Peter the Great Saint-Petersburg Polytechnic University

Institute of Energy and Transportation Systems
"Engineering of Power Units and Transport Systems" Department

“APPROVED”

Pro-rector for R&D

____________V.V. Sergheyev

TECHNICAL MEMORANDUM
of R&D Project

"Research in the influence of RESURS NEXT lube oil additive on techno-economic and environmental performance of automobile engines, and part rebuilding with said additive – feasibility study"

Test Director

_________________Shabanov A.Yu.

St. Petersburg
2017

Project team:

Shabanov A.Yu.	PhD, professor, project manager, expert competence certificate Nr. РОСС RU.И480.04ХД.Э006, valid until 31.12.2017
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SUMMARY TAB

92 sheets, 53 ill., 37 tables, 1 appendix

PETROL ENGINE, NON-INTRUSIVE REBUILDING, FRICTION, WEAR

This report presents the results of the research into the efficiency of antifriction remetallisant RESURS NEXT as an additive to lube oil for automobile petrol engine, and achievable rate of engine restoration (if any) through use of said additive.

The authors developed procedure and methods of stand tests based on artificial standard defects scratched on friction surfaces. Test results has been analysed.

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NOMENCLATURE

n	engine speed
m	engine strokes per cycle
N_e	engine effective power
η_i	indicated efficiency of engine
$\eta_м$	Effective efficiency of engine

η_e effective efficiency of engine

g_e effective specific fuel consumption

NORMATIVE REFERENCES

ГОСТ 17479.1-85. Motor oils. Classification and designation. Moscow, Standard Publishing House, 1984.

ГОСТ 18509-88. Tractor and combine diesel engines. Methods of bench tests. – Moscow, Standard Publishing House, 1988. – 70 p.

ГОСТ 621-87. Piston rings for internal combustion engines. General specifications. Moscow, Standard Publishing House, 1987, 34 p.

ГОСТ 7.32-2001. The research report. Structure and rules of presentation. Moscow, Standard Publishing House, 2001, 22 p.

ГОСТ 10541–78. Universal motor and automobile carburettor engine oils. Specifications.

ГОСТ 33–2000. Petroleum products. Transparent and opaque liquids. Determination of kinematic viscosity and calculation of dynamic viscosity

ГОСТ 14846-81. Automobile engines. Methods of bench tests

1 Objective of the work

Objective of this work is research into mechanical & environmental performance of car petrol engines operating on lube oil modified with RESURS NEXT remetallisant (specification ТУ 0257-018-45540231-2005) from JSV VMPAVTO, hereinafter referred to as "RESURS NEXT additive", and achievable rate of engine restoration (if any) through its use.

The authors made use of equipment and combustion research methods developed in "Engineering of Power Units and Transport Systems" Department of Peter the Great Saint-Petersburg Polytechnic University (Test Laboratory Certificate СДС ГСМ-FLM Nr. РОСС.RU. 04ХД.ИЛ 001, valid until 31 December 2017).

2 Object of the research

As agreed with Customer, the tests were carried out on two VAZ type car petrol engines. The first test series was carried out on 16-valve injector engine type VAZ-2112 in initially sound condition, with low wear rate. The second test series was carried out on VAZ-21083 engine with artificially damaged friction surfaces of certain engine parts (crankshaft bearing shells and piston rings).

Artificial damages of bearing shells in form of standard scratches ca. 100 µm in depth were applied using specially adapted lathe (Fig.1).

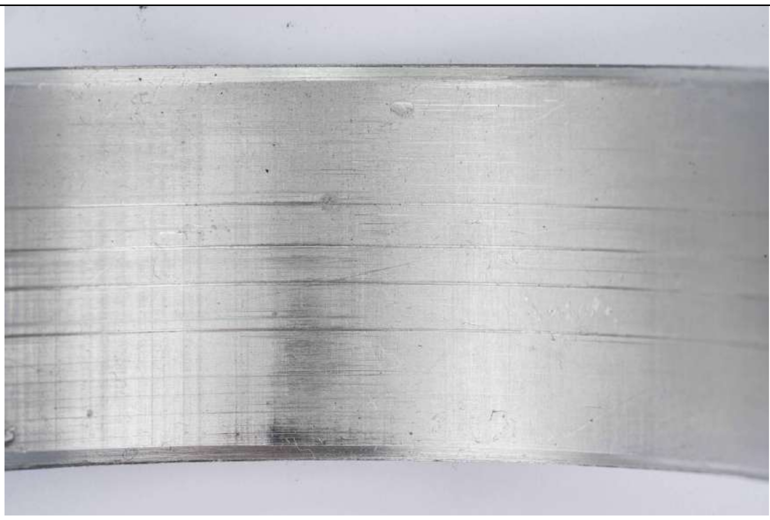

Fig.1. Artificially damaged bearing shell surface

As to artificial damages of the upper piston rings, they were applied manually with a chisel. One scratch was made near a piston ring lock, while scratches Nrs. 2, 3 and 4 were made at the angles of 90, 180, and 270 degrees relative to the piston ring lock.

Measurements of oil pressure and compression in cylinders of the engine with artificially damaged parts showed reduction in lube oil pressure during idling by 10…12%, while gas pressure in cylinders dropped by 1,0…1,2 bar. Such a combination of measured diagnostic variables is typical for engine status usually referred to as heavy wear, which calls for medium repair involving replacement of parts with friction surfaces.

All the tests were carried out with synthetic motor oil Lukoil Lux SAE 5W-30.

Needed amount of Lukoil Lux motor oil and RESURS NEXT additive for the tests had been from Customer.

3 Test bed and metering equipment

Stand tests of motor oils were carried out on a special test bed belonging to "Engineering of Power Units and Transport Systems" Department of Peter the Great Saint-Petersburg Polytechnic University.

Two car engines of VAZ family – 16-valve injector engine type VAZ-2112 (1st test series) and 8-valve carburettor engine type 21083 (2nd test series) – had been selected for the tests.

The above engines, designed for front-wheel drive small class cars, are the most common models in Russia.

The test bed is equipped with all the systems needed for its normal running in any operation mode, as well as process instrumentation and control/monitoring equipment, which enables recording of all the relevant parameters of engine and its systems (such as fuel supply, cooling, etc.).

The test bed is equipped with the following systems and devices:

- dynamometer
- remote control panel with monitoring equipment
- engine-dynamometer coupling
- engine cooling system
- lube oil system
- fuel supply system with fuel meter
- aspiration system
- exhaust system

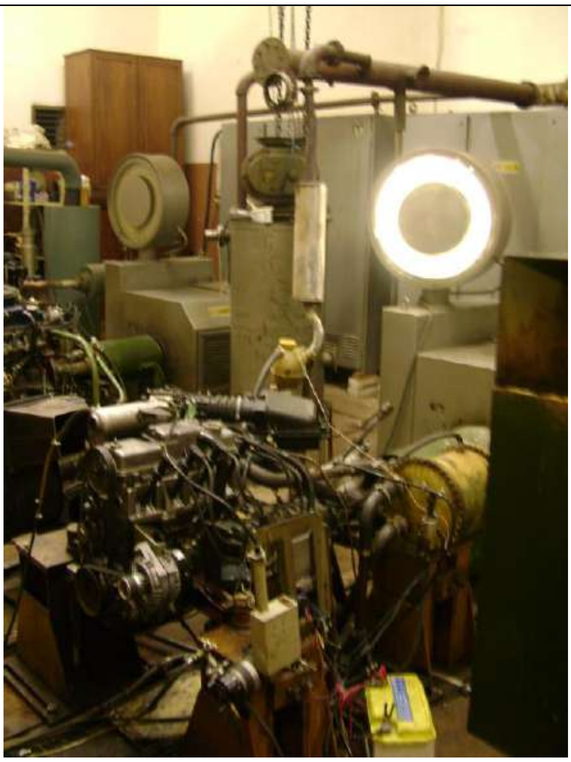

Fig. 2. VAZ-2112 engine on the test bed

Fig. 3. Control panel. Fuel meter and gas analyzer

Fig. 4. Control panel. Control console and computerized diagnostic system

The dynamometer system, MEZ VSETIN (Czech Republic) make, consists of:

- balancer dynamometer type DS 926-4 V complete with scales, torque sensor, photoelectric speed sensor and separate cooling fan;
- Leonard converter (motor dynamo) type DP 1126-4;
- switchboard type 4 RN 2088 complete with twin exciter and dynamometer controller to manage system speed and torque;
- panel with control gear, speed indicator (voltmeter calibrated in 1/min, accuracy class 1.5), and ammeter in armature circuit.

The engine, dynamometer and auxiliary systems are controlled from the remote control panel. The control panel features controller to manage system speed and torque, instruments for analogue measurement of system speed and current in armature circuit, switches to select rotation direction, and other I&C equipment.

The engine is coupled with the dynamometer through Cardan joint drive shaft to offset misalignment of engine and dynamometer axes.

Exhaust gas noxious components were measured with digital laboratory gas analyzer type OPTOGAZ-1.

Instrument specifications

Gas analyzers:

Parameter	Instrument model	Measurement range	Calibration gas concentration	Error,%
NOx concentration	OPTOGAZ 500-1	0…4500 ppm	1035 ppm	±2,0
CO concentration	OPTOGAZ 500-1	0…7500 ppm	2000 ppm	±2,5
CO_2 concentration	OPTOGAZ 500-1	0…20%	4.12%	±2,5
O_2 concentration	OPTOGAZ 500-1	0…25%	20.8%	±2,5
CH concentration	OPTOGAZ 500-1	0…1000 ppm	513 ppm	±3,0

Other instruments

Parameter, unit	Instrument	Model	Measurement range	Error
Principal parameters:				
Speed, RPM	Tachometer	ТМ и ЗД	0-8000	±10 RPM
Torque, Nm	Balancer dynamometer	DS 926-4 V	0-800	±1,0%
Instant fuel consumption, kg/h	Automatic digital fuel meter	Д-1	0…50	±0,5%
Auxiliary parameters:				
Temperatures:				
Coolant, ^{0}C	Built-in sensor	-	30-140	±2,0
Lube oil temperature, ^{0}C	Thermocouple type L	КСП3-П	0-250	±4,0
Exhaust gas, ^{0}C	Thermocouple type K	КСП3-П	50-850	±2,0
Intake air, ^{0}C	Thermometer	ГОСТ 2823-73	0-50	±2,0
Fual, ^{0}C	Thermometer	ГОСТ 18481-81	5-50	±2,0
Pressure:				
Atmospheric pressure, mm Hg	Barometer gauge	М-98	300-800	±0,2
Air/fuel mixture downstream of the throttle, bar	Pressure gauge	МТИ	0-2,5	±0.02 bar
Humidity:				
Intake air, %	Psychrometer	М-34	0-100	±1,0

Fuel and lube oil:

Fuel:	
Fuel type according to ГОСТ 51105-97 classification	High-octane lead-free automobile petrol "Premium-95" produced by JSV Lukoil
Density according to ISO 3765, kg/dm^3	0,745
Net calorific value, MJ/kg	44,2
Fuel composition (as reported by the chemical laboratory)	
C, mass.%	87,54
H, mass.%	12,42
S, ppm	18
N, mass.%	0
O, mass.%	0,82
Lube oil	
Oil type	Lukoil Lux 5W-30

Exhaust gas sampling:

Exhaust pipe sampling section diameter, mm	80
Exhaust pipe sampling section length, mm	2,5
Distance between the flange and the sampler, m	2,0
Heat insulation	No

4 Test program

The test program for the 1st series of experiments complies with the Voluntary Certification System for fuels, oils and chemicals FLM MM-003-2009 "MOTOR OILS FOR AUTOMOBILE ENGINES. COMPARATIVE TEST METHOD” The text of the above standard is cited in Appendix 1 to this Report.

Tests of engines with imitated (artificial) wear, using RESURS NEXT additive, and analysis of the test results were carried out according to the following sequence approved by Customer:

- preparation of the engine – dismantling, measurements, manufacturing of artificially damaged parts, and characterization of part microprofiles in the damaged zone;
- reassembling of the engine and short-term (1 hour) running-in;
- running the engine on 2 load curves (at 2000 RPM and 3000 RPM), taking measurements of torque, instant fuel consumption, exhaust gas toxic components, oil pressure and temperature, and in-cylinder compression peak pressure;
- injection of RESURS NEXT additive into lube oil;
- running the engine for 50 hours with periodic measurements of the above working parameters;
- intermediate measurements of engine working parameters according to initial measurement program, in-cylinder compression peak

pressure; dismantling of the engine, examination of selected parts and characterization of part microprofiles in the damaged zone;

- reassembling of the engine, returning it onto the test bed, and short-term running-in;
- repeated treatment the engine with RESURS NEXT additive;
- running the engine for 50 hours with periodic measurements of the above mentioned working parameters;
- final measurements of engine working parameters according to initial measurement program, in-cylinder compression peak pressure; dismantling of the engine, examination of selected parts and characterization of part microprofiles in the damaged zone;
- reassembling the engine and refilling it with fresh oil (free of RESURS NEXT additive);
- running the engine for 50 hours with periodic measurements of the above working parameters, so as to evaluate duration of treatment aftereffect;
- measurements of engine working parameters according to initial measurement program, in-cylinder compression peak pressure; dismantling of the engine, examination of selected parts and characterization of microprofiles in their damaged zones;
- processing and analysis of the test results.

5. Test results

5.1 Phase 1. Comparative tests of VAZ-2112 engine operating on lube oil with RESURS NEXT additive

This part of the test program has been carried out with a view to evaluate instant effects of treatment of initially sound engine with

RESURS NEXT additive in concentration recommended by the producer, i.e. 75 g (1 flask) for 4 litre lube oil.

As agreed with Customer, synthetic motor oil Lukoil Lux 5W-30 was used for these tests.

Measurements were carried out thrice:

1. before treatment with RESURS NEXT (on baseline motor oil);
2. in 5 hours since injection of RESURS NEXT additive;
3. in 10 hours since injection of RESURS NEXT additive.

Test results are presented below.

The following designations are used in the tables below:

n	engine speed
Me	effective torque
Ne	effective power
Gт	fuel consumption per hour
ge	specific fuel consumption
ηe	effective efficiency of engine
ηм	Effective efficiency of engine
Pм	lube oil pressure
Tм	oil temperature in engine sump
CO	concentration of carbon oxide in exhaust gas
NO	concentration of nitrogen oxide in exhaust gas
CH	concentration of residual hydrocarbons in exhaust gas
Texg	exhaust gas temperature

See tables 1-3 and Figs. 5…14 for the results of the tests of VAZ-2112 engine operating on motor oil modified with RESURS NEXT additive.

Load characteristic of VAZ-2112 engine n=2000 RPM

Before the treatment

Test point Nr.	Me, Nm	Ne, kW	Gт, kg/h	ge, kg/ kw-h	ηe	CO,%	CO_2, %	CH, ppm	NO, ppm	Tehg, ^0C
1	20,53	4,30	2,47	0,575	0,142	1,084	14,08	211	1684	350
2	41,06	8,60	3,40	0,396	0,207	1,056	14,14	217	2420	394
3	60,83	12,74	4,24	0,333	0,246	1,225	14,15	218	2685	443
4	81,11	16,99	5,14	0,303	0,270	1,324	14,16	225	2704	495
5	114,32	23,94	7,62	0,318	0,257	4,156	12,05	245	820	530

In 5 hours after the treatment

Test point Nr.	Me, Nm	Ne, kW	Gт, kg/h	ge, kg/ kw-h	ηe	CO,%	CO_2, %	CH, ppm	NO, ppm	Tehg, ^0C
1	20,40	4,27	2,42	0,565	0,145	1,065	14,02	202	1650	347
2	41,82	8,76	3,34	0,382	0,214	1,045	14,11	210	2449	391
3	61,20	12,82	4,11	0,321	0,255	1,236	14,12	211	2641	440
4	82,11	17,20	5,06	0,294	0,278	1,336	14,14	214	2736	491
5	116,54	24,41	7,43	0,305	0,269	4,048	12,10	232	885	524

In 10 hours after the treatment

Test point Nr.	Me, Nm	Ne, kW	Gт, kg/h	ge, kg/ kw-h	ηe	CO,%	CO_2, %	CH, ppm	NO, ppm	Tehg, ^0C
1	20,66	4,33	2,42	0,559	0,146	1,060	14,05	204	1637	348
2	41,31	8,65	3,32	0,384	0,213	1,052	14,15	208	2415	390
3	61,20	12,82	4,13	0,322	0,254	1,249	14,15	213	2610	441
4	81,60	17,09	5,03	0,294	0,278	1,352	14,10	217	2685	492
5	116,28	24,35	7,51	0,308	0,265	4,145	12,15	230	868	527

Table 1. Load characteristics of VAZ-2112 engine @ 2000 RPM after treatment with RESURS NEXT additive, vs. exposure period

Load characteristic of VAZ-2112 engine n=3000 RPM

Test point Nr.	Me, Nm	Ne, kW	Gт, kg/h	ge, kg/ kw-h	ηe	CO,%	CO_2, %	CH, ppm	NO, ppm	Tehg, ^0C
Before the treatment										
1	20,53	6,45	2,94	0,456	0,179	0,714	14,42	139	2780	442
2	41,06	12,90	4,28	0,332	0,247	0,910	14,38	162	3350	485
3	61,59	19,35	5,44	0,281	0,291	0,752	14,53	168	3495	502
4	82,12	25,80	6,67	0,258	0,317	0,994	14,41	191	3352	531
5	129,34	40,63	11,21	0,276	0,297	6,143	11,21	235	550	594
In 5 hours after the treatment										
Test point Nr.	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	**ηe**	**CO,%**	**CO_2, %**	**CH, ppm**	**NO, ppm**	**Tehg, ^0C**
1	20,67	6,49	2,87	0,441	0,185	0,698	14,40	131	2685	435
2	41,33	12,99	4,18	0,322	0,254	0,885	14,31	154	3287	478
3	62,00	19,48	5,32	0,273	0,299	0,768	14,47	157	3440	499
4	82,67	25,97	6,49	0,250	0,328	0,950	14,44	180	3310	524
5	132,53	41,64	11,01	0,265	0,309	5,877	11,25	219	585	587
In 10 hours after the treatment										
Test point Nr.	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	**ηe**	**CO,%**	**CO_2, %**	**CH, ppm**	**NO, ppm**	**Tehg, ^0C**
1	20,67	6,49	2,89	0,445	0,184	0,704	14,42	133	2670	437
2	41,85	13,15	4,17	0,318	0,258	0,910	14,35	159	3304	481
3	62,00	19,48	5,29	0,272	0,301	0,761	14,45	158	3455	497
4	82,93	26,05	6,44	0,247	0,331	0,974	14,41	185	3355	522
5	132,27	41,55	11,24	0,270	0,303	5,742	11,21	224	610	586

Table 2. Load characteristics of VAZ-2112 engine @ 3000 RPM after treatment with RESURS NEXT additive, depending on exposure period

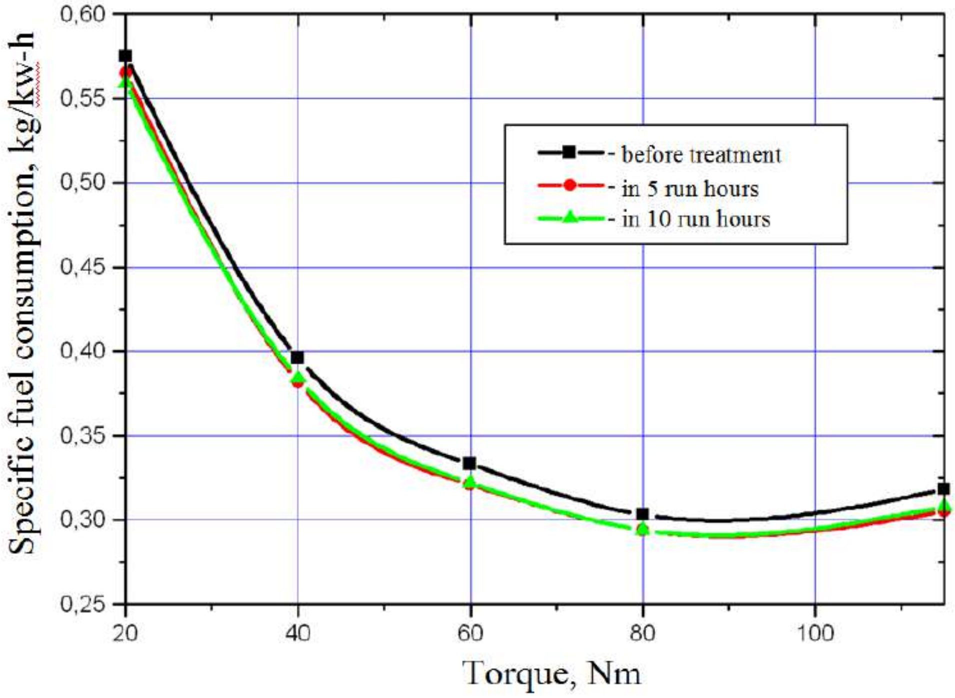

Fig. 5. Specific fuel consumption vs. torque @ 2000 RPM for VAZ-2112 engine after treatment with RESURS NEXT additive, depending on exposure period

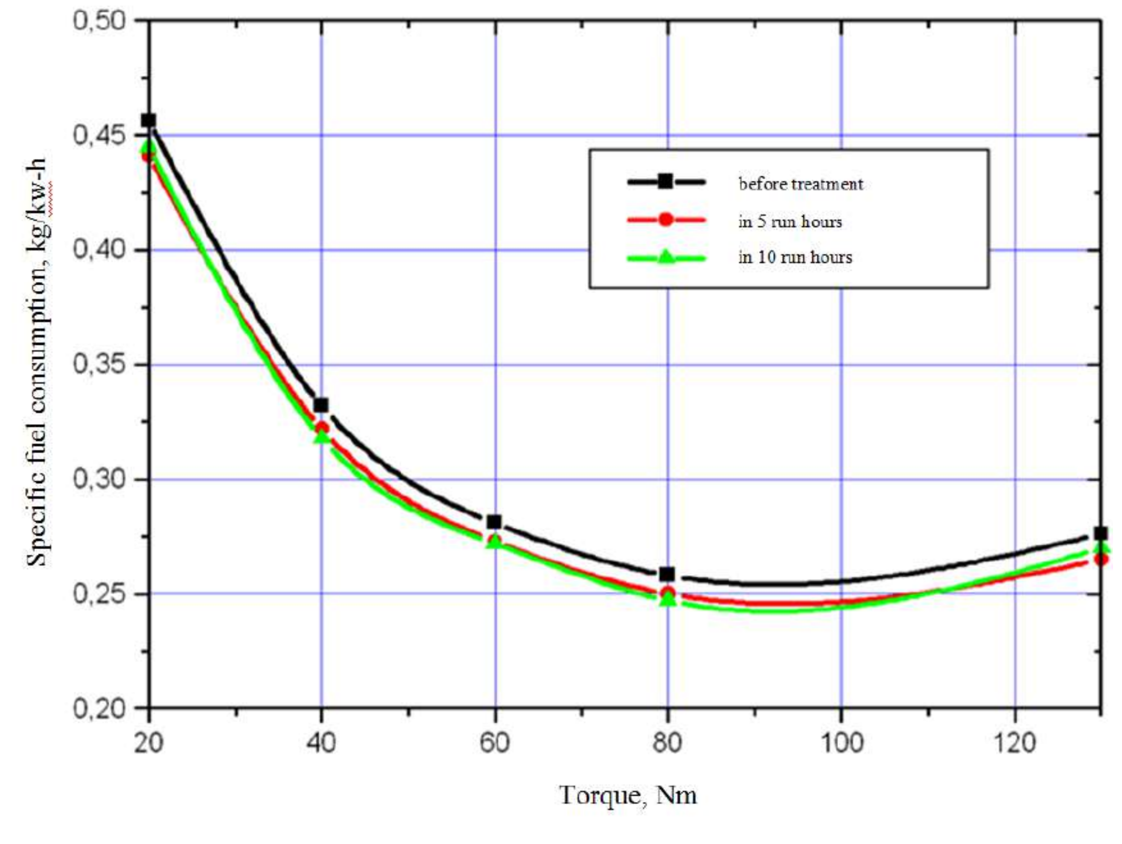

Fig. 6. Specific fuel consumption vs. torque @ 3000 RPM for VAZ-2112 engine after treatment with RESURS NEXT additive, depending on exposure period

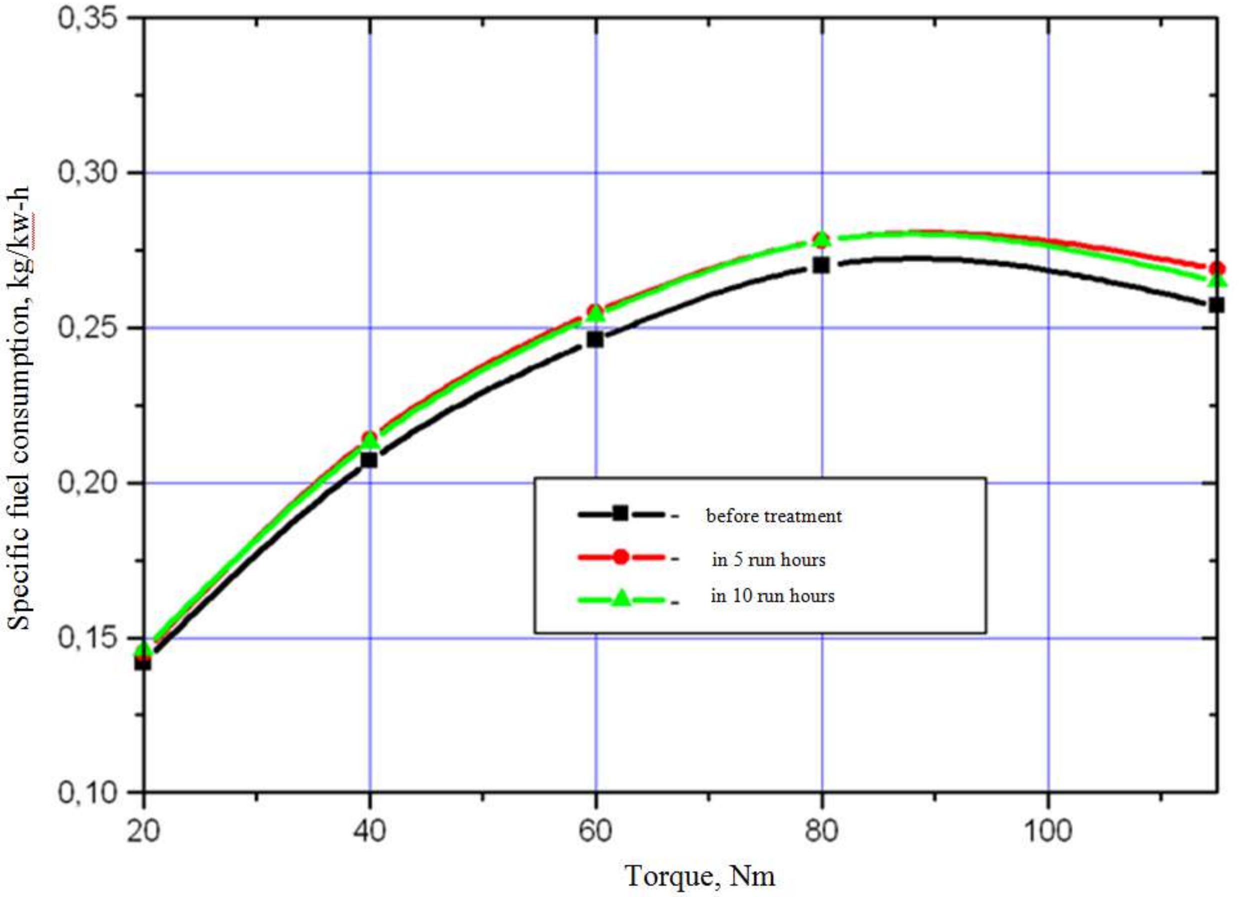

Fig.7. Effective efficiency vs. torque @ 2000 RPM for VAZ-2112 engine after treatment with RESURS NEXT additive, depending on exposure period

