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ANALYSIS OF VEHICLE ENERGY EFFICIENCY AND TEST RESULTS USING AN INTELLIGENT START-STOP SYSTEM OF THE VEHICLE ON THE NEW EUROPEAN DRIVE CYCLE AT THE PISKENT AUTO POLYGON

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Abstract– In this paper, the energy efficiency of automobiles through the intelligent start-stop system as a part of the intelligent transport systems was determined by the research method. In the research method, the vehicle's driving mode was analyzed according to the NEDC (New European Driving Cycle) standard at the Piskent auto polygon. The M1 category Chevrolet Nexia used the method of measuring fuel consumption by volume on the drive cycle. The data were obtained via OBD-II from onboard the vehicle through the Scanmatic diagnostic device.

Key words– drive cycle, start-stop system, intelligent transport system, fuel economy, environmental standards.

I Introduction

Nowadays, the development of the automotive industry in the world requires constant monitoring of car quality. It is known that vehicles must meet several requirements in the exploitation conditions when performing cargo, passenger, and other similar tasks. The level of satisfaction of the requirements for the car in the exploitation conditions determines its quality. In order to meet today's requirements, road transport and its industry must perform the following tasks:

- increase and improve the range of cars that fully meet the needs of the economy;
- reduction of specific fuel consumption, ensuring fuel economy;
- further, increase the efficiency of the vehicle;
- improving the quality of manufactured cars [1]. Therefore, testing of cars allows determining the quality level of their multifaceted constructive and exploitation characteristics.

The vehicle can use in different exploitation conditions and must be adapted to it. Therefore, during the design of the car, it is necessary to include the basics of its exploitation characteristics. They are production requirements, using requirements, consumer‘s requirements and safety requirements. Environmental safety is one of the main parts of the safety requirements. We focused on environmental safety requirements because our research work is directly related to the fuel economy and environmental safety. Environmental safety is about reducing the damage a car can do to the environment. These include the release of harmful gases and dust into the environment, high levels of noise, and vibration in the car. In foreign countries, prescriptive drive cycles describing typical conditions are widely used by car manufacturers to determine the energy efficiency of automobiles in a research method [2]. A driving cycle is a form of data that represents the velocity of a vehicle in relation to time. The drive cycle has been developed by different countries and organizations and evaluates the performance of vehicles in different ways, such as energy efficiency, environmental safety of vehicles, and so on [3]. Currently, the implementation of new and innovative technologies and techniques in the area of vehicle design is leading to a change in regulatory requirements. More specifically, the European Union has set stringent environmental standards for motor vehicles for car manufacturers. For example, according to the approved new

European Driving Cycle (NEDC) [4] standard for determining the energy efficiency and environmental standards of automobiles, to increase the number of exhaust gases to 95 g CO2 / km for passenger cars by 2020-2021, Worldwide Harmonized Light Vehicles Test Procedure (WLTP) [5], the target for 2020 is 100 g CO2 / km [6]. The internal combustion engine, which is one of the main components of a car, is an energy source that converts the heat energy generated by fuel combustion to mechanical energy [7]. According to the experience of experts, the amount of harmful substances that pollute the atmosphere as a result of complete combustion of 1 kg of fuel in cars for gasoline engines is 0.6 kg of carbon monoxide (CO), 0.1 kg of hydrocarbons (HC), 0,04 kg nitrogen oxides (NOx) [8]. We believe that it is very important to implement new innovative technologies in the automotive industry to reduce those values. 100 percent of light vehicles are manufactured on the basis of gasoline engines in our country.

II METHODOLOGY

The starting system is one of the engine‘s systems, which provides an engine start. This system converts electrical energy from the batteries into mechanical energy to turn the engine over. A starter is a special device used to rotate crankshaft an internal-combustion engine [9]. When the alternator is not running or its power is insufficient to start the engine using a starter, the battery is responsible for supplying electricity to all current consumers in the vehicle [10] (Fig. 1).

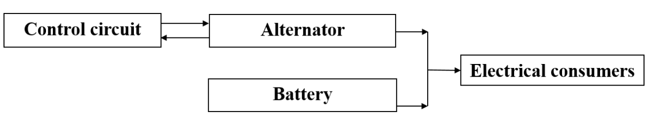


Fig. 1: Structural scheme of the power supply system.

