International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 13, Number 12 (2020), pp. 4421-4426
© International Research Publication House. http://www.irphouse.com

Decrease in the Transport Process Indicators Due To Wear of the Elements of the Power Unit of the Truck

Ruslan Nailevich Engalychev[1], Aleksandr Tikhonovich Kulakov[2], Elena Petrovna Barylnikova[3], Irina Petrovna Talipova[4]

[1]*Master's degree student, Department of automobile transport operation, Automobile Department,*
Naberezhnye Chelny Institute (branch), Kazan (Volga region) Federal University, Russia.
ORCID iD: 0000-0001-6649-8145.

[2]*Doctor of Technical Sciences, Professor, head of the Department of road transport operation,*
Automobile Department, Naberezhnye Chelny Institute (Branch) Kazan Federal University, Russia.
Scopus Author ID: 56454050300, ORCID ID: 0000-0002-6443-0136.

[3]*PhD in Technical Sciences, Associate Professor, Department of road transport operation, Automobile Department,*
Naberezhnye Chelny Institute (Branch) Kazan Federal University, Russia.
Scopus Author ID: 56454440300, ORCID ID: 0000-0002-1457-1598.

[4]*PhD in Technical Sciences, Associate Professor, Department of mechanics and design, Automobile Department,*
Naberezhnye Chelny Institute (Branch) Kazan Federal University, Russia.
Scopus Author ID: 57212538412, ORCID ID: 0000-0001-7296-339X.

Abstract

The efficiency of the transport process depends both on the level of its organization and on the performance of the road transport equipment involved in transportation. An increase in operating time, as well as operation in constantly changing operating conditions deteriorates the technical condition of a truck [1], and, as a consequence, changes technical and economic indicators, namely, productivity decreases, and maintenance and repair costs increase. The purpose of the study is to confirm that the indicators of the transport process are closely dependent on the technical condition of the elements of the power unit and can be, along with other factors, the cause of a decrease in the efficiency of using a truck. The article presents the results of a scientific study on the reasons for the decrease in the efficiency of using a truck in operation. The relationship of the indicators of the transport process and the parameters of the power unit is shown. One of the parameters of a truck's performance is its carrying capacity. During operation, due to wear of parts and components of the power unit, the possible carrying capacity of the vehicle changes due to a decrease in the power characteristics of the power unit. A decrease in traction properties leads to ineffective loading of a truck, i.e. the impossibility of ensuring its full load, taking into account the rated carrying capacity, which ultimately affects one of the main indicators of the transport process - the productivity of a truck.

Keywords: truck efficiency, transport process, carrying capacity, power unit, technical condition of a truck, power characteristics

I. INTRODUCTION

Operation, an increase in operating time, as well as work in constantly changing conditions leads to the deterioration of the technical condition of a truck, and, as a result, changes technical and economic indicators, namely, decrease in productivity, and increase in maintenance and repair costs. So, for example, the prime cost of freight road transport, which is 12-15% of transport costs in the prime cost of finished products, increases 2-3 times during operation, and the performance of KAMAZ vehicles decreases 3-4 times to run 500 thousand km [2].

The car can not be isolated neither from its operating conditions, nor from the processes occurring in its units and assemblies. When operating in constantly changing conditions (loads, road conditions, temperature and atmospheric pressure, dustiness, etc.), the performance of a truck decreases due to wear of its structural elements. It is known that there is a systemic relationship between the structural elements of a vehicle, its performance and performance indicators. The efficiency of the transport process is usually considered to be the productivity of a truck and the cost of transportation.

A number of factors affect truck performance

$$W = \frac{q \cdot \gamma \cdot \beta \cdot V \cdot T}{L + t_{l-u} \cdot \beta \cdot V}, \tag{1}$$

where q – the rated lifting capacity, t; γ - load factor; L – the average length of a ride with a load, km; β - mileage factor; V - average technical speed, km/h; T - on-duty time, h; $t_{l\text{-}u}$– time of loading and unloading operations, h.