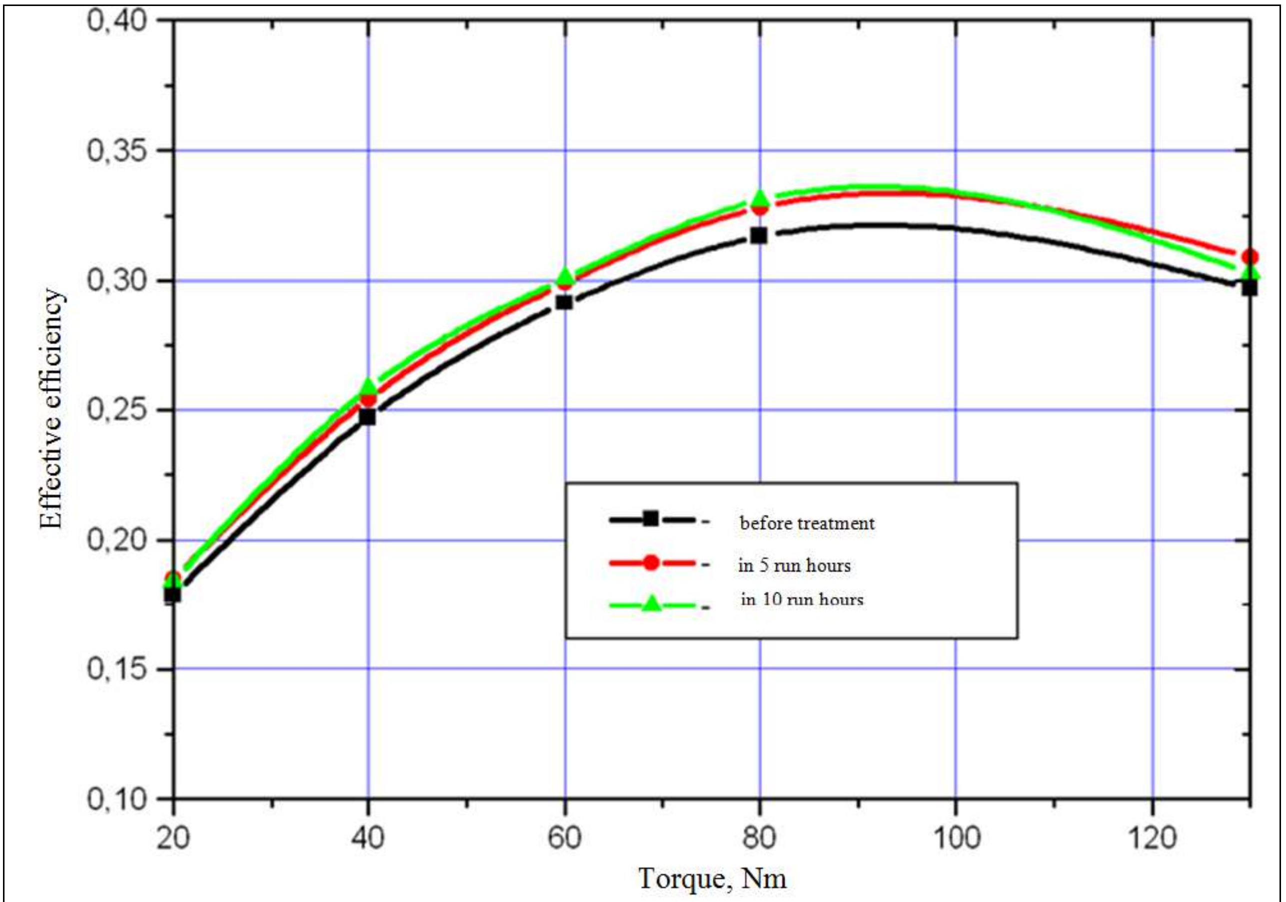

Fig.8. Effective efficiency vs. torque @ 2000 RPM for VAZ-2112 engine after treatment with RESURS NEXT additive, depending on exposure period

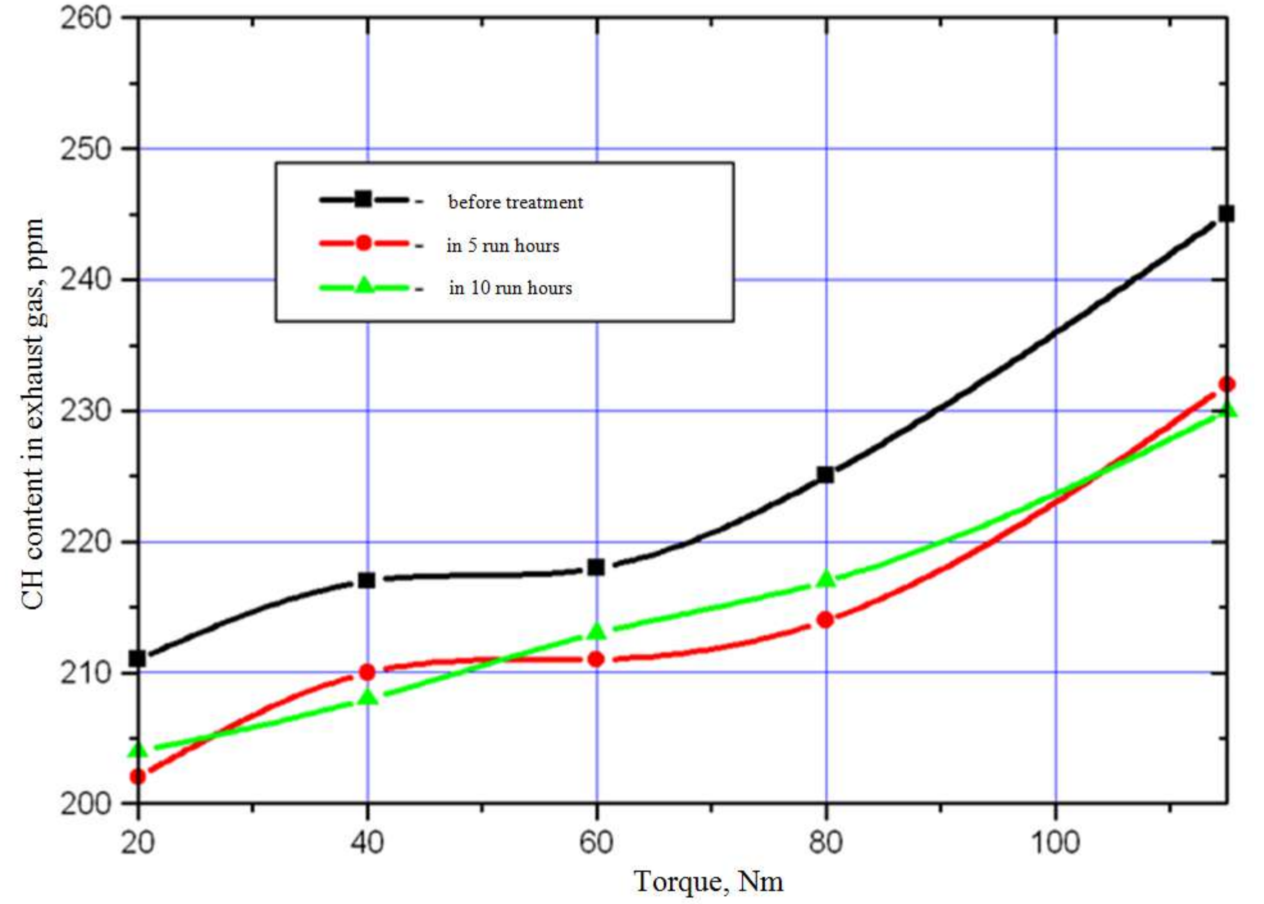

Fig. 9. Content of residual hydrocarbons in exhaust gas vs. torque @ 2000 RPM for VAZ-2112 engine after treatment with RESURS NEXT additive, depending on exposure period

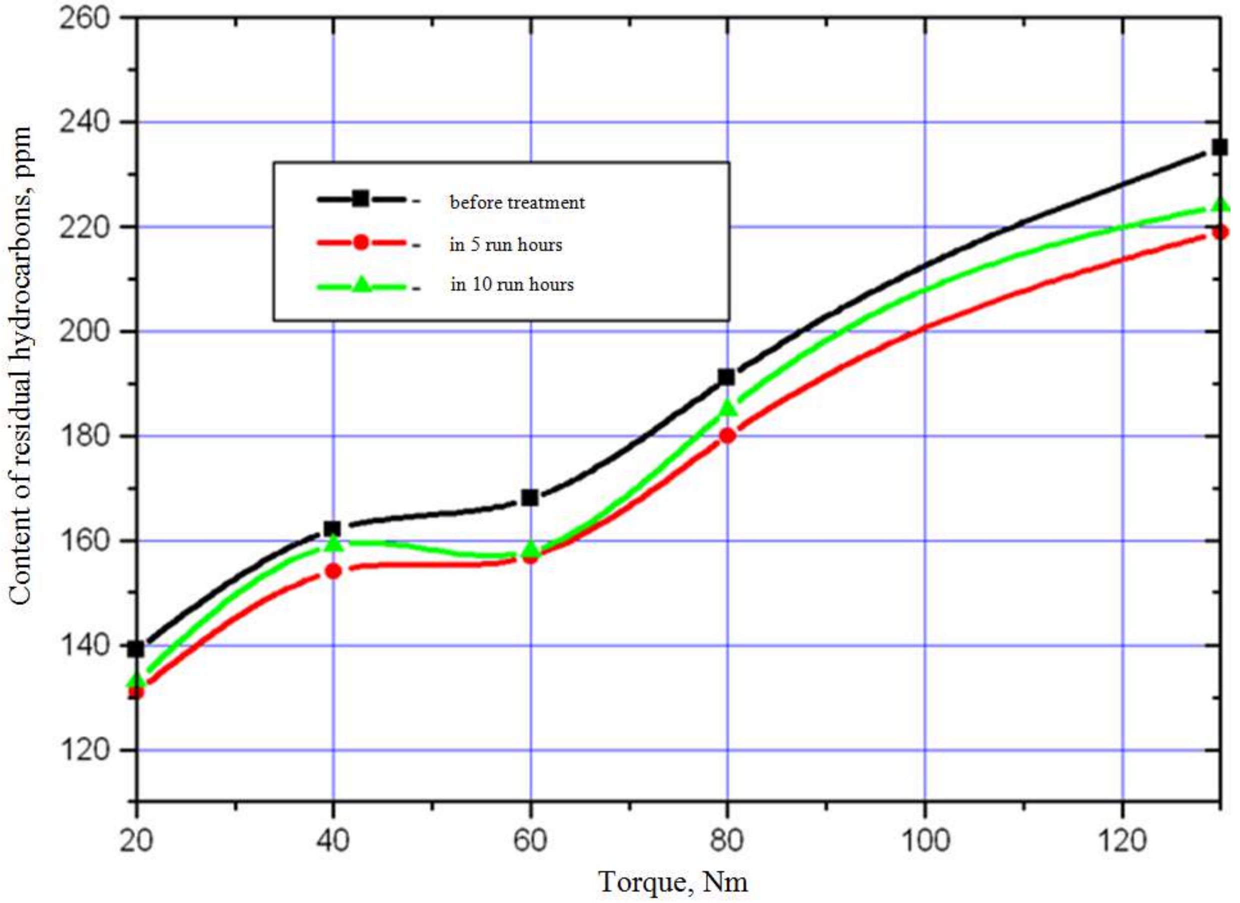

Fig. 10. Content of residual hydrocarbons in exhaust gas vs. torque @ 3000 RPM for VAZ-2112 engine after treatment with RESURS NEXT additive, depending on exposure period

Full-load torque curve of VAZ-2112 engine							
Before the treatment							
Test point Nr.	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	**ηe**	**CO,%**	**CO_2,%**
1500	102,50	16,10	6,37	0,396	0,207	0,892	492
2000	116,15	24,33	7,77	0,320	0,256	0,880	532
2500	122,59	32,09	9,44	0,294	0,278	0,875	570
3000	129,80	40,78	11,43	0,280	0,292	0,872	588
3500	134,43	49,27	13,46	0,273	0,299	0,849	605
4000	127,74	53,51	16,28	0,304	0,269	0,815	640
In 5 hours after the treatment							
1500	104,04	16,34	6,18	0,378	0,217	0,897	487
2000	117,69	24,65	7,58	0,308	0,266	0,887	530
2500	124,13	32,50	9,29	0,286	0,286	0,878	567
3000	132,12	41,51	11,23	0,271	0,302	0,875	585
3500	137,01	50,22	13,12	0,261	0,313	0,856	600
4000	129,28	54,15	16,17	0,299	0,274	0,819	632
In 10 hours after the treatment							
1500	104,04	16,34	6,26	0,383	0,213	0,896	488
2000	117,44	24,60	7,66	0,311	0,263	0,887	531
2500	124,65	32,63	9,41	0,288	0,284	0,877	569
3000	131,86	41,42	11,46	0,277	0,296	0,877	587
3500	136,49	50,03	13,30	0,266	0,308	0,855	601
4000	128,77	53,94	16,29	0,302	0,271	0,818	633

Table 3. Full-load torque curves of VAZ-2112 engine after treatment with RESURS NEXT additive, depending on exposure period

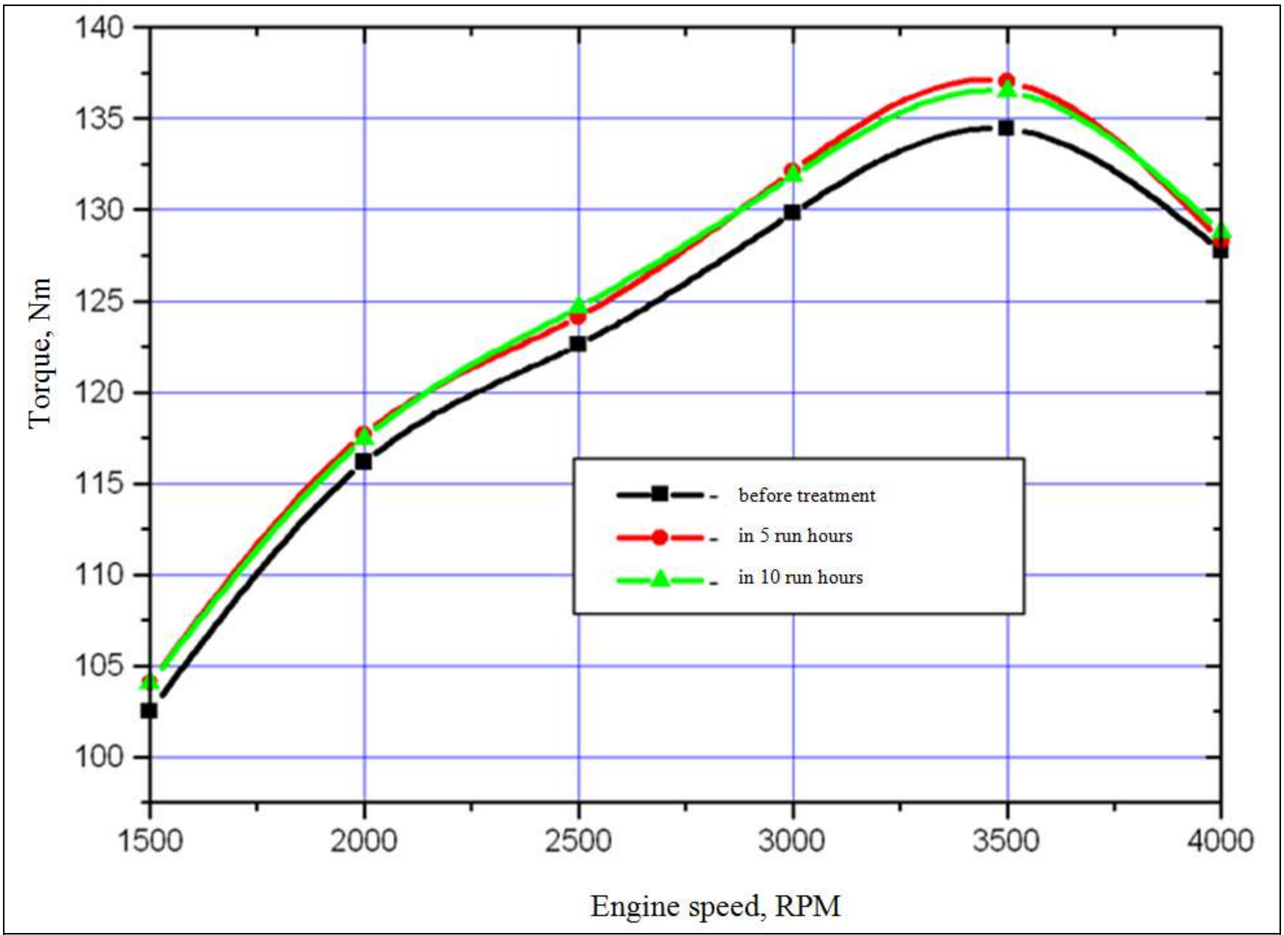

Fig. 11. Torque vs. speed curves for VAZ-2112 engine after treatment with RESURS NEXT additive, depending on exposure period

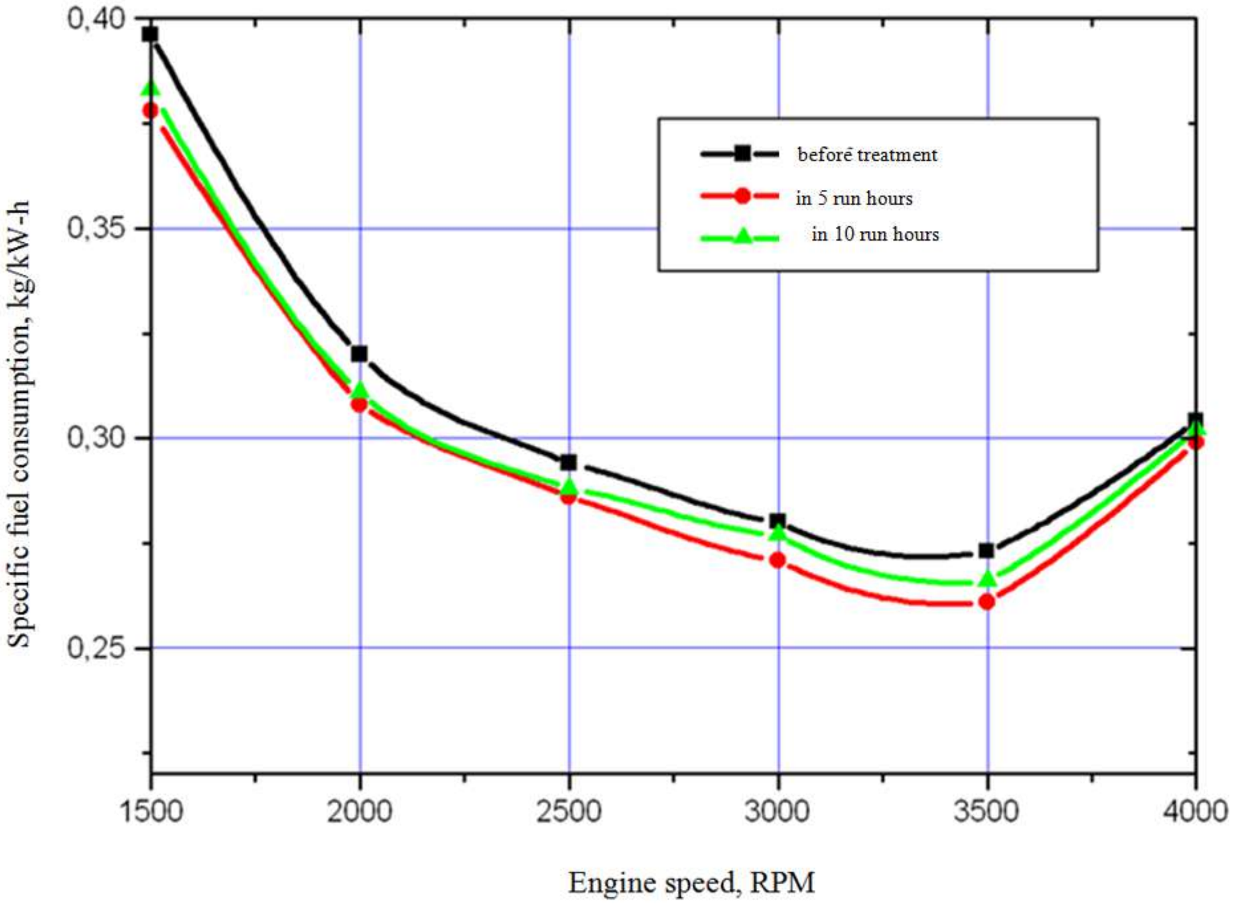

Fig.12. Specific fuel consumption vs. speed curves for VAZ-2112 engine after treatment with RESURS NEXT additive, depending on exposure period

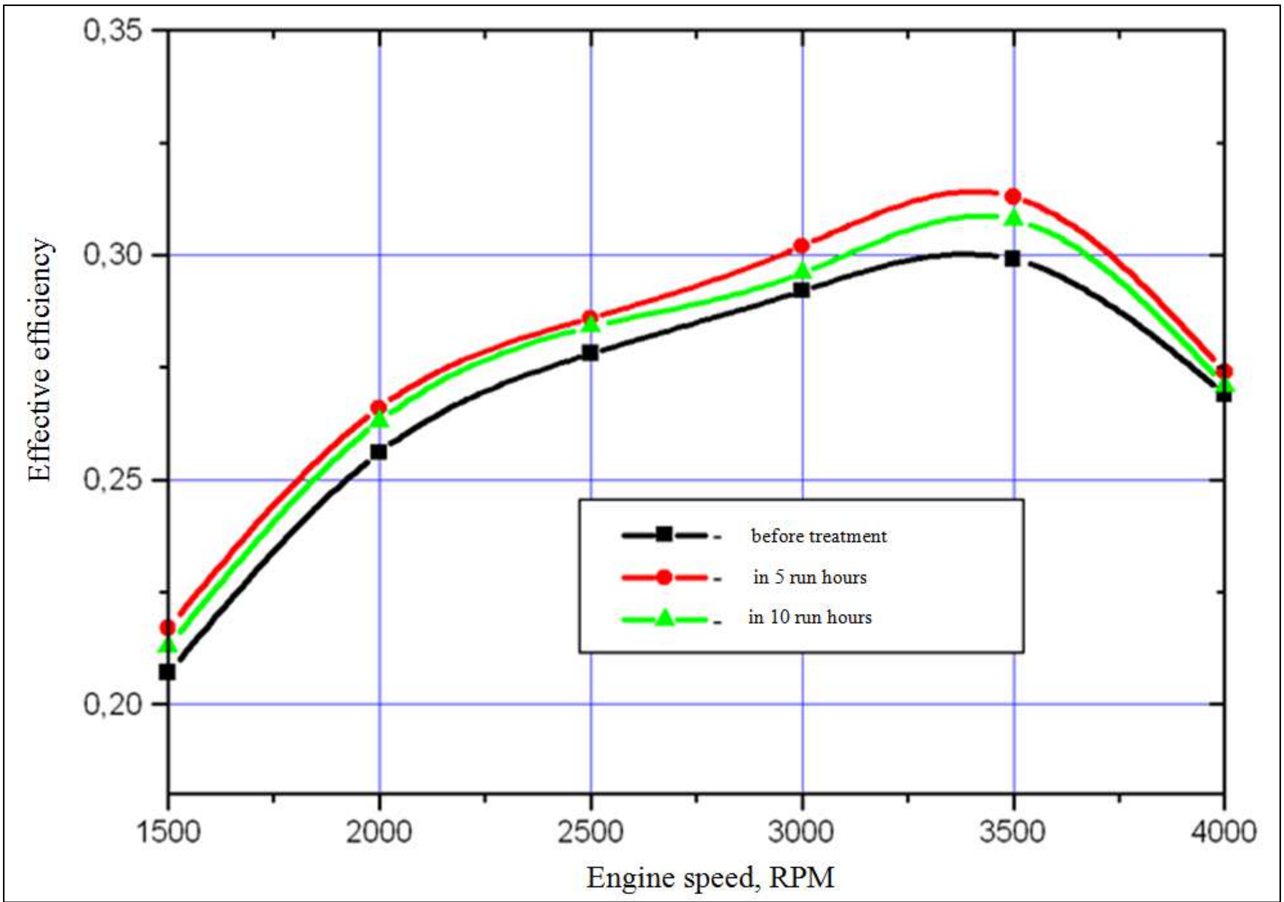

Fig.13. Effective efficiency vs. speed curves for VAZ-2112 engine after treatment with RESURS NEXT additive, depending on exposure period

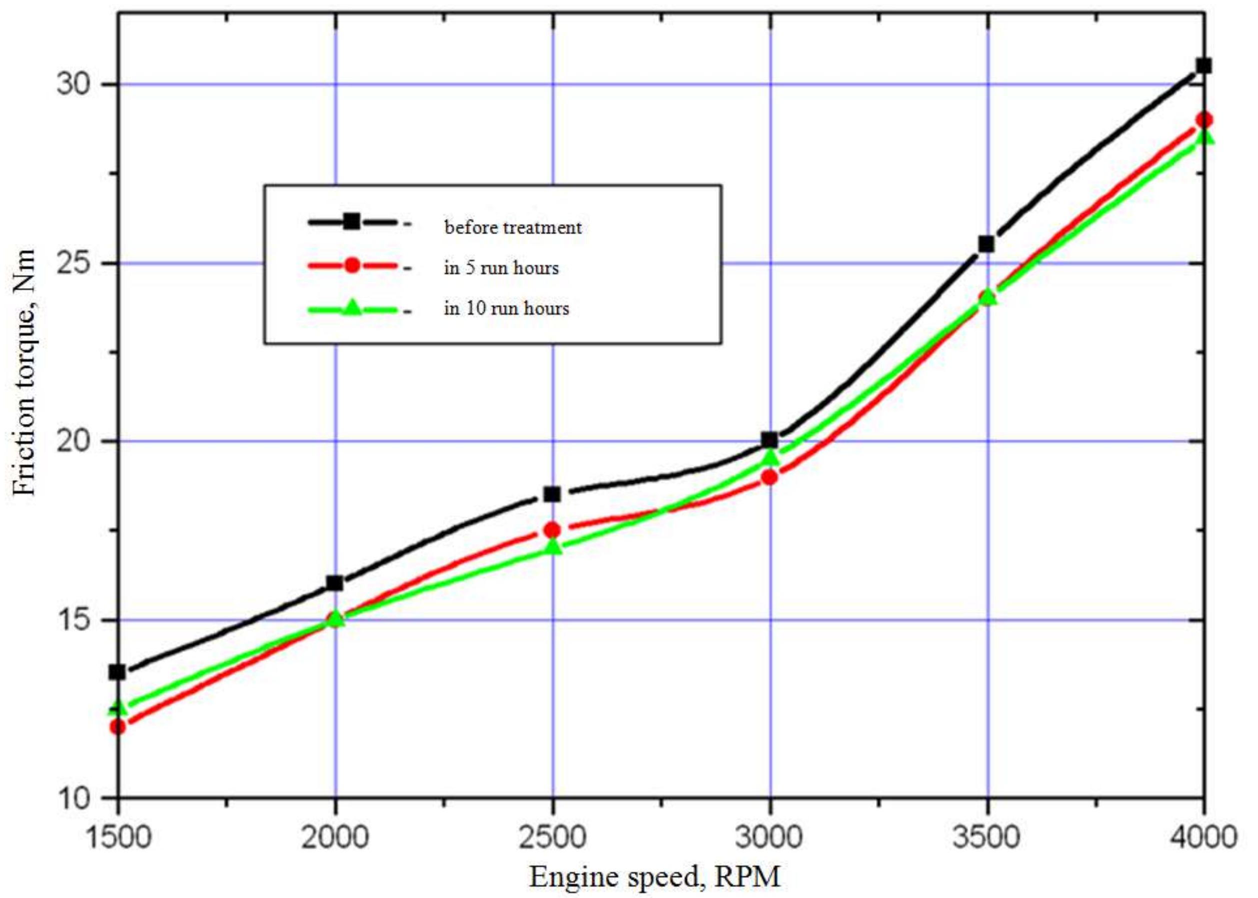

Fig.14. Friction torque vs. speed curves for VAZ-2112 engine after treatment with RESURS NEXT additive, depending on exposure period

Mechanical loss torque after treatment with RESURS NEXT additive, depending on exposure period, were measured when the engine was cranked from the dynamometer in reverse mode. The results are shown in Table 4.

Mechanical loss torque after treatment with RESURS NEXT additive, depending on exposure period			
n, RPM	**Before the treatment**	**In 5 running hours after the treatment**	**In 10 running hours after the treatment**
1500	13,5	12,0	12,5
2000	16,0	15,0	15,0
2500	18,5	17,5	17,0
3000	20,0	19,0	19,5
3500	25,5	24,0	24,0
4000	30,5	29,0	28,5

Table 4. Mechanical loss torque after treatment with RESURS NEXT additive, depending on exposure period

Engine operating values during idling were measured at each time point. As the whole fuel energy during idling transforms into friction losses, the test results demonstrate graphically the influence of the additive in question on the friction losses. The results are presented in Table 5 and Fig. 15.