In this scheme, the alternator voltage and the accumulator battery show the relationship between the EMF and how their currents are consumed, including:

If $U_a > E_a$ then, $I_a = I_{ch} + I_{lc}$;

If $U_a < E_a$ then, $I_a + I_{dch} = I_{lc}$;

If $U_a = 0$ then, is equal to $I_{dch} = I_{lc}$.

where: U_a –voltage of alternator; E_a – EMF of accumulator battery; I_a – current of alternator; I_{ch} - the charging current of the battery; I_{dch} - discharge current of the battery; I_{lc} - load current consumed by consumers. Start-stop system automatically shuts down and restarts the internal combustion engine of vehicles to cut down the amount of time the engine spends idling (Fig. 2). Additionally, the system helps in reducing fuel consumption and emissions. The growth in start-stop system market is driven by continuous improvement in vehicle performance and fuel efficiency levels. Strict regulations regarding exhaust gases set by various government and legislative bodies are serving as an advantage to this market. Major suppliers of these systems and automotive manufacturers adopting these systems are in the Asia-Oceania and European regions, which enables these regions to become the largest markets for start-stop technology [11].

Nowadays, “UzAuto Motors” JSC manufactures 13 types of light vehicles. 23 percent of them have 1,5 liter engine [13]. This include the Chevrolet Nexia, Chevrolet Cabalt and Chevrolet Lecetti. In addition, cars of this model are in demand not only in the domestic market, but also in foreign markets. The main goal of this research is to test fuel economy using a start-stop system in the engine besed on Chevrolet Nexia segment. Selected technical parameters of the combustion engine of the discussed vehicle are shown in Table 1.

Quantity	Units	Value
Engine type		B15D2, DOHC
No. of cylinders		4, in-line
Compression ratio		10.5
Power	[kW]/n [rpm]	105 / 5800
Torque	[N·m]/n [rpm]	141 / 3800
Engine displacement	m3	1485
Fuel system		Gasoline, fuel injector
Fuel type		Ai - 91
Accumulator battery	/ (20h) / A EN	12 / 55 Ah / 610 CCA

TABLE 1: TECHNICAL CHARACTERISTICS OF CHEVROLET NEXIA [13].

In this research we used the Uzbek state standards such as Uz DSt 1010: 2001 - “Method for determination of basic expenditure for fuel in auto vehicle” [14], Uz DSt 3311: 2018 - “The model program and methodology of realization of the climatic proof-testing of vehicles are in the natural and climatic terms of the Republic of Uzbekistan” [15] and also the New European Drive Cycle [4]. The system was tested based on the guideline “Determining the impact of the intelligent start-stop system on energy efficiency in the drive cycle” [16] at the auto polygon condition. The measurement of fuel consumption by volume was used in a test using an intelligent start-stop system in the vehicle drive cycle. In this method, based on the capabilities of the vehicle’s design and electronic control unit in determining fuel consumption and vehicle speed, the NEDC was tested on the drive cycle using Scanmatic diagnostic device. The testing place was selected in the Piskent district of the Tashkent region. This area is specifically designed for car testing and fully meets all requirements (Fig. 3). To determine the arithmetic mean of the test results, three motions were made on both sides of the specified trajectory.

