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STUDY OF FUEL AND EQUIVALENT ECONOMY OF TRANSPORT VEHICLES, OPERATING ON CONVENTIONAL AND ALTERNATIVE TYPES OF FUEL

Development of the automobile industry leads to annual increase of the quantity of the automobiles. In 2020 more than 78 mil. motor vehicles were manufactured in the world, lion share of the quantity falls on such manufactures as Toyota Motor Corporation (9.5 mil) and Volkswagen Group (8.7 mil). It is obvious that such amount of the world auto pool will cause numerous problems, first of all, it is the pollution of the environment by the exhaust gases and traffic jams. In particular, over 20% of all carbon dioxide (CO_2) emissions is generated by motor vehicles.

The paper contains the list of the basic alternative sources of fuel, used in transport vehicles, such as ethanol, butanol, liquefied natural gas (LNG) and compressed natural gas (CNG), hydrogen, biogas, also the sources of electric energy for transport vehicles are: power lithium-ion batteries, fuel and hydrogen cells, solar cells and supercapacitors.

Technique for determination of the fuel and equivalent efficiency, used in the USA and problems dealing with its implementation in Ukraine is considered. It was established that the Ukrainian legislation does not contain statutory-instruments, regulating the technique for determination of fuel efficiency of the transport vehicles, including the vehicles which use the alternative sources of energy. Equivalent fuel efficiency of the following motor vehicles was studied and analyzed: Chevrolet Lacetti (petrol), Renault Logan (diesel), Honda FCX Clarity (hydrogen), Ford C-Max (alcohol-containing fuel), Renault Sandero (biodiesel fuel), Nissan Qashqai (biogas), Citroën C4 (liquefied natural gas), Nissan Leaf (electric energy). Results are presented in the form of graphic dependences.

Key words: *electric vehicles, fuel efficiency, hybrid transport vehicles, equivalent consumption of fuel, electric power.*

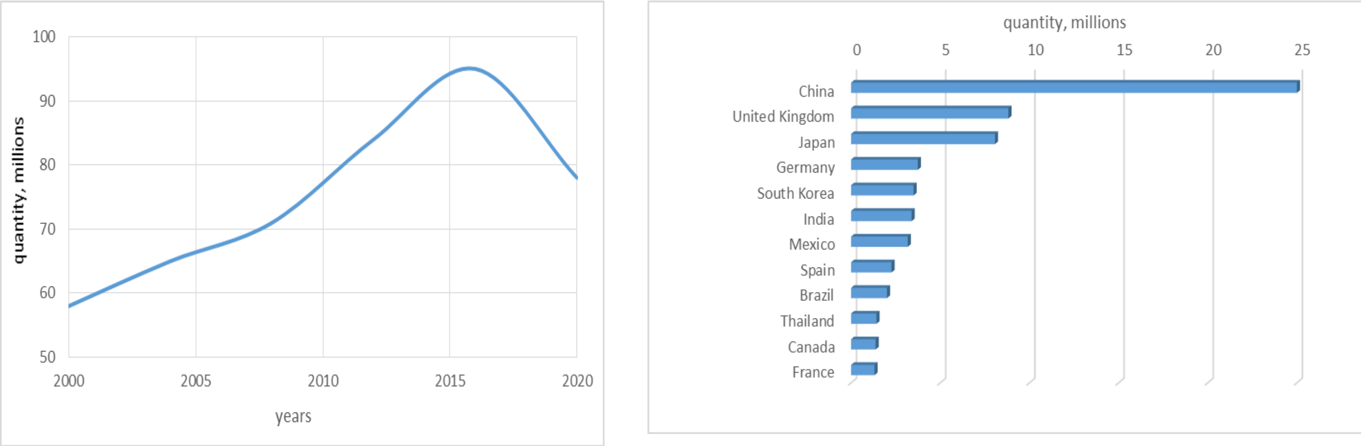
Introduction

Automobile industry continues rapid development, meeting the requirements and providing comfort of use for the consumers in the sphere of passenger and cargo transportations. Buses, cars and trucks are referred to motor vehicles [1].

It is quite obvious, that greater part of the world automobile pool generates a number of different problems, first and foremost among them it is contamination of the environment with the exhaust gases and traffic jams. In particular automobile transport generates over 20% of all carbon dioxide (CO_2) emissions in the atmosphere. To reduce the harmful emissions world engineering community every years puts forward more strict ecological standards, limiting the content of harmful substances in the exhaust gases. In 2015 ecological standard Evro-6 was introduced on the territory of European Union. More strict Evro-7, that limits the oxides nitrogen emissions from 60 mg/km to 10 mg/km for petrol engines and from 80 mg/km to 30 mg/km for diesel engines (as compared with Evro-6) [2, 3] is prepared for the implementation.