Idling fuel consumption of VAZ-2112 engine	
Before the treatment	
RPM	**Gт, kg/h**
1500	0,89
2000	1,34
2500	1,65
3000	1,97
3500	2,30
4000	3,07
In 5 hours after the treatment	
RPM	**Gт, kg/h**
1500	0,78
2000	1,21
2500	1,47
3000	1,81
3500	2,11
4000	2,87
In 10 hours after the treatment	
RPM	**Gт, kg/h**
1500	0,79
2000	1,19
2500	1,51
3000	1,77
3500	2,14
4000	2,82

Table 5. Fuel consumption of VAZ-2112 engine at idling after treatment with RESURS NEXT additive, depending on exposure period

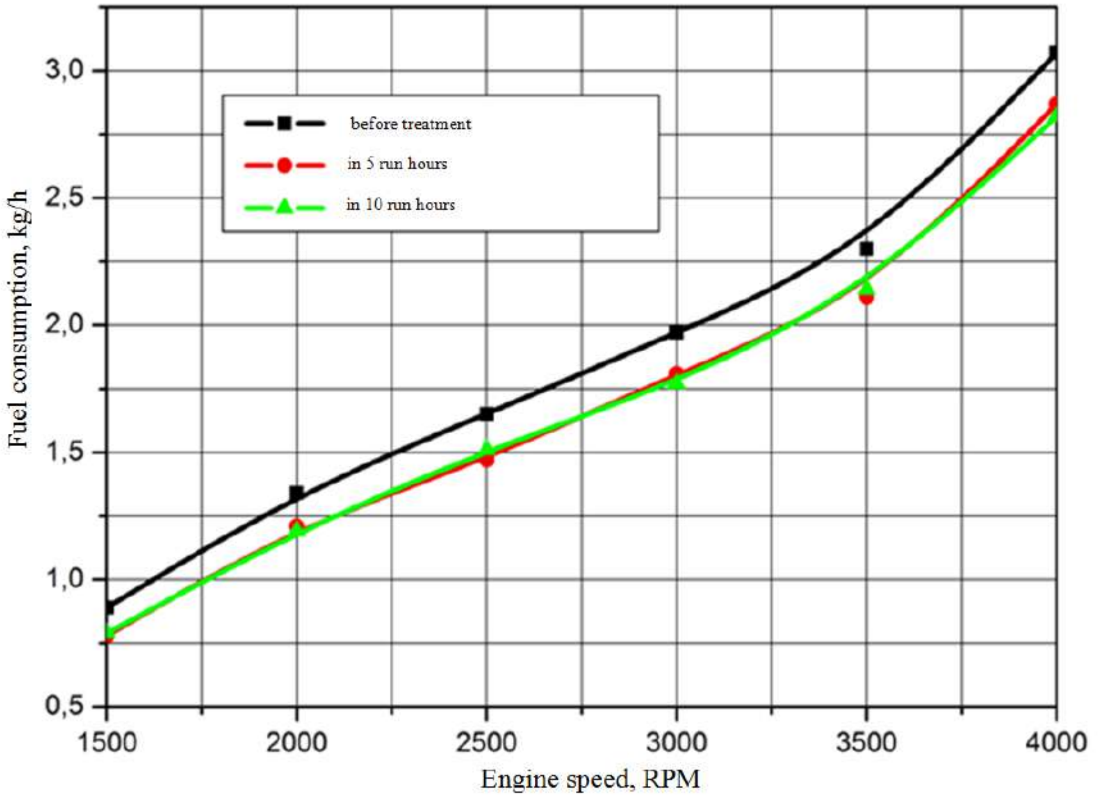

Fig. 15. Fuel consumption of VAZ-2112 engine vs. speed at idling after treatment with RESURS NEXT additive, depending on exposure period

1st phase of the research: discussion

Analysis of the results of the 1st phase of the tests leads to the following conclusions:

- Injection of RESURS NEXT in motor oil obviously results in decrease in friction horsepower. This follows from direct measurement of friction horsepower (Fig. 4) and fuel consumption during idling (Fig. 4). Treatment of sound engine with low wear level resulted in decrease in friction horsepower by 6%, and decrease in fuel consumption during by 9%.

- Treatment of an engine with RESURS NEXT additive results in certain improvement of engine performance characteristics. This statement is supported by the test results including calculated values of averaged specific fuel consumption, effective and mechanical engine efficiency. See Table 6 for (averaged) effects of oil modification with additive in question. Presented in the Table are percentage values of improvement or deterioration in engine performance indices relative to those with pure oil. The results were averaged over 20 measuring points interpolated from measured values.

№	Time point	Power, kW	Fuel consumption, kg/h	Effective efficiency	Effective efficiency	CO, %	CH, ppм	NOx, ppм
1	Before the treatment	36,01	0,353	0,245	0,863	1,836	201	2384
2	In 5 running hours after the treatment	36,56	0,341	0,254	0,872	1,791	191	2367
		+1,5	-3,4	+3,7	+1,0	-2,5	-5,0	-0,7
3	In 10 running hours after the treatment	36,49	0,342	0,253	0,871	1,795	193	2361
		+1,3	-3,1	+3,3	+0,9	-2,2	-4,0	-1,0

Table 6. Averaged performance indices of VAZ-2112 engine after treatment with RESURS NEXT additive, depending on exposure period

Colour marking: green – improvement in a performance index, red – deterioration of a performance index, blue - change of a performance index within metering error

To sum up, treatment with RESURS NEXT additive resulted in lowering of specific fuel consumption for the test cycle by 3% at average, or, in other words, the identical increase in effective efficiency.

No perceptible changes in engine performance indices for the test period (10 hours) have been observed. Results of the tests taken in 5 and 10 running hours (respective equivalents of mileage 500 and 1000 km) remained within metering error.

5.2 Phase 2. Long-term tests of VAZ-21083 engine with artificially damaged parts, running on motor oil modified with RESURS NEXT additive

5.2.1 Objectives of 2nd test phase

The objectives of this test phase were as follows:

- confirmation of positive effects of RESURS NEXT additive on another car engine type;
- check of achievable rate of engine restoration (if any) through the use of said additive;
- evaluation of time-related changes in efficiency of the additive during long-term run period;
- evaluation of dynamics in scale deposit on engine parts (both high-temperature and low-temperature) when using RESURS NEXT additive;
- evaluation of the duration of treatment aftereffect, with the engine operating on fresh lube oil.

The test were carried out in strict compliance with methods described above in Part 3 of this Report.

The test results are presented below.

5.2.2 Results of the motor tests

The engine with artificially damaged parts (piston rings and crankshaft bearing shells), primed with motor oil type Lukoil Lux 5W-30 modified with RESURS NEXT additive, operated for 100 running hours (equivalent of cumulative 10000 km mileage). During the test period RESURS NEXT additive doses were injected into the oil twice, thus increasing its concentration stepwise. First, it was injected in the very beginning of the test run in recommended concentration, i.e. 75 g (1 flask) for 4 litre lube oil. The second injection of the additive of the same concentration took place in 50 running hours (equivalent of cumulative 5000 km mileage). There were no intermediate oil changes between the 1st and the 2nd injections.

On completion of the 1st two test phases the engine was primed anew with fresh motor oil type Lukoil Lux 5W-30, whereupon the 3rd test phase (50 running hours) was carried out, in order to assess aftereffect of the treatment.

Each test phase was finalized with complete dismantling of the engine, followed by fault detection, evaluation of level of scale sedimentation on parts' surfaces and changes in state of artificially damaged surfaces. Also, on completion of every test phase in-cylinder compression peak pressure was measured for each particular cylinder.

See Tables 7…12 and Figs. 16…27 for test results of each test phase (load characteristics).

Long-term tests. Phase 1 Load characteristic of VAZ-21083 engine n=2000 RPM												
Before the treatment												
Test point Nr.	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	**ηe**	**ηм**	**CO, %**	**CO_2, %**	**CH, ppm**	**NO, ppm**	**Pм, bar**	**Tм, ^0C**
1	20,66	4,33	2,27	0,524	0,156	0,541	0,058	14,45	125	1245	1,95	90
2	41,31	8,65	3,24	0,374	0,219	0,706	0,064	14,52	134	1875	1,95	90
3	61,20	12,82	4,04	0,315	0,260	0,783	0,114	14,64	139	2412	1,90	91
4	81,60	17,09	4,85	0,284	0,288	0,830	0,314	14,24	115	2360	1,85	92
5	99,96	20,94	6,72	0,321	0,255	0,858	4,552	11,04	187	956	1,80	95
In 25 hours after the treatment												
1	21,68	4,54	2,22	0,490	0,167	0,575	0,061	14,51	118	1193	2,10	84
2	41,31	8,65	3,19	0,368	0,222	0,724	0,059	14,59	127	1810	2,10	85
3	61,71	12,92	3,93	0,304	0,269	0,799	0,109	14,61	138	2298	2,05	86
4	81,60	17,09	4,70	0,275	0,298	0,842	0,317	14,21	106	2325	2,00	88
5	103,0	21,58	6,61	0,306	0,267	0,873	4,485	11,15	172	931	1,95	91
In 50 hours after the treatment												
1	21,17	4,43	2,21	0,500	0,164	0,562	0,057	14,51	116	1201	2,10	84
2	41,82	8,76	3,21	0,367	0,223	0,720	0,061	14,54	130	1855	2,05	85
3	61,20	12,82	3,89	0,304	0,269	0,792	0,112	14,64	141	2272	2,00	87
4	82,11	17,20	4,73	0,275	0,298	0,839	0,325	14,21	109	2306	1,95	89
5	103,5	21,68	6,73	0,310	0,264	0,870	4,551	11,10	177	915	1,90	92

Table 7. Load characteristics of VAZ-21083 engine @ 2000 RPM after treatment with RESURS NEXT additive, depending on exposure period

Long-term tests. Phase 1 Load characteristic of VAZ-21083 engine n=3000 RPM											
Before the treatment											
Test point Nr.	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	**ηe**	**ηм**	**CO, %**	**CO_2, %**	**CH, ppm**	**NO, ppm**	**Pм, bar**	**Tм, ^0C**
1	20,67	6,49	2,97	0,458	0,179	0,456	0,134	14,75	108	2114	2,35	90
2	41,33	12,99	4,01	0,312	0,258	0,630	0,142	14,81	124	2780	2,30	92
3	62,00	19,48	5,15	0,264	0,310	0,722	0,154	14,85	121	3017	2,20	94
4	83,44	26,21	6,64	0,253	0,323	0,781	0,542	14,62	114	2895	2,10	95
5	108,5	34,09	10,03	0,294	0,278	0,825	6,843	10,45	195	846	2,05	98
In 25 hours after the treatment												
1	21,93	6,89	2,88	0,418	0,196	0,487	0,124	14,79	99	2043	2,50	87
2	42,30	13,29	3,89	0,298	0,279	0,640	0,127	14,84	106	2665	2,45	88
3	63,19	19,85	4,98	0,251	0,326	0,738	0,148	14,90	114	2894	2,45	89
4	83,81	26,33	6,51	0,247	0,331	0,792	0,510	14,67	105	2872	2,35	90
5	111,8	35,11	9,90	0,282	0,290	0,839	6,557	10,52	178	889	2,25	92
In 50 hours after the treatment												
1	20,89	6,56	2,80	0,427	0,191	0,472	0,126	14,75	101	2074	2,50	88
2	42,82	13,45	3,96	0,304	0,268	0,638	0,122	14,89	110	2590	2,50	88
3	62,66	19,69	4,92	0,250	0,328	0,734	0,151	14,97	117	2865	2,40	90
4	83,55	26,25	6,46	0,246	0,332	0,788	0,516	14,71	109	2910	2,30	92
5	112,3	35,27	10,03	0,284	0,288	0,836	6,776	10,50	181	865	2,25	93

Table 8. Load characteristics of VAZ-21083 engine @ 3000 RPM after treatment with RESURS NEXT additive, depending on exposure period

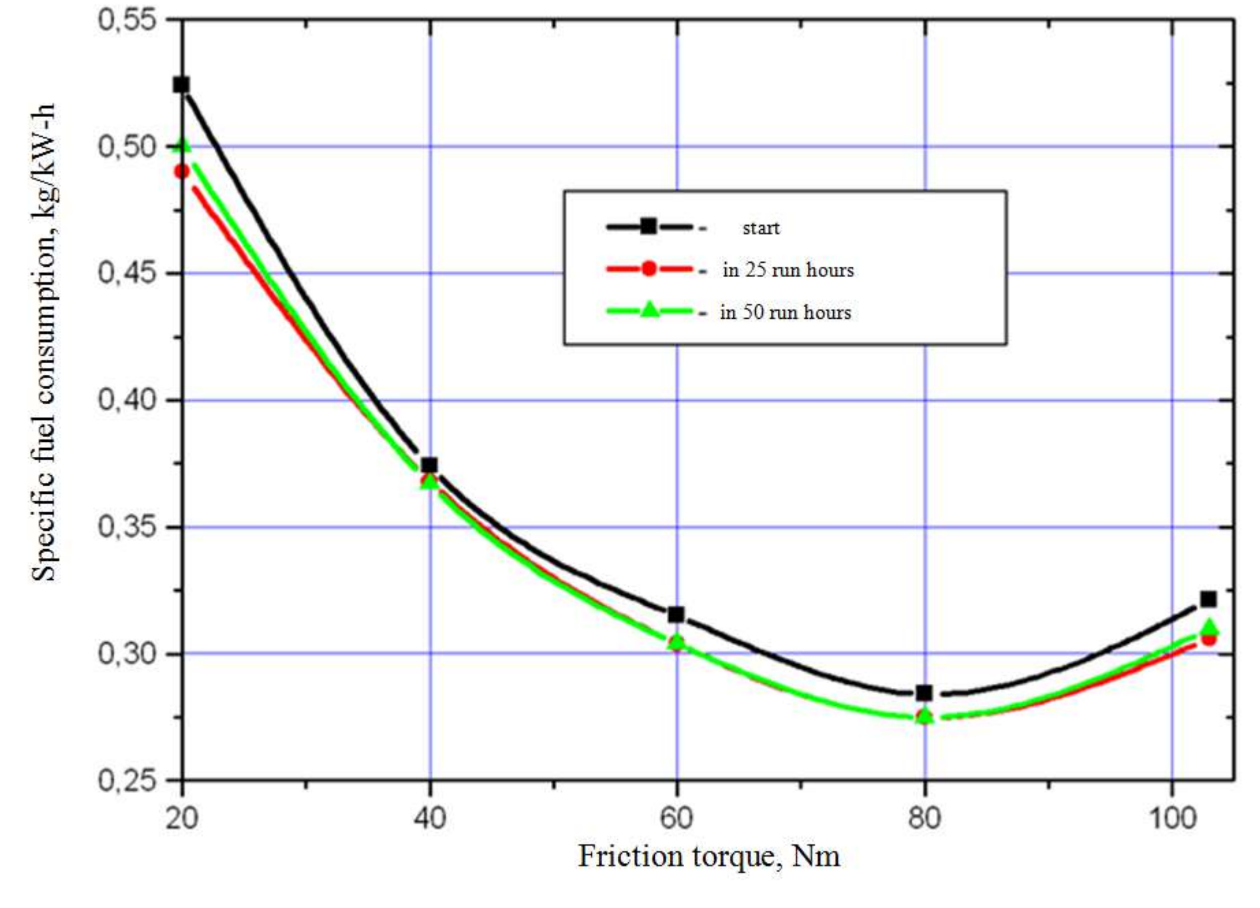

Fig. 16. Specific fuel consumption vs. torque @ 2000 RPM for VAZ-21083 engine after the first treatment with RESURS NEXT additive, depending on exposure period

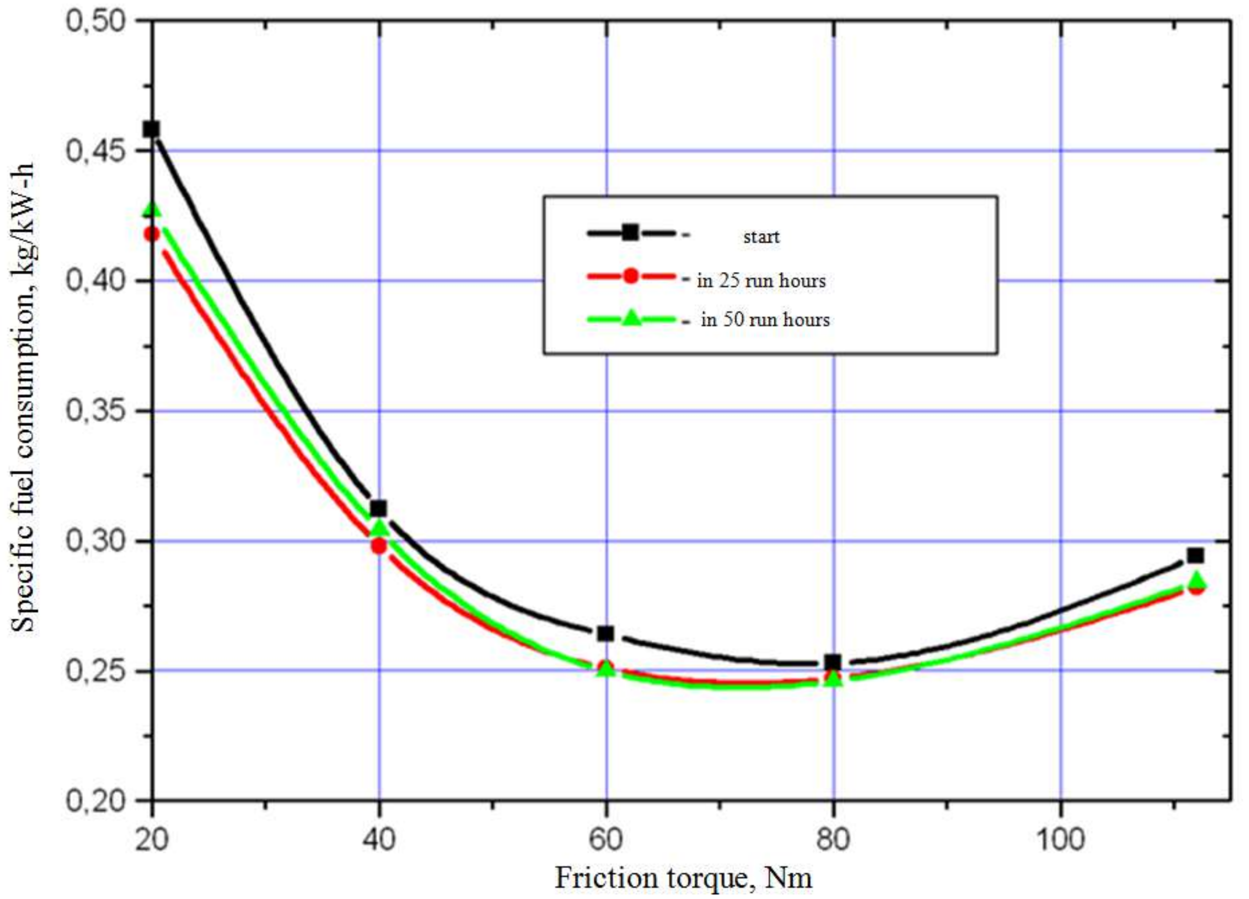

Fig. 17. Specific fuel consumption vs. torque @ 3000 RPM for VAZ-21083 engine after the first treatment with RESURS NEXT additive, depending on exposure period

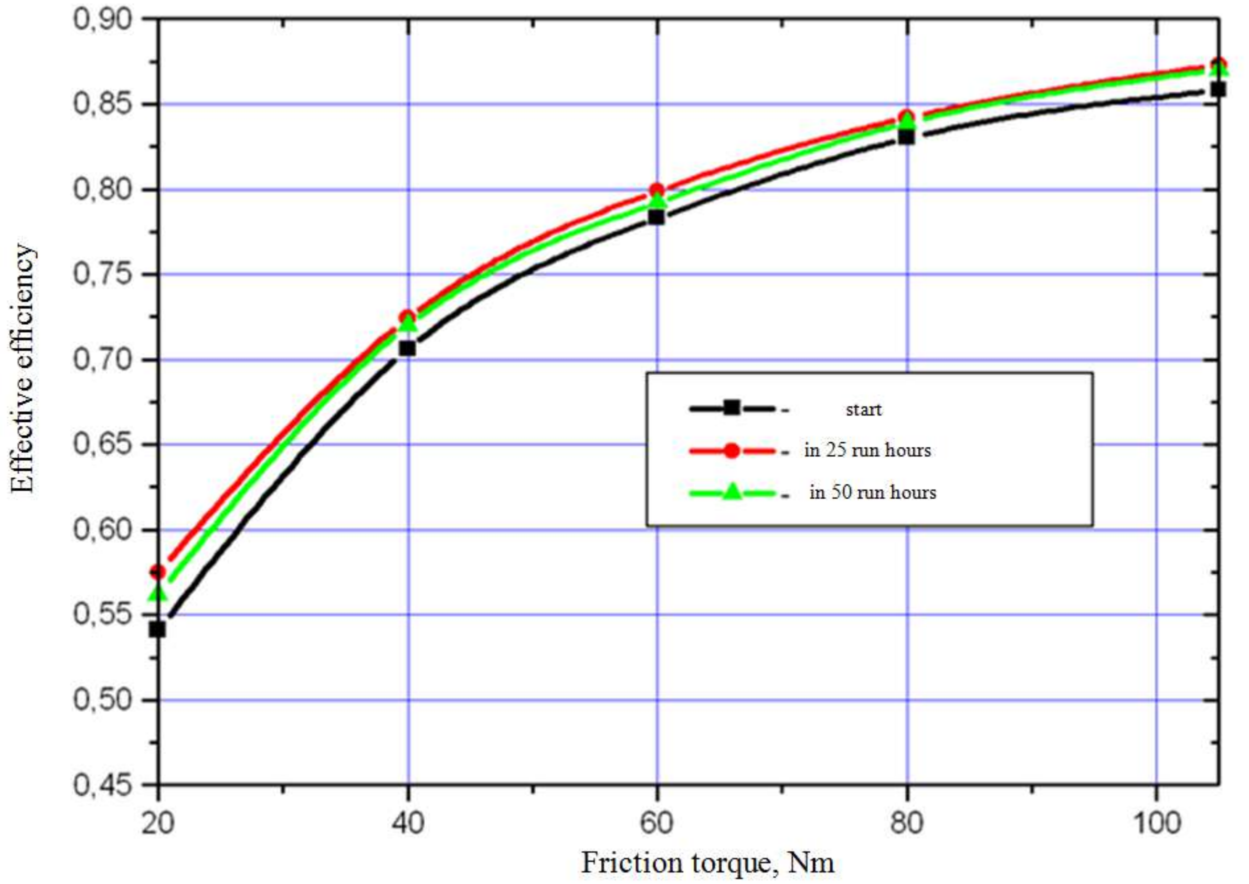

Fig. 18. Effective efficiency vs. torque @ 2000 RPM for VAZ-21083 engine after the first treatment with RESURS NEXT additive, depending on exposure period

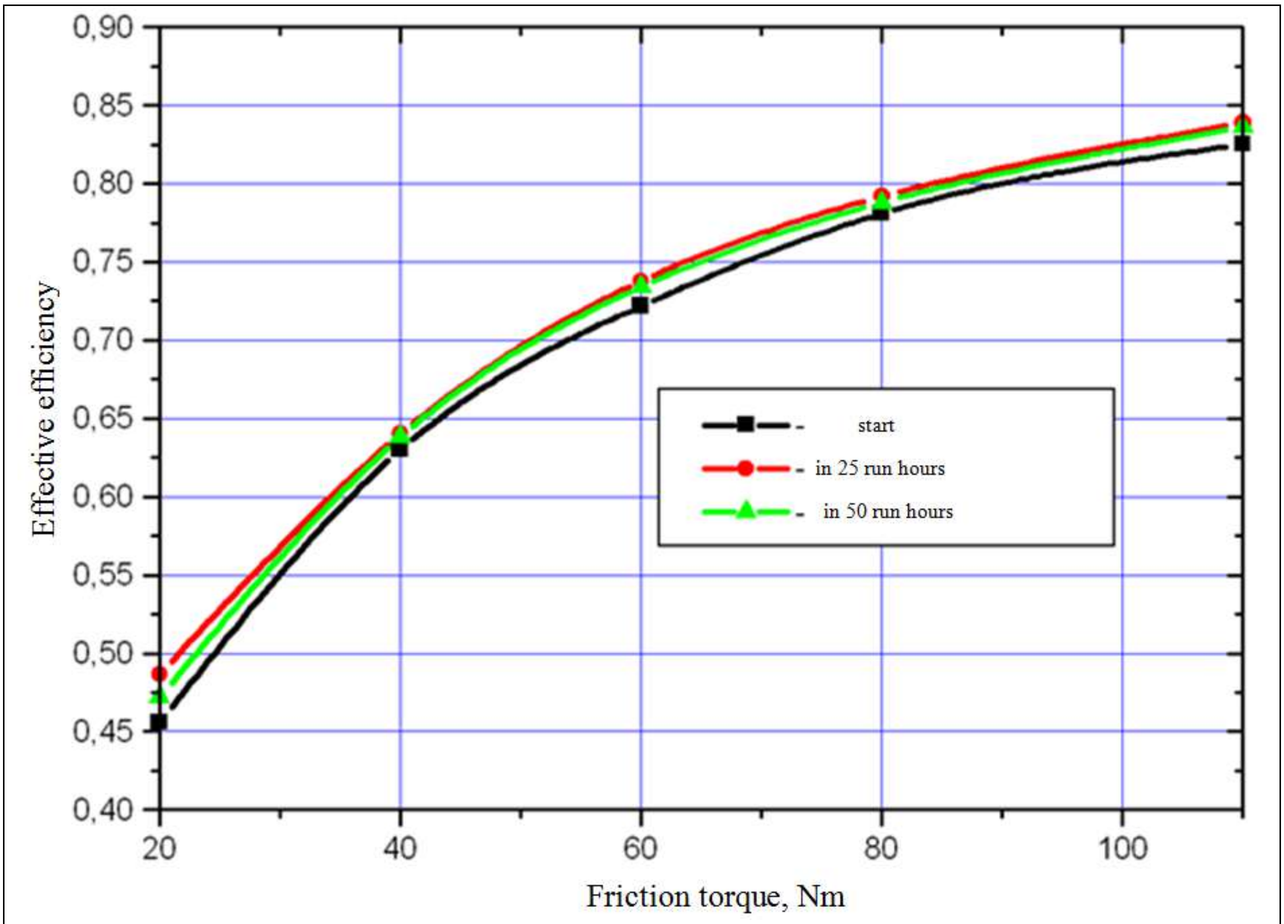

Fig. 19. Effective efficiency vs. torque @ 3000 RPM for VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

Long-term tests. Phase 2 Load characteristic of VAZ-21083 engine n=2000 RPM											
Before the treatment											
Test point Nr.	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	**ηe**	**ηм**	**CO, %**	**CO_2, %**	**CH, ppm**	**NO, ppm**	**Pм, bar**	**Tм, ^0C**
1	20,54	4,30	2,21	0,513	0,160	0,554	0,062	14,48	119	1246	2,15	85
2	40,57	8,50	3,13	0,369	0,222	0,716	0,065	14,57	132	1816	2,10	87
3	61,36	12,85	3,94	0,307	0,267	0,798	0,115	14,61	140	2340	2,05	88
4	81,13	16,99	4,61	0,271	0,302	0,844	0,346	14,40	115	2294	2,00	90
5	103,4	21,66	6,63	0,306	0,268	0,877	4,778	11,25	184	902	1,95	93
In 25 hours after the treatment												
1	20,28	4,25	2,09	0,492	0,166	0,566	0,057	14,42	110	1169	2,25	83
2	40,57	8,50	3,09	0,364	0,225	0,726	0,060	14,52	119	1750	2,15	85
3	59,83	12,53	3,80	0,293	0,270	0,799	0,107	14,57	124	2267	2,10	86
4	81,13	16,99	4,48	0,263	0,311	0,846	0,311	14,46	104	2204	2,10	89
5	105,0	21,98	6,54	0,297	0,275	0,879	4,480	11,40	168	870	2,00	90
In 50 hours after the treatment												
1	20,42	4,28	2,10	0,492	0,166	0,552	0,059	14,42	107	1184	2,25	84
2	41,86	8,77	3,17	0,361	0,226	0,720	0,064	14,56	118	1715	2,20	86
3	61,25	12,83	3,87	0,301	0,271	0,793	0,114	14,51	122	2158	2,15	86
4	81,67	17,10	4,53	0,265	0,309	0,838	0,335	14,40	107	2235	2,10	90
5	105,2	22,02	6,65	0,302	0,271	0,872	4,579	11,46	172	849	2,05	91

Table 9. Load characteristics of VAZ-21083 engine @ 2000 RPM after treatment with RESURS NEXT additive, depending on exposure period

Long-term tests. Phase 2 Load characteristic of VAZ-21083 engine n=3000 RPM											
Before the treatment											
Test point Nr.	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	**ηe**	**ηм**	**CO, %**	**CO_2, %**	**CH, ppm**	**NO, ppm**	**Pм, bar**	**Tм, ^0C**
1	20,43	6,42	2,79	0,434	0,188	0,462	0,131	14,70	104	2114	2,50	87
2	41,37	13,00	3,90	0,308	0,270	0,628	0,129	14,84	119	2675	2,45	90
3	61,29	19,26	4,90	0,254	0,322	0,725	0,155	14,91	122	2928	2,40	90
4	81,22	25,51	6,39	0,251	0,326	0,780	0,498	14,65	105	2875	2,35	92
5	110,8	34,82	10,13	0,291	0,281	0,831	6,884	10,41	187	828	2,30	93
In 25 hours after the treatment												
1	20,20	6,35	2,77	0,436	0,187	0,470	0,124	14,76	101	2056	2,60	84
2	40,92	12,85	3,77	0,298	0,279	0,637	0,118	14,80	108	2580	2,55	87
3	62,15	19,53	4,83	0,248	0,331	0,739	0,148	14,84	115	2876	2,45	88
4	82,87	26,03	6,21	0,239	0,343	0,793	0,512	14,69	99	2744	2,40	90
5	113,7	35,72	9,87	0,276	0,296	0,844	6,740	10,67	170	895	2,35	91
In 50 hours after the treatment												
1	21,05	6,61	2,83	0,428	0,191	0,474	0,130	14,71	107	2148	2,60	84
2	41,59	13,07	3,81	0,291	0,281	0,633	0,122	14,65	110	2528	2,60	88
3	62,90	19,76	4,89	0,247	0,331	0,735	0,141	14,80	119	2790	2,50	89
4	83,70	26,29	6,27	0,238	0,343	0,789	0,559	14,60	102	2775	2,45	91
5	113,9	35,77	10,05	0,281	0,291	0,838	6,893	10,72	176	870	2,40	92

Table 10. Load characteristics of VAZ-21083 engine @ 3000 RPM after treatment with RESURS NEXT additive, depending on exposure period