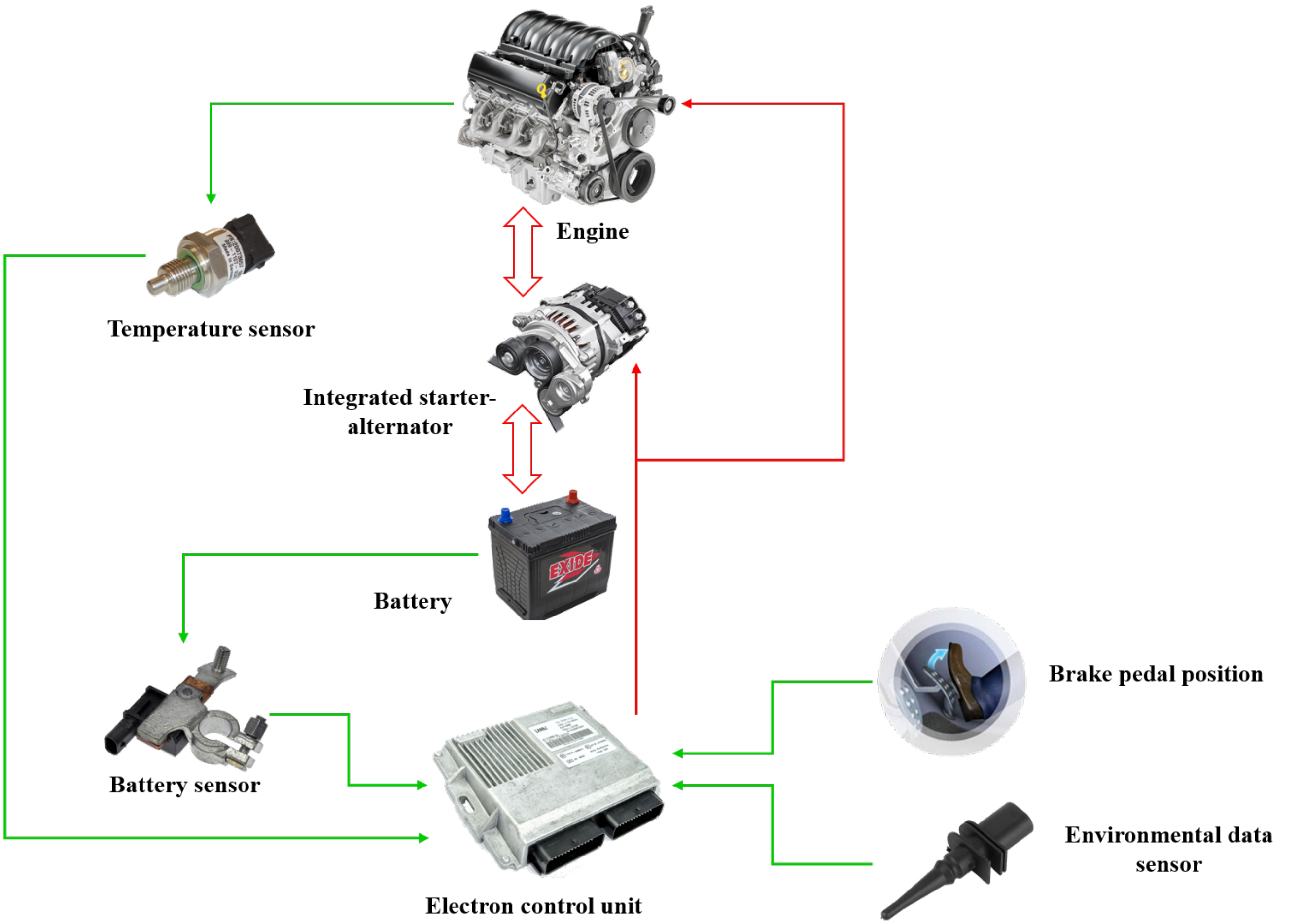


Fig. 2: Model of electronic control system for start–stop system [12].

III Result and Discussion.

The spectral results were obtained in this drive cycle. As well as the diagrams representing the speed of the vehicle relative to time were created in computer technology (Fig. 4, 5).

The fuel consumption of the Chevrolet Nexia was calculated using the following formulas at the auto polygon. The mean velocity of the vehicle is Vav, km/h and the average fuel consumption is calculated according to the formula QS, l/100 km [14-16]:

$$V_{av} = \frac{3,6 * S}{t} \quad (1)$$

$$Q_{S-av} = \frac{100 * Q_n}{S} \quad \text{or} \quad G_S = \frac{100 * m_T}{\gamma_T * S} \quad (2)$$

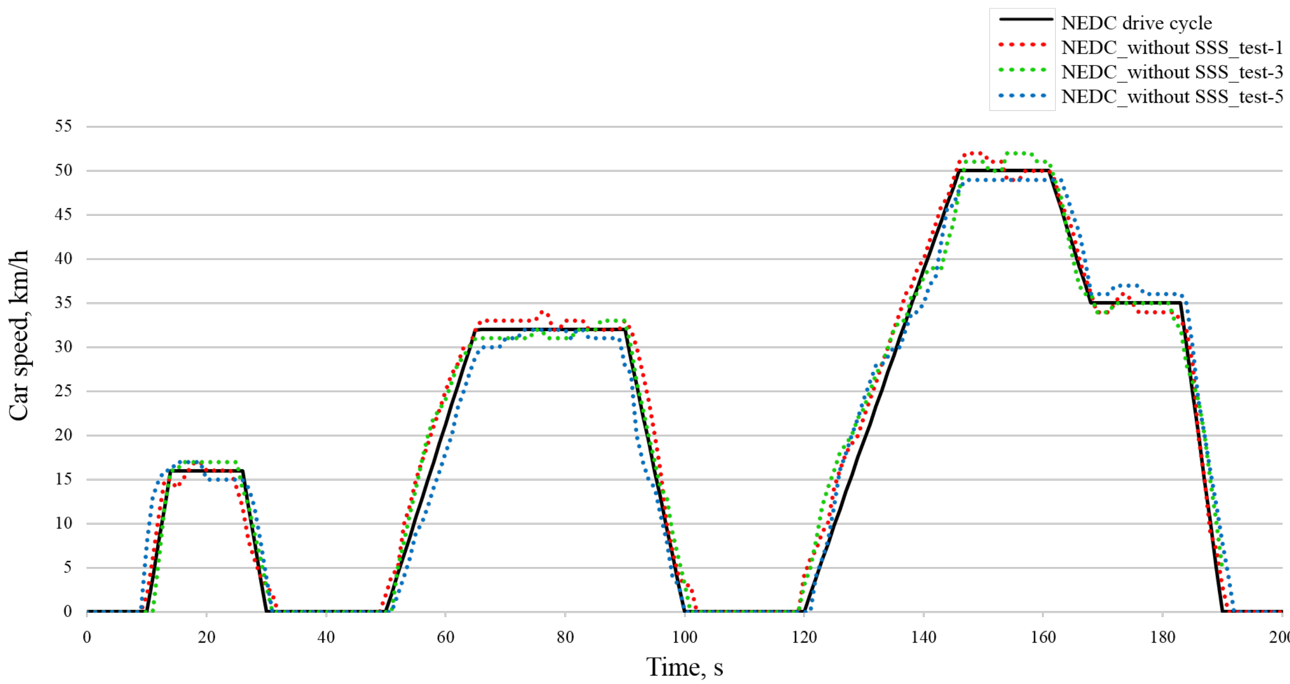
where: S - distance of the measuring part, m; t - mean time taken to pass the measurement part, s; Q_n – the absolute consumption of fuel obtained during the tests, cm^3. m_T – fuel mass, g; $_T$ – the density of the fuel reduced to 20 °C, g/m^3.