The considered indicators in expression (1) are determined by two types of parameters: independent of the vehicle design (L, β, T) and dependent on it (q, γ, V, tl-u). If we evaluate the performance of a truck in terms of technical capabilities, the most important of the parameters, which depends on the technical condition of the structural elements of the truck and affects the result, is the carrying capacity of the vehicle.

The choice in favor of this performance parameter is due to the fact that its value is closely dependent on the operation of the elements of the vehicle power unit. During operation, carrying capacity changes (i.e. the impossibility of ensuring the loading of the car, taking into account its rated carrying capacity) due to a decrease in the power characteristics of the engine. Let's trace this dependence. The carrying capacity is determined by the formula [3]

$$q = \frac{P_t - P_a - D \cdot q_{\text{a}}}{D}, \tag{2}$$

where q – the carrying capacity of the vehicle, kg; P_{t} - vehicle traction force, N; P_{a} – air resistance force, N; D – the dynamic factor of the vehicle, N/kg; q_{a} – vehicle curb weight, unloaded, kg.

The traction force of the car depends on the amount of torque on the engine shaft

$$P_{\text{т}} = \frac{M_{\text{кр}} u_{\text{к}} u_0}{r_{\text{к}}} \eta, \tag{3}$$

where $M_{\text{кр}}$ - motor shaft torque, N·m; $u_{\text{к}}$ - gear ratio of the gearbox; u_0 - final drive ratio; η - transmission efficiency; $r_{\text{к}}$ - wheel radius, m.

$$M_{\text{кр}} = 716{,}2 \frac{N_{\text{e}}}{n} \eta, \tag{4}$$

where N_{e} – effective motor power, h.p.; n – the crankshaft rotation speed, min^{-1}.

Investigation of the reasons for the decrease in the performance of the power unit found that the efficiency of the vehicle is affected by the wear of the elements of the power unit, such as the clutch mechanism and the turbocharger [4, 5].

The analysis showed that one of the least reliable units of diesel engines is the TKR-7N turbocharger [6, 7]. It accounts for over 26% of engine failures. Failures of a turbocharger lead to inoperability or a decrease in engine parameters, an increase in the cost of fuels and lubricants, spare parts, labor costs for maintenance, repairs.

Effective engine performance depends not only on the perfection of the engine itself, but also on the operation of the turbocharger [6, 7]. Its reliable operation maintains efficient engine power. The analysis of the formula for the effective engine power shows that if we take the effective volume of the cylinders and the composition of the mixture unchanged, then N_{e} at n=const will be determined by the n_{e}/a ratio, the value of n_{v} and the parameters of the air entering the engine

$$N_e = \frac{H_u \cdot \eta_e}{I_0 \cdot \alpha} \cdot \eta_v \cdot V_l \frac{2 \cdot n \cdot 10^3}{\tau} \cdot \rho, \tag{5}$$

where H_u – the lowest fuel calorific value; η_e - effective efficiency; η_v – the filling factor; V_{l} - engine capacity; n – the crankshaft rotation frequency; p – air density; α - excess air factor; τ - the engine cycle; I_0 – the theoretically required amount of air.

Since the mass charge of air is $G_v = V_l * p * n_v$, then

$$N_e = \frac{H_u \cdot \eta_e \cdot 2}{I_0 \cdot \alpha} \cdot \frac{n \cdot 10^3}{\tau} \cdot G_v, \tag{6}$$

Equations (5) and (6) show that the effective power N_e decreases with a decrease in the supply of air entering the engine. A decrease in effective engine power leads to a deterioration in efficiency and economic performance.

II. METHODS

Traction bench test procedure. During operation, the technical condition of the clutch deteriorates. To establish the degree of influence of the clutch operation on the parameters of the power unit, an experiment was carried out. The objective of the experiment was to compare the output parameters of the engine, which was equipped with an initially serviceable and then worn out clutch [8].