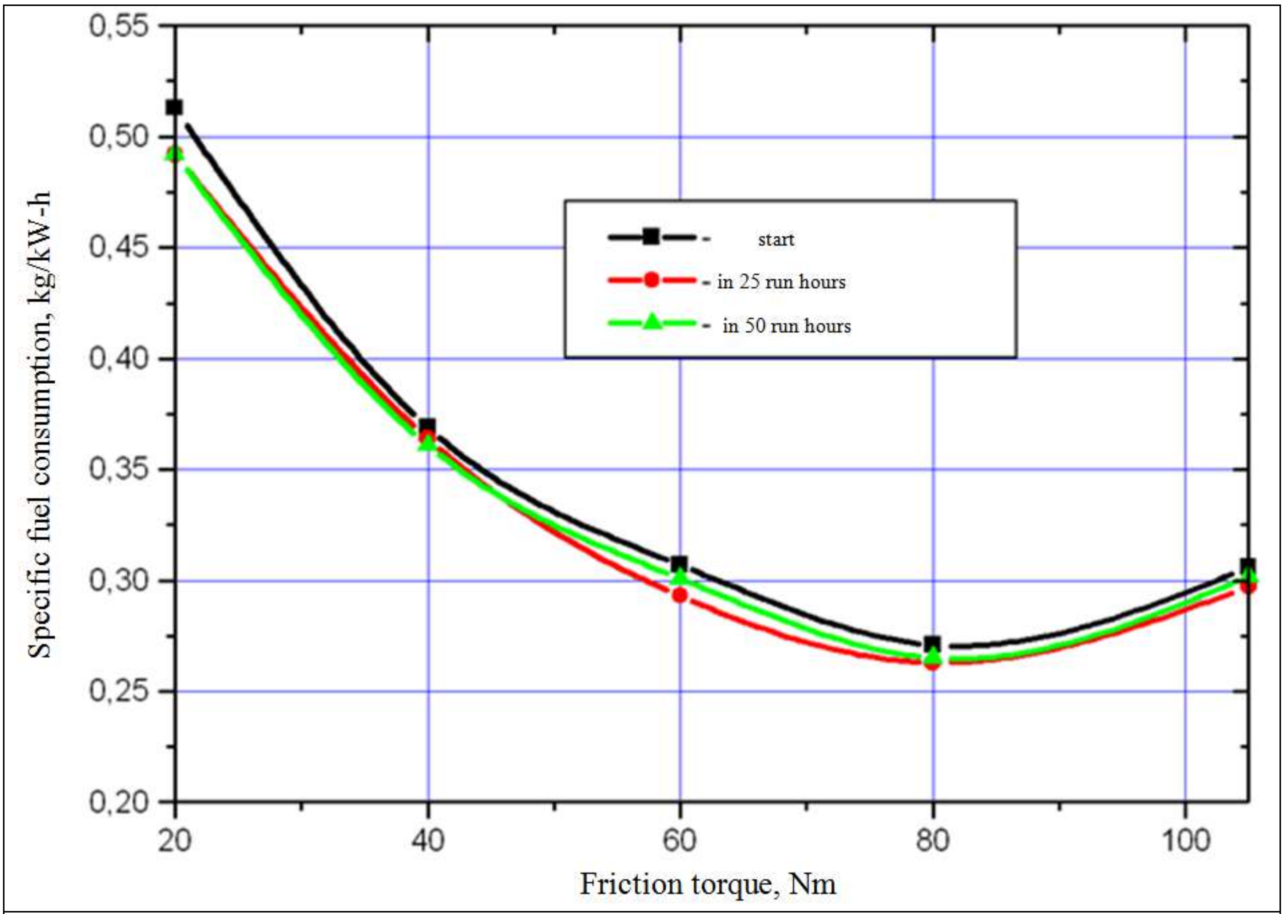

Fig. 20. Specific fuel consumption vs. torque @ 2000 RPM for VAZ-21083 engine after the second treatment with RESURS NEXT additive, depending on exposure period

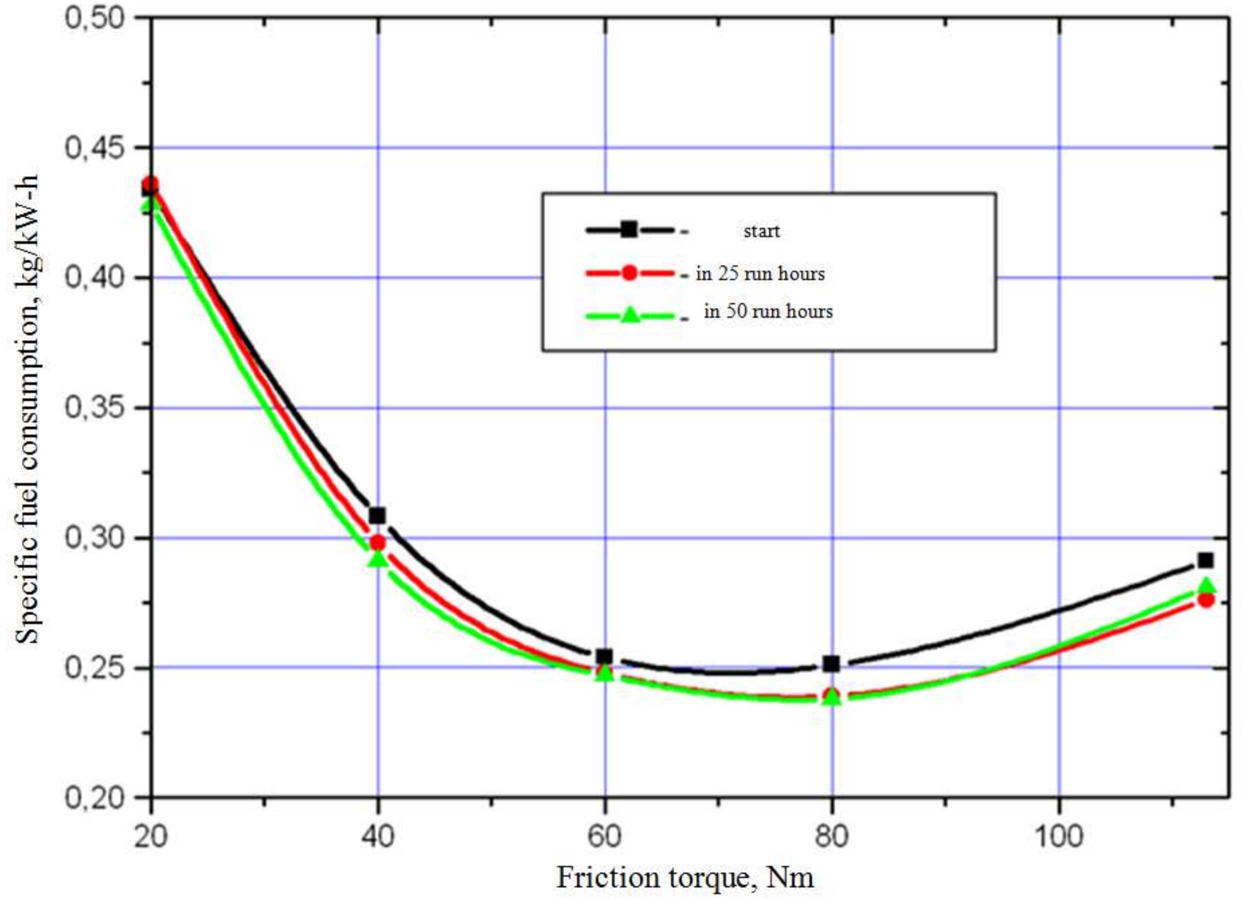

Fig. 21. Specific fuel consumption vs. torque @ 3000 RPM for VAZ-21083 engine after the second treatment with RESURS NEXT additive, depending on exposure period

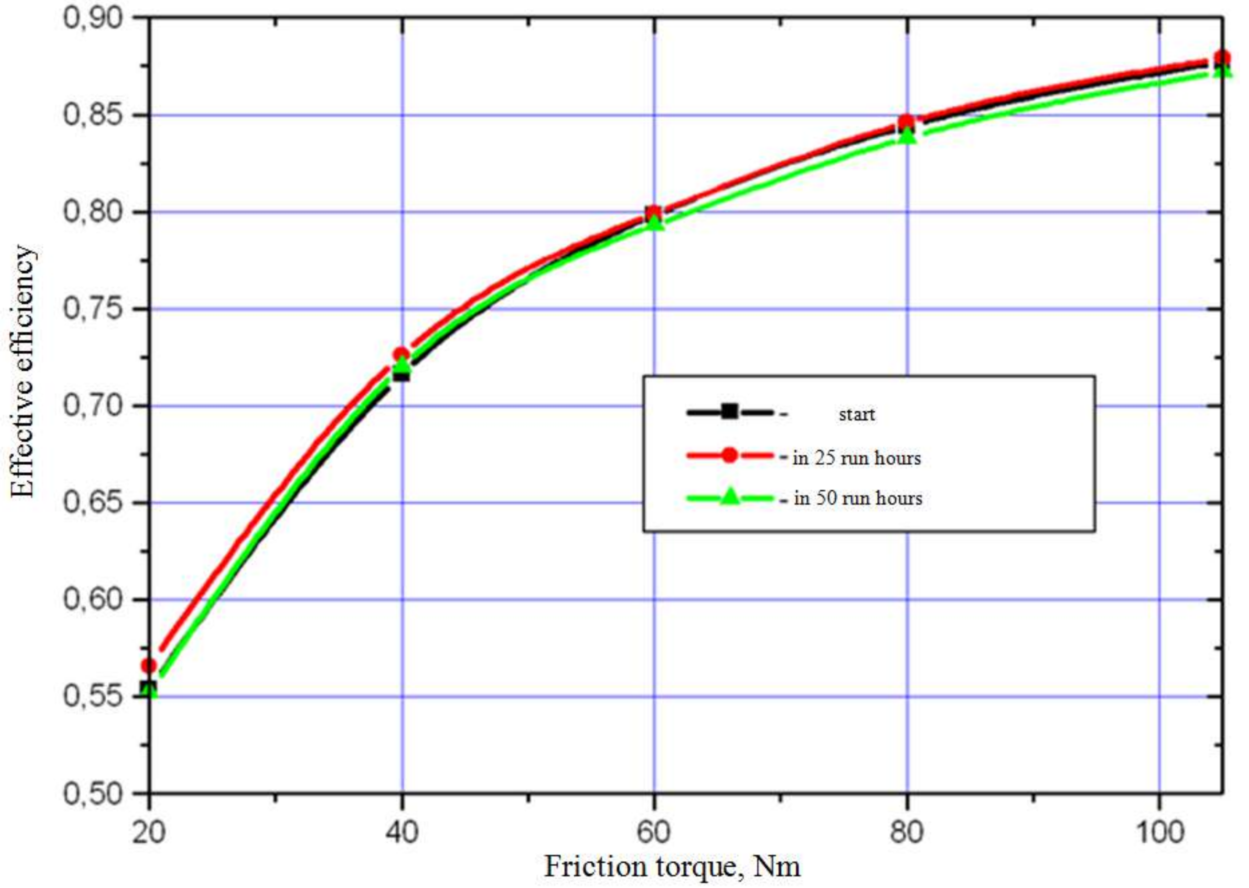

Fig. 22. Effective efficiency vs. torque @ 2000 RPM for VAZ-21083 engine after the second treatment with RESURS NEXT additive, depending on exposure period

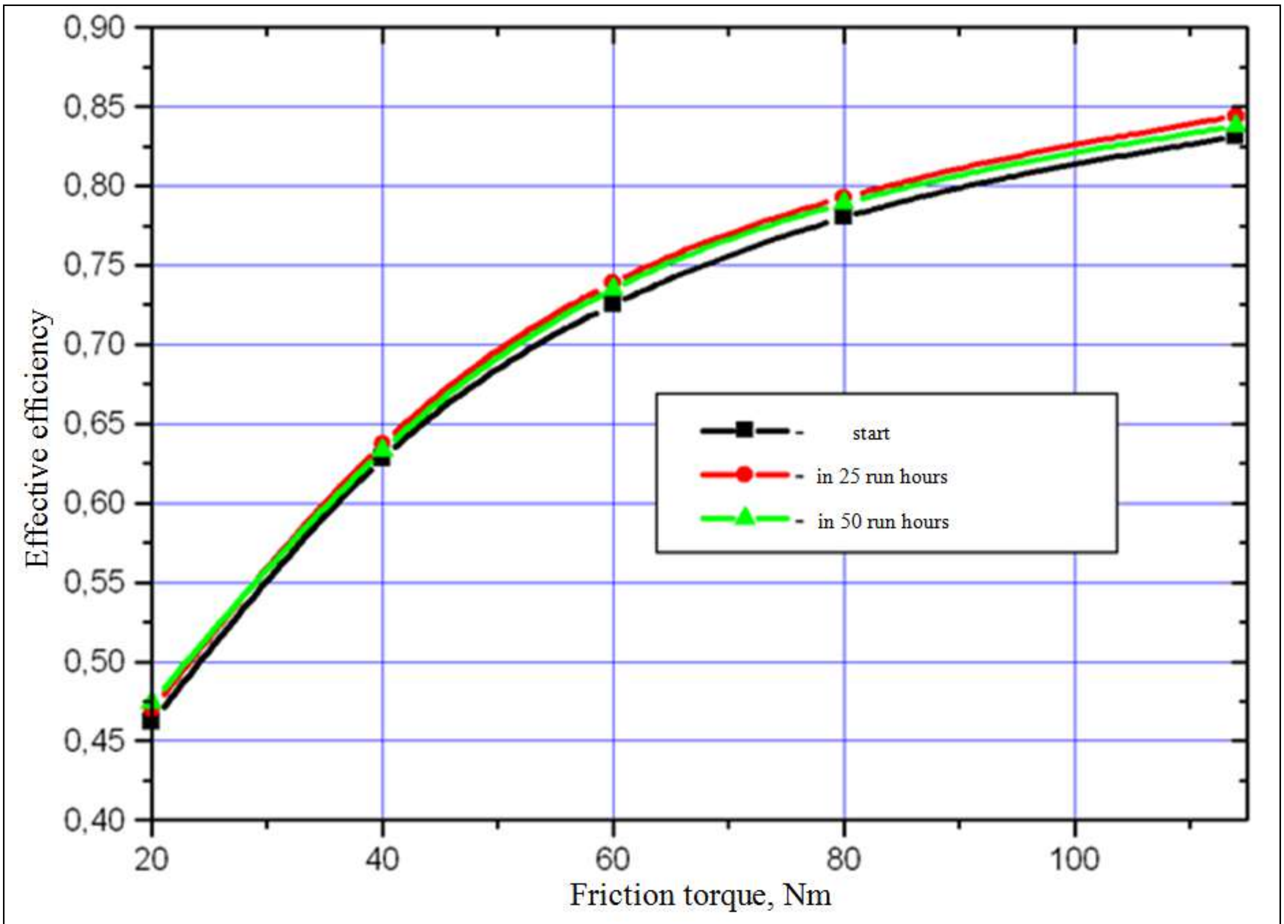

Fig. 23. Effective efficiency vs. torque @ 3000 RPM for VAZ-21083 engine after the second treatment with RESURS NEXT additive, depending on exposure period

Long-term tests. Assessment of the duration of treatment aftereffect
Load characteristic of VAZ-21083 engine
n=2000 RPM

Test point Nr.	Me, Nm	Ne, kW	Gт, kg/h	ge, kg/ kw-h	ηe	ηм	CO, %	CO_2, %	CH, ppm	NO, ppm	Pм, bar	Tм, ^0C
Start												
1	21,55	4,51	2,19	0,490	0,167	0,551	0,057	14,42	110	1199	2,25	84
2	42,05	8,81	3,05	0,346	0,237	0,718	0,061	14,53	125	1874	2,25	85
3	64,13	13,43	3,89	0,290	0,282	0,798	0,104	14,58	130	2215	2,20	87
4	84,63	17,72	4,57	0,258	0,318	0,842	0,325	14,42	116	2316	2,15	90
5	108,3	22,68	6,69	0,295	0,278	0,875	4,550	11,17	178	945	2,10	91
In 25 running hours after the treatment												
1	20,50	4,29	2,17	0,505	0,162	0,544	0,059	14,47	112	1215	2,20	86
2	42,58	8,92	3,02	0,338	0,242	0,709	0,064	14,50	130	1995	2,15	88
3	63,60	13,32	3,94	0,295	0,277	0,787	0,115	14,53	139	2262	2,10	90
4	84,63	17,72	4,60	0,259	0,315	0,834	0,574	14,36	122	2345	2,10	92
5	106,7	22,35	6.79	0,300	0,272	0,866	4,694	11,02	189	887	2,05	93
In 50 running hours after the treatment												
1	19,97	4,18	2,22	0,522	0,154	0,533	0,062	14,38	118	1246	2,15	88
2	42,05	8,81	3,12	0,354	0,231	0,700	0,070	14,36	141	2055	2,10	89
3	64,13	13,43	3,99	0,297	0,275	0,782	0,124	14,42	143	2335	2,10	91
4	84,63	17,72	4,71	0,266	0,308	0,827	0,652	14,26	131	2376	2,05	94
5	105,1	22,02	6,63	0,301	0,272	0,857	4,887	10,58	204	695	2,00	96

Table 11. Assessment of the duration of treatment aftereffect. Load characteristics of VAZ-21083 engine @ 2000 RPM after treatment with RESURS NEXT additive, depending on exposure period

Long-term tests. Assessment of the duration of treatment aftereffect Load characteristic of VAZ-21083 engine n=3000 RPM											
Start											
Test point Nr.	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	**ηe**	**ηм**	**CO, %**	**CO_2, %**	**CH, ppm**	**NO, ppm**	**Pм, bar**	**Tм, ^0C**
1	21,39	6,72	2,74	0,408	0,201	0,471	0,122	14,61	106	2045	2,65	84
2	42,26	13,28	3,91	0,300	0,272	0,630	0,121	14,80	118	2625	2,60	87
3	63,92	20,08	4,94	0,246	0,333	0,731	0,152	14,87	124	3004	2,55	88
4	83,99	26,39	6,04	0,229	0,258	0,783	0,552	14,60	101	2778	2,50	90
5	115,7	36,34	10,24	0,282	0,290	0,834	7,041	10,27	190	856	2,40	91
In 25 running hours after the treatment											
1	21,13	6,64	2,83	0,427	0,192	0,458	0,134	14,54	112	2180	2,60	86
2	43,32	13,61	3,99	0,307	0,272	0,626	0,140	14,62	121	2695	2,55	88
3	64,45	20,25	4,98	0,246	0,332	0,724	0,164	14,57	137	2954	2,50	90
4	85,57	26,88	6,04	0,225	0,364	0,779	0,620	14,42	115	2710	2,40	92
5	115,2	36,18	10,45	0,291	0,285	0,828	7,154	10,10	196	805	2,30	93
In 50 running hours after the treatment											
1	22,19	6,97	3,00	0,430	0,190	0,462	0,151	14,48	120	2270	2,45	88
2	42,26	13,28	4,06	0,309	0,269	0,624	0,162	14,40	126	2684	2,40	90
3	64,45	20,25	5,07	0,250	0,327	0,719	0,175	14,54	142	2810	2,35	92
4	84,52	26,55	6,14	0,231	0,354	0,772	0,740	14,15	126	2784	2,25	94
5	113,0	35,51	10,25	0,289	0,284	0,822	7,421	10,08	210	710	2,20	96

Table 12. Assessment of the duration of treatment aftereffect. Load characteristics of VAZ-21083 engine @ 3000 RPM after treatment with RESURS NEXT additive, depending on exposure period

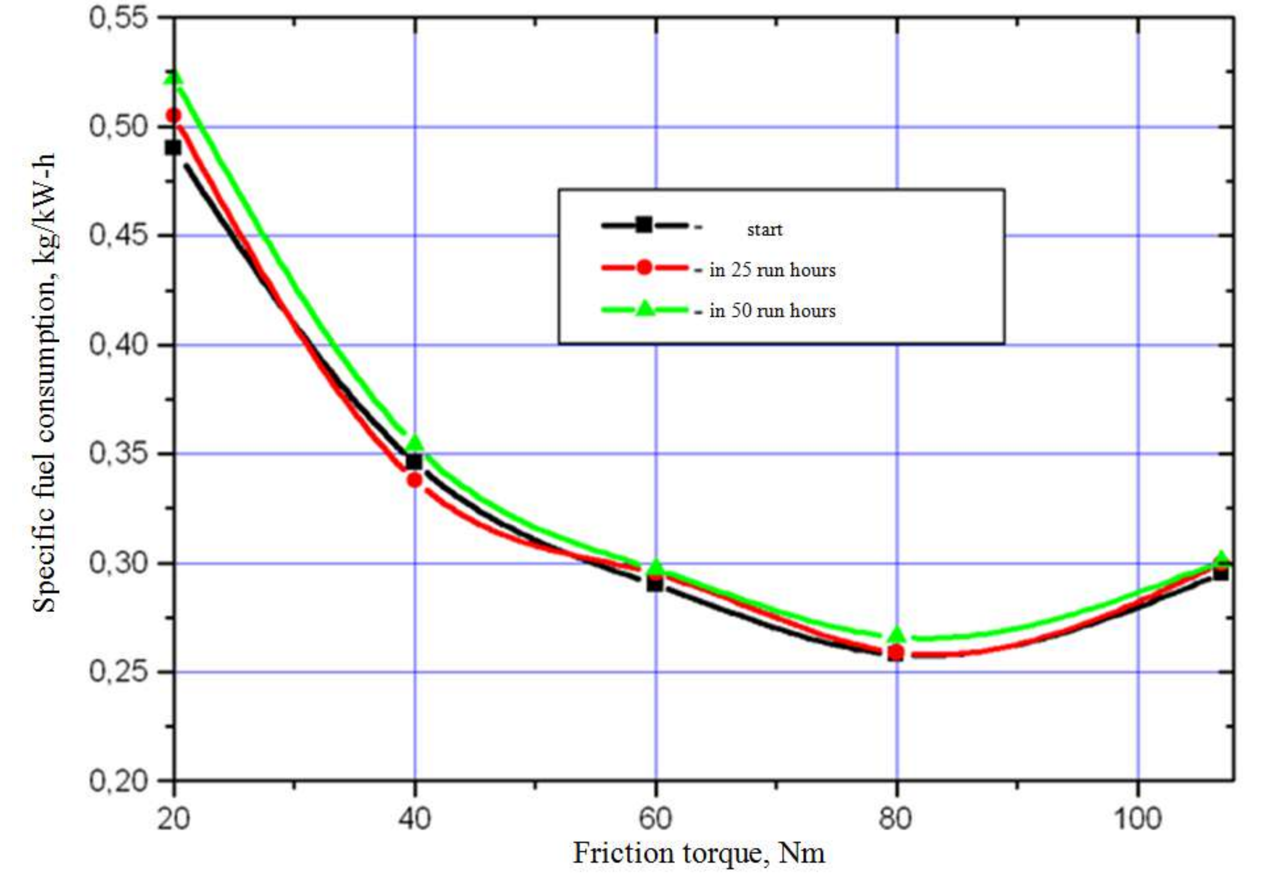

Fig. 24. Assessment of the duration of treatment aftereffect. Specific fuel consumption vs. torque @ 2000 RPM for VAZ-21083 engine after the second treatment with RESURS NEXT additive, depending on exposure period

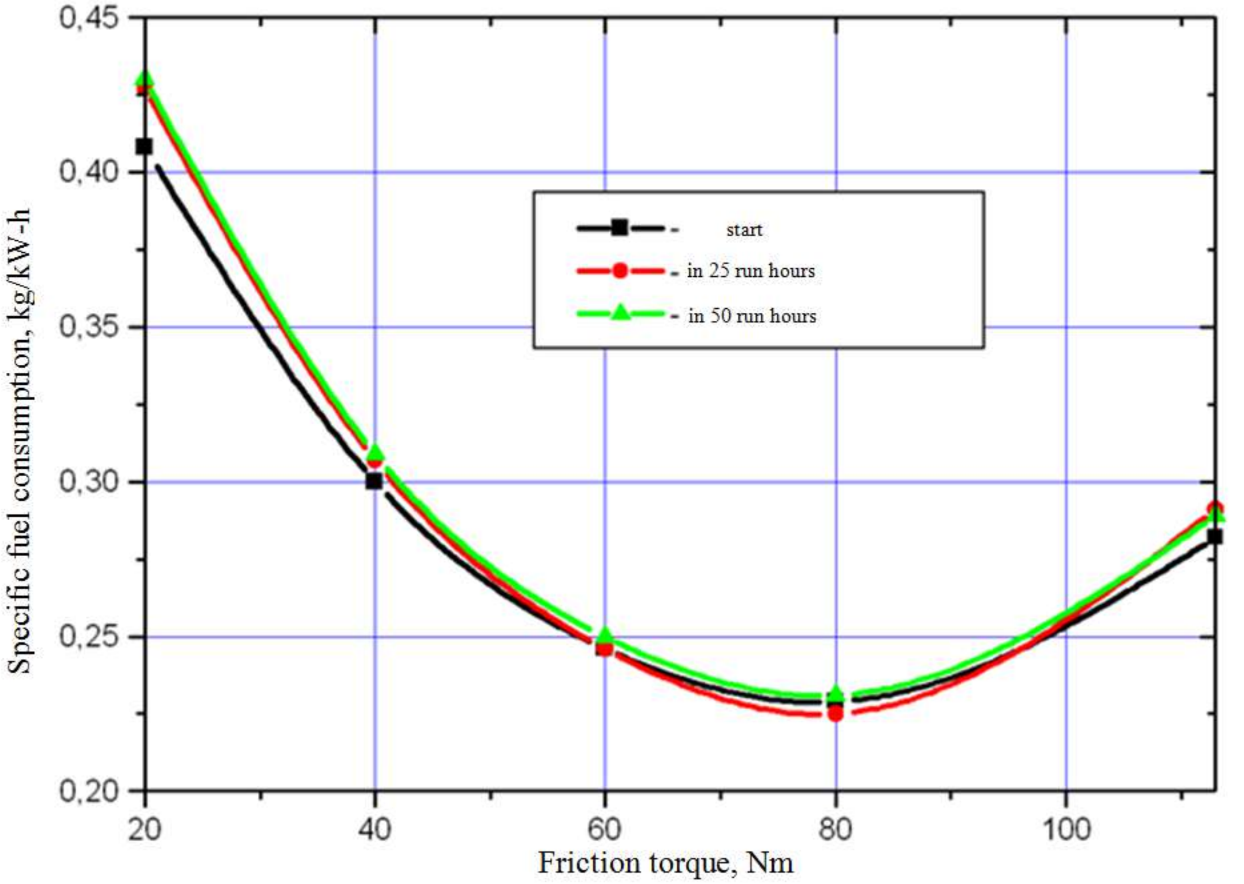

Fig. 25. Assessment of the duration of treatment aftereffect. Specific fuel consumption vs. torque @ 3000 RPM for VAZ-21083 engine after the second treatment with RESURS NEXT additive, depending on exposure period

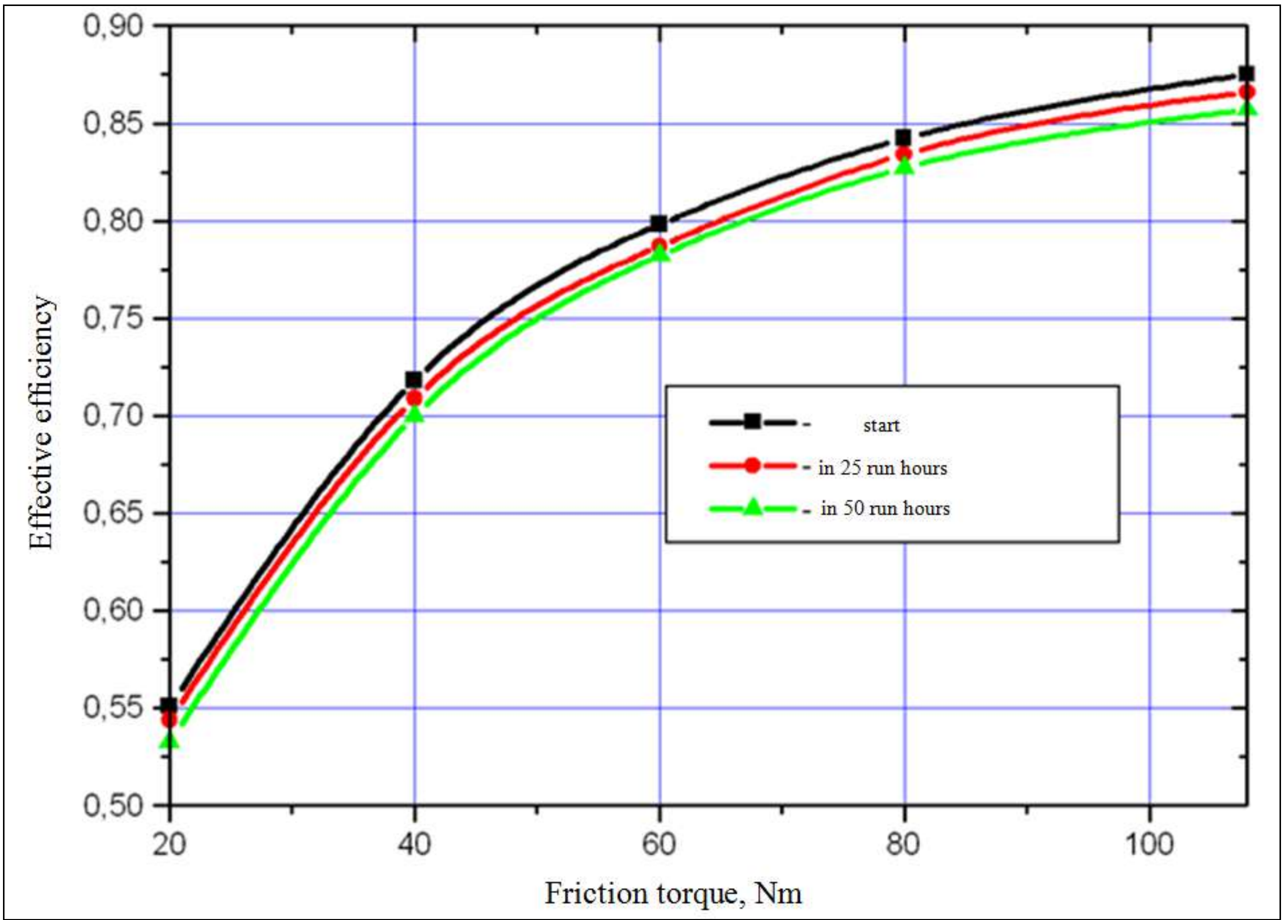

Fig. 26. Assessment of the duration of treatment aftereffect. Effective efficiency vs. torque @ 2000 RPM for VAZ-21083 engine after the second treatment with RESURS NEXT additive, depending on exposure period

