Modular heavy duty truck transmission

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Abstract. The design of a modular gearbox for heavy trucks, which consists of a differential divider, a main gearbox and a differential demultiplicator with an integrated rear gear is described. The proposed design has smaller dimensions, weight and inertial masses of rotating parts, has greater rigidity and speed of the gear shifting process. A vehicle equipped with this transmission will make better use of the engine power and save fuel, which will increase its competitiveness in the market.

1. Introduction
For heavy goods vehicles to increase the range of gear ratios it is necessary to use a gearbox with a combined kinematic scheme which consists of a main reducer, formed by the several pairs of gears located on parallel shafts fixed axes of rotation, and an additional gear (dividers and a demultiplicator), and a divizor which is a two-step gear drive and a dual planetary gear mechanism [1, 2].

It is obvious that designers of multi-stage gearboxes have the following tasks:
- ensuring the general requirements for any new vehicle units, namely improved reliability and rigidity, as well as modularity of the structure with smaller dimensions and weight;
- implementation of special requirements for gearboxes, namely, improving speed, providing the required number of stages and the required range of gear ratios, ensuring smooth gearshift without breaking the power flow, providing the ability to test individual modules of the gearbox, the transmission of full power when reversing, etc.

2. Analogues of the proposed transmission
The devices which are the closest in terms of the set of characteristics to the claimed invention for the step change of the torque and its transfer to the driving wheels of the car are known. For example, the most successful European version of the gearbox for trucks is the ZF Ecosplit (fig.1.) [3].

They are a mechanical gearbox, consisting of a main four-stage gearbox, a two-stage gear divider, built into the main gearbox, and a two-stage demultiplicator, formed by a three-tier planetary gear.

Arrangement of the divider consisting of two pairs of gears and a synchronizer in the main gear housing increases the length and weight of the secondary and intermediate shafts, respectively, increases the dimensions of the main gear. In addition, the main gearbox has an additional number of gears to provide a rear gear, which also increases the length of the shafts and dimensions of the main gearbox housing. A number of gears of the rear transmission, due to design features, do not provide the transmission of full engine power in case of necessity to use it in the operation of the car.

The synchronizer is used to switch the divider switches four times more often than each synchronizer of the main box when driving the car, which leads to more intensive wear. In this case, each switch has the divider off-on clutch, which leads to increased wear of friction clutch parts, the rupture of the power flow transmitted to the driving wheels of the car. This reduces the utilization of the engine power, decreases efficiency of the box and reduces the comfort of driving.
3. Modular gearbox design

A modular gearbox design, which consists of the following modules: a main gearbox, a differential divider and a differential demultiplicator, was made in the Naberezhnye Chelny Institute (branch) of the Kazan Federal University.

3.1. Main gearbox reducer.

The kinematic scheme and the design of the main gearbox are shown in fig. 2.

The main gearbox reducer has four gears, which are switched by means of synchronizers 5 and 6. Synchronizer 5 includes the first and second gear of the main gear, while the synchronizer 6 is in the neutral position. The first gear of the main gear is activated by moving synchronizer 5 clutch to the far right position when the first gear wheel with the secondary shaft 4 is locked. The second gear of the
main gear is activated by moving the clutch synchronizer 5 to the far left position when the second gear is locked with secondary shaft 4. The third and fourth gears are switched on by the synchronizer 6, while the synchronizer 5 is in the neutral position. The third gear is activated by moving the main gear clutch synchronizer 6 to the far right position when the third gear is locked with the secondary shaft 4. The fourth gear of the main gear is direct, it is activated by moving the synchronizer coupling 6 to the extreme left position when the main shaft 2 is blocked with the secondary shaft 4.

3.2. Differential divider.

The kinematic scheme and the design of the main gearbox are shown in fig. 3.

![Figure 3 – The kinematic scheme and the design of the differential divider: 1 – a main gear housing; 2 – a main shaft of the main gearbox; 11 – a clutch housing (crankcase differential divider); 12 – an input shaft-gear differential divider; 13 – two-crown satellites of the differential divider; 14 – a carrier differential divider; 15 – a band brake; 16 – a free-wheeling clutch](image)

The differential divider contains an input shaft-gear 12, which is engaged with two-crown satellites 13 mounted on the axes pressed into the carrier of the differential divider 14. The carrier of the differential divider is supported by ball bearings mounted in the clutch housing and in the differential divider cover, and is locked by the band brakes 15. Roller free-wheeling clutch 16 is installed between the carrier 14 and the main shaft of the main gearbox 2.

