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THE USE OF ALTERNATIVE ENERGY CARRIERS IN AUTOMOBILE TRANSPORT AND THEIR ENVIRONMENTAL IMPACT

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Abstract

The technical-economical indexes of using different types of fuel in motor transport are determined. The estimation of applying different types of fuel in motor transport taking into account the specific cost of power equivalent and the influence on the environment has been carried out. It is shown that the use of hydrogen as an energy carrier allows promoting an output-input ratio due to the introduction of fuel elements. The conception of account of the ecological factors as an element of innovative directions basis has been developed.

Keywords: environment, motor transport, fuel, hydrogen, fuel elements, energy carrier.

Purpose

The paper is aimed at determination of technical-economical indexes (warmth of combustion and cost of energy) of alternative types of fuels for motor transport; comparison of expenses on traditional and hydrogen technologies of motor transport on 100 km of run, \$/100 km; the development of conception of account of the ecological factors as an element of innovative directions basis.

Introduction

The problem of ecological safety of motor transport is a part of the problem of ecological safety of the country. The emission of contaminating substances in Ukraine into the atmosphere from vehicles annually increases on the average by 3,1%. From the movable sources of contamination 2,7 million tons of harmful substances entered atmospheric air of our country in 2008, the greater part of which (2420,3 tons or 90,1%) is emissions of motor transport. Out of total amount of contaminating substances about 1,7 million tons or 63% are thrown out by cars which are in private ownership of population. Motor-car engines throw out in the air of cities more than 95% of oxide of carbon, about 65% of hydrocarbons and 30% of oxides of nitrogen. In the process of combustion of 1kg of petrol 465g of carbon monoxide, 25g of hydrocarbons, 1g of oxides of nitrogen enter the atmosphere. In addition, for combustion of 1kg of petrol 14,5kg of air are needed. A combustion engine during an hour expends about 200 l of oxygen – by 2,5 times more than a man inhales for a day.

In total atmospheric air contamination by the toxic car substances the share of engines with spark ignition makes up 93–95%, for diesel engines this value is 5–7%. The latter have the level of soot emissions by 5–6 times higher. The searches for alternative fuel which would be cheap and not give the harmful emissions have been intensively conducted during this decade. All motor-car fuels, except petrol, belong to the alternative fuels.

Formulation of the problem and its solution

Today taking into account the ecological factors becomes an important element of innovative directions in different industries of economy. In this connection in the 90s of the last century the works on evaluation of the social consequences of using different types of fuel were carried out abroad (USA and Western Europe) [1, 2]. As a result of these works the rate of ecological damage for the population, agriculture, timber industry, city environment and other objects, subjected to the influence of contaminates appearing in the process of power plants operation is estimated. At present time the conclusions of these researches have become the recommendations for developing the strategies for long-term development of territories and business. Estimation of external effects in addition to the direct expenses allows finding a new approach to the choice of

new technologies, promotes recommendations on defining the basic directions of scientific researches and designing developments. In Ukraine these works are at their initial stage.

Taking into account a great share of contamination of atmospheric air by motor transport, especially in urban conditions, it is reasonable to estimate the influence of the burned fuels type on the contamination, and study the ways of reducing these emissions.

Nowadays three types of fuels are used: diesel, petrol and gases (methane and propane). The type of fuel and its cost substantially influences both ecological and economic indicators of motor transport exploitation.

Recently the tendencies to a wider use of the fuels from biological raw material have been observed in the world practice. These tendencies are dictated mainly by three realities of the present time:

1) the consumption of resources of energy in the world grows rapidly (as one of the largest world's oil and gas companies the British Petroleum predicts that the growth of consumption of energy resources in 2030 will make 50% against 2005);

2) the world's resources of oil and gas are being reduced. Many of the deposits that are left have complicated geological and economic conditions and are often remote from the places of consumption;

3) the ecological situation on the planet is getting worse and that has a very negative influence on people's health and other living organisms.