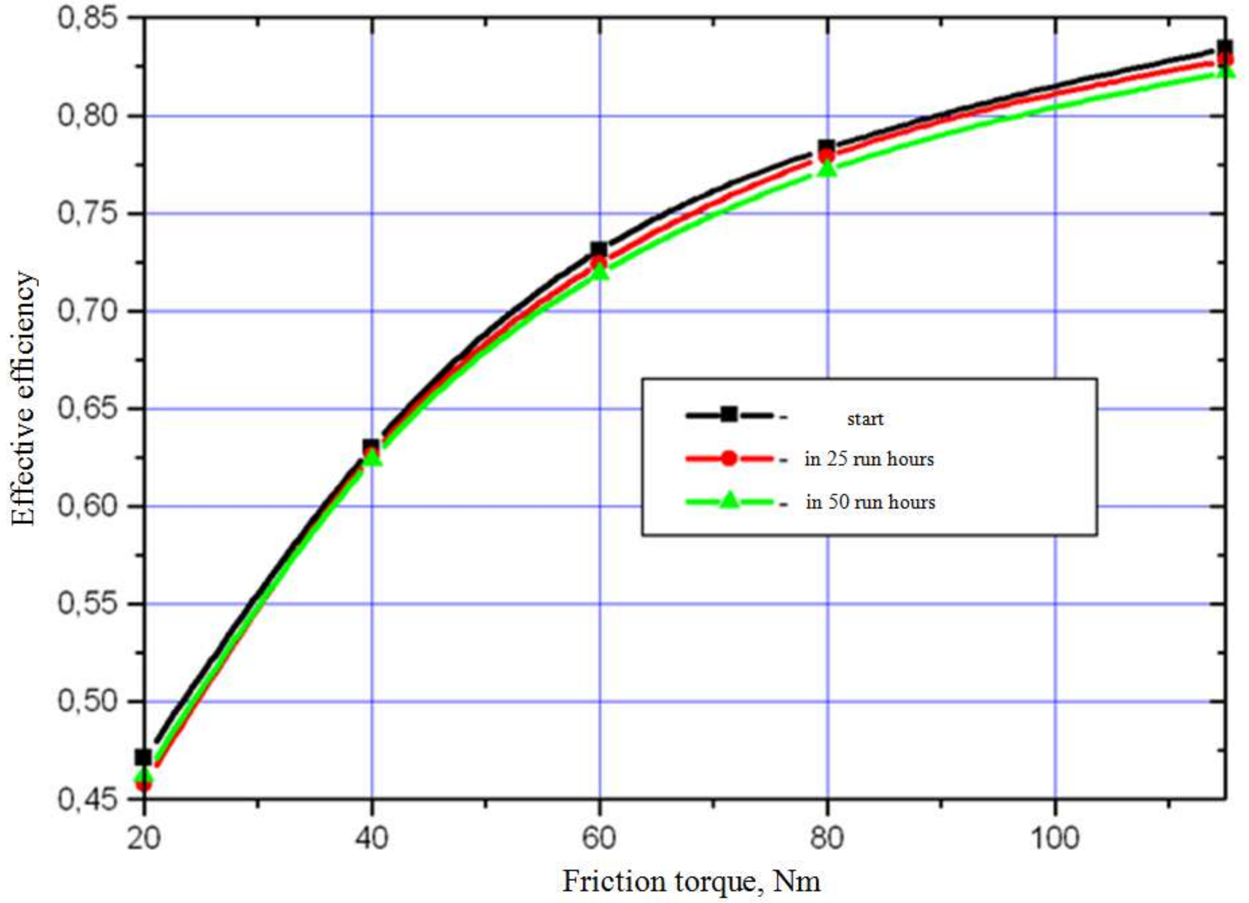

Fig. 27. Assessment of the duration of treatment aftereffect. Effective efficiency vs. torque @ 3000 RPM for VAZ-21083 engine after the second treatment with RESURS NEXT additive, depending on exposure period

See Tables 13…15 and Figs. 28…39 for the results of each test phase (load characteristics).

Engine type VAZ-21083: full-load curve.
Long-term tests, 1st treatment with RESURS NEXT

Before the treatment								
RPM	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	η_e	$\eta_м$	**Pм, bar**	**Tм, ^{0}C**
1500	89,62	14,08	5,44	0,387	0,212	0,845	1,60	89
2000	100,95	21,14	6,85	0,324	0,253	0,840	1,85	94
2500	104,04	27,24	8,68	0,319	0,257	0,829	1,95	96
3000	108,17	33,98	10,23	0,301	0,272	0,809	2,10	98
3500	112,29	41,15	11,96	0,291	0,281	0,786	2,25	99
4000	110,23	46,17	14,21	0,308	0,266	0,759	2,40	101
In 25 hours after the treatment								
1500	92,71	14,56	5,40	0,371	0,221	0,865	1,75	84
2000	104,04	21,79	6,79	0,312	0,260	0,863	1,95	90
2500	105,07	27,51	8,61	0,315	0,269	0,837	2,10	92
3000	110,23	34,63	10,09	0,291	0,281	0,821	2,25	93
3500	114,35	41,91	12,04	0,287	0,285	0,806	2,40	94
4000	113,25	47,47	14,15	0,298	0,275	0,780	2,45	97
In 50 hours after the treatment								
RPM	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	η_e	$\eta_м$	**Pм, bar**	**Tм, ^{0}C**
1500	93,23	14,64	5,46	0,373	0,220	0,865	1,75	85
2000	104,56	21,90	6,86	0,313	0,261	0,860	1,90	91
2500	105,07	27,51	8,76	0,318	0,57	0,833	2,10	92
3000	110,74	34,79	10,23	0,294	0,278	0,822	2,30	94
3500	113,32	41,53	12,23	0,295	0,278	0,802	2,40	95
4000	112,29	47,03	14,27	0,303	0,270	0,778	2,45	98

Table 13. Speed characteristics at maximum load of VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

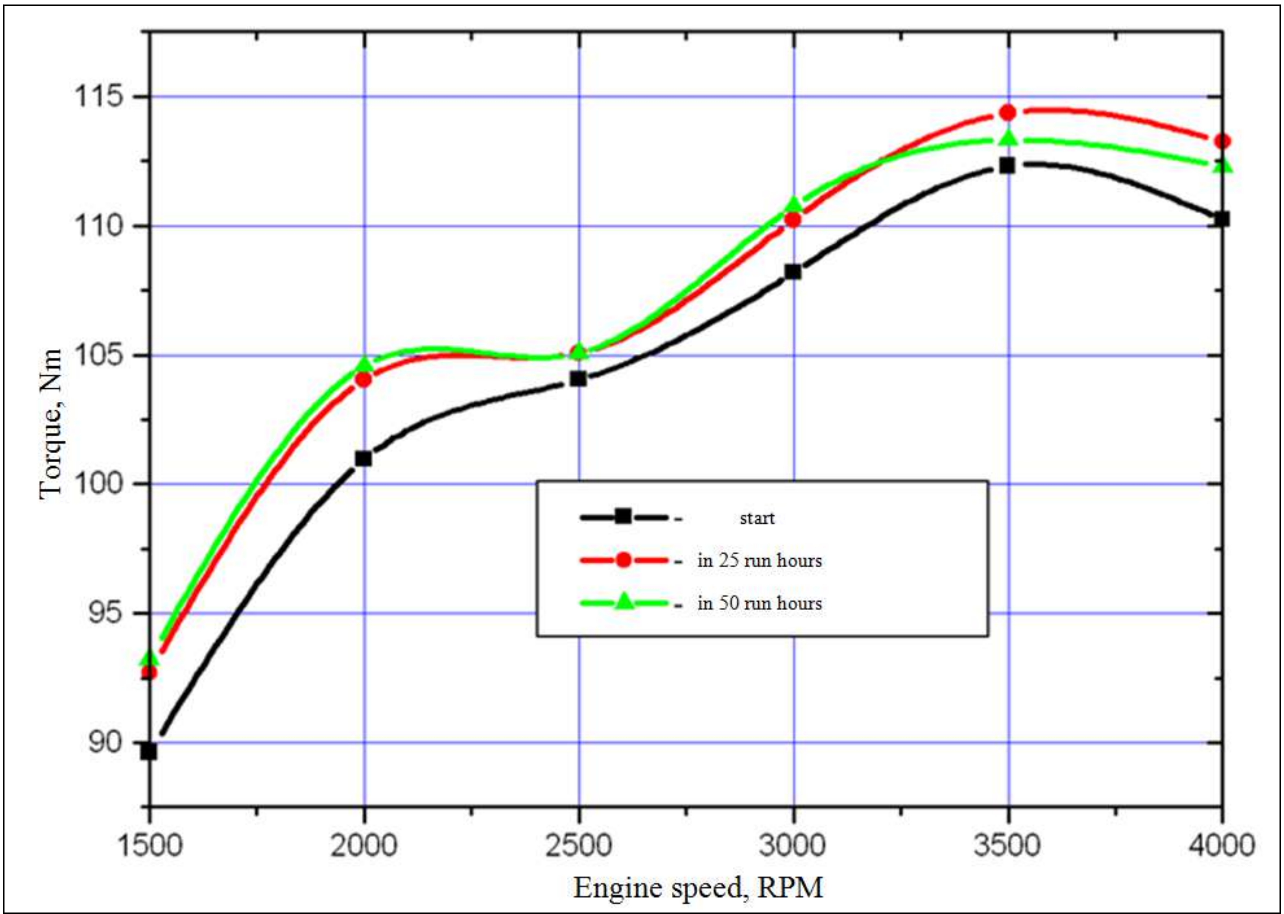

Fig. 28. Torque vs. speed curves for VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

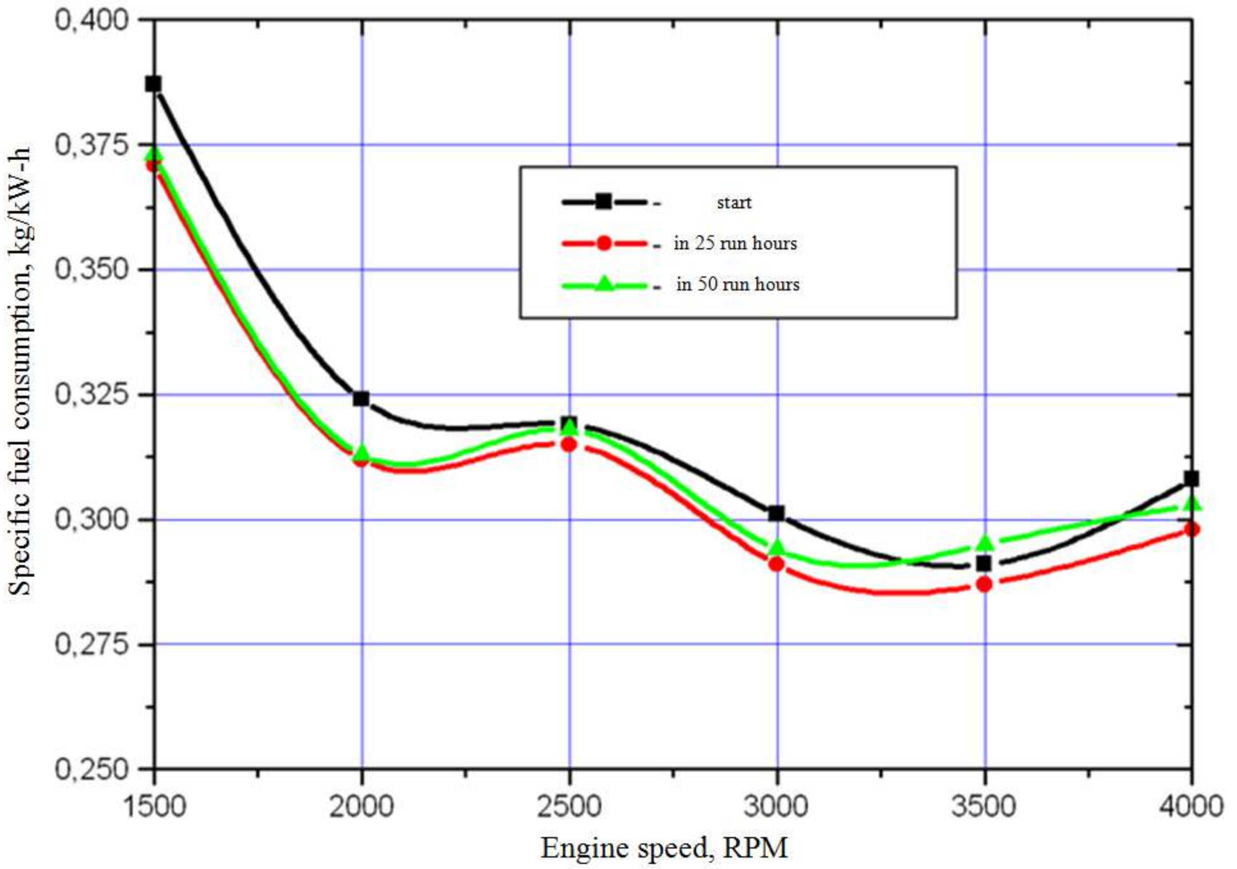

Fig. 29. Specific fuel consumption vs. speed curve for VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

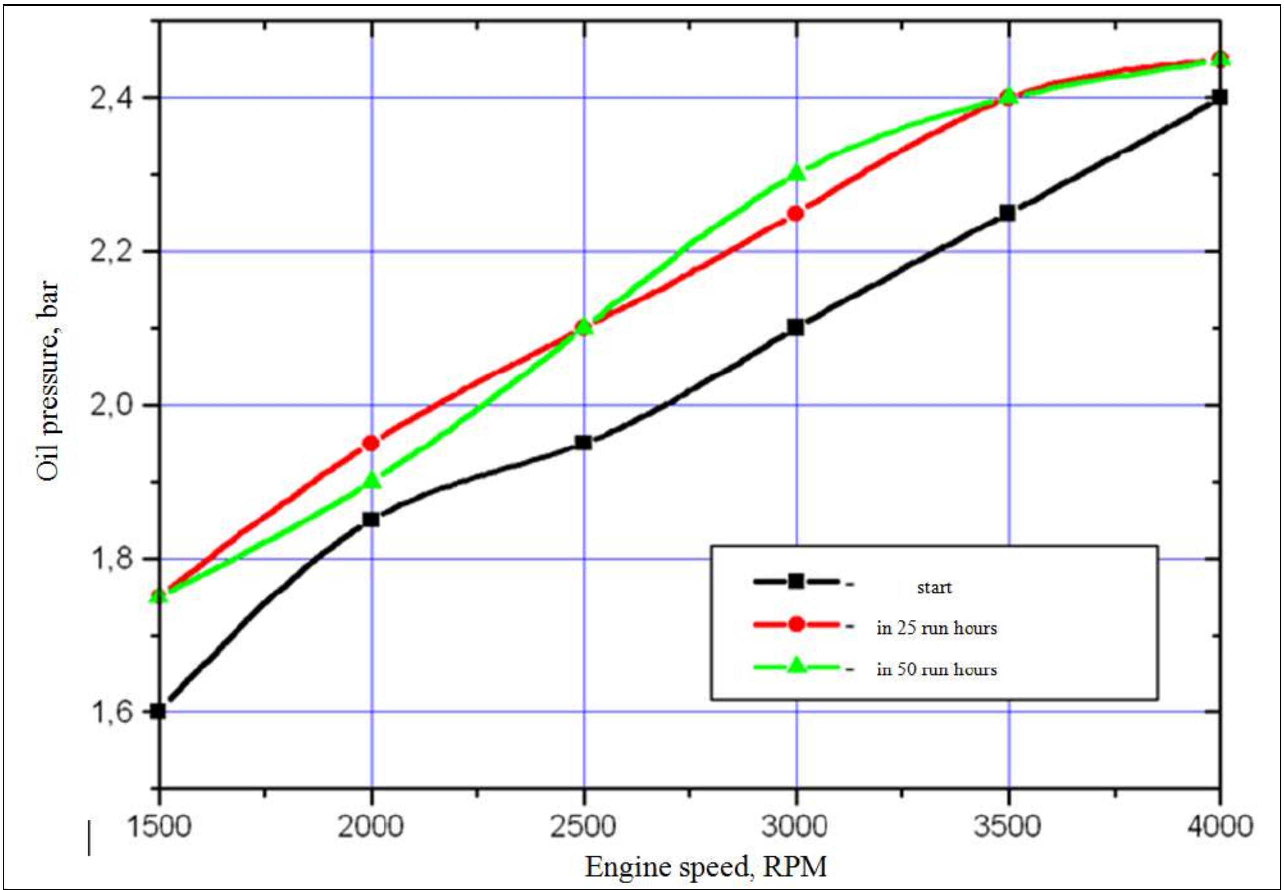

Fig. 30. Lube oil pressure vs. speed curve for VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

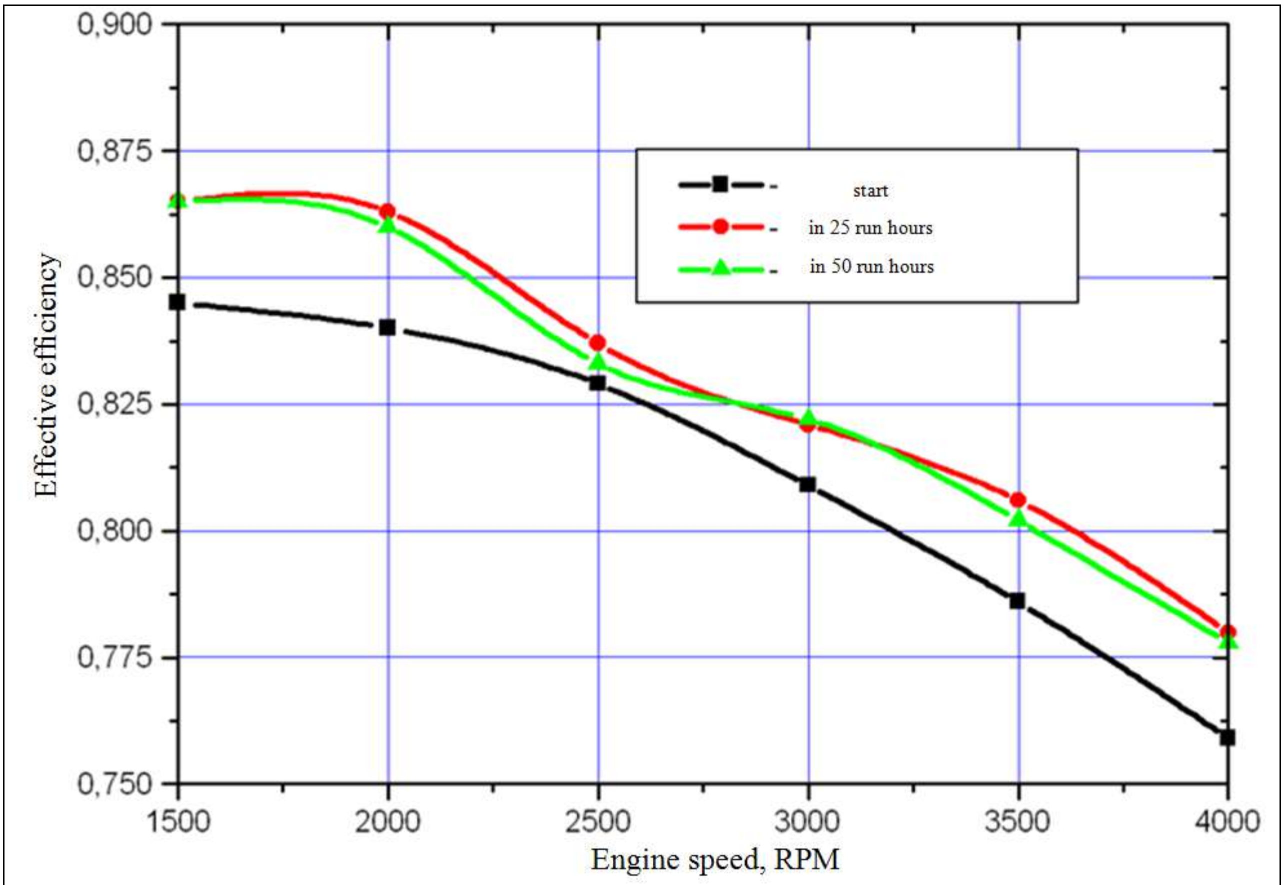

Fig. 31. Effective efficiency vs. speed curves for VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

Engine type VAZ-21083: full-load curve. Long-term tests, 2nd treatment with RESURS NEXT								
Before the treatment								
RPM	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	**η_e**	**$\eta_м$**	**Pм, bar**	**Tм, ^{0}C**
1500	94,47	14,84	5,59	0,376	0,217	0,867	1,75	84
2000	105,31	22,06	6,96	0,336	0,257	0,857	1,90	91
2500	107,37	28,11	8,77	0,312	0,262	0,833	2,05	93
3000	112,02	35,19	10,34	0,294	0,279	0,821	2,25	94
3500	113,57	41,62	12,12	0,291	0,281	0,802	2,30	95
4000	111,50	46,71	14,37	0,308	0,266	0,774	2,40	97
In 25 hours after the treatment								
1500	97,09	15,25	5,47	0,359	0,228	0,874	1,75	83
2000	108,05	22,63	6,97	0,315	0,258	0,871	1,95	90
2500	110,14	28,83	8,78	0,304	0,269	0,846	2,10	92
3000	114,57	35,99	10,07	0,280	0,292	0,830	2,30	93
3500	116,14	42,57	12,23	0,287	0,285	0,811	2,40	93
4000	113,79	47,66	14,26	0,299	0,273	0,789	2,45	95
In 50 hours after the treatment								
RPM	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	**η_e**	**$\eta_м$**	**Pм, bar**	**Tм, ^{0}C**
1500	95,24	14,96	5,53	0,369	0,222	0,868	1,75	84
2000	106,34	22,27	6,98	0,320	0,249	0,862	1,90	91
2500	108,40	28,38	8,79	0,310	0,264	0,838	2,10	92
3000	113,05	35,52	10,25	0,289	0,283	0,825	2,25	94
3500	114,60	42,00	12,05	0,287	0,285	0,804	2,35	94
4000	112,02	46,92	14,21	0,303	0,270	0,778	2,40	96

Table 14. Speed characteristics at maximum load of VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

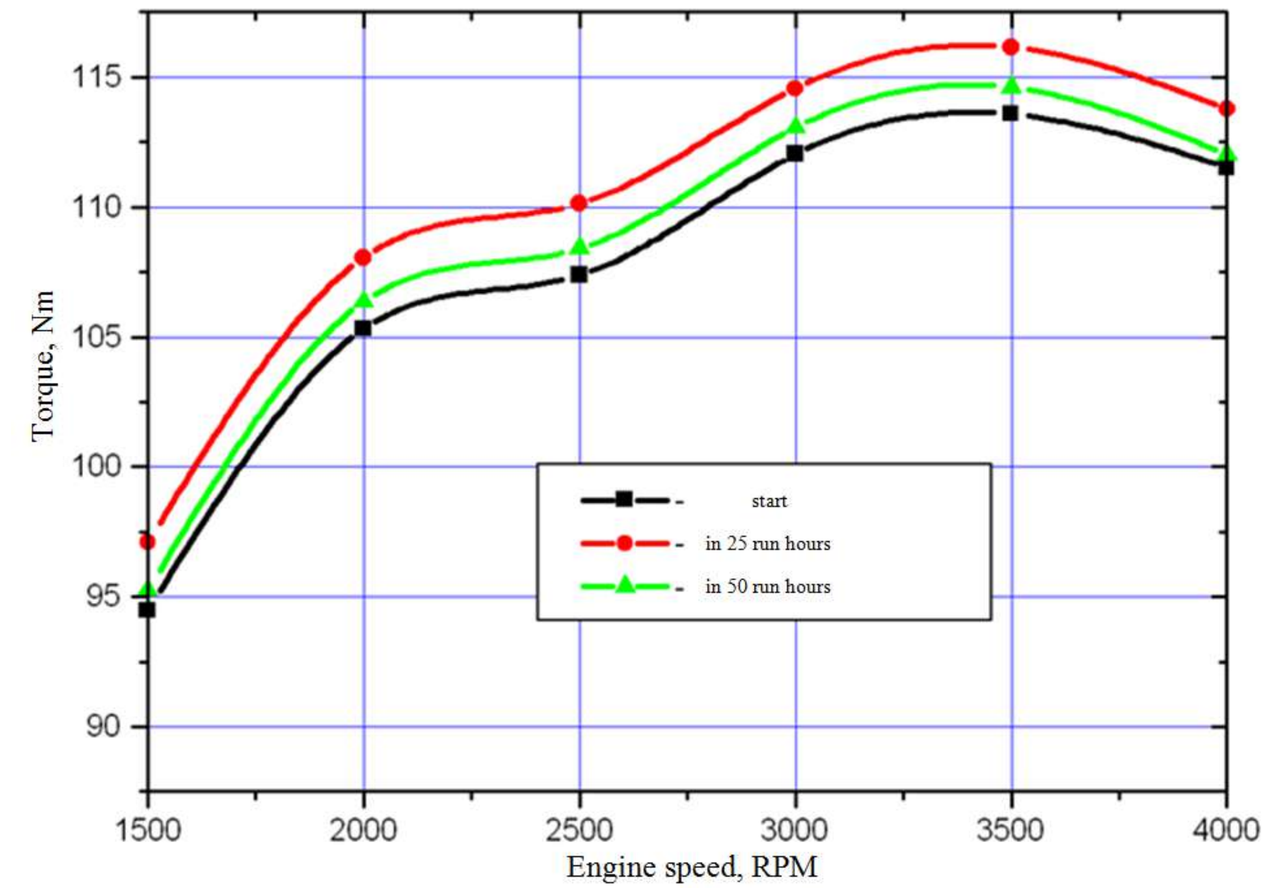

Fig. 32. Torque vs. speed curves for VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

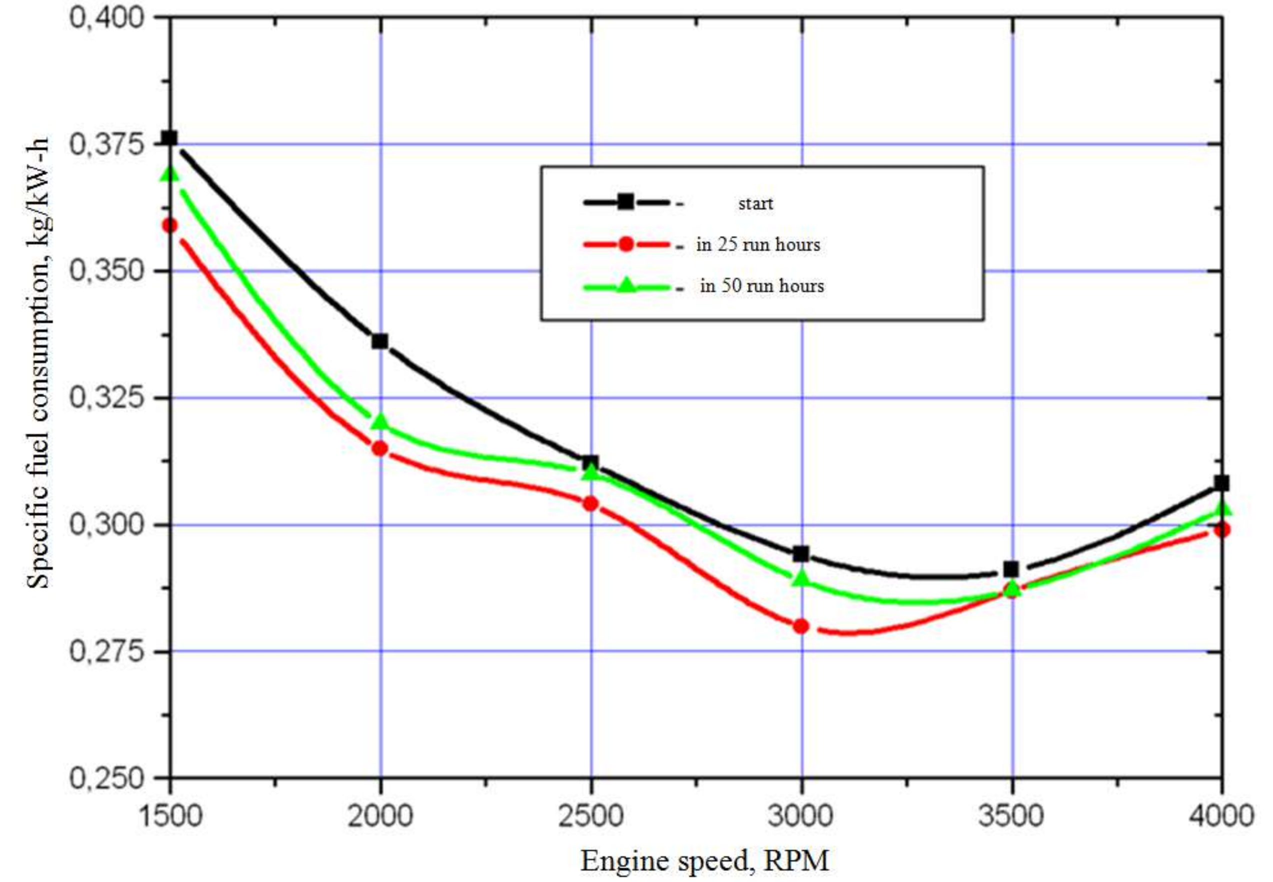

Fig. 33. Specific fuel consumption vs. speed curve for VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