KAMAZ vehicles are equipped with a double-disc clutch (Fig. 1).

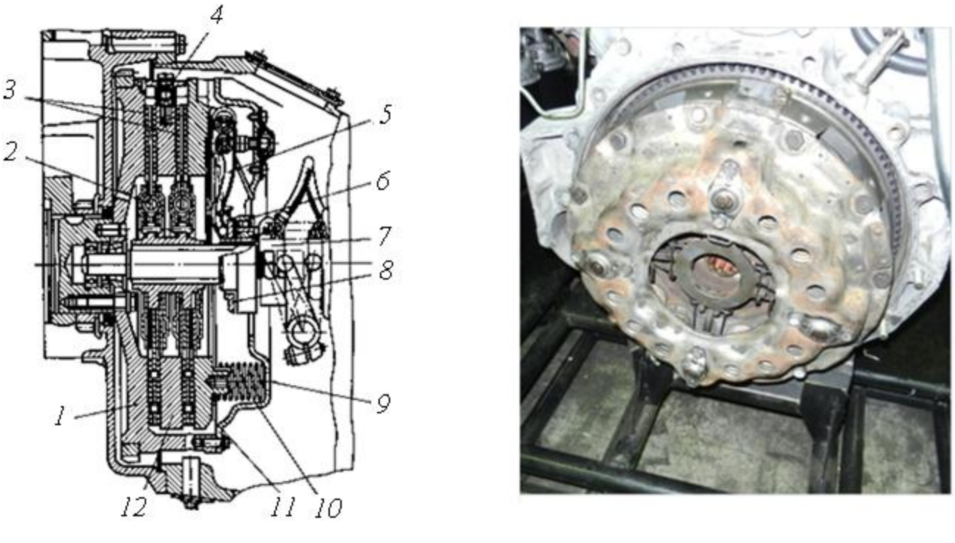

Figure 1. Clutch Assembly of the KAMAZ car (model 142):

1 –flywheel; 2 – extinguisher; 3 – driven disks; 4 – lever mechanism; 5 – lever; 6 – bearing; 7 – coupling; 8 – ring; 9 – spring; 10 – casing; 11 – pressure disk; 12 – middle drive disk

Bench tests were carried out on the KAMAZ-7403 engine, assembled with model 142 clutch sets.

The transmission of torque from the crankshaft of the engine to the driving clutch discs is carried out through protruding spikes located in the grooves of the flywheel crosswise along the outer diameter (Fig. 2).

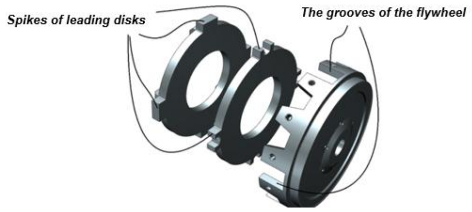

Figure 2. Flywheel, middle drive and pressure discs of a two-disc clutch

During operation, when the contact surfaces of the “thorn-groove” interface are worn out, the driving discs are displaced relative to the flywheel, their centering is disturbed, and this, in turn, leads to an increase in the imbalance in the clutch unit, having a negative effect on the operation of the engine and its reliability [9]. At a crankshaft speed of 2600 min^{-1}, a centrifugal force acts on the drive clutch disc (whose mass is 13.2 kg), which reaches 400 kg ·s, which leads to an imbalance and vibration of the entire vehicle. Under such conditions, part of the engine's energy leaves the clutch for secondary processes of excitation of vibrations of the vehicle elements, thereby losing useful power. During the bench test, vibration processes were investigated [10] and the parameters of the engine were measured.

Turbocharger bench and motor test procedure.

Comparative bench tests of the KamAZ-740.11-240 engine with TKR7N-1 turbochargers were carried out during operation in comparison with the parameters after repair with the modernization of the bearing assembly. The external speed characteristics of the engine were filmed. Comparative motor tests were carried out in versions equipped with serial turbochargers and repaired turbochargers with modernized bearing assemblies in terms of speed characteristics.

