THE INFLUENCE OF METHANOL ON ECOLOGICAL AND ENERGETIC PARAMETERS OF SI ENGINES

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Abstract

One of the most effective methods to reduce air pollution by SI engine exhaust emission is the use of alcohol, though due to its hygroscopicity it makes unstable blends with gasoline. The present paper describes the impact of gasoline-methanol blend on major characteristics of an engine including fuel consumption and ecological parameters. A blend of 75 per cent gasoline and 25 per cent methanol was tested which was mixed in such a way as to ensure its long-term stability. The data on fuel consumption, engine power, torque, exhaust emission (CO, CO_2, CH, NO_x, O_2) and air-fuel ratio of motor vehicles working on pure gasoline (95 RON) and gasoline-methanol blend (M25) are presented. The results of measurements demonstrate much lower exhaust emission for engines operating on blend M25.

Keywords: methanol, alcohol, gasoline-methanol blend, SI engine, exhaust emission, fuel consumption.

1. Introduction

To reduce fuel consumption by Lithuanian transport means to achieve the goal of reducing the consumption of oil products because nearly all oil produced in Lithuania is exported. The reduction of oil fuel consumption in transport would proportionally improve the environmental conditions in the country, especially in large cities.

A promising way of reducing the consumption of liquid oil products in motor vehicles is the use of alternative fuels in the internal combustion engines.

Alternative fuels include liquid and gaseous fuels obtained from non-traditional sources. Most of them differ considerably from commonly used gasoline and diesel oil in their physical, chemical and operational characteristics, therefore their application affects the operational characteristics of engines and maintenance of transport facilities.

Since Lithuania heavily depends on the imported oil, oil products should be either replaced by the alternative fuels or oil consumption should be reduced. The most appropriate alternative fuels under conditions of Lithuania are alcohol-based products of which methanol and ethanol are most commonly used in internal combustion engines.

The main problem arising in the application of alcohol is its instability and high sensitivity to water. Since the density of gasoline and alcohol differs, with alcohol being well soluable in water, the addition of a small amount of water to the blend leads to its segregation into layers, with consequent deposition of water or alcohol phases. The present investigation is aimed at determining fuel consumption and ecological parameters of gasoline-methanol blend obtained by a patented mixing technique. A special technique for mixing of gasoline and methanol developed by the authors of the present paper can ensure long-term stability of the obtained blend. The use of a stable gasoline-methanol blend in internal combustion engines as an alternative fuel could help reduce harmful exhaust emission and air pollution causing the greenhouse effect.

2. Methods and technique of experimental research

Experimental research was carried out according to the methods developed by the authors taking into account the available laboratory equipment and the existing conditions. The automobile Hyundai Accent using gasoline which was made in 1998 was tested. The volume of the automobile's engine is 1495 cm^3; compression – 10.0; power – 50 kW, torque – 105 Nm; injection system – ECI multi; it is not provided with the catalytic exhaust neutralizer.

First, an automobile filled up with gasoline was tested according to the suggested technique. Then, the same tests were made with a gasoline-methanol blend (referred to as M25):

1. The automobile's velocity characteristic was determined.
2. By testing the automobile in the modes described in Table 1, its fuel consumption, the composition of exhaust gases (CO, CO_2, HC, NO_x, O_2) and the excess air coefficient were found:

Table 1

№	Speed, km/h	Traction, kW	№	Speed, km/h	Traction, kW	№	Speed, km/h	Traction, kW
1.	60	5	5.	90	5	9.	120	5
2.	60	10	6.	90	12	10.	120	15
3.	60	15	7.	90	20	11.	120	25
4.	60	max*	8.	90	max*	12.	120	max*

* accelerator is maximally pressed

3. The velocity characteristic of the automobile was determined for the second time.
4. Spot measurements to determine relative fuel consumption and toxicity of exhaust were made, with the throttle valve completely (100 %) open and the engine revolutions ranging from 1500 to 5500 min^{-1}, the variability step being 1000 min^{-1} revolutions.
5. The velocity characteristic of the automobile was determined for the third time.
6. The automobile's acceleration from 40 to 120 km/h was determined, with the throttle valve completely (100 %) open.
7. Spot measurement was repeated to determine relative fuel consumption, and toxicity of exhaust, with the throttle valve completely (100 %) open and the engine revolutions ranging from 1500 to 5500 min^{-1}, the variability step being 1000 min^{-1} revolutions.

Testing was made by using the following equipment:

- ***traction stand*** – MAHA LPS 2000: maximum traction 260 kW, maximum speed – 260 km/h, maximum axle loading – 2500 kg. The stand may be connected with the exhaust analyzer and fuel consumption meter;
- ***exhaust gas analyzer*** – AVL DiGas 465: operation principle is based on the absorption of infrared rays;
- ***fuel meter*** – AIC-BC 2022: discharge in the range of 1...80 l/h, allowable pressure – 25 bar, measurement error - < 1 %.