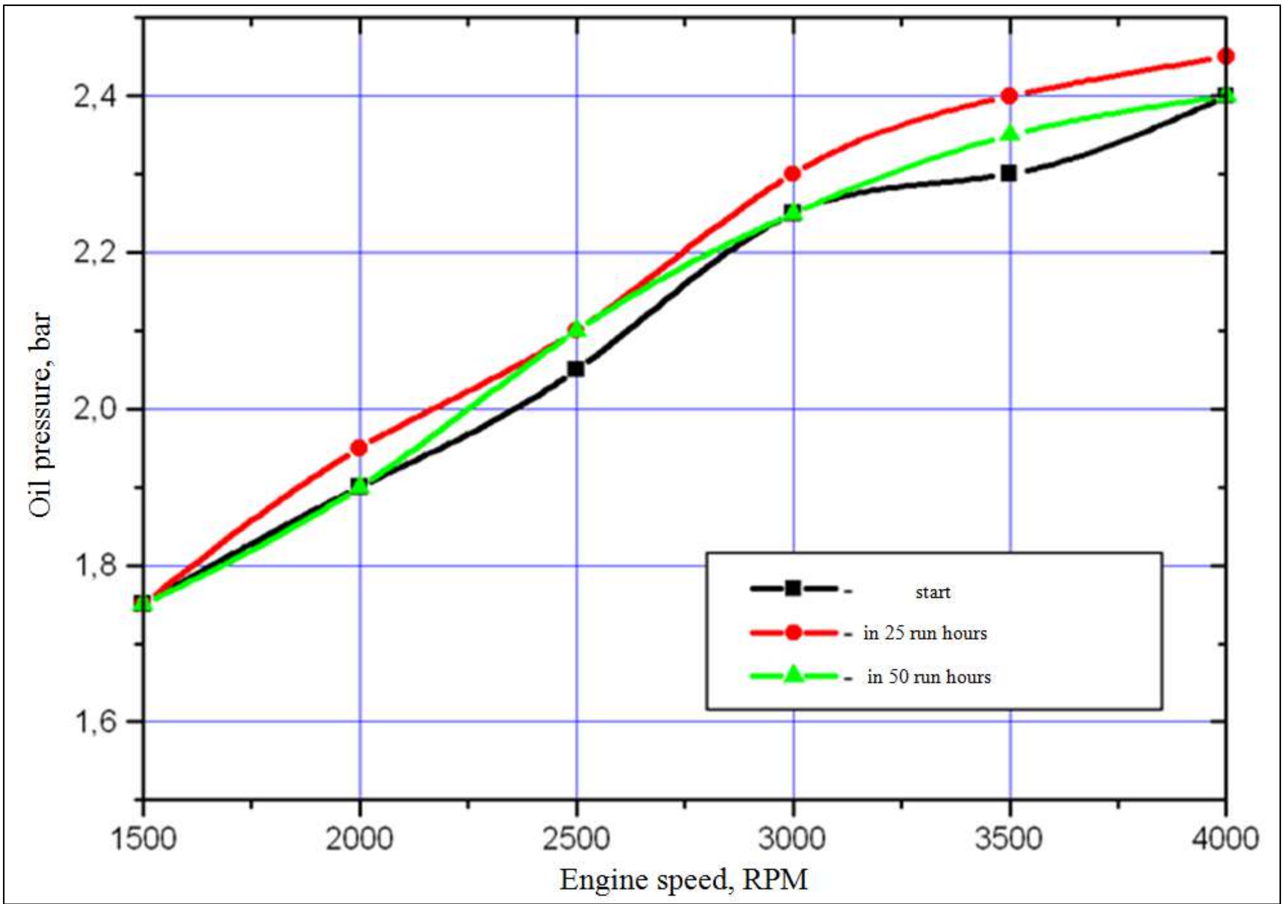

Fig. 34. Lube oil pressure vs. speed curve for VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

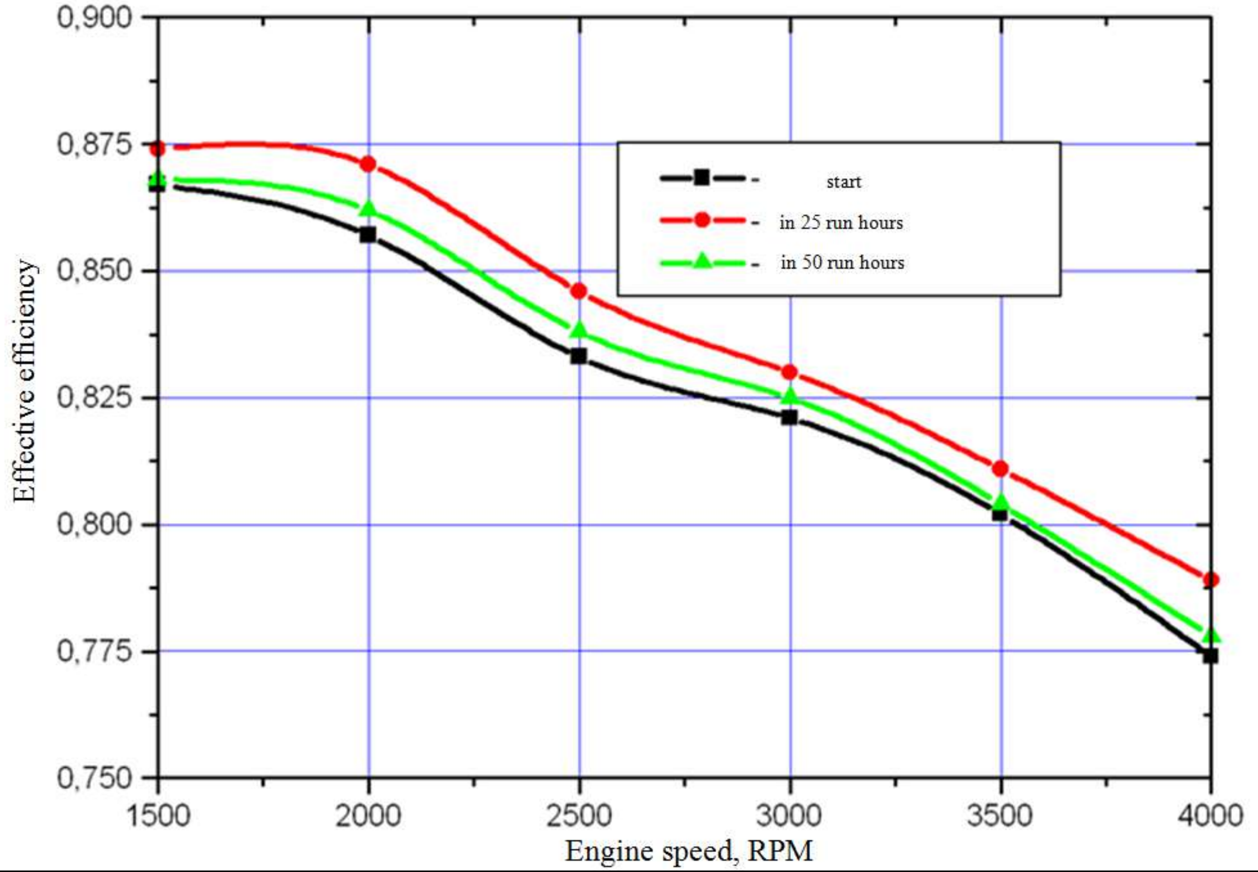

Fig. 35. Effective efficiency vs. speed curves for VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

Engine type VAZ-21083: full-load curve.
Assessment of sustainability of RESURS NEXT injection effect

Start								
RPM	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	η_e	$\eta_м$	**Pм, bar**	**Tм, ^{0}C**
1500	97,22	15,27	5,47	0,359	0,228	0,874	1,75	84
2000	108,84	22,80	6,99	0,314	0,263	0,875	1,90	91
2500	110,96	29,05	8,76	0,301	0,271	0,847	2,05	93
3000	115,71	36,35	10,45	0,287	0,285	0,834	2,25	94
3500	116,77	42,80	12,32	0,288	0,284	0,812	2,30	95
4000	114,66	48,03	14,03	0,292	0,280	0,793	2,40	96
In 25 running hours after the treatment								
1500	95,63	15,02	5,57	0,371	0,221	0,864	1,70	85
2000	107,26	22,46	6,82	0,319	0,258	0,867	1,85	93
2500	109,37	28,63	8,74	0,305	0,268	0,839	2,00	96
3000	115,18	36,19	10,25	0,283	0,289	0,828	2,15	97
3500	116,24	42,60	12,59	0,295	0,277	0,803	2,25	98
4000	113,07	47,36	14,30	0,302	0,271	0,782	2,30	99
In 50 running hours after the treatment								
RPM	**Me, Nm**	**Ne, kW**	**Gт, kg/h**	**ge, kg/ kw-h**	η_e	$\eta_м$	**Pм, bar**	**Tм, ^{0}C**
1500	94,05	14,77	5,63	0,381	0,215	0,859	1,65	86
2000	105,67	22,13	6,96	0,325	0,248	0,858	1,75	95
2500	108,32	28,36	8,84	0,312	0,262	0,831	1,85	96
3000	113,07	35,52	10,45	0,294	0,278	0,822	2,10	98
3500	113,60	41,64	12,47	0,300	0,273	0,799	2,15	98
4000	111,49	46,70	14,48	0,310	0,264	0,772	2,20	100

Table 15. Assessment of the duration of treatment aftereffect. Speed characteristics at maximum load of VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

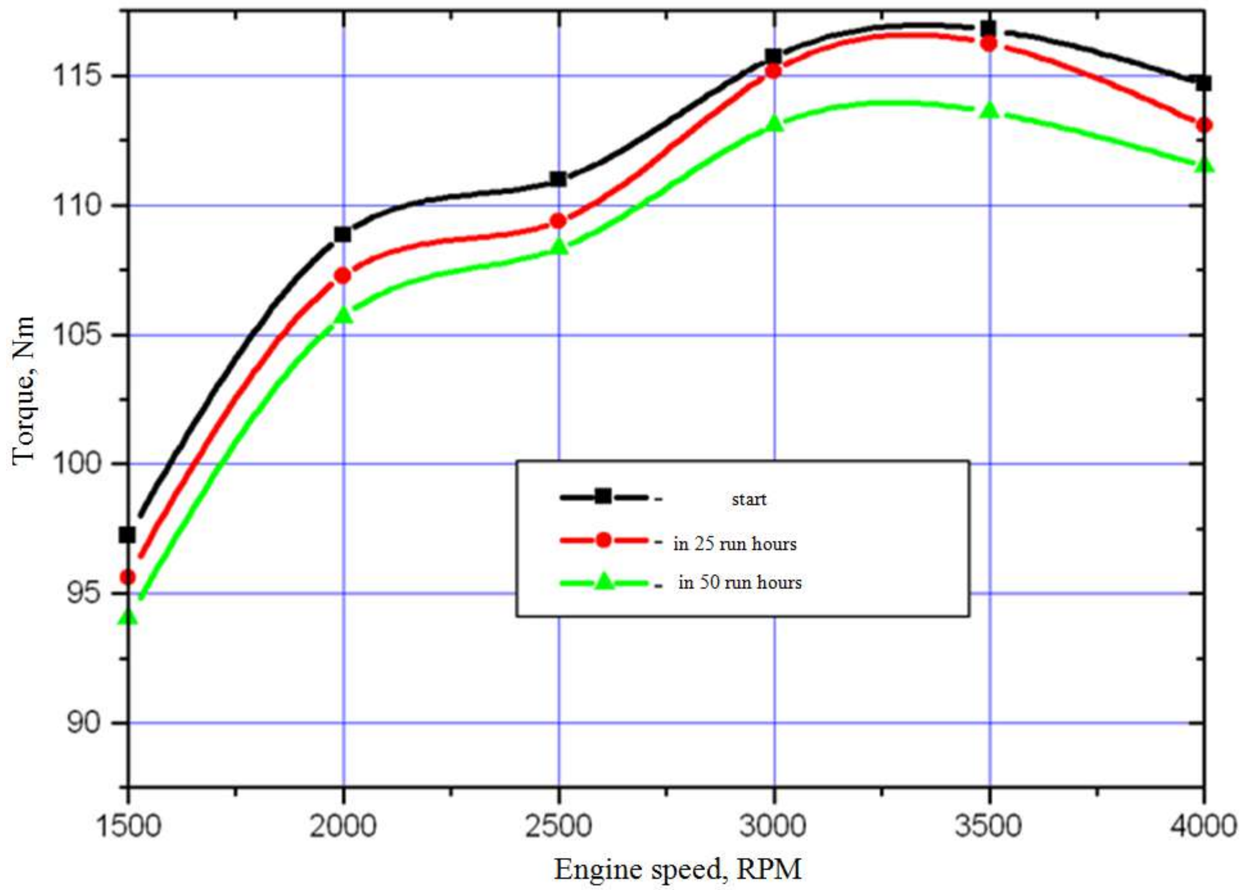

Fig. 36. Assessment of the duration of treatment aftereffect. Torque vs. speed curves for VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

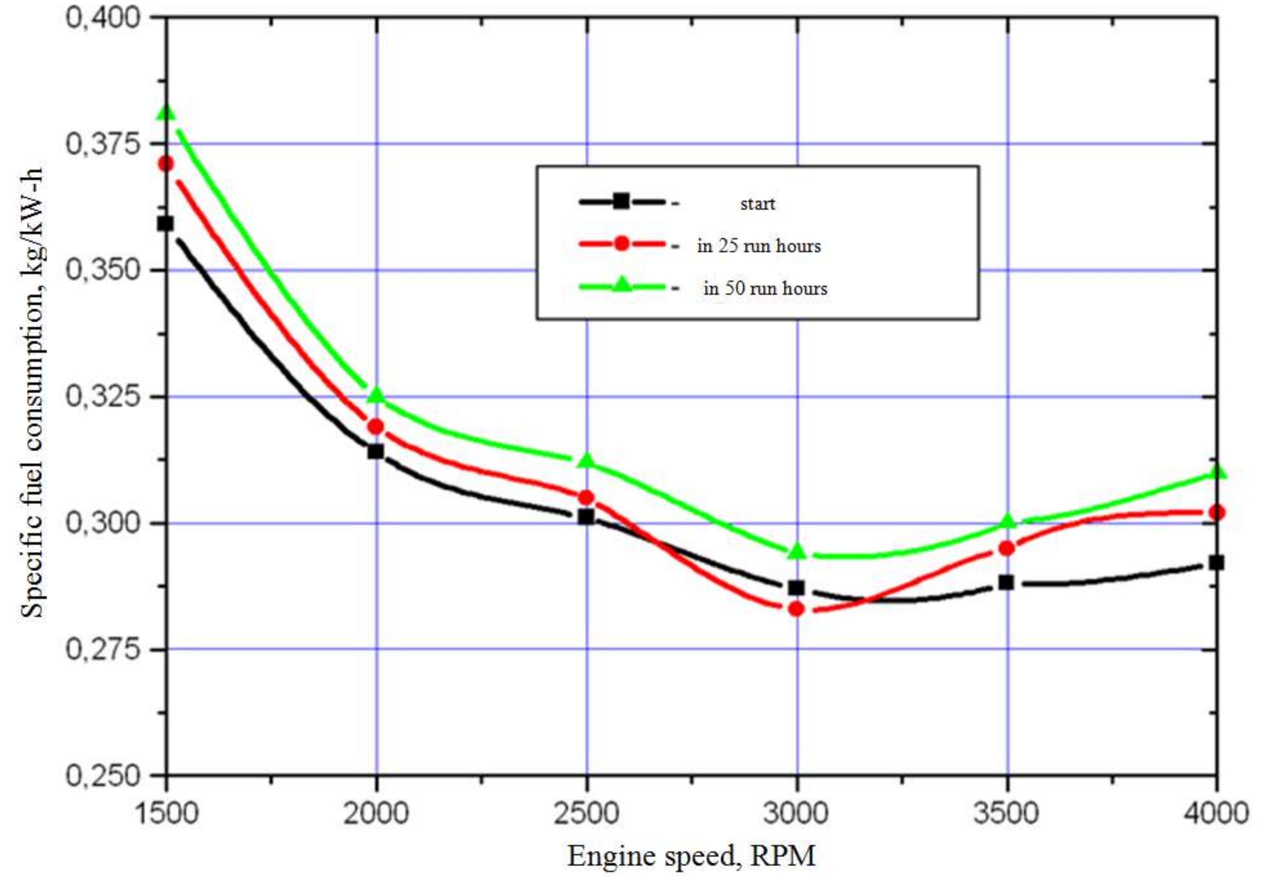

Fig. 37. Assessment of the duration of treatment aftereffect. Specific fuel consumption vs. speed curves for VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

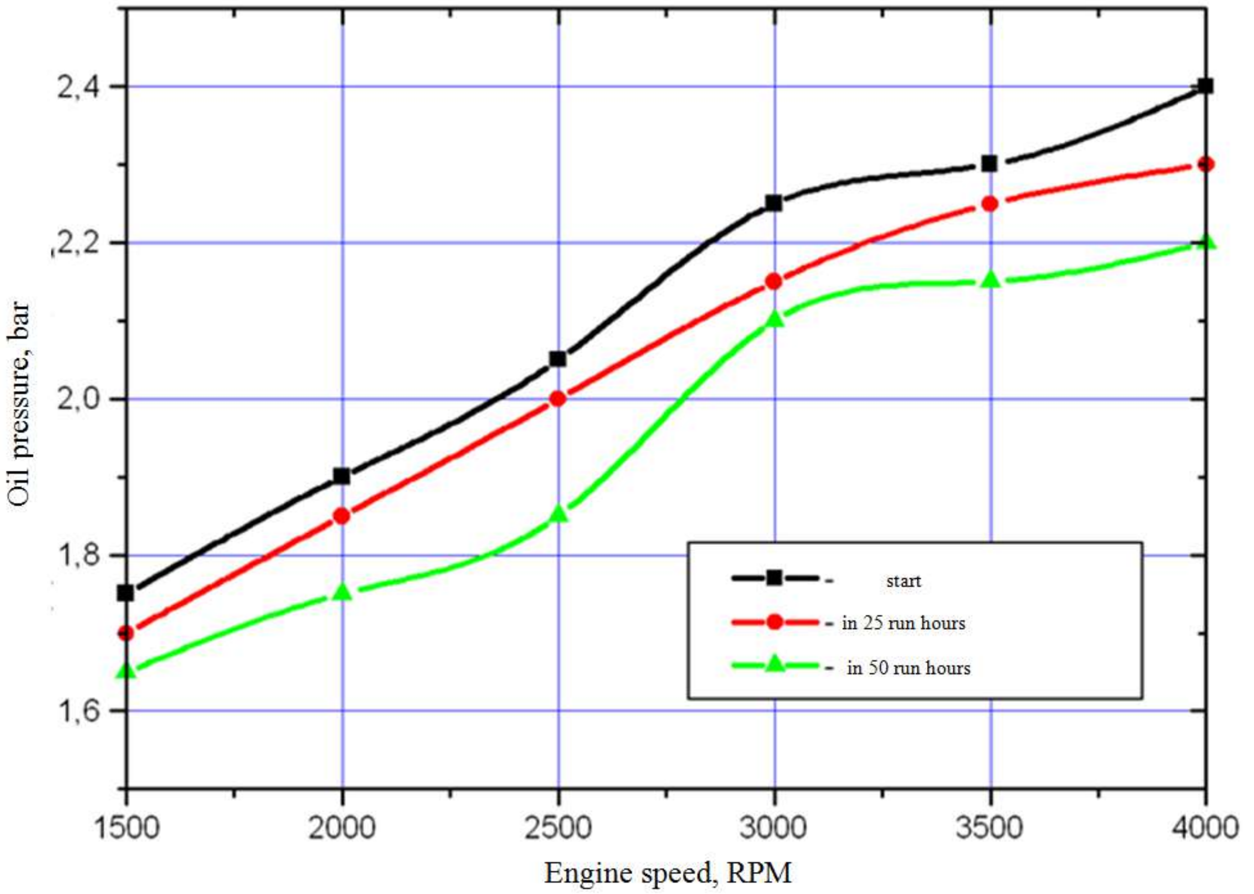

Fig. 38. Assessment of the duration of treatment aftereffect. Lube oil pressure vs. speed curves for VAZ-21083 engine after the treatment with RESURS NEXT additive, depending on exposure period

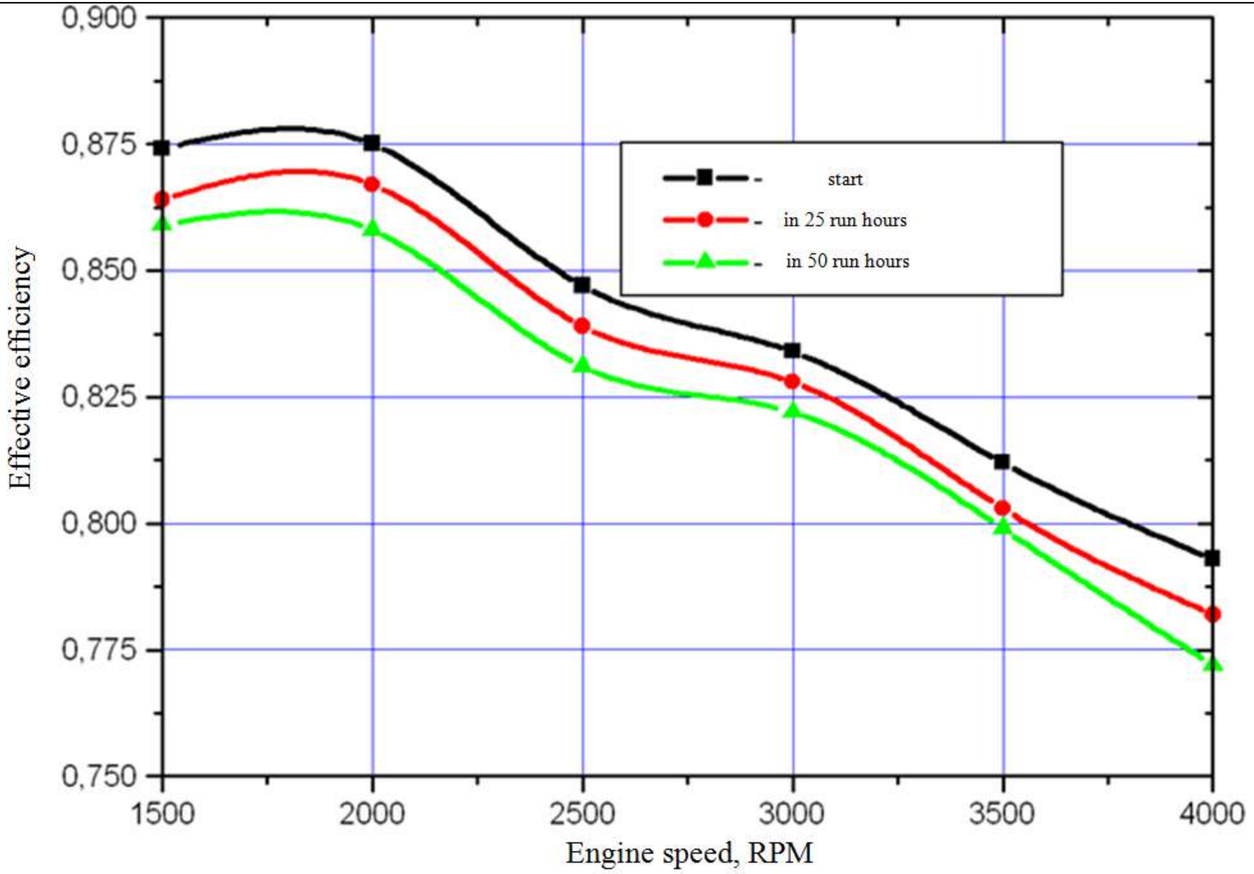

Fig. 39. Assessment of the duration of treatment aftereffect. Effective efficiency vs. speed curves for VAZ-21083 engine after the treatment with RESURS NEXT additive, depending on exposure period

See Tables 16…18 for measured mechanical losses torque in VAZ-21083 engine, depending on the period of exposure to RESURS NEXT action.

Mechanical loss torque, Nm, after treatment with RESURS NEXT additive, depending on exposure period Treatment 1.			
RPM	**Before the treatment**	**In 25 running hours after the treatment**	**In 50 running hours after the treatment**
1500	16,5	14,5	14,5
2000	18,0	16,5	17,0
2500	21,5	20,5	21,0
3000	25,5	24,0	24,0
3500	30,5	27,5	28,0
4000	35,0	32,0	32,0

Table 16. Mechanical loss torque (measured through engine cranking) after the 1st treatment with RESURS NEXT additive, depending on exposure period

Mechanical loss torque, Nm, after treatment with RESURS NEXT additive, depending on exposure period Treatment 2.			
RPM	**Before the treatment**	**In 25 running hours after the treatment**	**In 50 running hours after the treatment**
1500	14,5	14,0	14,5
2000	17,5	16,0	16,0
2500	21,5	20,0	20,0
3000	24,5	23,5	23,5
3500	28,0	27,0	27,5
4000	32,5	31,0	30,5

Table 17. Mechanical loss torque (measured through engine cranking) after the 2nd treatment with RESURS NEXT additive, depending on exposure period

Mechanical loss torque, Nm, after treatment with RESURS NEXT additive, depending on exposure period Assessment of treatment aftereffect duration			
RPM	**Before the treatment**	**In 25 running hours after the treatment**	**In 50 running hours after the treatment**
1500	14,0	15,0	15,5
2000	15,5	16,5	17,5
2500	20,0	21,0	22,0
3000	23,0	24,0	24,5
3500	27,0	28,5	29,5
4000	30,0	31,5	33,0

Table 18. Assessment of the duration of treatment aftereffect. Mechanical loss torque after the treatment with RESURS NEXT additive, depending on exposure period

See Table 19…21 for fuel consumption measured on idling engine, depending on the period of exposure to RESURS NEXT action.

Idling speed curve of VAZ-21083 engine Long-term test, after the 1st treatment	
Before the treatment	
RPM	**Gт, kg/h**
1500	0,91
2000	1,46
2500	1,72
3000	2,14
3500	2,39
4000	3,15
In 25 hours after the treatment	
RPM	**Gт, kg/h**
1500	0,85
2000	1,29
2500	1,59
3000	2,01
3500	2,17
4000	2,94
In 50 hours after the treatment	
RPM	**Gт, kg/h**
1500	0,87
2000	1,32
2500	1,54
3000	1,99
3500	2,19
4000	2,97

Table 19. Idling speed curve of VAZ-21083 engine after the 1st treatment with RESURS NEXT additive, depending on exposure period

Idling speed curve of VAZ-21083 engine Long-term test, after the 2nd treatment	
Before the treatment	
RPM	**Gт, kg/h**
1500	0,85
2000	1,35
2500	1,61
3000	2,02
3500	2,21
4000	3,04
In 25 hours after the treatment	
RPM	**Gт, kg/h**
1500	0,79
2000	1,24
2500	1,48
3000	1,91
3500	2,10
4000	2,85
In 50 hours after the treatment	
RPM	**Gт, kg/h**
1500	0,80
2000	1,27
2500	1,50
3000	1,90
3500	2,07
4000	2,88

Table 20. Idling speed curve of VAZ-21083 engine after the 2nd treatment with RESURS NEXT additive, depending on exposure period

Idling speed curve of VAZ-21083 engine Long-term test, assessment treatment aftereffect duration	
Start	
RPM	**Gт, kg/h**
1500	0,78
2000	1,24
2500	1,48
3000	1,87
3500	2,04
4000	2,90
In 25 running hours after the treatment	
RPM	**Gт, kg/h**
1500	0,82
2000	1,35
2500	1,55
3000	1,93
3500	2,15
4000	3,06
In 50 running hours after the treatment	
RPM	**Gт, kg/h**
1500	0,86
2000	1,39
2500	1,60
3000	1,99
3500	2,27
4000	3,18

Table 21. Assessment of the duration of treatment aftereffect. Idling speed curve of VAZ-21083 engine after the treatment with RESURS NEXT additive, depending on exposure period

The results of motor tests lead to the following conclusions:

- These results confirm the conclusion made on the completion of the 1st phase of this research, concerning positive effect of the treatment of artificially damaged engine with RESURS NEXT additive. In particular, specific fuel consumption decreased considerably (by 4…6% after the 1st treatment, and by another 2…3% after the 2nd treatment).

