ON THE INTERRUPTION IN TORQUE DELIVERY OF PASSENGER CARS

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ABSTRACT

The article discusses the phenomenon of power flow interruption in transmission of passenger cars, which is observed when switching the gear of a moving vehicle, as well as the conditions under which the car will roll back. Analysis of the principle of operation of speed change boxes of various types allows us to conclude that a rollback of a car with power flow interruption in transmission will not be observed for preselective transmission – in contrast to manual and robotized ones.

Keywords: car, transmission, speed change box, power flow interruption, manual transmission, automatic transmission, stepless transmission, continuously variable transmission, robotized transmission.

Background. *When driving a car, it is not uncommon for a car to roll back when driving uphill. This phenomenon is mostly explained by the driver's lack of experience when starting off when he spends more time shifting his foot from brake to gas, or by releasing the parking brake. Naturally, a significant rollback can lead to a traffic accident, especially if the required distance is not met.*

But the car's rolling back can be caused by operation of the speed change box of a certain type. So, for the mechanical and robotic boxes there is a phenomenon of a torque rupture (power flow) transmitted to the driving wheels of a car, which leads to a rollback.

Objective. *The objective of the authors is to consider power flow interruption in different types of transmission of passenger cars.*

Methods. *The authors use general scientific and engineering methods, comparative analysis, graph construction.*

Results.

The principle of operation of speed change boxes of passenger cars. *The speed change box is necessary to maintain the optimum driving force on the driving wheels when the torque value is changed over a wide range of speeds by changing the gear ratio and the direction of travel of the vehicle. In the production cars, four main types of speed change boxes are distinguished (see Pic. 1): mechanical, automatic, stepless and robotized [3].*

As for their principle of operation, for example, in the manualspeed change box (hereinafter – manual transmission), the change in the gear ratio is provided by several pairs of gears of different diameters.

The main advantages of manual transmission are: simplicity of construction, low cost, low weight, high efficiency, high reliability, possibility of towing a car.

Manual transmission also has shortcomings: the need for correct choice of optimal transmission to maintain traction at the right level, the power rupture at the time of gear changes, fatigue of the driver when switching gears.

Due to the drawbacks inherent in the manual, transmission a need arose for an automatic speed change box (hereinafter – automatic transmission), not distracting the driver for gear changes.

The automatic transmission consists of the following units: a torque converter, manual transmission – a set of friction clutches and gears with a planetary series, a control system.

The use of automatic transmission makes it possible to automate the shifting of gears and to avoid the power flow interruption. However, there are drawbacks, among which loss of power and increased fuel consumption of the car, the complexity of the design, the high cost of the unit.

Due to complexity of the design and increased fuel consumption, stepless transmission – continuously variable transmission (CVT), in which the change in the gear ratio is not provided with gears, but with two conical pulleys and a belt in between.

Advantages of cars equipped with continuously variable transmission are high fuel efficiency in comparison with automatic transmission and smooth operation, and disadvantages are the psychological factor (continuously variable transmission supports the engine on the revolutions providing the maximum torque), the high cost of repair in case of a malfunction.

To meet environmental standards and reduce average fuel consumption, new requirements have arisen: a speed change box is needed that will maintain the same fuel consumption as a car with a manual transmission, but the gear selection control will be automatic.

So automated mechanical transmissions (hereinafter – AMT) appeared, in which control is provided by electronics with the help of servo drives (actuators). Accordingly, AMT consists of a clutch, gearbox, clutch and transmission actuators, control unit.

Automated mechanical transmissions are called robotic speed change boxes and two types are distinguished: one-clutch (robotic speed change box) and two clutches (preselective).