Upgraded repaired turbochargers (10 pcs.) were compared with serial turbochargers installed in series on the engine on the test bench of the AVL engine plant (Fig. 3).

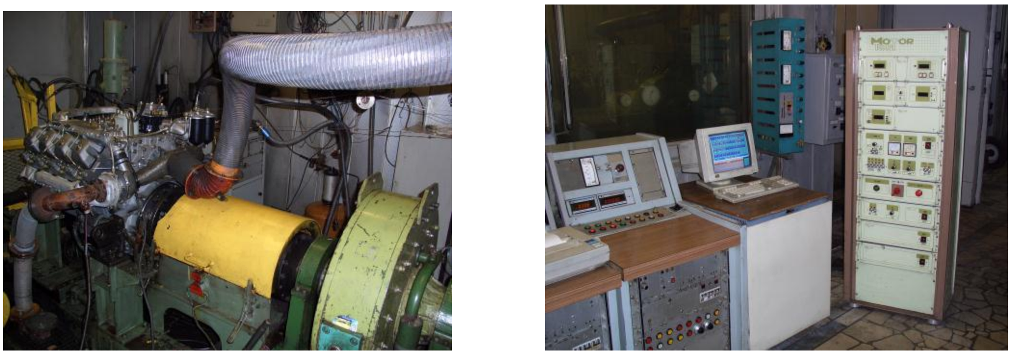

Figure 3. Stand engine test

To measure the required parameters, the stand is equipped with the necessary measuring equipment, corresponding in terms of measurement accuracy to the conditions for the manufacturer's plant.

III. RESULTS AND DISCUSSION

III.I. The Effect of the Clutch on the Efficiency of the Power Unit

During the bench test, vibration processes were investigated and the parameters of the engine were measured. The results of bench studies are presented in Table 1 and Fig. 3.

Table 1. Engine parameters for bench studies

Engine with new flywheel and clutch				**Engine with a worn flywheel and clutch**				**Change**	
n, min^{-1}	N_e, h. p.	$M_{кр}$, N·m	g_e, g/h.p.·h	n, min^{-1}	N_e, h. p.	$M_{кр}$, N·m	g_e, g/h.p.·h	ΔN_e, h. p.	Δg_e, g/h/p.·h
2600	258.1	71.1	181.7	2600	256.7	70.7	184.2	-1.5	2.5
2400	246.0	73.4	175.6	2400	244.6	73.0	178.0	-1.3	2.4

Engine with new flywheel and clutch				**Engine with a worn flywheel and clutch**				**Change**	
2200	234.4	76.3	171	2200	232.5	75.7	171.8	-1.8	0.8
2000	222.0	79.5	167.4	2000	221.4	79.3	168.9	-0.6	1.5
1800	208.9	83.1	166.1	1800	206.8	82.3	167.7	-2.0	1.6
1600	176.0	78.8	165.5	1600	175.6	78.6	165.7	-0.4	0.2
1400	131.2	67.1	163.8	1400	131.9	67.5	164.1	0.8	0.3
1200	99.0	59.1	164.4	1200	97.5	58.2	164.6	-1.5	0.2