- Mechanical loss power decreased by 5…8% on average. This value is growing with increase in RESURS NEXT concentration. These data are also confirmed with measured values of fuel consumption during engine idling.

- Furthermore, lube oil pressure and temperature curves witness the trend of partial restoration of friction surface. The same is true for the positive trend of cylinder leak-tightness.

Details of engine rebuilding rate and trends of changes in engine operation values caused by treatment with RESURS NEXT additive are provided below.

5.2.3 Visual inspection of engine conditions on completion of long-term test cycle

On completion of long-term test cycle the engine were removed from the test bed, dismantled and examined for possible faults. No faults were detected.

5.2.4 Measurements of cylinder leak-tightness

Measurements of cylinder leak-tightness (compression) have been taken in the beginning and in the end of each test cycle.

The engine was cranked at constant speed of 250 RPM. Compression meter readings were averaged based on three measurements for each cylinder. The throttle was fully closed during the measurements.

See Tables 22…24 and bar charts on Figs. 40…42 for the test results.

Compression in individual cylinders, bar				
Time point	Cylinder Nr.			
	1	2	3	4
Start of the test	9,5	9,8	10,4	8,9
In 25 running hours after the start	9,9	10,4	10,5	9,7
	+4,2%	+6,1%	+0,9%	+9,0%
In 50 running hours after the start	9,9	10,6	10,6	9,6
	+4,2%	+8,2%	+1,9%	+7,9%

Table 22. Results of compression measurements, long-term tests, after the 1st treatment with «RESURS NEXT additive»

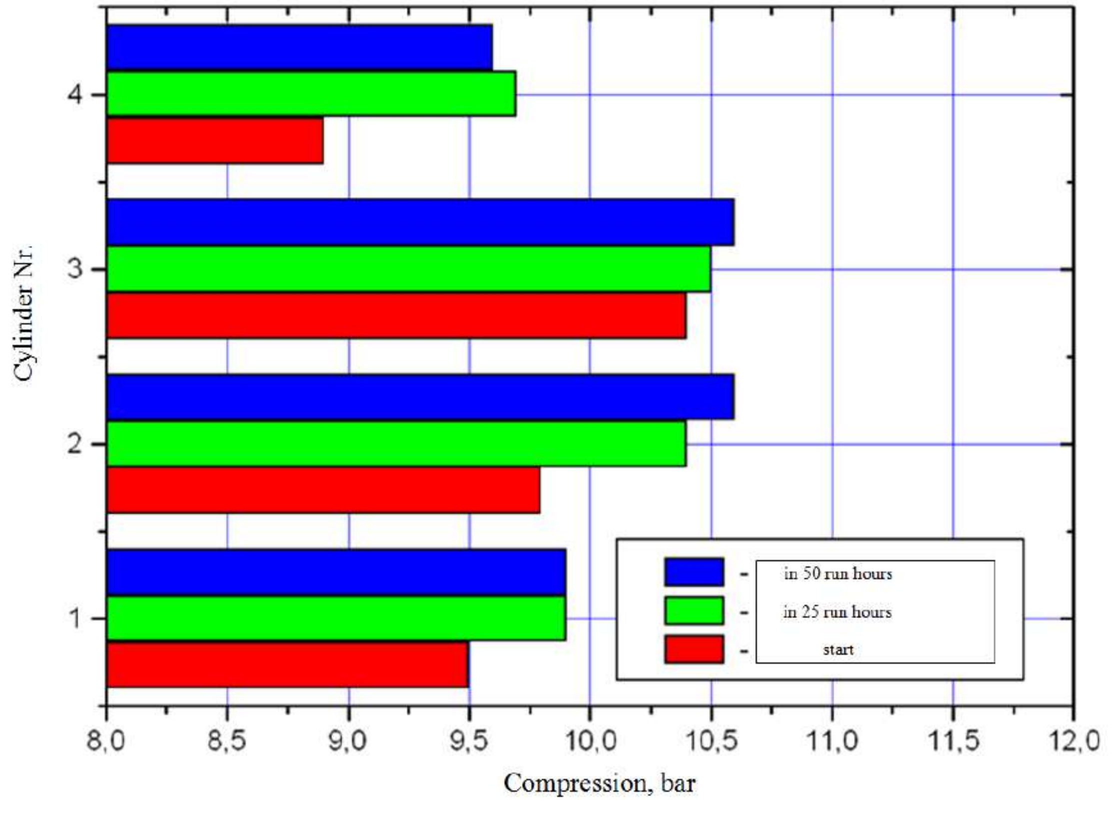

Fig. 40. Compression in engine cylinders after the 1st treatment with «RESURS NEXT additive», depending on exposure period

Compression in individual cylinders, bar				
Time point	Cylinder Nr.			
	1	2	3	4
Start of the test	9,7	10,9	10,5	9,7
In 25 running hours after the start	10,1	11,3	10,9	10,2
	+4,1%	+3,5%	+3,8%	+5,1%
In 50 running hours after the start	10,0	11,2	11,0	10,2
	+3,1%	+2,8%	+4,8%	+5,1%

Table 23. Results of compression measurements, long-term tests, after the 2nd treatment with «RESURS NEXT additive»

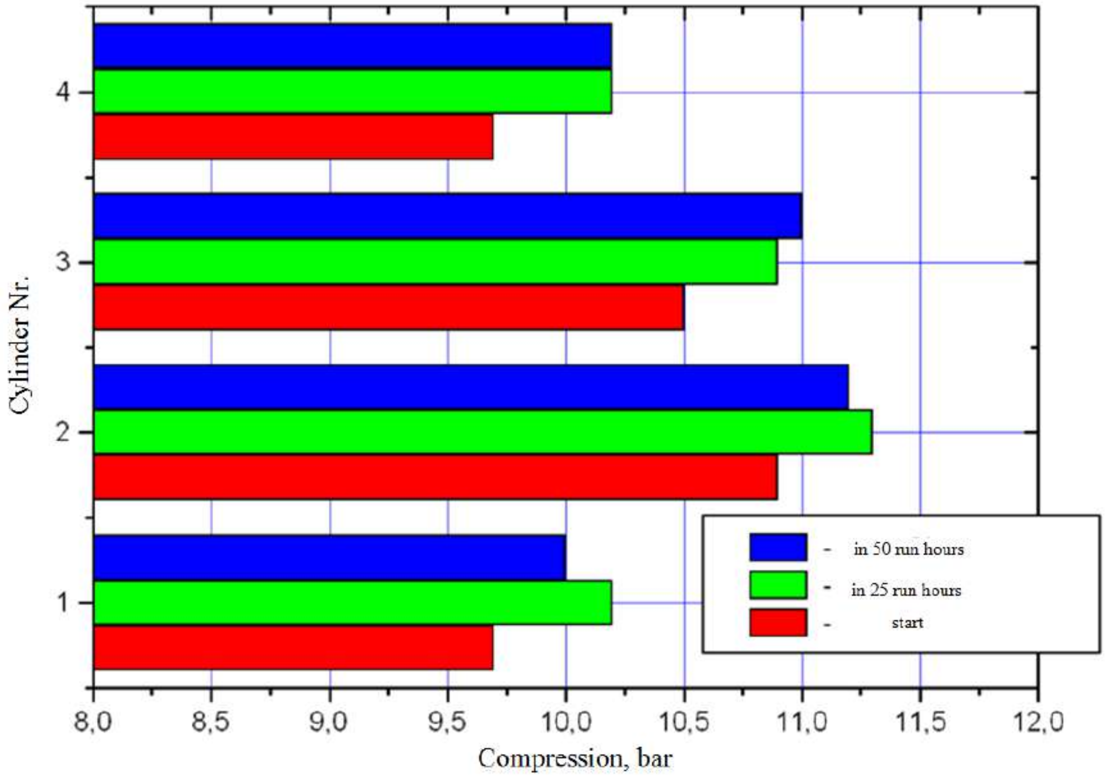

Fig. 41. Compression in engine cylinders after the 2nd treatment with «RESURS NEXT» additive, depending on exposure period

Compression in individual cylinders, bar				
Time point	Cylinder Nr.			
	1	2	3	4
Start of the test	10,6	11,7	11,2	10,7
In 25 running hours after the start	10,6	11,5	11,4	10,4
	0,0%	-1,7%	+1,8%	-2,8%
In 50 running hours after the start	10,2	11,4	11,3	10,1
	-3,8%	-2,6%	+0,9%	-5,6%

Table 24. Assessment of the duration of treatment aftereffect. Results of compression measurements, long-term tests, depending on exposure period

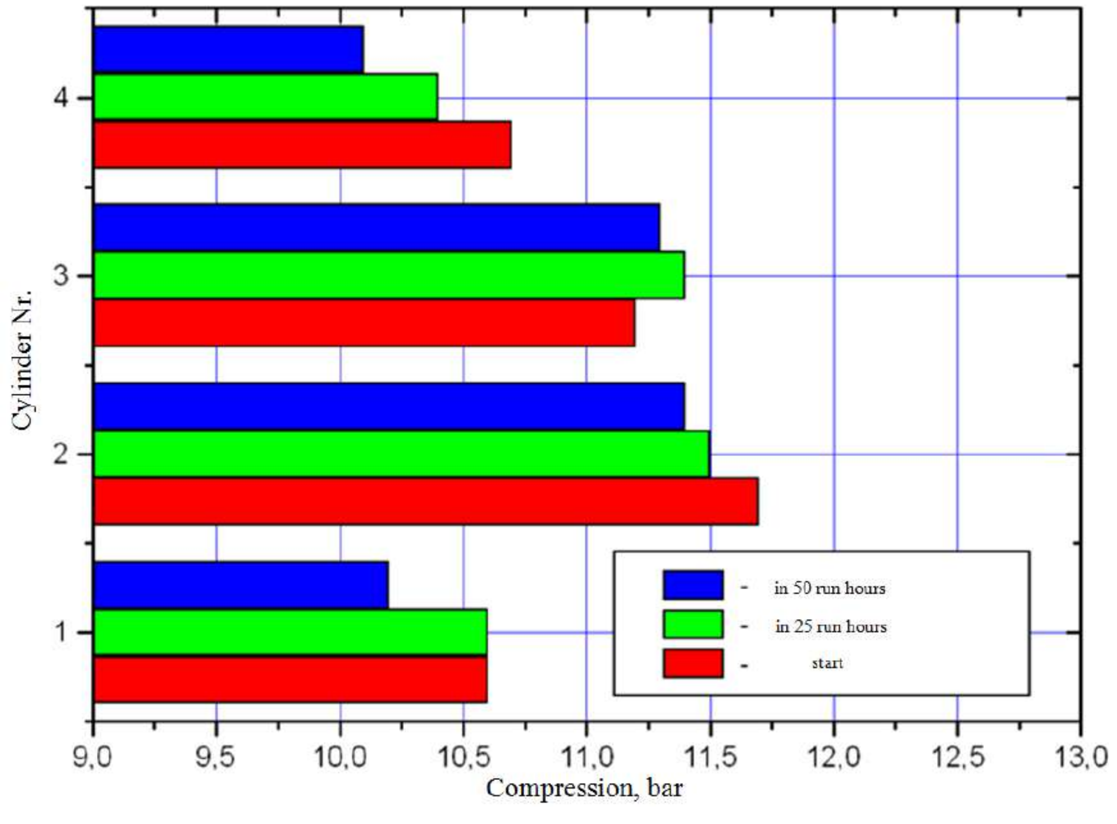

Fig. 42. Assessment of the duration of treatment aftereffect. Compression in engine cylinders after the treatment with «RESURS NEXT» additive, depending on exposure period

The above data form the basis for preliminary evaluation of engine parts rebuilding rate due to treatment with RESURS NEXT additive. One can easily detect a positive trend of increasing compression in engine cylinders with RESURS NEXT additive concentration. The 1st treatment results in compression increase by 6% (on average), the 2nd – by another 4%. Thus, two consequent treatments resulted in cumulative compression increase by 10%. It was not before the end of final test phase that some decrease in compression revealed itself.

5.2.5 Evaluation of the level of low-temperature sediments on engine parts after the long-term tests.

The level of low-temperature sediments was evaluated by changes in the mass of sample parts, viz., the oil baffle installed in the valve head, and the grease port of the oil pump, installed in the engine crank case (Fig. 43). The sample parts were weighted with precision analytical balance (accuracy within 0.0001 g). See Tables 25…26 for the results weighting.

Fig 43. The sample parts

	Before, g	After, g	Increase in mass, mg
Oil baffle	115.034	115.052	18
Grease port	228.711	228.747	36

Table 25. Masses of the sample parts after the long-term tests, 1st treatment with «RESURS NEXT» additive

	Before, g	After, g	Increase in mass, mg
Oil baffle	115.052	115.073	21
Grease port	228.747	228.779	32

Table 26. Masses of the sample parts after the long-term tests, 2nd treatment with «RESURS NEXT» additive

	Before, g	After, g	Increase in mass, mg
Oil baffle	115.073	115.088	15
Grease port	228.779	228.805	26

Table 27. Assessment of the duration of treatment aftereffect. Masses of the sample parts after the long-term tests, «RESURS NEXT» additive

The test results show but slight oil deposit, which is true for all the test cycles. Such results are typical for high-quality synthetic oils, industry standard API SL/CF. The results of control weighing show that contribution of RESURS NEXT additive into the level of low-temperature sediments is negligible.

5.2.6 Evaluation of the level of low-temperature sediments on engine parts after long-term tests.

Level of high-temperature sediments was evaluated based on visual inspection of piston lateral surface. The evaluation was carried out by group of expert using scale similar to that used in PZV method (GOST 5726-2013). This scale uses two baseline points: Nr. 0 – clean piston, Nr. 6 – absolutely fouled piston. See Figs. 44...45 for photos of engine pistons after long-term tests of motor oils.

Piston contamination level according to the expert group are presented in Table 28.

Motor oil	Piston contamination level in cylinders:				Average level
	1	2	3	4	
Lukoil Lux 5W-30 modified with RESURS NEXT additive, after the 2nd test cycle (100 running hours)	0.0	0.5	0.0	0.0	0.125
Assessment of the duration of treatment aftereffect (after 50 running hours)	0.0	0.5	0.0	0.5	0.25

Table 28. Level of high-temperature sediments on piston lateral surfaces

	
Piston 1. Contamination level 0 on ПЗВ scale	Piston 2. Contamination level 0.5 on ПЗВ scale
	
Piston 3. Contamination level 0 on ПЗВ scale	Piston 4. Contamination level 0 on ПЗВ scale

Fig. 44. High-temperature sediments (HTS) after long-term tests (100 running hours) on Lukoil Lux oil added with RESURS NEXT

	
Piston 1. Contamination level 0 on ПЗВ scale	Piston 2. Contamination level 0.5 on ПЗВ scale
	
Piston 3. Contamination level 0 on ПЗВ scale	Piston 4. Contamination level 0.5 on ПЗВ scale

Fig. 45. High-temperature sediments (HTS) after long-term tests (50 running hours, assessment of the duration of treatment aftereffect) on Lukoil Lux oil added with RESURS NEXT

Such test results confirm high detergency of Lukoil Lux motor oil. Moreover, injection of Lukoil Lux in concentration twice as high as recommended did not affect the level of high-temperature sediments.

5.2.7 Evaluation of parts rebuilding rate due to treatment with RESURS NEXT

Artificial damages of bearing shells in form of standard scratches were applied in the course of preparing the engine to the tests (Fig.46).

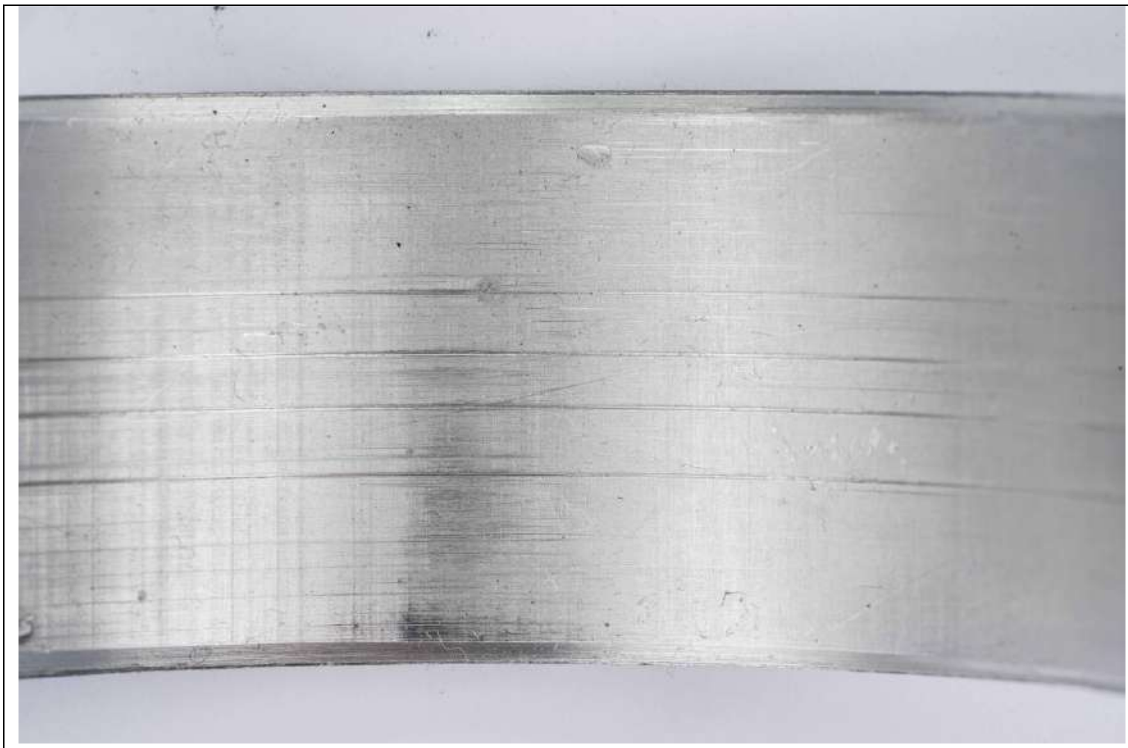

Fig. 46. Crankshaft bearing shells with artificial defects

At every control time point of the tests – before the tests, after the 1st maintenance (in 50 running hours), after the 2nd treatment (in 100 running hours), and on test completion (in 150 running hours) – friction surfaces in immediate vicinity of an artificial defect were closely inspected. In particular, microprofiles were examined and surface average roughness Ra was measured.

See Figs. 47 and 48 for surface roughness measurement areas of journal bearings and cylinder walls. Roughness of piston ring surfaces was measured in the vicinity of a ring lock (point 1) and on the opposite side (point 2). The results are presented in Tables 29…32.

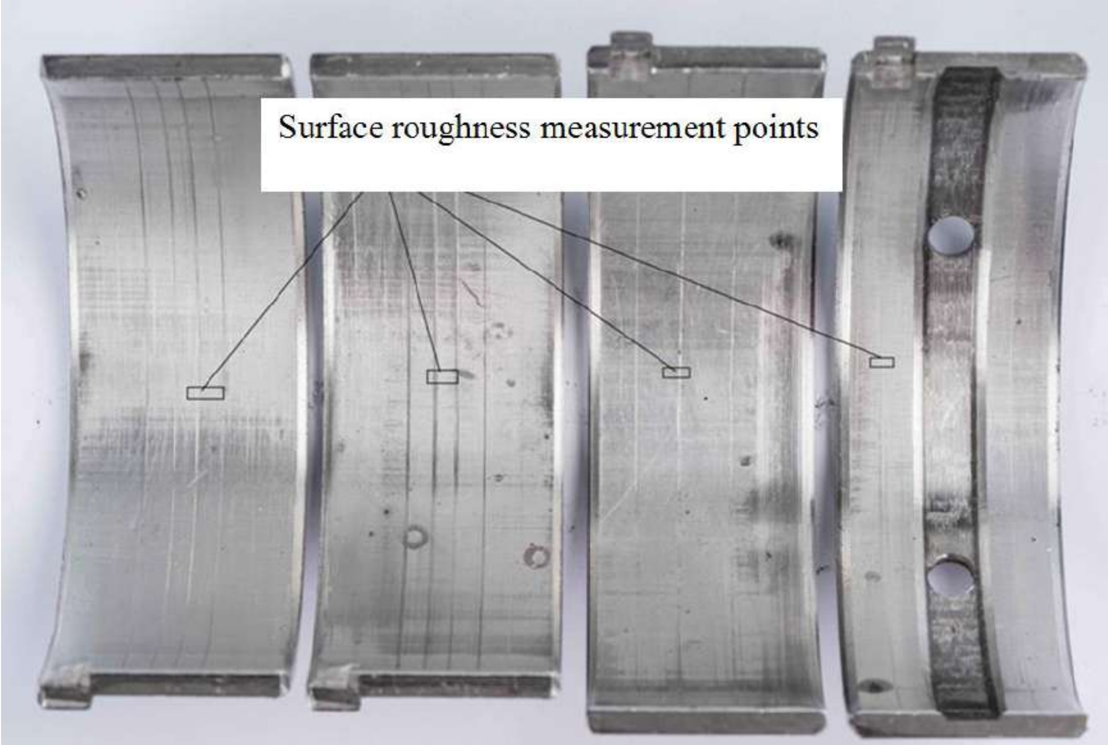

Fig. 47. Surface roughness measurement points of journal bearings

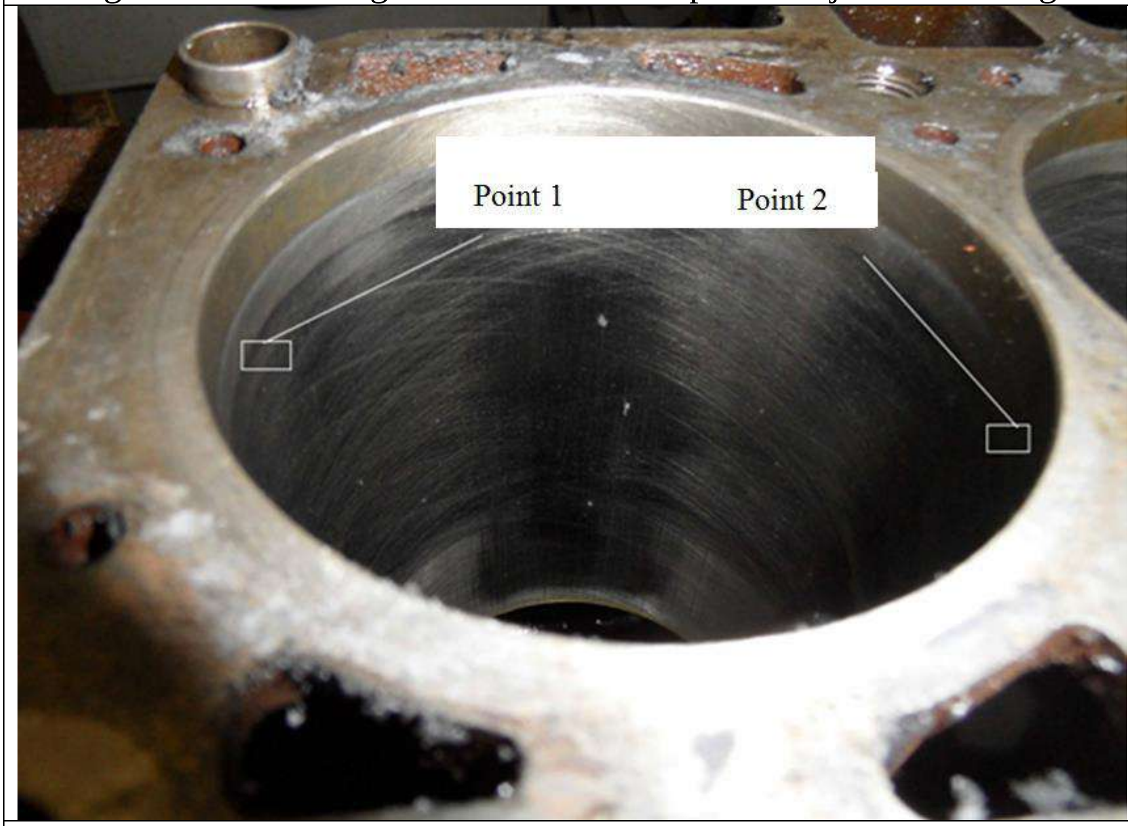

Fig. 48. Surface roughness measurement points of cylinder walls

Connecting-rod bearing shells				
	Time point			
	Before the treatment	After the 1st treatment	After the 2nd treatment	On completion of the tests
№1 Upper	2,049	1,321	0,317	1,027
№1 Lower	2,236	0,939	0,592	1,386
№2 Upper	1,414	0,771	0,639	1,296
№2 Lower	1,478	0,592	0,559	1,678
№3 Upper	1,432	0,546	0,503	0,996
№3 Lower	1,553	0,435	0,389	0,814
№4 Upper	1,329	0,577	0,563	0,976
№4 Lower	1,284	0,822	0,765	1,120
Mean value % measurement	**1,597**	**0,750/ -53%**	**0,541/-66%**	**1,161/-27%**

Table 29. Ra values measured in control points of connecting-rod bearing shells

Journal bearing shells				
	Time point			
	Before the treatment	Before the treatment	Before the treatment	Before the treatment
№1 Upper	0,320	0,176	0,087	0,287
№1 Lower	0,414	0,265	0,199	0,425
№2 Upper	0,454	0,276	0,224	0,365
№2 Lower	0,378	0,243	0,210	0,287
№3 Upper	0,896	0,476	0,298	0,710
№3 Lower	0,381	0,187	0,143	0,341
№4 Upper	0,716	0,353	0,224	0,665
№4 Lower	0,356	0,141	0,097	0,229
№5 Upper	0,867	0,321	0,194	0,667
№5 Lower	0,330	0,190	0,112	0,278
Mean value /% measurement	**0,511**	**0,263/-49%**	**0,179/-65%**	**0,425/-17%**

Table 30. Ra values measured in control points of journal bearing shells

1st piston ring				
	Time point			
	Before the treatment	Before the treatment	Before the treatment	Before the treatment
№1 Point 1	1,103	0,998	0,870	0,998
№1 Point 2	0,807	0,652	0,612	0,716
№2 Point 1	0,791	0,554	0,463	0,654
№2 Point 2	1,707	1,106	0,990	1,256
№3 Point 1	0,701	0,545	0,462	0,669
№3 Point 2	1,910	1,854	1,721	1,811
№4 Point 1	1,259	0,756	0,768	1,262
№4 Point 2	0,778	0,635	0,593	0,669
Mean value /% measurement	**1,132**	**0,888/-22%**	**0,810/-28%**	**1,004/-11%**

Table 31. Ra values measured in control points of 1st piston rings

Cylinder				
	Time point			
	Before the treatment	Before the treatment	Before the treatment	Before the treatment
№1 Point 1	0,106	0,092	0,084	0,110
№1 Point 2	0,131	0,106	0,093	0,119
№2 Point 1	0,174	0,126	0,095	0,136
№2 Point 2	0,122	0,099	0,075	0,097
№3 Point 1	0,130	0,105	0,084	0,122
№3 Point 2	1,584	0,984	0,745	1,385
№4 Point 1	0,186	0,145	0,136	0,172
№4 Point 2	0,089	0,081	0,082	0,094
Mean value /% measurement	**0,315**	**0,217/-31%**	**0,174/-48%**	**0,279/-11%**

Table 32. Ra values measured in control points of cylinder walls

The results of the measurements show clear trend of surface roughness decrease after each treatment with RESURS NEXT additive, which is obviously accounted for by decrease in scratch depth due to cladding with active component of the additive. This effect is more evident in parts with softer friction surfaces. Thus, total decrease in Ra of journal bearing shells after two treatments amounted to 50…60%. For harder parts, such as chromium-plated piston ring surfaces and cylinder wall surfaces, the above effect is less manifest (30…40%). This is a sign of partial restoration of worn engine, which is indirectly evidenced by higher compression in cylinders, lower mechanical losses power and lube oil pressure recorded during the tests. It should be noted that removal of the RESURS NEXT additive from motor oil results in visible reduction of partial restoration effects.

2nd phase of the research: discussion

Results of long-term testing of engine featuring parts with artificially damaged friction surfaces leads to the following conclusions.

First of all, these results confirm the conclusion from the results of the 1st phase of research, concerning considerable decrease in friction losses due to treatment of the engine with RESURS NEXT additive. This is supported by direct measurements of mechanical losses torque, fuel consumption and engine output taken at various phases of the test cycle.

Presented in Tables 33…35 are some calculated performance indices, averaged over the test cycle.