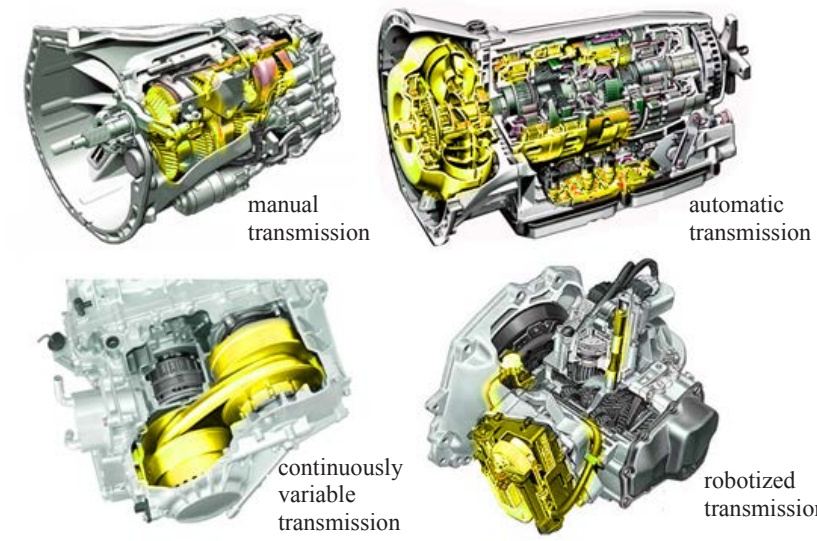
The robotized speed change box (hereinafter – robotized transmission) is a manual transmission in which the gears are switched and the engine and box are separated by electronics.

Among the advantages of robotized transmission, one can note the low cost of the node in comparison with the automatic transmission or the continuously variable transmission.

Despite the advantages, cars equipped with robotized transmission with one clutch, have their drawback – a long switching time (about 1,5 s) adversely affects the acceleration time. With intensive overclocking, the driver feels a long burst of power flow, which causes discomfort.

To reduce the switching time, a robotized transmission was proposed that virtually eliminated the power flow disruption. This design was called the automated transmission with dual clutch, otherwise called preselective.

We note the design features of cars equipped with a preselective speed change box: flywheel of a special form, two clutches with different diameters, two primary shafts (one – hollow, the other – solid). The solid shaft provides the transmission of torque to the gears of odd gears, and the hollow shaft to the gears of the even gears. Among the shortcomings is worth noting the increased cost in relation to the robotized transmission with one clutch or manual transmission.



Pic. 1. Different types of speed change boxes. Distinctive elements: manual transmission – shafts and gears; automatic transmission – hydrotransformer, blocks of friction and control; continuously variable transmission – cone pulleys and belt; robotized transmission – control unit and clutch and gear actuators.

All types of speed transmission boxes of passenger cars, as well as the distinguishing features of each type of speed change box are shown in the picture below.

The work of speed change box and conduct of a car when the road conditions change. *The problem of power flow interruption and, as a consequence, in some cases, the rollback of a car under certain circumstances is inherent in cars equipped with a manual or robotized transmission. In other words, not all modern models of cars are fully adapted to the operating conditions.*

It should be borne in mind that the rollback of the car will take place in the case of a combination of road conditions, primarily due to the presence of a longitudinal slope, a change in the direction of travel (turn), and other factors that cause a decrease in the speed of the car [2].

For an understanding of the problem, let us highlight the possible road and transport situations leading to a rollback of the car. Let's say that the model with the robotized transmission is moving along the road with asphalt concrete evenly at a speed of 20 km/h. The algorithm of the robotized transmission assumes the use of the second gear. Let's consider the work of the robotized transmission and the conduct of the car when changing road conditions – increasing the slope and (or) changing the direction of the road in the plan.

A. Absence of cessation of movement and rollback. *For example, the direction of the road changes by 90 degrees, which forces the driver to slow down to 10 km / h. In this case, the robotized transmission lowers the gear: the first turns on. After exiting the turn, the car continues to move without a rollback.*

In this case, the value of the inertia force exceeds the value of the resistance to movement, and the car at the time of the gear shift moves down (in the absence of traction on the driving wheels), that is:

$$F_j > F_\psi, \quad (1)$$

where F_j – car inertia force; F_ψ – force of resistance to movement of the car [6].

Let's express the required force values:

$$F_j = ma, \quad (2)$$

where m – mass of a car; a – acceleration of a car.

$$F_\psi = G(f \cos \alpha + \sin \alpha), \quad (3)$$

where G – force of gravity; f – coefficient of rolling resistance; α – longitudinal slope of the road.