The test performance of the light vehicle in the NEDC drive cycle is given in Table 2.

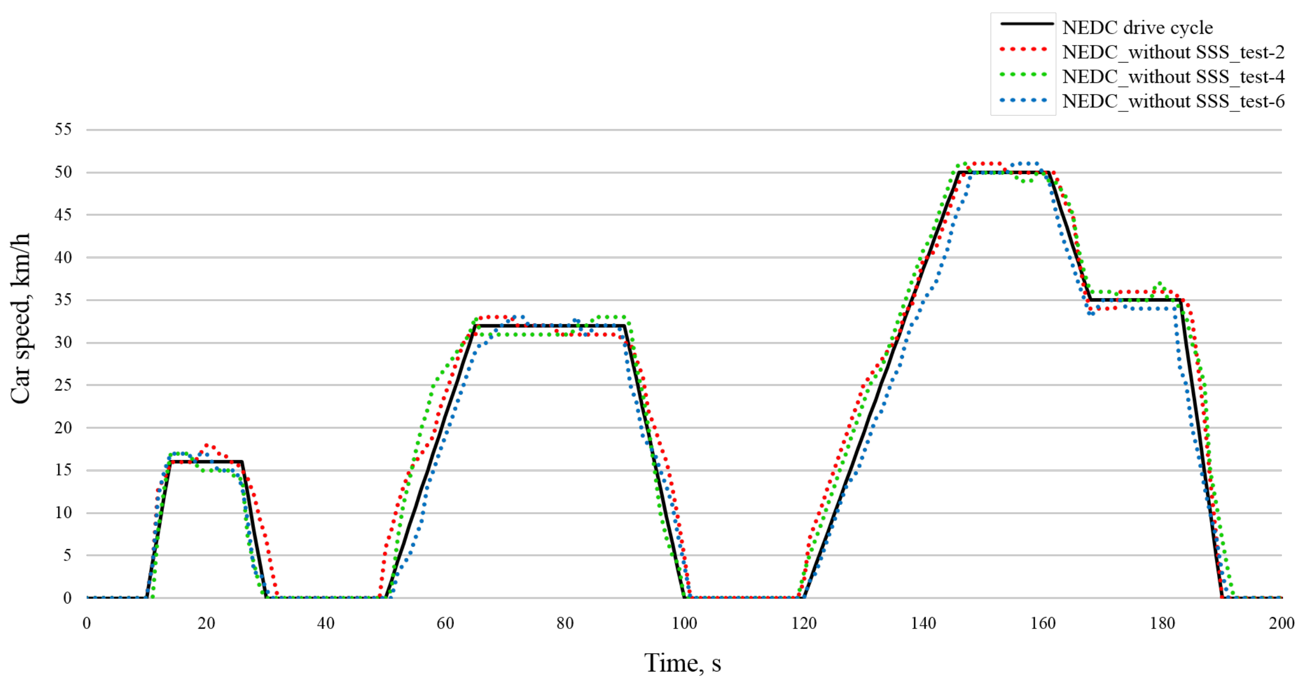
Using the scanmatic diagnostic device, about 90 exploitation parameters depending on the driving mode of the vehicle for the drive cycle were obtained through On-Board Diagnosticts (OBD-II) Controller Area Network (CAN) on board the electronic control system of the engine [17]. These include vehicle speed for fuel consumption, engine speed, torque (Fig. 6), load engine (in, percent), temperature, ignition timing (in, grades), detonation (in, voltage), fuel injection pulse duration, fuel tank reserve (in l, % position), -zond sensor voltage, such as the discharge and charge voltage of the battery when starting the engine on the electrical supply, as well as the voltage generated by the alternator (Fig. 7) and so on.