The rate of using biological raw material in the fuel sector increases every year. For example, the share of biomass in the production of thermal and electric energy in the countries of the European Union in 1995 made up 44,80 million t.o.e. (oil equivalent). In 2010 the share of biomass fuel increased to 135 million t. There are two directions of using biological fuel in motor transport: biological diesel fuel and biological ethanol. Leading positions in the production of biological ethanol belong to America, but in the production of biological diesel fuel the countries of the European Union are the leaders (Germany, France, Italy). By 2030 the use of biological fuel will have been increased considerably [3-5].

To obtain biological diesel fuel it is possible to use any type of vegetable oil (sunflower, linen, rape, etc.). By estimations [6] to produce biological diesel fuel rape oil (84%), sunflower oil (13%), soy-bean oil (2%) are used. The share of other oils is less than 1%. Thus biological diesel fuels obtained from different sources of raw materials are somewhat different. Palm biological diesel fuel is characterized by the highest calorie content, the highest filterability and low temperature of hardening. Rape biological diesel fuel contains fewer calories than the palm one, but is more resistant to cold temperatures; therefore it suits many European countries. In addition, different types of raw material differ by a different output of the prepared product: rape (Europe) output of oil is about 1200 l/ga; soya (The USA, Argentina) – 446 l/ga; kanola (Canada) – 1000 l/ga; castor oil (Brazil) – 1410 l/ga; yatrofa (India) – 1900 l/ga; palm-oil (Indonesia, Philippines) – up to 5900 l/ga.

Three basic technologies of obtaining biological diesel fuel from oils are used: transesterification of oil with addition of alcohol in the presence of a catalyst (alkali), direct acid transesterification from oil, transformation of oil into fatty acids, and then into a biological diesel fuel with the use of acid catalyst [7]. The oil obtained by pressing after elementary sediment and cleaning is ready for transformation using a facility. The facilities for transformation of any vegetable oil occupy the area less than 20 m², and can provide about 12 m³ of the product per day. The cost price of the produced biological diesel fuel makes up "oil price" plus 30-35 kop. Approximate cost of a facility with its installation and staff training is about 200 thousand UAH.

Etherification can be carried out using ethyl or methyl alcohol.

The advantages of dimethyl ether are the following:

- it does not contain aromatic hydrocarbons and sulphur;
- it is characterized by high combustion efficiency;
- it has no soot and oxides of nitrogen in exhaust gases, it does not require the changes in the construction of diesel engines (insignificant modernization in the system of fuel feed is needed only);
- it provides a good cold engine start, its production conditions have more advantages as compared to diesel fuel.

As compared to mineral oil, 1 l of which is able to pollute 1 million l of drinking-water, vegetable oil if it comes to water does not cause harm to neither plants nor animals. In addition, it is subjected to almost complete biological disintegration: in soil or in water microorganisms can process 99% of oil for 28 days, that allows speaking about minimization of rivers and lakes contamination.

The basic advantages of biological diesel fuel are:

- the possibility of using in ordinary, unmodified diesel engines;
- the storage conditions of biological diesel fuel are similar to those of the ordinary diesel fuel;
- in the process of producing and using biological diesel fuel the emission of carbon dioxide reduces approximately by 80% and the emission of sulphur dioxide is less by almost 100% ;
- the amount of unburnt hydrocarbons is reduced by more than 90%, and the amount of poly-cyclic aromatic hydrocarbons decreases by 75-90%;
- due to the reduction of mutagenicity and carcinogenic properties biological diesel fuel considerably decreases the risk of tumor diseases;
- possibility of extension of diesel engines life due to higher lubricating ability;
- low toxicity and high temperature of self-ignition (about 150°C against 55°C for an oil diesel fuel) caused by high content (8-10 %) of oxygen.