The differential divider has two gears. The accelerating transfer of the divider is activated by blocking the carrier of the divider 14 on the clutch housing 11, which are carried out by the band brakes 15. The direct gear of the divider is switched on automatically when the band brakes are released by locking the divider to the free-wheeling clutch 16 mounted on the main gear shaft 2. Automatic blocking of the divider drive to the free-wheeling clutch is possible due to the features of differential mechanisms with a positive gear ratio less than one, in which all the links of the differential mechanism rotate in one direction, and the carrier has greater angular rotation speed than angular velocities of the input and output shafts. Switching the range of the differential divider is carried out without switching off the clutch and, therefore, without breaking the power flow. The brake torque on the band brakes is a part of the motor torque transmitted to the output shaft. For example, when the gear ratio of the differential divider is equal to 0.75, the band brake operates 0.25 torque and the output shaft 0.75 torque developed by the engine. The hydraulic system band brake switching algorithm ensures fast and smooth switching of the differential divider ranges.

A small difference in the gear ratios of the neighboring gears of the gearbox allows you to choose the optimal driving mode in the economic range of the engine speed. In addition, it facilitates the control of the gearbox and reduces the noise level.

In contrast to the prototype, in which the switching range of the divider is carried out by means of a synchronizer, in the proposed gearbox to enable the accelerating transfer is braking the carrier of the differential divider by the band brakes. To enable a direct gear, the band brakes are released, and the differential divider is automatically locked by the free-wheeling clutch onto the output shaft of the differential divider.

3.3. Differential demultiplicator with an integrated reverse gear.
The kinematic scheme and construction of the differential demultiplicator are shown in Fig. 4.

**Figure 4** – The kinematic scheme and the design of the differential demultiplicator: 17 – a leading gear ring of the differential demultiplicator; 18 – satellites of the differential demultiplicator; 19 – two-crown satellites of the differential demultiplicator; 20 – reverse idler satellites; 21 – a crown wheel (reverse clutch) of the differential demultiplicator; 22 – a carrier (output shaft of the transmission) of the differential demultiplicator; 23 – a crown wheel; 24 – a synchronizer of the differential demultiplicator; 25 – a ring gear lock of the reverse clutch; 26 – a toothed crown locking the crown wheel of the differential demultiplicator; 27 – a ring gear locking differential demultiplicator

The kinematic scheme and construction of the differential demultiplicator are shown in Fig. 4. The differential demultiplicator comprises a drive gear ring 17, cut on the secondary shaft of the main gear, satellites 18 and twin satellites 19, parasitic satellites 20, a crown wheel 21, which is simultaneously a reverse clutch, a demultiplier 22, which at the same time output shaft of the gearbox, and a crown wheel 23. There is a synchronizer for dual 24 on the splines of the hub of the crown wheel 23.

The differential demultiplicator with integrated reverse gear has two forward and neutral gears, one reverse gear. When driving a loaded truck in heavy traffic conditions included a reduction gearing of the differential demultiplicator. For this purpose, the synchronizer 24 gear coupling moves to the extreme right position and, after aligning the angular velocities of the connected parts engages with the toothed crown 26. When switching the differential demultiplicator to the upshift, the gear coupling of the synchronizer 24 moves to the extreme left position and engages with the gear ring 27. The reverse gear is switched on by moving the crown wheel 21, which is also the reverse gear, to the far left position and engaging it with the gear ring 25, while the synchronizer clutch 24 is moved to the neutral position.

4. Conclusions

The developed modular transmission for heavy trucks provides the following technical results:

1. The exclusion of the old divider design, consisting of two pairs of gears and a synchronizer, in the main gearbox housing, with its replacement by a differential divider, which provides reduction in the axial dimensions of the gearbox, the weight of the secondary and intermediate shafts.

2. The differential divider module also provides smooth gear ratio control, which allows to switching the divider range without turning off the clutch, smoothly and without breaking the power flow. This provides some reduction in wear of friction clutch parts, increased power utilization and increased fuel efficiency of the engine, as at the moments of switching the range of the divider, which occur four times more often than the gear shift of the main gearbox, the engine does not go into partial load modes.

3. The differential divider is controlled by a hydraulic drive, which is activated only by means of a button located on the shift lever, which facilitates control when driving, increases comfort and reduces the physical load on the driver.