The test results of Chevrolet Nexia on the NDEC are given in Table 3.

Fig. 3: The testing area is 2 km at the Piskent auto polygon.



a



b

Fig. 4: The drive cycle of the vehicle without an intelligent start-stop system according to the NEDC at the auto polygon.a) a drive cycle in one direction. b) a drive cycle in opposite directions.

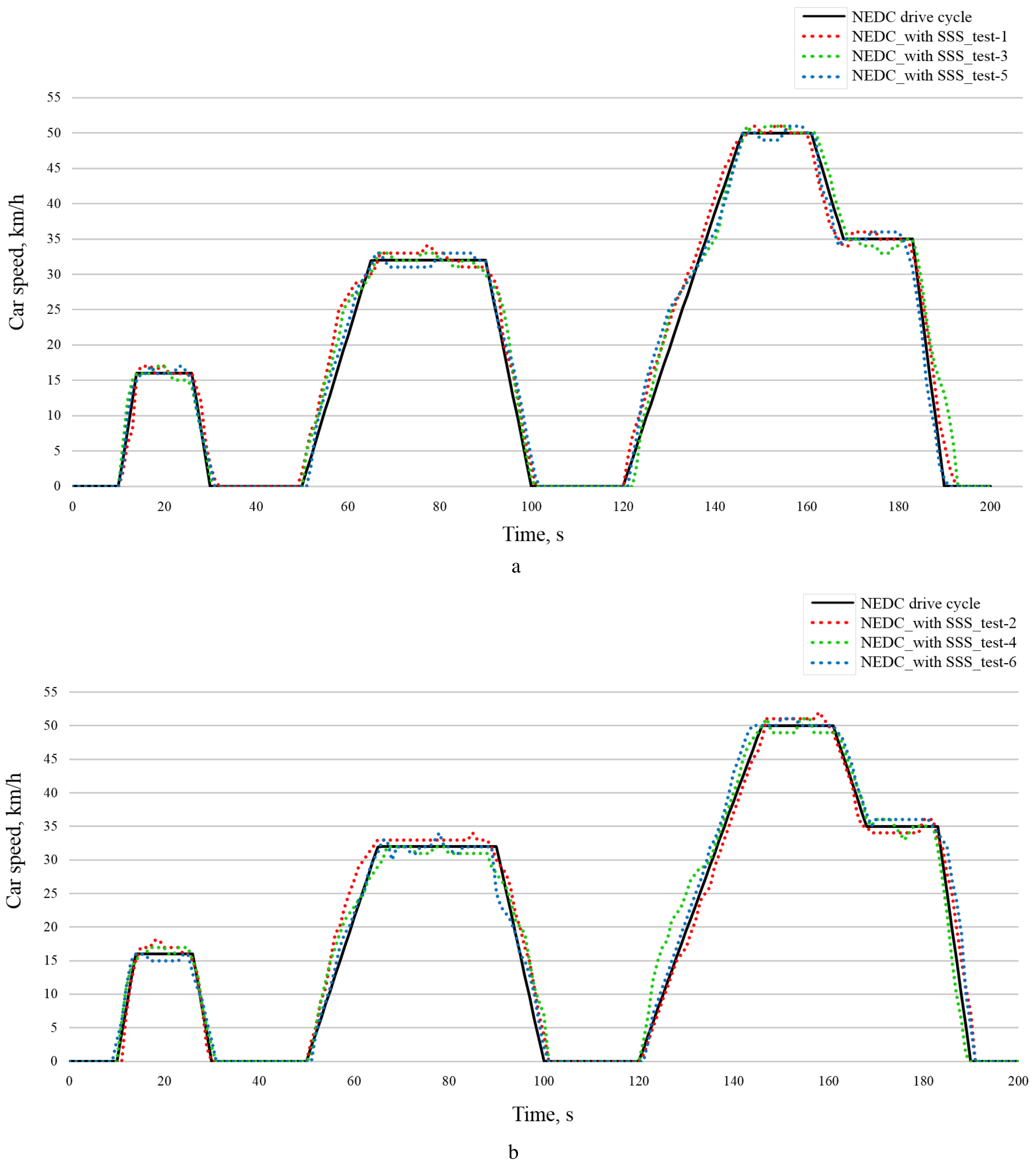


Fig. 5: The drive cycle of the vehicle with an intelligent start-stop system according to the NEDC at the auto polygon. a) a drive cycle in one direction. b) a drive cycle in opposite directions.