Also, it is necessary to mention some insignificant drawbacks: a biological diesel fuel is more aggressive to the rubber and polymeric details of engines, and to paint-and-lacquer coatings of carbodies as compared to mineral fuel; the engine power in the nominal mode is by 6-8% lower; operating properties during the work of engines at low temperatures get worse as well.

Another direction of applying biological fuels is the use of biological ethanol.

Ethanol is a less “energy-intensive” source of energy than petrol. The run of hybrid cars working on E85 (a mixture of 85 % ethanol and 15 % petrol; letter E stands for Ethanol) per a unit of fuel volume makes up approximately 75 % from the run on petrol. Ordinary machines cannot work on E85, although standard combustion engines work perfectly on E10. Only the so-called “Flex-Fuel” cars can work on the “real” ethanol. These cars can also work on ordinary petrol or on the arbitrary mixture of this and the other. Brazil is the leader in production and use of biological ethanol from sugar-cane as a fuel.

The basic advantages of the technique of obtaining mixed petrols are:

- economic profitability (the application of only one hydrodynamic mixing facility for production of mixed petrols, biological ethanol, mixed biological diesel fuel can bring to an oil processing factory 3-5 million dollars USA every year if the annual production of petrols is one million tons);
- reduction of tank battery exploitation (due to the acceleration of technological processes fewer reservoir tanks are required. Thus, about 1-2 million dollars can be saved);
- optimum use of the components (0,25–1,12 dollars per 1000 liters of the produced petrol can be saved);

- reduction of labour expenses of the staff (the expected amount of money that can be saved by an oil processing factory can make up 500 thousand dollars), the increase of productivity;

- effective and optimum use of the equipment; simplicity of mixing processes;

- reducing to the minimum the influence of the changes in the processes of raw material processing at oil factories on the quality of the prepared products obtained from mixing facilities.

The combustion of ethanol leads to the appearance of aldehydes (formaldehyde and acetaldehyde) in exhaust gases of engines. Their influence on living organisms is as harmful as the influence of aromatic hydrocarbons. These substances appear even at the use of catalytic afterburners.

Another advantage of using methane consists in greater resources as compared to oil and less toxic exhausts. However, there is the problem of storing the compressed gas in passenger cars, because light and durable containers made of composite materials able to resist the pressure up to 20 MPa are needed for this purpose.

As compared to petrol methane has the following advantages: it is cheaper by 1,5–2 times, has a higher detonation characteristic, engine life grows by approximately 1,5 times, and the service life period of motor oil increases by two times.

The representatives of Renault together with French Agency on Environment Protection are successfully developing a technique of using dimethyl ether (a liquid gas which is used as an aerosol). This gas can be used in cars with diesel engines, as it has a higher octane number than diesel fuel.

The efficiency of applying the fuels can be estimated by combustion heat. According to the data about the costs of different fuels in Ukraine the following calculations have been carried out. They are presented in Table 1.

Table 1. Technical-economical indexes of different types of fuels (information of 2005)

Type of fuel	Cost		Combustion heat, Mj/kg	Cost of energy, UAH/Mj
	UAH	UAH/kg		
Petrol A76	7.10	5.78	41,87	0,169
Petrol A95	7.95	5.96	44	0,181
Extra	8.30	6.47	46	0,180
Diesel fuel	7.60	6.38	41,90	0,181
Natural gas	4.90	3.72	36,63	0,134
Rape oil	4.75	4.56	39,90	0,119
Biological diesel fuel	5.55	4.88	42,7	0,130
Hydrogen	-	38	11,14	0,346

Production of biological fuel from plants or algae by bacteria is another direction of applying alternative fuels. This process requires several intermediate stages before fuel processing. The process of fermentation is slow, it is recommended to use catalysts.