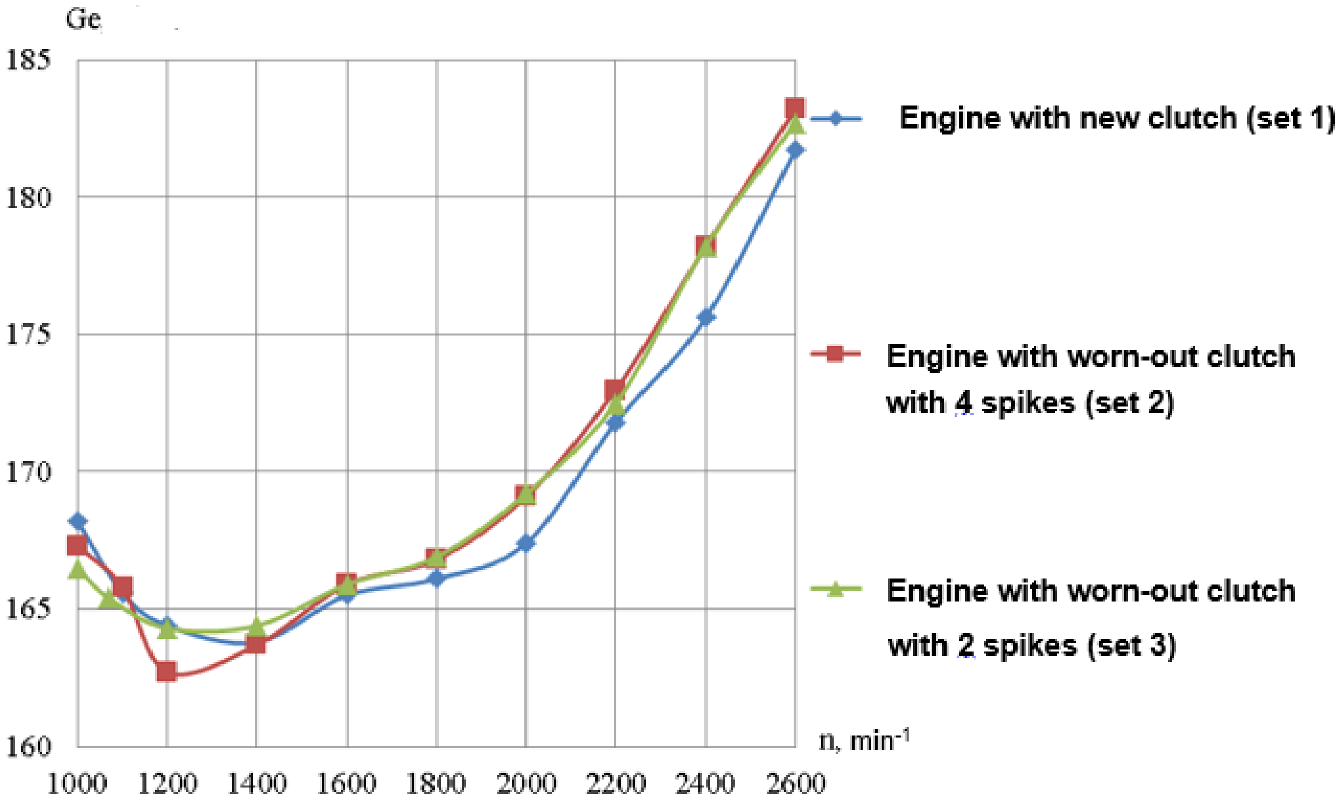

Figure 3. Effective specific fuel consumption of an engine with different clutch sets by external speed characteristic

At a crankshaft speed over 1200 min^{-1} (Fig. 3) with practically identical loads, a deterioration in the effective power and specific fuel consumption of the engine was revealed.

During operation, when the contact surfaces of the "thorn-groove" interface are worn out, the driving discs are displaced relative to the flywheel, their centering is disturbed, and this, in turn, leads to an increase in the imbalance in the clutch unit, having a negative effect on the operation of the engine and its reliability [9]. At a crankshaft speed of 2600 min^{-1}, a centrifugal force acts on the drive clutch disc (whose mass is 13.2 kg), which reaches 400 kg ·s, which leads to an imbalance and vibration of the entire vehicle. Under such conditions, part of the engine's energy leaves the clutch for secondary processes of excitation of vibrations of the vehicle elements, thereby losing useful power.

III.II. The effect of a turbocharger on engine performance

Comparative motor tests of the KamAZ-740.11-240 engine were carried out in versions equipped with serial after operation and repaired turbochargers at external speed characteristics (Table 2).