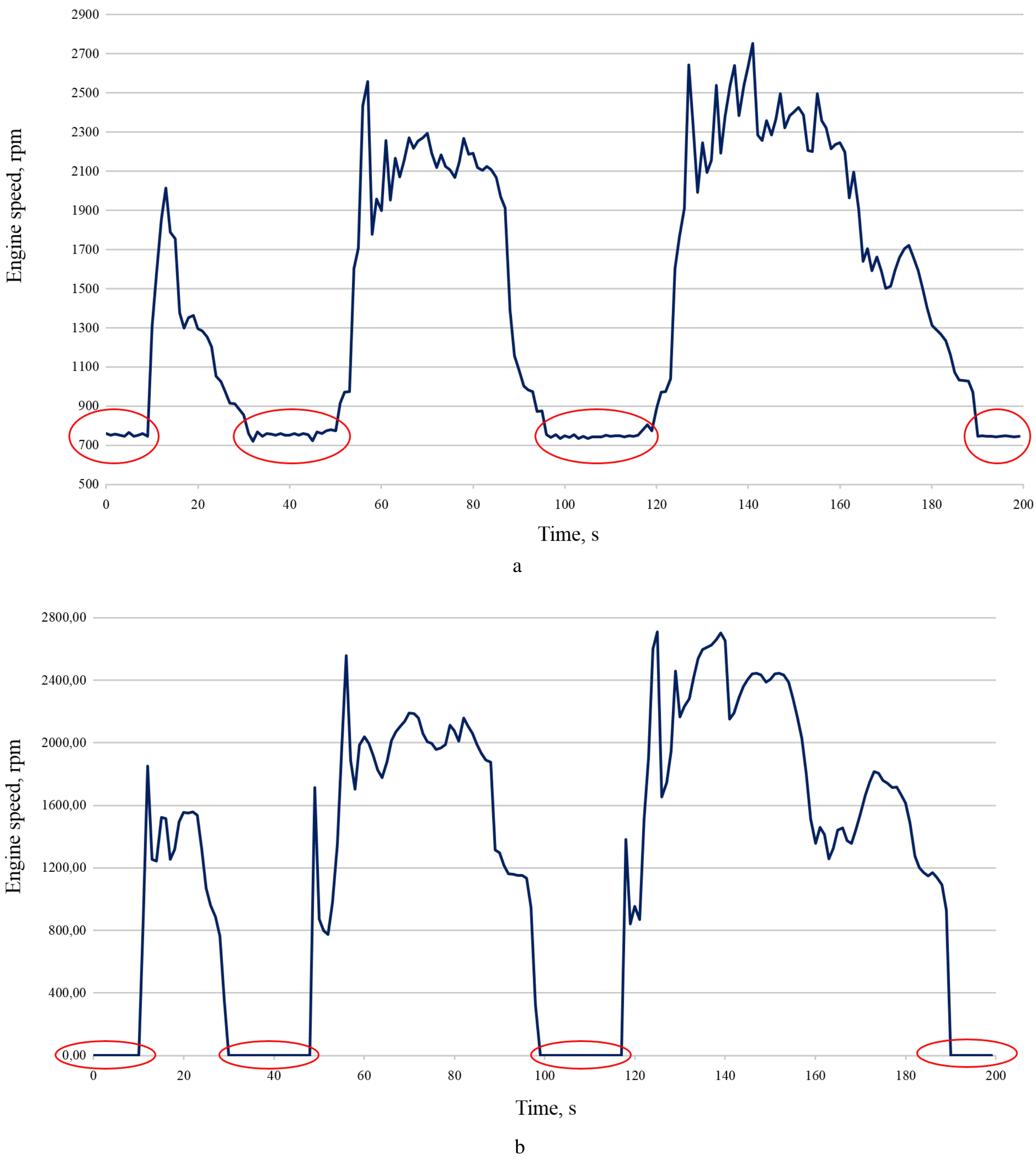


Fig. 6: The engine speed of the vehicle on the drive cycle (NEDC). a) without start-stop. b) with start-stop.

