable linear displacement sensor; 10 – strain gauges glued into the gear shift cables.

The torque measurement on the cardan shaft was carried out using KMT measuring telemetry with subsequent calibration for the range of the measured value. The torque sensors installed on the shaft are shown in figure 2.

Figure 2. Installing strain gauges and telemetry on the propeller shaft to measure torque: 1 – torque strain gauges mounted on the shaft; 2 – measuring, control and transmitting module of KMT telemetry.

In order to determine the power of the actuators, which is responsible for the selection of gears, it was necessary to determine the efforts developed in the drive. In this regard, the measuring cable was
made and calibrated, followed by installation on the test vehicle. Calibration and location in the test vehicle are shown in figures 3 and 4.

Figure 3. Calibration of measuring cables of the gearshift mechanism.

Figure 4. Installation in the changer gear mechanism.

The recording equipment itself was installed in the vehicle cabin (figure 5).

Figure 5. Installation of recording equipment in the vehicle cabin: 1 – Multifunctional Racelogic VBOX 3i 100HZ speed meter; 2 – Movement speed display; 3 – CAN-hub; 4 – Racelogic file manager; 5 – Dynamic data acquisition system TMR-200; 6 – Receiving antenna module telemetry processor; 7 – Power unit displacement sensors.

3. Testing
Vehicle tests were carried out in the following driving modes:
   - acceleration with maximum fuel supply (analysis of gear changes 1- 3-4-5-5-6);
- braking by the “engine” from the maximum speed (gearshift analysis 6-5-4-3-2-1);
- acceleration with partial engine performance;
- movement in the main and urban cycles (GOST 20306-90);
- start at maximum fuel supply (with 1 gear, with 2 gears);
- start driving with partial engine performance (with 1 and 2 gears).

An example of the obtained experimental graphs is presented in figures 5, 6 and 7 - test mode “start at maximum fuel flow”.

![Graph of engine speed and acceleration pedal position](image)

Figure 6. Graphics of cardan and primary shaft revolutions.

![Engine torque and vehicle speed plots](image)

Figure 7. Engine torque and vehicle speed plots.
Figure 8. The vehicle acceleration graph.

The obtained experimental data will be used when writing the program code of the algorithm for controlling the gear shift mechanisms and the clutch coupling.

At present, experts of Nizhny Novgorod State Technical University have developed actuators for an automated manual gearbox, as well as an electronic control unit.

References

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