Transforming expression (1) through expressions (2) and (3), we find that the rollback does not happen under the condition that

$$a > g(f \cos \alpha + \sin \alpha). \quad (4)$$

B. Termination of movement without rollback. *For example, the car turns and starts to move on the rise. In this case, the robotized transmission also lowers the gear, the initial gear turns on – the car continues to drive, but with one peculiarity: it is possible that the car can stop for the time the gears are switched. And then the forces of inertia and resistance to movement are equalized, that is:*

$$F_j = F_\psi. \quad (5)$$

In other words, the movement will stop if:

$$a = g(f \cos \alpha + \sin \alpha). \quad (6)$$

C. Rollback after termination of movement. *For example, the car turns and starts to move on the rise. Robotized transmission lowers the gear, turning on the first gear. During the time that the transmission was switched, a stop occurs due to the increased resistance to movement. And when torque is applied to the driving wheels, it is possible to roll backwards due to insufficient adhesion of the drive wheels to the supporting surface [7].*

The condition for rolling back the car after the movement terminates is:

$$F_j < F_\psi. \quad (7)$$

That is, the rollback will occur provided that:

$$a < g(f \cos \alpha + \sin \alpha). \quad (8)$$

The car must be safe. Therefore, uncontrolled situations should be excluded, including the design of its nodes and mechanisms.

In order to avoid rollback of the car, it is necessary must either to manually select the first gear in advance (which contradicts the meaning of the robotized transmission), or change the design of the speed change box in such a way as to exclude emergency situations.

Table 1

Dependence of switching time on type of speed change box

Type of transmission	Manual transmission	Automatic transmission	Continuously variable transmission	Robotized transmission	Preselective transmission
Duration of power flow interruption (gear switching time)	1 ... 2 s[1)]	0[2)]	0[3)]	1 ... 2 s	0,08 ... 0,1 s

Notes: 1) Depends on the driver's qualification, engine type, speed change box construction. For manual transmisstion take 1 ... 2 s [1]. 2) In automatic transmission there is no power flow interruption due to the peculiarities of the speed change box design: at the time of the change of gears, a slight slippage of the clutches is provided, which allows smooth switching of the gear and prevents power flow from interruption. 3) In continuously variable transmission there is no interruption in power flow due to a smooth change in transmission ratio [4].

Duration of power flow interruption. Rollback of the car shows that the car is not fully adapted to the operating conditions. This problem, however, occurs only under the action of a combination of factors.

The duration of the power flow interruption on vehicles equipped with manual transmission and robotized transmission is determined by the switching time. To reduce it, it is necessary to organize the operation of the speed change box so that after switching off the previous gear the clutch of the next one is already in driven engagement. That is, in order to reduce the duration of the torque rupture, a preselective robotized transmission is required.

The time required to switch gears will depend on the design of the gearbox used in the car. In the version with manual transmission, the time will depend both on the time of operation of the clutch to equalize the angular velocities of the synchronizer, and on the time required for the driver to act on the lever.

In the automatic transmission, a power flow interruption does not occur due to hydraulics. The continuously variable transmission due to a smooth change in the gear ratio also eliminates the interruption in power flow.

In the robotized transmission this time will depend on the speed of the actuators (actuators of clutch and gear changes) and the clutch response time.

In the preselective transmission, the power flow interruption is so insignificant (0,08–0,1 s [5]) that it can be ignored.

More clearly, the dependence of the duration of the power flow interruption on the type of speed change box is presented in the table.

Conclusions. *The identified problem of interruption in power flow, transmitted to the driving wheels of a car, currently does not have the due attention of specialists.*

When comparing the types of speed change boxes for duration of the power flow interruption, it can be assumed that automatic transmission, continuously variable transmission and preselective transmission have the advantage over manual transmission and robotized transmission, since there is no power flow interruption in these speed change boxes.

As the comparative analysis shows, the speed change box with two clutches looks the most promising, as it combines the advantages of all existing types: no power flow interruption, smooth switching and smooth running, control comfort, high fuel efficiency, high traction-dynamic characteristics. The programming algorithm of the robotized transmission is adjusted under the driver's driving style, which is an important advantage of robotized transmission.

Moreover, if we compare the preselective transmission with the first mechanical transmissions, then we can conclude that the speed change box with two clutches is two mechanical boxes combined into one casing and made using modern technologies – electronic automated control.

Are such conclusions legitimate and can they be disputed? Apparently, all the same, the issues are debatable. But we repeat, that they deserve the attention of specialists.

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Article received 23.04.2017, accepted 02.06.2017.