№	Time point	Power, kW	Fuel consumption, kg/h	Effective efficiency	CO, %	CH, ppм	NOx, ppм
1	Before the treatment	101,5	0,409	0,212	0,107	121	2074
2	In 25 running hours after the start	104,0	0,389	0,222	0,100	114	1968
		2,5	-5,0	5,1	-5,7	-6,0	-5,1
3	In 50 running hours after the start	104,5	0,391	0,221	0,100	116	1981
		3,0	-4,3	4,3	-5,7	-4,6	-4,5

Table 33. Averaged performance indices of VAZ-21083 engine after the 1st treatment with RESURS NEXT additive, depending on exposure period

№	Time point	Power, kW	Fuel consumption, kg/h	Effective efficiency	CO, %	CH, ppм	NOx, ppм
1	Before the treatment	105,2	0,394	0,220	0,105	119	2041
2	In 25 running hours after the start	106,6	0,386	0,225	0,099	111	1979
		1,3	-2,2	2,2	-6,1	-7,0	-3,0
3	In 50 running hours after the start	106,3	0,386	0,224	0,102	112	1957
		1,0	-2,1	1,8	-3,8	-6,1	-4,1

Table 34. Averaged performance indices of VAZ-21083 engine after the 2nd treatment with RESURS NEXT additive, depending on exposure period

№	Time point	Power, kW	Fuel consumption, kg/h	Effective efficiency	CO, %	CH, ppм	NOx, ppм
1	Before the treatment	106,3	0,380	0,227	0,098	115	1973
2	In 25 running hours after the start	105,3	0,388	0,224	0,106	120	2046
		-0,9	2,2	-1,5	8,9	4,3	3,5
3	In 50 running hours after the start	103,5	0,401	0,217	0,107	124	2082
		-2,6	5,4	-4,3	9,2	7,8	5,51

Table 35. Assessment of the duration of treatment aftereffect. Averaged performance indices of VAZ-21083 engine after treatment with RESURS NEXT additive, depending on exposure period

Colour marking: green – improvement in a performance index, red – deterioration of a performance index, blue - change of a performance index within metering error

Comparison of the results of the 1st (Table 6) and the 2nd (Tables 33,34) test phases shows that the more engine in question is worn, the more noticeable is effect of treatment with RESURS NEXT additive. This an obvious consequence of partial restoration of normal lubrication for engine bearings due to cladding of defects on friction surfaces with RESURS NEXT additive.

Based on the test results the authors traced the dynamics of principal engine operating values through the whole test cycle. Measurements were taken at two representative points: Point 1 – n=2000 RPM, Me=20 Nm; Point 2 – n=3000 RPM, Me=40 Nm. The results of the measurements are presented in Tables 36, 37, and Figs. 49…53.

Point 1 – n=2000 RPM, Me=20 Nm						
Time point	Time elapsed since the start of the tests, running hours	Fuel consumption, kg/h	Eff ective efficiency	Oil pressure, bar	Oil temperature, ^{0}C	CH content in exhaust gas, ppм
Before the treatment	0,0	0,529	0,536	1,95	90	125
In 25 hours after the treatment	25,0	0,502	0,560	2,10	85	120
In 50 hours after the treatment	50,0	0,507	0,553	2,10	84	115
Immediately after the 2nd treatment	51,0	0,510	0,549	2,15	85	119
In 25 hours after the 2nd treatment	75,0	0,494	0,569	2,25	83	114
In 50 hours after the 2nd treatment	100,0	0,495	0,560	2,25	84	107
Immediately after the oil change for fresh one	101,0	0,496	0,549	2,20	85	109
In 25 hours after the oil change	125,0	0,509	0,545	2,15	87	112
In 50 hours after the oil change	150,0	0,519	0,542	2,10	89	118

Table 36. Engine operating values vs. time, Control Point 1 – n=2000 RPM, Me=20 Nm

Control Point 2 – n=3000 RPM, Me=40 Nm						
Time point	Time elapsed since the start of the tests, running hours	Fuel consumption, kg/h	Ef fective efficiency	Oil pressure, bar	Oil temperature, ^0C	CH content in exhaust gas, ppм
Before the treatment	0,0	0,322	0,615	2,30	92	128
In 25 hours after the treatment	25,0	0,307	0,632	2,50	88	105
In 50 hours after the treatment	50,0	0,311	0,628	2,50	88	109
Immediately after the 2nd treatment	51,0	0,309	0,626	2,45	90	114
In 25 hours after the 2nd treatment	75,0	0,300	0,636	2,55	87	108
In 50 hours after the 2nd treatment	100,0	0,302	0,630	2,60	88	110
Immediately after the oil change for fresh one	101,0	0,307	0,629	2,60	87	117
In 25 hours after the oil change	125,0	0,313	0,625	2,55	88	120
In 50 hours after the oil change	150,0	0,315	0,622	2,45	90	123

Table 37. Engine operating values vs. time, Control Point 2 – n=3000 RPM, Me=40

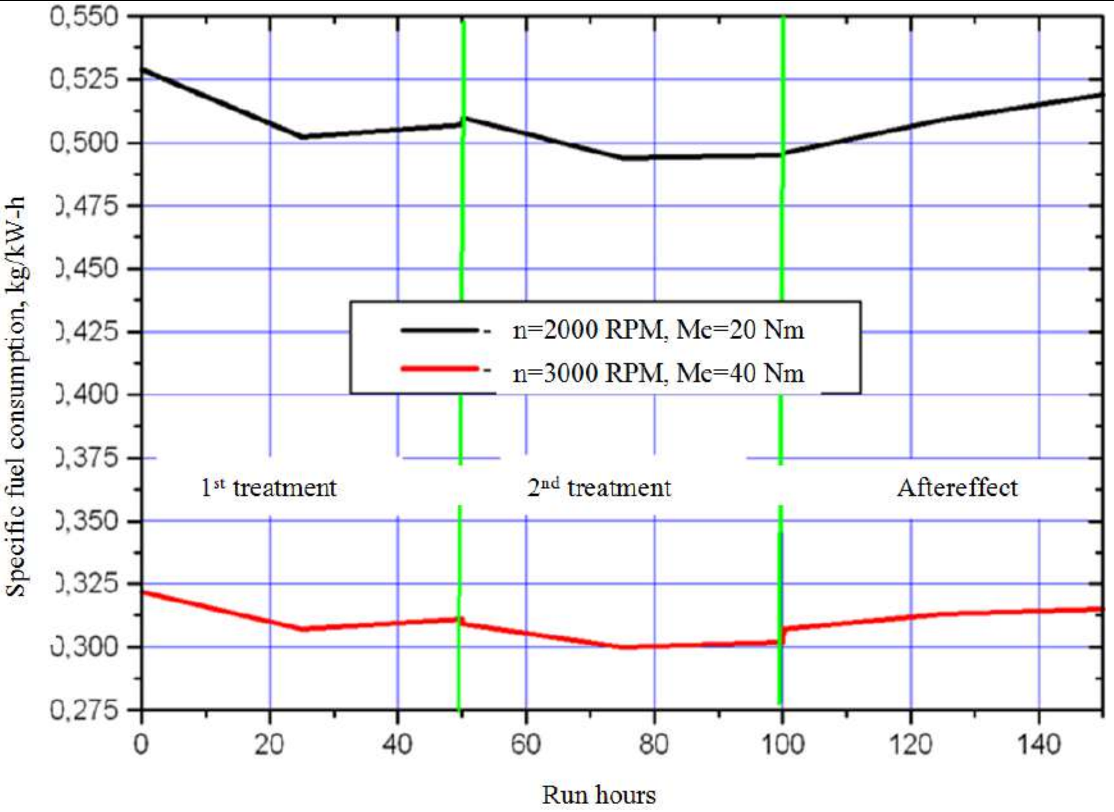

Fig. 49. Dynamics of specific fuel consumption change during the long-term tests at Time Control Points

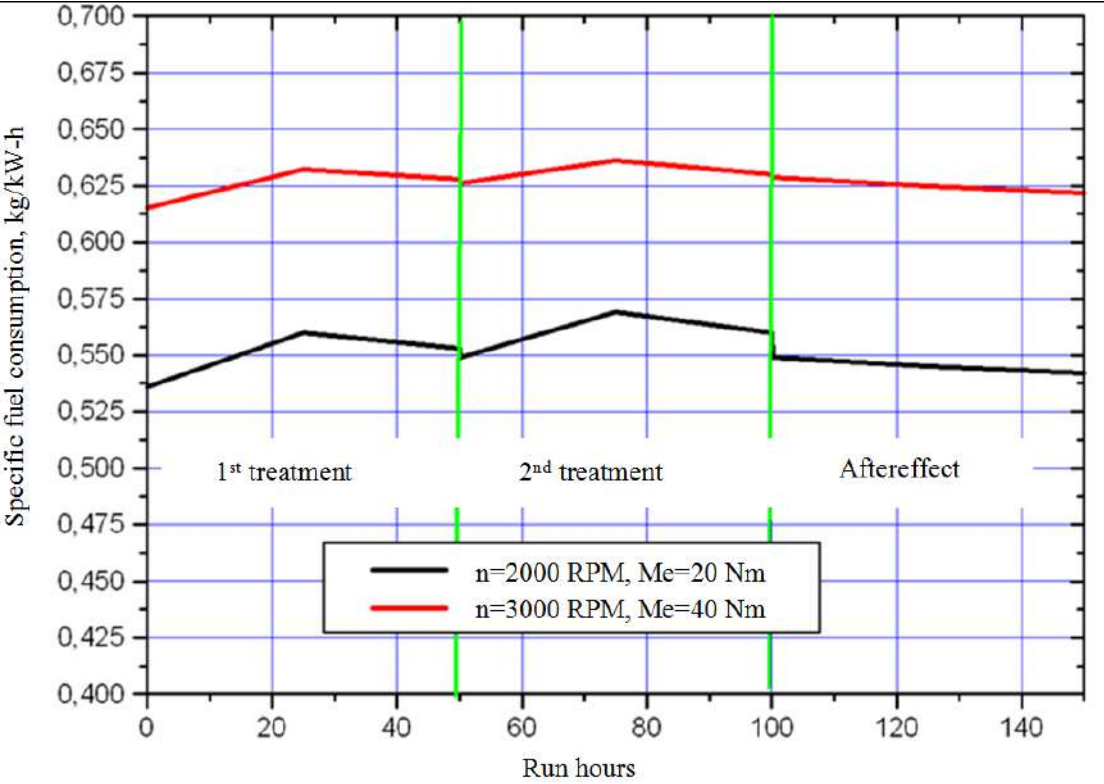

Fig. 50. Dynamics of engine Effective efficiency change during the long-term tests at Time Control Points

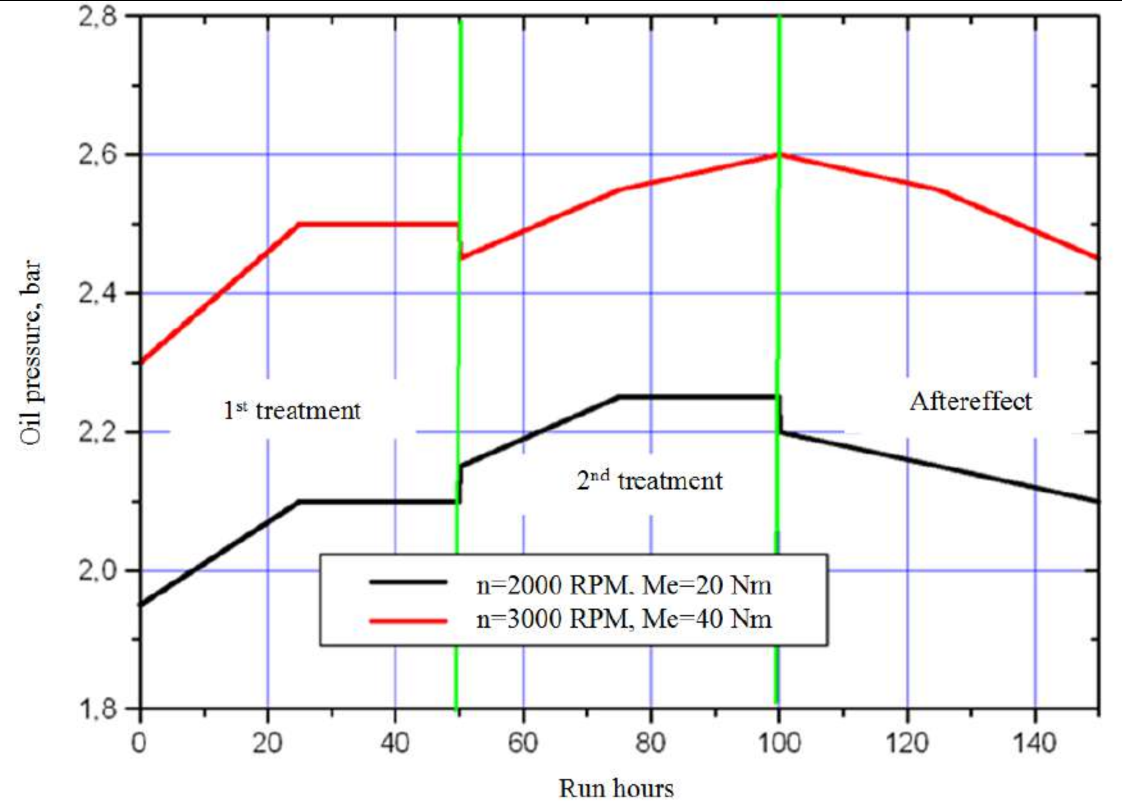

Fig. 51. Dynamics of lube oil pressure change during the long-term tests at Time Control Points

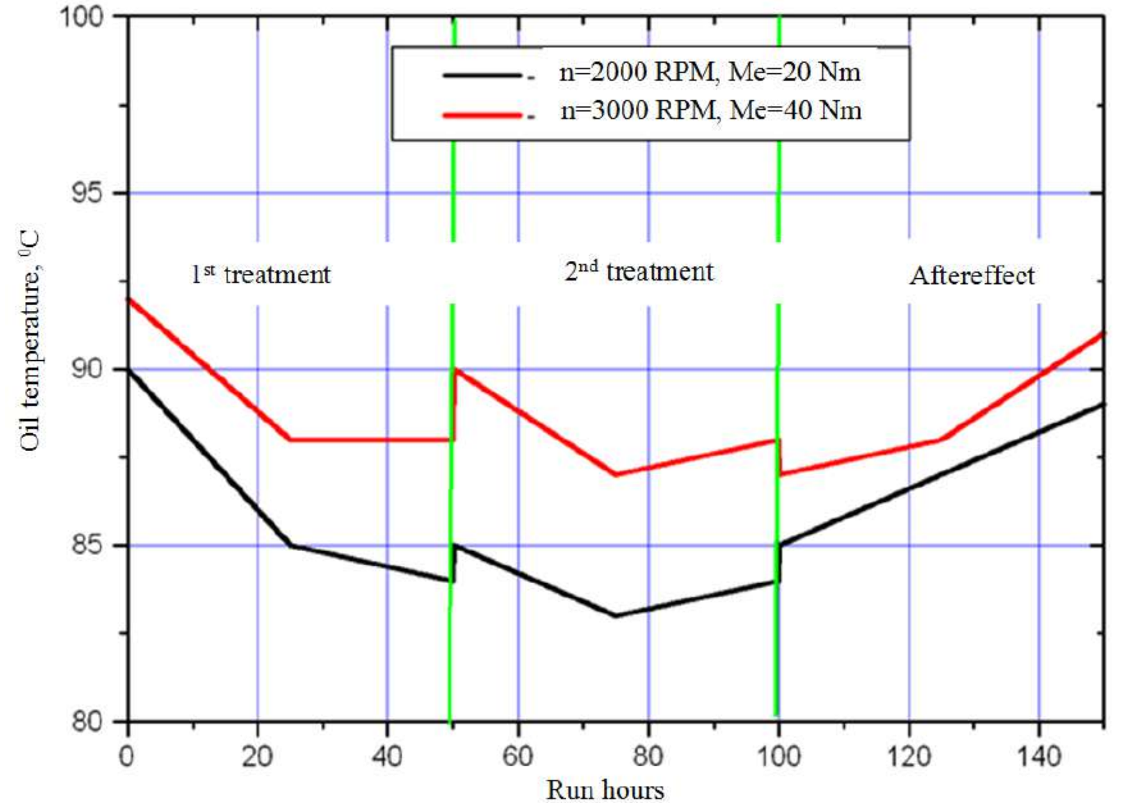

Fig. 52. Dynamics of lube oil temperature change in the oil pan during the long-term tests at Time Control Points

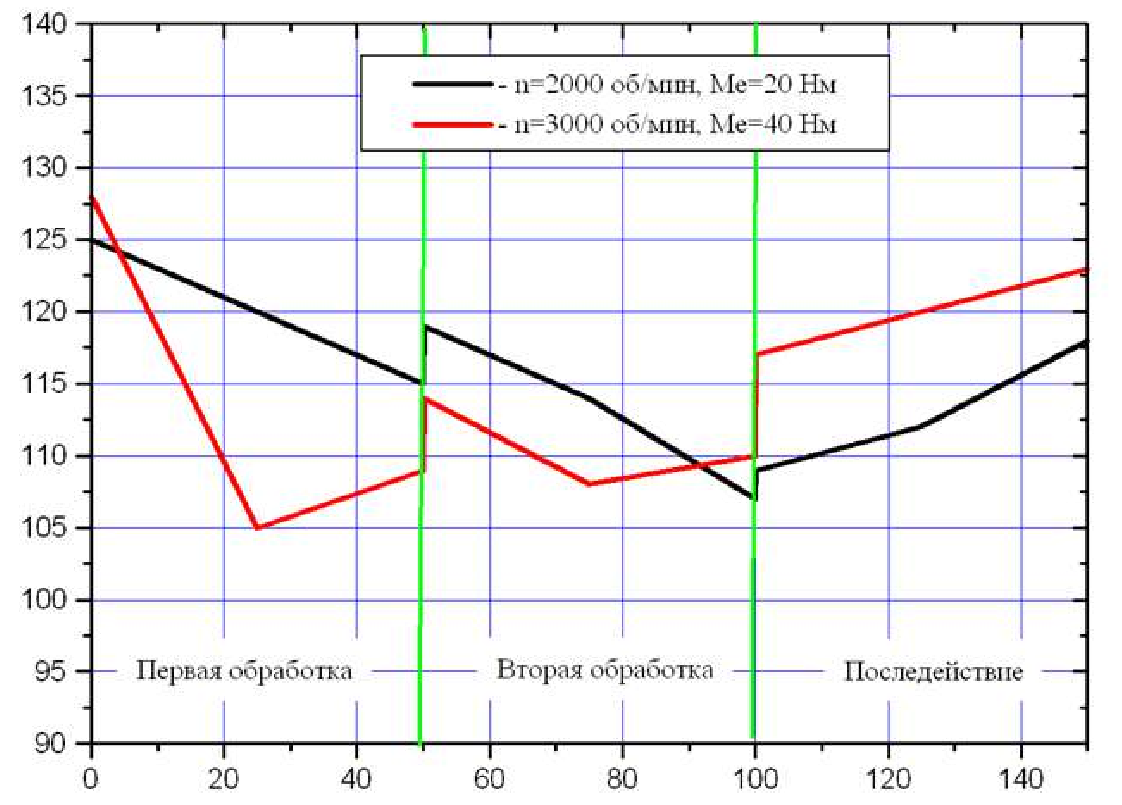

Fig. 53. Dynamics of residual hydrocarbon content change in exhaust gas during the long-term tests at Time Control Points

Analysis of the test results demonstrates remarkable effect of treatment with additive RESURS NEXT reached at the 1st phase of treatment. Higher concentration of the additive at the 2nd phase of treatment also contributes into improvement of friction pair conditions, however, its effect is weaker than that reached at the 1st phase of treatment.

Removal of the additive from lube oil (at the phase of assessment of treatment aftereffect) results in gradual decay of treatment effect. Nevertheless, on completion of the above phase (that lasted for 50 running hours, which is equivalent of 5000 km mileage) certain improvement of engine performance over initial state still remained. This leads to supposition of the dynamics of protective layer formed by active component of RESURS NEXT additive, whose effect depends on its presence and concentration in motor oil. One may further suppose that permanent presence of the additive in motor oil results in stabilization of said effect on certain level, which depends on engine initial conditions. Proof of this assumption, however, needs longer test cycle on a representative sample of engines varying in wear level.

6. Conclusions

The results of the whole test cycle lead to the following conclusions:

- Use of RESURS NEXT additive results in certain improvement in petrol engine performance, viz., increase in power (by 2...3%) and decrease in specific fuel consumption (by 2...5% at average). Also, increase in lube oil pressure (by 5…8%) and decrease in lube oil temperature (by 3…7^{0}C) are observed. Additionally, there is certain reduction in residual hydrocarbons (HC) contents in exhaust gas, which increases with RESURS NEXT concentration in motor oil.
- Fuel economy is more pronounced in engines with middle and high wear level and damaged surfaces of friction pairs. Friction horsepower decreases by 8…10% due to better leak-tightness of "piston-cylinder sleeve" pair (cumulative increase in compression after two treatments up to 10…12%), better lubrication and restoration of lube oil pressure (by 7…12%). Therefore, further fuel economy (by 5…7%) is observed, as compared with fuel consumption of sound engine with low wear level.
- Clear trend is observed of partial restoration of friction surfaces exposed to RESURS NEXT additive. It is readily apparent from the dynamics of changes in engine operating values, as well as direct measurement of roughness of friction pair surfaces, such as journal bearings, cylinder walls and piston rings. Total decrease in Ra of journal

bearing shells after two treatments amounted to 50…60%, of piston rings and cylinder walls – to 30…40%.

- The 2nd phase of the research showed a dependence of RESURS NEXT effect on its concentration in lube oil. The most pronounced effect is achieved at the 1st phase, immediately after initial injection of the additive into lube oil. Further injection of RESURS NEXT in lube oil still contributes into engine performance improvement, but the rate of improvement drops down considerably.
- After the removal of RESURS NEXT additive from lube oil (at the phase of assessment of treatment aftereffect) the effect of the treatment is retained for certain period of time, whereupon gradual decay of engine performance is observed. However, even after 50 running hours (which is equivalent of 5000 km mileage) of previously treated engine on fresh oil some residual effects are still there.
- This leads to supposition of the dynamics of protective layer formed by active component of RESURS NEXT additive, whose effect depends on its presence and concentration in motor oil. One may further assume that permanent presence of the additive in motor oil results in stabilization of said effect on certain level, which depends on engine initial conditions. Proof of this assumption, however, needs longer test cycle on a representative sample of engines varying in wear level.

APPENDIX I

STANDARD

СДС ГСМ-FLM MM-003-2009 "MOTOR OILS FOR AUTOMOBILE ENGINES COMPARATIVE TEST METHOD”

S T A N D A R D
voluntary certification schemes for fuels, lube oils and chemicals СДС ГСМ-FLM

СТО ММ-003-2009

MOTOR OILS FOR AUTOMOBILE ENGINES

Comparative motor test method

This instruction establishes comparative test method allowing evaluation of dependence of engine techno-economic and environmental performance on motor oil used.

1. METHOD BASICS

The essence of the method is establishing guidelines regarding tests of motor oils from the viewpoint of their influence on:

- engine power and fuel economy characteristics;
- concentration of toxic components in exhaust gas;
- engine friction horsepower.

Besides, evaluated is rate of change in oil properties at initial period after oil change in field.

Tests shall be carried out on VAZ-2111 or VAZ-2112 engines installed on a motor test bed.

Test engine shall be perfectly sound, with negligible wear rate (if any).

2. TEST EQUIPMENT, MATERIALS, AND CHEMICALS

Test equipment, materials, and chemicals shall be as follows:

- engine type ВАЗ-2111 or ВАЗ-2112**;**
- motor test bed;
- Lead-free motor petrol type REGULAR or PREMIUM, GOST 51105

3. PREPARATION FOR THE TESTS

3.1 The tests shall be carried out on VAZ-2111 or VAZ-2112 type engine with new piston assembly and new journal bearing shells.

3.2 The engine shall be installed on the test bed and given running-in for 6 running hours according to Table 1. The engine shall be primed with lube oil to be tested. The amount of oil for running-in mode shall equal (3,5±0.1) l.

Time, min	Engine speed, RPM	Torque, Nm
20	800	0,0
20	1500	0,0
20	2000	0,0
30	2000	30,0
30	2500	30,0
30	2500	60,0
30	3000	30,0
30	3000	60,0
30	3500	30,0
30	3500	70,0
30	4500	50,0
30	4500	Max
30	5600	Max

Table 1.Running-in cycle parameters

3.3 Running-in sequence

Start of each running-in mode shall be the moment the engine reaches speed specified in Table 1. Engine warm-up time shall be included into total running-in time. Length of each of the following modes shall be counted from the moment engine speed changes.

Length of start-up, downtime and consequent warm-up periods shall not be included into total running-in time.

Cooling water temperature during running-in period shall not exceed (85±5)°C; temperature of oil in the oil pan shall not exceed (105±5)°C.

3.4 Upon completion of running-in**:**

3.4.1 Measure compression pressure in each cylinder with compression meter; it shall not be below 1,20 MPa.

3.4.2 Measure full and residual vacuum in cylinders with a vacuum-gauge. Full vacuum shall be not below 0.82, residual vacuum shall be not below 0.36.

3.4.3 On completion of running-in mode drain oil from the engine and install new oil filter. Oil shall be drained from hot engine; oil draining period shall at least 180 min.

4 RUNNING THE TESTS

4.1 In order to remove the remnants of used oil, change oil as follows:

4.1.1. Start the engine and warm up in idling mode until temperature in the oil pan reaches 80^0C.

4.1.2. Shut off the engine, unscrew the drain plug and drain oil from the engine; oil draining period shall be at least 180 min.

4.1.3. Prime the engine with 1.5 l of oil to be tested, start the engine and warm up in idling mode for 5 minutes.

4.1.4. Shut off the engine and drain the oil; oil draining period shall be at least 20 min.

4.1.5. Prime the engine with 1.5 l of oil to be tested and repeat steps 4.1.3…4.1.4.

4.1.6. Change the filter.

4.2 Prime the engine with (3,5±0,1) l of oil to be tested; make sure that oil level in the oil pan is at the top mark of level indicator.

4.3 Ambient air temperature in motor compartment shall not exceed 40°C, relative humidity shall be within the range of 60%...80%.

4.4 Start the engine, warm it up at constant speed and load until temperatures of coolant and oil in the oil pan stabilize. Take measurements of engine operating values (torque, crankshaft RPM, instant air flow, lube oil pressure, temperatures of coolant, exhaust gas and lube oil), and emissions of CO, CH, CO_2, NO_x in operation modes specified in Table 2.

Time length, min	Engine speed, RPM	Torque, Nm
1	2000	20,0
2	2000	40,0
3	2000	60,0
4	2000	80,0
5	2000	Max
6	2500	Max
7	3000	Max
8	3500	Max
9	3000	80,0
10	3000	60,0
11	3000	40,0
12	3000	30,0

Table 2. Test cycle parameters

4.5 All the measurement shall be taken not before temperature of lube oil and cooling water are stabilized; each value shall be measured thrice in each test mode according to Table 2. Prior to the start of the test cycle shut down the injection gasoline engine, switch off power supply of the control unit, in 60 sec switch on power supply again in order to reset memory.

4.6. Friction horsepower shall be measured as follows:

4.6.1 Warm up the engine until temperature in the oil pan reaches operation level (by temperature indicator).

4.6. 2 Cut off fuel to the engine, let the engine run until all the residual fuel is burnt, whereupon cut off ignition.

4.6.3 Prior to start friction horsepower measurement cycle take measurement of oil temperature.

4.6.4 Set speed of the engine driven with test bed dynamometer and throttle position according to Table 3; register friction horsepower and temperature in the oil pan.

Engine speed, RPM	Throttle opening, %	Engine speed, RPM	Throttle opening, %
300	0		
500	0	4000	100
800	0	3500	100
1000	0	3000	100
1500	0	2500	100
2000	0	2000	100
2500	0	1500	100
3000	0	1000	100
3500	0	800	100
4000	0	500	100
		300	100

Table 3. Friction horsepower test modes

4.6.5 On completion of the test cycle switch on fuel to engine and ignition, set engine speed at 3000 RPM, torque at 80 Nm, and run the engine for 10 min, whereupon friction horsepower test cycle shall be considered completed.

4.7 On completion of the test cycle of each lube oil composition sample oil for analysis as follows:

4.7.1 Immediately on completion of the test phase shut down the engine for 20 min. During the downtime use the sampler to take 300 ml oil from level indicator orifice to flush the sampler, then take sample in the amount of 100 ml.

4.8 The test phase shall be considered completed if:

- the test cycle is ran in full;
- oil level dropped blow minimum mark on level indicator; or
- an emergency arose, whose removal involves engine dismantling and replacement of control parts, or essential change in engine settings (fuel supply or ignition system).

4.9 Finalize test cycle for each oil composition drain the oil and flush the engine according to paragraph 4.1. Replace used oil into a clean can to store. Samples of tested oils shall be stored for 6 months.

4.10 Test the oil samples for the following characteristics:

Nr.	Characteristic	Test method
1	Density	ASTM D 1298
2	Kinematic viscosity	ASTM D 445
3	Kinematic viscosity @ 150^{0}C	SPBGPU method
4	Alkaline number	GOST 11362
5	Mass fraction of active components	ASTM D 4927
6	Lubricating properties	GOST 9490
7	Pour and solidification points	ASTM D 97

4.11 During the whole series of oil sample tests no dismantling of the engine or change in its settings capable to affect test results is acceptable. Should any fault arise that call for engine dismantling, test series shall be repeated.

5. ASSESSMENT OF TEST RESULTS

5.1 Measured values of engine power, fuel consumption, friction horsepower and emissions shall be reduced to standard atmospheric conditions, their variation during the tests shall be evaluated.

5.2 Test result shall be evaluated though comparison of cycle-averaged effective power at maximum torque speed curve, specific fuel consumption, friction horsepower, and noxious emissions.

5.3 The above values shall be compared with similar test results for baseline lube oil.