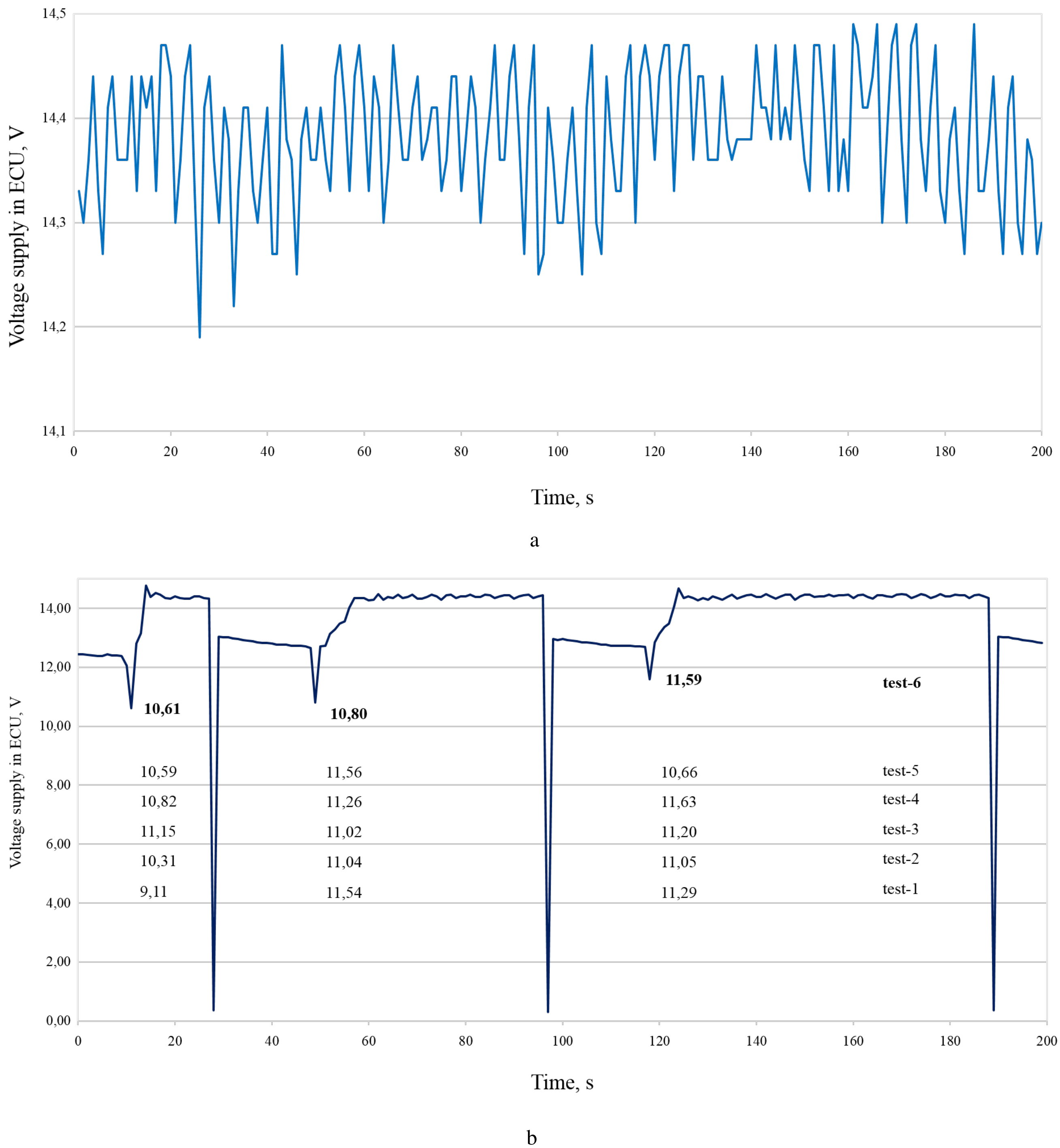


Fig. 7: The voltage supply of the vehicle on the drive cycle (NEDC). a) without start-stop. b) with start-stop.

Name of test process	Units	NEDC (1-cycle)		
		Fixed	Test type	
			Without SSS	With SSS
Duration	s	200		
Distance	m	1054,3		
Mean velocity	km/h	19,03		
Max .velocity	km/h	50±2		
Stop phases		4		
Duration:				
Idling time of the engine	s	60	59,5	
Stop	s			60
Constant driving	s	67	68,5	62,5
Acceleration	s	45	42	44
Deceleration	s	28	30	33,5
Shares:				
Stop		30%	29,75%	30%
Constant driving		33,50%	34,25%	31,25%
Acceleration		22,50%	21%	22%
Deceleration		14%	15%	16,75%

TABLE 2: DESCRIPTIVE PARAMETERS OF CHEVROLET NEXIA ON DRIVING CYCLE AT THE AUTO POLYGON.