The most promising in terms of environmental safety is the hydrogen fuel. Water is the product of hydrogen combustion. It can be easily seen from the simple chemical reaction $2H_2 + O_2 = 2H_2O$. It makes hydrogen the most attractive type of fuel for cars. In an engine, except fuel, oil is burnt too, though its amount is not so great. Nowadays the engines, which use hydrogen both directly and indirectly, are being developed. These are fuel elements and combustion engines working on hydrogen.

Fig. 1 provides the comparative estimation of the influence of different types of fuel on the ecological characteristics of motor-car engines.

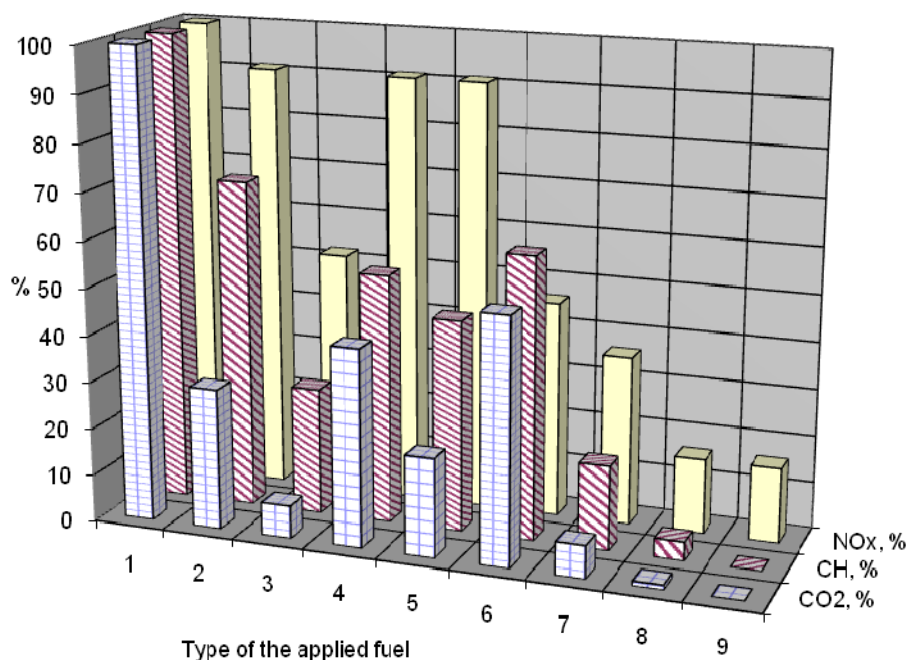


Figure 1 – Comparative estimation of the influence of alternative types of fuel on the ecological characteristics of motor-car engines with the forced self-ignition: 1- petrol; 2 - petrol + products of its conversion; 3 - petrol + H₂; 4 - pressed oil gas; 5 - compressed natural gas; 6 - methanol; 7 – methanol +H₂; 8 - synthetic gas (H₂ + CO); 9 - hydrogen (H₂)

Conclusions

Application of alternative fuels will provide the decrease of the emission of toxic components of cars working gases. In the world practice hydrogen is widely used for motor transport. There are two directions of using hydrogen: its generation in a vehicle and refuelling with hydrogen at the road stations. Generation of hydrogen in a vehicle does not depend on external non-traditional sources of fuel. However it requires considerable changes in car design. Refuelling of a car by gaseous or liquid hydrogen is a more reliable solution. Construction of factories producing hydrogen and creating a network of filling stations are required for this purpose. In the nearest 10 years in our country this solution can not be implemented.

Biological diesel fuel and biological ethanol can be regarded as another alternative source. Taking into account that in Ukrainian agriculture rape has already been cultivated on considerable areas it would be reasonable to begin producing biological diesel fuel. The use of biological diesel fuel will allow reducing the emissions of CO₂ by 65-90% as compared to the use of traditional fuel. Besides, it will decrease the emission of solid particles with exhaust gases and other harmful emissions.

The given paper confirms the necessity of estimating the costs of power carriers taking into account their heating value and ecological consequences of using this or that power carrier.

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