Table 2. Parameters of the KamAZ-740.11-240 engine with a serial and repaired turbocharger and with a modernized bearing during bench tests

N, min^{-1}	N_e, h. p.		M, N3m		G_T, kg/h		g_T, g/hp, h		$t_{T2\ Lev}$, °C		$t_{T\ 2\ right}$, °C		P_H, MPa	
	s	u	s	u	s	u	s	u	s	u	s	u	s	u
1000	112	113	801	809	18.7	19.1	167	169	510	510	510	520	0.016	0.018
1200	140	142	837	849	22.8	23.1	163	162	530	500	530	510	0.024	0.026
1400	166	169	848	866	27.1	26.9	163	159	540	500	540	510	0.032	0.034
1600	187	193	837	861	30.6	30.8	164	160	540	510	540	520	0.042	0.046
1800	209	213	831	840	34.4	34.4	165	161	530	510	530	520	0.052	0.065
2000	233	238	834	852	38.4	38.7	165	163	520	500	520	510	0.062	0.070
2200	237	240	772	779	40.3	40.2	170	168	510	500	510	500	0.068	0.082

Notes: n – speed of rotation of the crankshaft; N_e – power; M – torque; G_T – hourly fuel consumption; g_t – specific effective fuel consumption; $t_{T2\ Lev}$ – gas temperature behind the turbine of the left turbocharger; $t_{T\ 2\ right}$ – the same of the right turbocharger; P_H – boost pressure; s – serial; u – upgraded

As Table 2 shows, an engine equipped with a repaired and modernized TKR has the improved characteristics compared to the serial one from operation. In nominal mode, the power is 3 h.p. higher (1.25%), the boost pressure is 0.014 MPa higher (20.6%), the effective minimum fuel consumption has decreased by 4 g/h.p. per hour (2.5%); the maximum torque increased by 7 Nm (2.12%).

This indicates that the KamAZ-740.11-240 engines equipped with repaired turbochargers with modernization, more completely burn fuel in the cylinders due to the higher cylinder pressurization degree.

IV. SUMMARY

1. Wear of the clutch elements causes the power and economic indicators of the engine to decrease, which is caused by the formation of an imbalance and the transfer of part of the engine power to secondary processes that occur in the clutch mechanism in the form of vibration and shaking. In all modes, an increase in specific fuel consumption and a decrease in effective engine power are noted.

2. An engine with a serial turbocharger after operation has worse parameters than after repair with modernization. Comparative characteristics at nominal mode: the power is 3 h.p. higher (1.25%), the boost pressure is 0.014 MPa higher (20.6%), the effective minimum fuel consumption has decreased by 4 g/h.p. per hour (2.5%); the maximum torque increased by 7 Nm (2.12%). This simultaneously affects the increased harmful emissions and smoke of the exhaust gases.

V. CONCLUSIONS

The technical condition and dynamics of the decrease in the efficiency of the elements of the power unit affect the decrease in the carrying capacity of the vehicle, and, as a consequence, lead to a decrease in the truck (road train) usability.

The research results show that the processes of wear of the elements of the power unit such as the turbocharger and the clutch affect the effective engine power, torque and specific fuel consumption.

Wear of the elements of the power unit leads to a decrease in torque, which inevitably affects the parameters of the traction force, and, accordingly, causes a decrease in the actual load of the truck in operation, which undoubtedly affects the indicators of the transport process.

ACKNOWLEDGMENTS

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

REFERENCES

[1] Makarova I, Pashkevich A, Buyvol P, Mukhametdinov E. Risk Analysis in the Appointment of the Trucks' Warranty Period Operation. Ininternational Conference on Information Systems Architecture and Technology 2018 Sep 16 (Pp. 293-302). Springer, Cham.

[2] Barylnikova EP, Kulakov AT, Talipova IP. Influence of the technical condition of the elements of the power unit

on the vehicle efficiency. Scientific and technical bulletin of the Volga region. 2018;1:43-45.