Aim and problem set-up

Only in 2020 more than 78 mil motor vehicles were manufactured in the world, lions share of this quantity falls on such manufactures as Toyota Motor Corporation (9.5 mil) and Volkswagen Group (8.7 mil). Rates of motor vehicles production in the world are shown in Fig. 1a, total number of motor vehicles is more than 1.3 billion units. In 2020 greater part of the motor vehicles were manufactured in China, Japan and Germany (Fig. 1b).



a) b)

Fig. 1. Dynamics of motor vehicles production in the world a) dynamics of motor vehicles production in the world; b) number of motor vehicles, manufactured in 2020 in leading countries

In Ukraine, according to S.E. Scientific Research Institute «StateatotransNDIproject», total number of the registered transport vehicles is over 4.6 mil.

At the same time motor vehicles started to use the alternative sources of fuel such as: ethanol, butanol, liquefied and compressed natural gas, hydrogen and biogas. It is worth noting individually the electric energy, that is the most ecologically friendly type of fuel. Most widely spread sources of energy for transport vehicles are lithium-ion cells, fuel and hydrogen elements, solar cells and supercapacitors [4, 5, 6]. Classification of the motor vehicles, using electrical and hybrid drives is shown in the paper [7].

Aim of the study is to determine fuel and equivalent efficiency of the motor vehicles, using conventional and alternative types of fuel by improving the technique of determination.

Object of the study – motor vehicles, using conventional and alternative type of fuel.

Subject of the study – fuel and equivalent efficiency of the motor vehicles, using conventional and alternative types of fuel.

The following tasks are determined for the realization of the given aim: analyze the state-of the -art-of the problem, regarding the study of the fuel and equivalent efficiency of the motor vehicles; proceeding from the results of the analysis, carried out, improve the technique of studying fuel and equivalent efficiency of the motor vehicles; applying the improved technique examine and analyze fuel and equivalent efficiency of the motor vehicles.

Scientific novelty of the obtained results is further development of the technique, aimed at studying of fuel and equivalent efficiency of the motor vehicles, using conventional and alternative types of fuel.

Practical impact of the results of the research is the creation of the base for the introduction in Ukraine statutory instruments, regulating the technique for determination of fuel and equivalent efficiency of motor vehicles using conventional and alternative types of fuel.

Analysis of the recent studies and publications

A number of papers consider the problem of fuel efficiency evaluation. In [7] the study, dealing with the equivalent fuel efficiency of electric cars is carried out. The paper [8] contains the assessment of fuel efficiency in case of the change of engine cylinders dimensions as a result of the repair. Paper [9] stresses that one of the important operation features of the motor vehicles is their fuel efficiency, the efficiency of the electric starting system of the internal combustion engine is investigated in the paper. Authors of the research [10] perform the study of the operation cost, taking into account the cost of maintenance and wear of the basic parts and components of the electric and hybrid transport vehicles. At the same time the fuel efficiency of the transport vehicles which use such alternative types of fuel as biogas, hydrogen, biodiesel fuel is not sufficiently studied, power of the transport vehicle is not taken into account too.

Results of the research and discussion. According to American standards [11], the measuring unit of economic efficiency of transport vehicle MPG (miles per gallon) is the distance in miles (1 mile = 1.609 km), that motor vehicle can run, consuming one gallon of fuel (1gal lig = 3.785 l).

On the contrary, economic efficiency of electric car is determined by the miles the transport vehicle can run, using electric energy, equivalent the energy, contained in the gallon of petrol. Such approach is used both regarding the hybrid motor vehicles and those, operating on the alternative types of fuel (NGV – natural gas vehicle; FCV – fuel cell vehicle). In other words , one gallon of the petrol equivalent is quantitatively comparable with kWh of electric energy, volume of natural gas, biogas, methanol, hydrogen, etc, that is equivalently equals the energy of the gallon of petrol (1 MPGe = 33,7 kWh = 121 MJ) on which motor vehicle can run the distance of one mile. In motor vehicles, using two or more types of fuel (PHEV, NGV, FCV), the consumption of each fuel is indicated in the gallons of petrol equivalent.

In Ukraine there are no statutory instruments, that regulate the technique of determination of fuel and equivalent efficiency of the motor vehicles, including vehicles, operating on the alternative types of fuel.