4. Elimination of extra rows of toothed gears reverse through the use of the differential demultiplicator with integrated reverse gear. This allows you to get multiple reverse gears, and also to
transfer the full power of the engine when it is reversing at different speeds, which is especially important for special purpose vehicles.

5. The differential demultiplicator with integrated reverse gear further reduces axial dimensions and weight of the secondary and intermediate shafts, which increases the rigidity of the main gear shafts and their moments of inertia. This contributes to a faster alignment of the angular velocities of the rotating masses, reducing the load on the synchronizers, and therefore, increases their durability.

6. Increasing the reliability of the gearbox, as the technological process of its assembly can be carried out after the preliminary bench tests of its individual components, namely, of the differential divider, of the main gearbox and of the differential demultiplicator, which in its turn creates prerequisites for automating the process of the gearbox general assembly.

Thus, the developed modular transmission meets all the requirements for modern units of heavy trucks.

References

[1] Faskhiev, H.A. New transmission for vehicles / H.A. Faskhiev, V.V. Voloshko, I.R. Mavleev, I.I. Salakhov // Handbook. Engineering journal with Appendix. – 2015. – №7. – p.47–51.

[2] Patent. 2508486 RU. Automotive multi-stage transmission / V.V. Voloshko, I.R. Mavleev, I.I. Salakhov. – Application № 2012148057/11; application date 12.11.2012; publishing date 27.02.2014.

[3] Hassle, H. 'Ecosplit' – a new gearbox series for heavy commercial vehicles / H. Hassle // AUTOMOBILTECH. Z. 82(7-8, Jul.-Aug. 1980), c. 369-374.

[4] Blokhin, A. Research of robotized manual transmissions for all-terrain vehicles / A. Blokhin, L. Barakhtanov, E. Fadeev, P. Lubichev // ARPN Journal of Engineering and Applied Sciences, 2017, 12 (1), pp.20-32.

[5] Salakhov, I.I. Kinematic scheme and design of automatic planetary gear boxes based on a new module / I.I Salakhov, V.V. Voloshko, I.D. Galimyanov, I.R. Mavleev. // Contemporary Engineering Sciences, Vol. 8, 2015, No.1, pp.1-6.

[6] Salakhov, I.I. Car gearbox on the basis of the differential mechanism / I.I. Salakhov, I.R. Mavleev, E.N. Tsybunov, R.R. Basyrov and N.I. Salakhov // Biosciences Biotechnology Research Asia, 2015; Vol. 12(Spl. Edn. 2), 41-44 pp.

[7] Naunheimer, H. Automotive transmissions: Fundamentals, selection, design and application / H. Naunheimer, B. Bertsche, J. Ryborz, W. Novak, P. Fietkau // Automotive Transmissions: Fundamentals, Selection, Design and Application. pp. 717

[8] Salakhov, I.I. Development of a gear box of the truck / I.I. Salakhov, I.R. Mavleev, I.R. Shamsutdinov, D.I. Nurudinov E.N., and N.I. Salakhov // Biosciences Biotechnology Research Asia, 2016; Vol. 13(2), 859-864 pp.

[9] Salakhov, I.I. Analysis workflows gear hydraulic machines/ I.I. Salakhov, I.R. Mavleev, V.V. Voloshko, I.D. Galimyanov, R.K. Takhaviev // Biosciences Biotechnology Research Asia, 2016; Vol. 13(2), 779-784 pp.

[10] Liao, Y.-G. Experiment and simulation of medium-duty tactical truck for fuel economy improvement / Y.-G. Liao, A.M. Quail Jr. // Energies, 4 (2), 2011, pp. 276-293. http://www.mdpi.com/1996-1073/4/2/276/pdf doi: 10.3390/en4020276

[11] Blokhin, A. Multistage mechanical transmissions with automatic control for advanced trucks and buses / A. Blokhin, A. Nedelyakov, L. Barakhtanov, A. Taratorkin, A. Kropp // Acta Mechanica et Automatica, 11(4), 260-266 pp.

[12] Karpukhin, K.E. Comprehensive life cycle analysis of different types of energy storage for electric or hybrid vehicles / K.E. Karpukhin, A.V. Kozlov, S.V Bakhmutov, A.S. Terenchenko // ICAT 2015 Proceeding the International Conference on Automobile Technology for Vietnam, 2015 pp. 7-14.

[13] Mavleev, I.R. Development of efficient schemes and designs high-torque hydromechanical CVTs for vehicles: Author. dis. Cand. tehn. Sciences. - Naberezhnye Chelny, 2007; 19.