[3] Ivaschenko NN. Car repair technology. - Kyiv: "Vyshcha Shkola" Publishing Association. 1977: - 360 p.

[4] Kapnopp DC. "System Dynamic" A Unified Aproach (1990), Wiley-Interscience, New York. 1990.

[5] Aboltin EV. Khanin NS, Liamtsev BF, et al. Turbocharged Automotive Engines. - M.: Mechanical Engineering. 1991: - 336 p.

[6] Galiev IG, Khafizov KA, Khaliullin FKh. Modernization of the lubrication system of the bearing unit of a turbocharger of an automotive engine. Bulletin of Kazan GAU. 2019;1(52):71-75.

[7] Galiev IG, Galimov AR, Mukhametzyanov NA. Ways to increase the efficiency of turbocharger for automotive engines. Materials of the XIV International vědecko - practical conference "Effective tools of modern science - 2018". Volume 3: Prague. Publishing house "Education and science»:53-57.

[8] Khusnetdinov ShS, Penkov EA, Garipov RI. Diagnostics of the vehicle clutch by vibration indicators of the power unit. Bulletin of the Orenburg State University. 2014;10:146-151.

[9] Makarova I, Mukhametdinov E, Gabsalikhova L, Garipov R, Shubenkova K, Pashkevich A. Justification of the possibility to use vibration measuring sensors in onboard diagnostic devices. International Seminar on Electron Devices Design and Production, SED 2019 - Proceedings. 2019: 8798442.

[10] Kulakov AT, Garipov RI. Diagnostics of the clutch of a truck with the use of vibration diagnostics methods. Problems of quality and operation of vehicles: Operation and development of road transport: Proceedings of the X International Correspondence Scientific and Technical Conference (May 15, 2015) - Penza: PGUAS.2015:186-192.

Ruslan Nailievich Engalychev, born on 07.11.1995 in Namangan, Republic of Uzbekistan. 2014 – graduated from the Namangan College of Transport and Information Technologies. 2015 – moved to the Russian Federation and entered the Naberezhnye Chelny Institute of the Kazan Federal University in "Operation of transport and technological machines and complexes". After graduation in 2019, entered the magistracy of the Naberezhnye Chelny Institute of KFU in "Technology of transport processes".

Aleksandr Tikhonovich Kulakov, born on 09.01.1951. 1974 – graduated from the Kuibyshev Aviation Institute. Worked in civil aviation, KAMAZ JSC. 1986 – defended his thesis for the degree of Candidate of Engineering. 2007 – defended his Ph.D. thesis in Engineering. Author of 240 scientific publications, including 4 monographs. Research interests: technical operation of vehicles, design and operation of internal combustion engines, technology of transport processes. Currently, the head of the department of road transport operation at the Naberezhnye Chelny Institute of the KFU, professor.

Elena Petrovna Barylnikova, born on 24.01.1969 in Bukhara, Republic of Uzbekistan. 1991 – graduated with honors from the Bukhara Technological Institute of Food and Light Industry. 2013 – successfully defended her thesis for the degree of Candidate of Engineering in "Operation of road transport". 2015 – graduated with honors from the magistracy of the Kazan Federal University with a degree in Operation of Transport and Technological Machines and Complexes. Research interests: technical operation of vehicles, freight and passenger transportation. Currently works as an associate professor of the Department of Road Transport Operation at the Naberezhnye Chelny Institute of the KFU.

Irina Petrovna Talipova, born on 23.10.1961 in Angren, Republic of Uzbekistan. 1982 – graduated with honors from the Bukhara Technological Institute of Food and Light Industry. 1990 – after graduating from graduate school, successfully defended her thesis for the degree of Candidate of Engineering. Since 1998 – associate professor of the Department of Mechanics and Design of the Naberezhnye Chelny Institute of the KFU.