Alternative fuel, used by motor vehicles, can be measured in the units of volume, mass or electric indices (kWh). Using low heating value, energy indices of certain types of alternative and conventional fuel can be compared. Quantity of the alternative and conventional fuels, needed for obtaining 1 MJ of energy (0.0083 MPGe) is shown graphically in Fig. 2.

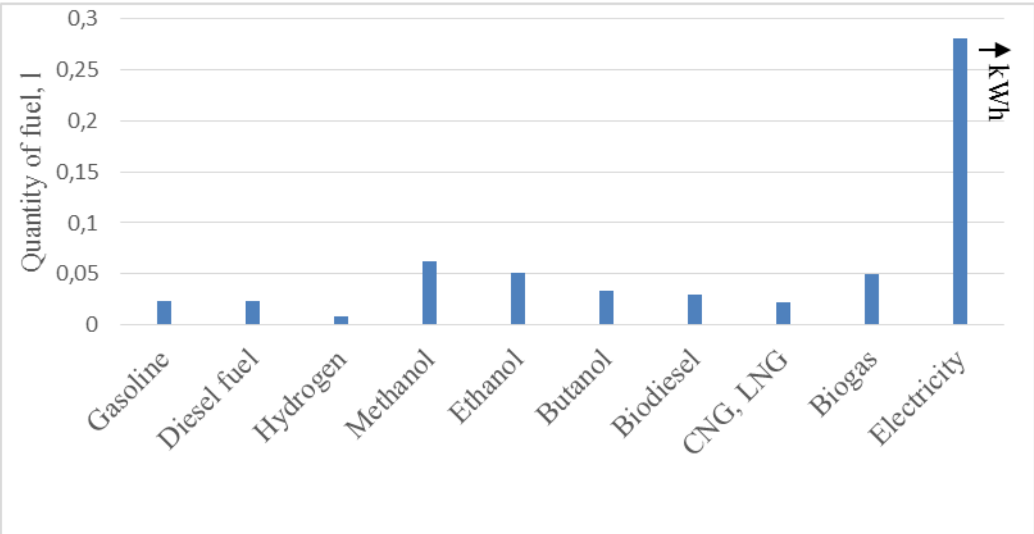


Fig. 2. Quantity of conventional and alternative fuel needed for obtaining 1 MJ of energy

Hydrogen has the highest energy intensity index (EII), that is why, consumption of fuel for obtaining energy is the lowest.

Table 1 presents motor vehicles, that use conventional and alternative sources of fuel and their specific technical characteristics.

Table 1

Technical characteristics of the motor vehicles, which use conventional and alternative sources of fuel

Vehicle brand	Type of fuel	Unit of fuel	Horse power hp. (kW)	Line fuel consumption (l/100 km)
Chevrolet Lacetti	Petrol	L	87 (64)	7.1
Renault Logan	Diesel	L	95 (70)	6.6
Honda FCX Clarity	Diesel	L	177 (130)	3.5
Ford C-Max	Alcohol-containing fuel (E85)	L	109 (80)	4.9
Renault Sandero	Biodiesel fuel (B100)	L	84 (62)	3.9
Nissan Qashqai	CNG, biogas	L	115 (85)	14.2
Citroën C4	LNG	L	110 (81)	8.4
Nissan Leaf	Electric energy	kW·h	108 (79)	10.5

It is obvious, that line fuel consumption (l/100 km) does not completely represent the real consumption of the transport vehicle.

Applying the equality (1) the specific consumption of fuel to run 1 km of route per 1 hp for each motor vehicle, operating on the conventional or alternative fuel will be determined.

$$Q = \frac{q}{100 \cdot N} \quad (1)$$

where Q – is specific fuel consumption (l/hp·km; kW·h/hp ·km); q – is linear consumption of fuel (l, kWh·); N – is power of the motor vehicle (hp).

Results of specific consumption of fuel are graphically shown Fig. 3.