Vehicle model	Time, s	According to technical description, *l / 100 km*	The fuel consumption on the drive cycle (NEDC)				Difference, +/-,	
			ml		*l/100 km*		*l/100 km*	
			Without SSS	With SSS	Without SSS	With SSS	Without SSS	With SSS
Chevrolet Nexia	200	8	0,088	0,083	8,38	7,5	0,38	-0,88

TABLE 3: THE FUEL CONSUMPTION OF THE VEHICLE ON THE DRIVE CYCLE

Measurement and test procedure	Battery discharge starting the vehicle's engine, V	Alternator voltage on the drive cycle, V	
		min	max
1.	11,26	13,29	14,96
2.	11,18	13,84	14,57
3.	10,95	14,19	14,52
4.	11,05	14,22	14,55
5.	10,58	14,19	14,49
6.	10,89	11,14	14,5
Average:	$U^{min}_{d.av} = 10,99$	$U^{min}_{a.av} = 13,48$	$U^{max}_{a.av} = 14,60$

TABLE 4: TECHNICAL CHARACTERISTICS OF THE BATTERY AND ALTERNATOR WITHOUT "START-STOP SYSTEM"

Measurement and test procedure	Battery discharge starting the vehicle's engine, V	Alternator voltage on the drive cycle, V	
		min	max
1.	$U^{i=1}_{d.av}B = 10.65$	$U^{min}_{a.av\_i=1} = 14,22$	$U^{max}_{a.av\_i=1} = 14,55$
2.	$U^{i=2}_{d.av}B = 11,14$	$U^{min}_{a.av\_i=2} = 14,30$	$U^{max}_{a.av\_i=2} = 14,77$
3.	$U^{i=3}_{d.av}B = 11,13$	$U^{min}_{a.av\_i=3} = 14,19$	$U^{max}_{a.av\_i=3}B = 14,71$
4.	$U^{i=4}_{d.av}B = 10,66$	$U^{min}_{a.av\_i=4} = 13,75$	$U^{max}_{a.av\_i=4} = 14,77$
5.	$U^{i=5}_{d.av}B = 10,93$	$U^{min}_{a.av\_i=5} = 14,38$	$U^{max}_{a.av\_i=5} = 14,68$
6.	$U^{i=6}_{d.av}B = 10,80$	$U^{min}_{a.av\_i=6} = 14,33$	$U^{max}_{a.av\_i=6}B = 14,77$
Average:	$U_{d.av} = 10,95$	$U^{min}_{a.av} = 14,20$	$U^{min}_{a.av} = 14,6$

TABLE 5: TECHNICAL CHARACTERISTICS OF THE BATTERY AND ALTERNATOR WITHOUT "START-STOP SYSTEM"

A battery is a chemical source of electricity that is capable of collecting (charging) chemical energy when supplied with electricity from the outside and deliver it to external consumers (discharging) in the form of electrical energy. The process of converting energy from one state to another is ongoing throughout the lifetime of the battery [9]. The use of Alternating current (AC) alternators is widely used in modern automobiles. They can control the maximum and minimum load current. The research process is related to the engine starting system too. As a result, we analyzed the battery discharge charge and voltage - generating alternator properties on the drive cycle (NEDC) (Tables 4-5).

IV CONCLUSION.

Based on world experience, it is necessary to introduce the concept of "energy efficiency" into industries and regulations. We can also note the dynamic growth of road transport in our country, the increase in energy demand for road transport. According to the results of the test, the car's fuel consumption was 8.38 liters per 100 km when not using start-stop system, while the technical consumption of the car was 7.5 liters per 100 km when using start-stop system in new European drive cycle. As a result, 6.25% of fuel was saved. In addition, according to environmental standards, the car emitted about less than 6 % of exhaust gases to the environment using this system. In the worldwide experience, it is noted that using the start-stop system reduced the fuel consumption and emission of carbon dioxide by 5–10%; taking into account the hybrid cars, this reduction might amount to 10–25% [12, 18-19]. According to the specifications of the battery and the alternator, the discharge voltage in the battery showed 9.11 V (76%) when starting the engine. This voltage is above the minimum voltage required to start the engine from 8.50 V (70%) to 0.61 V (5%). However, given that the alternator has the capacity to supply current to the battery and other consumers during the drive cycle, the rated voltage of the battery during the research is 10.99 V (91.6%) without the "start-stop system" (Tab.4), with "start-stop system" 10.95 V (91.2%) (Tab.5). So, according to preliminary results, it is recommended to use a "start-stop system" in 1.5-liter motor vehicles that produce in our country.

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