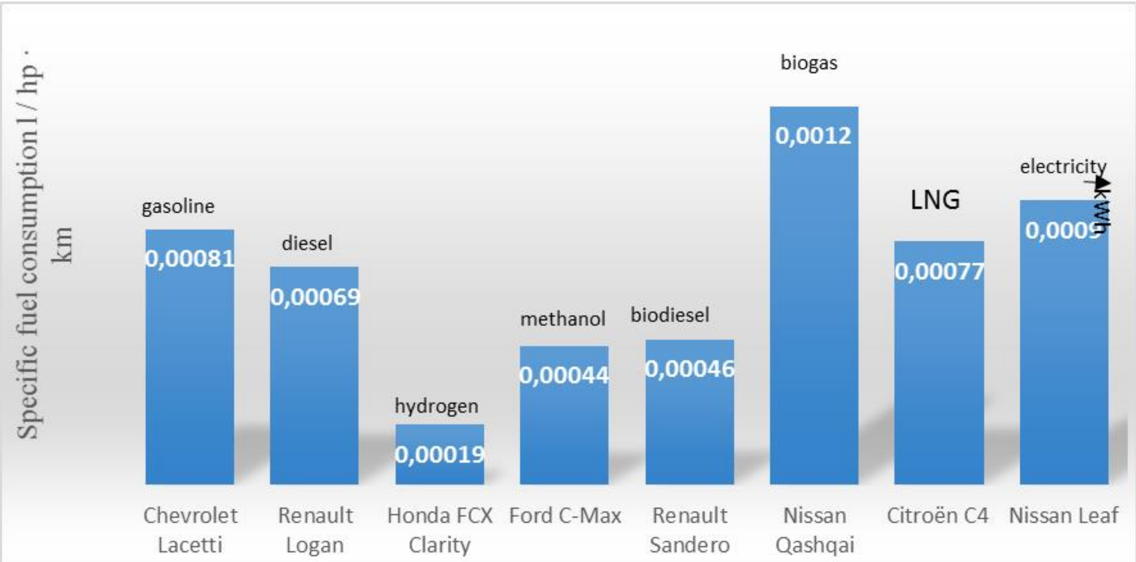


Fig. 3. Specific fuel consumption for certain brands of motor vehicles, operating on the conventional and alternative fuel (l (kWh)/h. p.·km)

With the account of the cost of the above-mentioned energy carriers in Ukraine the relative cost of the run, i. e., cost of the fuel, needed to run 1 km of the route, falling on the unit of power for the above-mentioned brands is determined, using the equality:

$$F = Q \times H \tag{2}$$

where F – is relative cost of the run, Hrs/hp·km; H – is the cost of fuel, Hrs/l.

Results of the relative cost of the run in Ukraine for motor vehicles, operating on the conventional and alternative fuel, are given in Fig. 4.

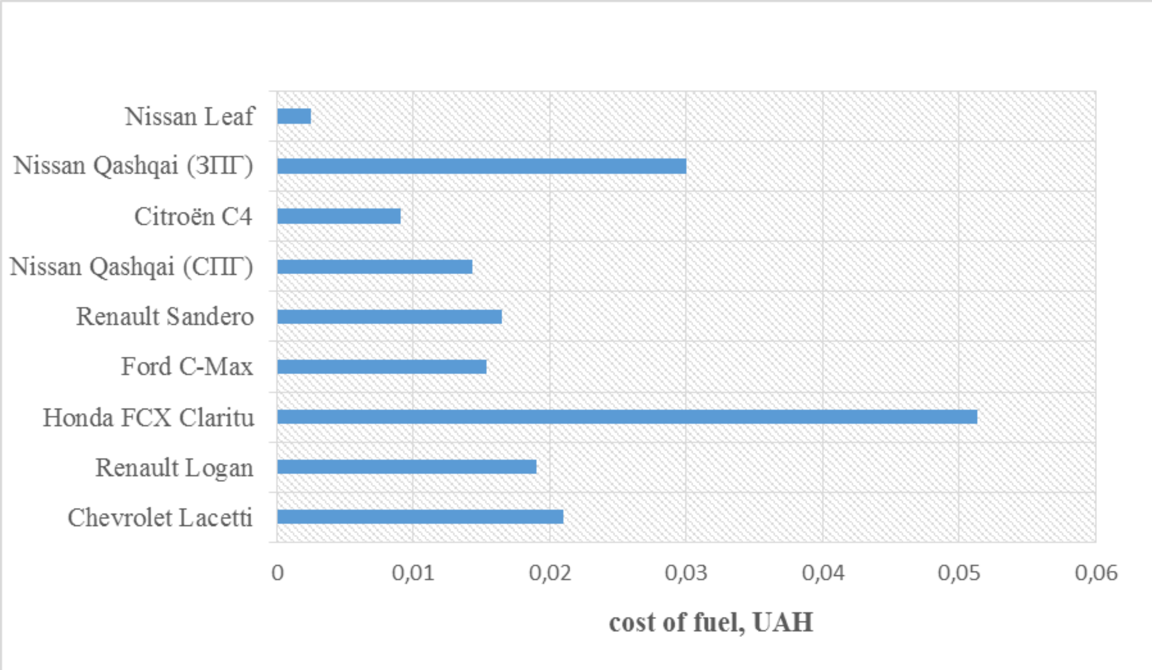


Fig. 4. Relative cost of the run in Ukraine, for motor vehicles, operating on the conventional and alternative fuel

Cost of energy carriers may change both in absolute and in relative values. That is why, it is expedient to introduce the factor, which would completely represent the real fuel efficiency of the transport vehicles, using conventional and alternative types of fuel. Objective index may be the equivalent fuel efficiency, which shows the amount of the conventional or alternative fuel, consumed by the transport vehicle to run 1 km of route and falls per unit of power (hp), converted into energy index(kJ). Using this technique specific fuel efficiency (kJ/km·hp) for the listed transport vehicles (kJ/km·hp) will be given. Results of the specific fuel efficiency are shown in Fig. 5.

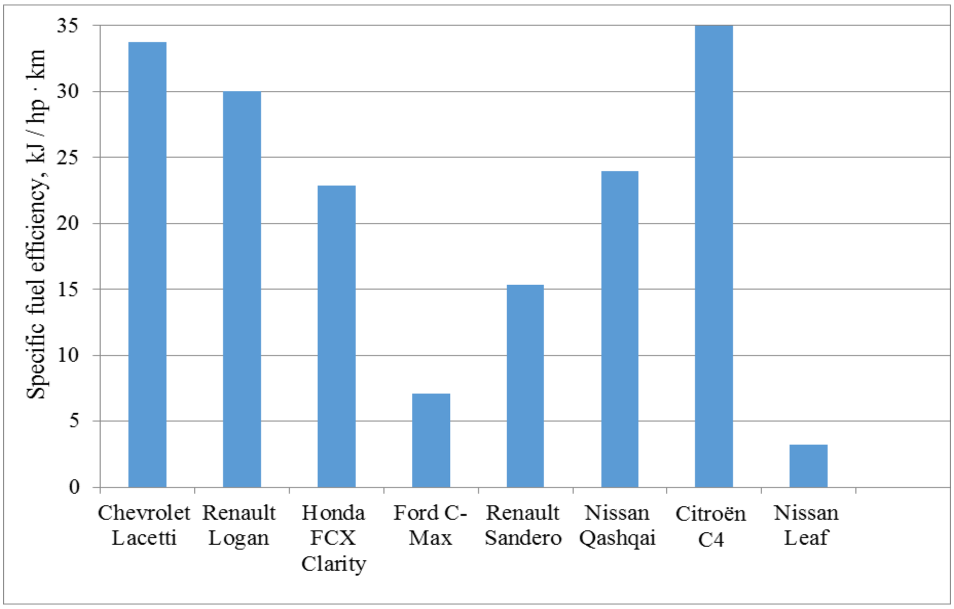


Fig. 5. Specific fuel efficiency (kJ/hp·km) for the listed brands of transport vehicles, operating on the conventional and alternative fuel

Analysis of the Fig. 5 shows that the motor vehicle with the electric drive (Nissan Leaf) to run 1 km of route and to provide 1 hp of power consumes least energy among all the studied motor vehicles – only 3.21 kJ/hp·km. It is far less than the motor vehicles, equipped with the internal combustion engines.

Conclusions and directions for further study

Usage of various types of fuel and electric energy in modern transport vehicles creates problems for assessment of fuel and equivalent efficiency, as this problem is not regulated by any available in Ukraine statutory instrument.

It is established that for the presentation of real fuel efficiency of the motor vehicles, using alternative types of fuel, it is expedient to analyze along with line fuel consumption also specific fuel consumption.

Using the suggested technique for the determination of fuel and equivalent efficiency, equivalent fuel efficiency of motor vehicles, using conventional and alternative types of fuel has been studied and analyzed. It is established that the specific fuel consumption of electric motor vehicle Nissan Leaf is the least, among all the studied motor vehicles and is only 3.21 kJ/hp·km. This index is 9.3 – 11 times less as compared with motor vehicles Chevrolet Lacetti, Renault Logan and Citroen C4, which use «classic» fuel: petrol, diesel fuel and natural gas, correspondingly.

It is expedient to direct further research at widening the range of the studied motor vehicles and take into consideration greater number of factors, influencing the fuel and equivalent efficiency. On the base of such studies determine and suggest transport vehicles with the best indices of fuel efficiency for the preset operation conditions.

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