3. Testing results

The results of testing are shown in the graphs given below. Since all automobile's parameters were determined when it was running at three various speeds, three pairs of graphs are provided in each figure.

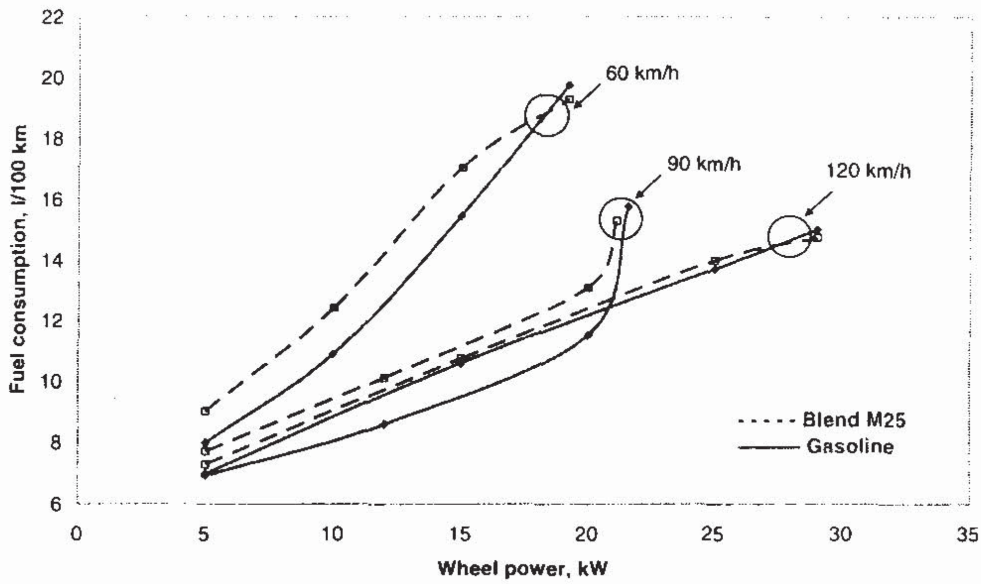

Fig. 1. The relationship between fuel consumption and loading of the automobile running at various speed

In Fig.1, relative fuel consumption of the automobile (l l/100 km) is given. It is clear that when the automobile's speed is lower (60 and 90 km/h) fuel (blend M25) consumption is higher than in the case of gasoline usage. However, when the speed reaches 120 km/h, fuel consumption is the same. Average fuel consumption using blend M25 is by 7 % higher.

This may be explained by the graph in Fig.2 showing relative fuel consumption (g/(kW·h). When the automobile makes small or medium-radius turns, the consumption of the blend M25 is considerably higher than that of gasoline. However, when the automobile is running at 120 km/h by using the 5^{th} gear and the revolutions of its engine exceed 3700 min^{-1}, relative consumption of the blend M25 decreases, approaching gasoline consumption.

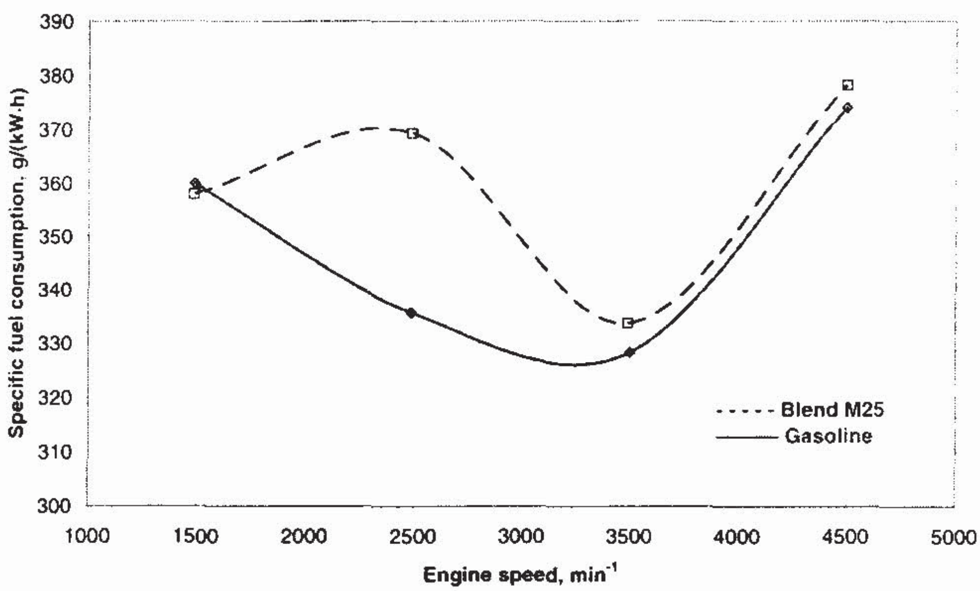

Fig. 2. Relative fuel consumption by the vehicle using various fuels

In the graphs given below, the data obtained in ecological testing of vehicle running at different speed and with varying loads are presented.

Fig.3 shows the composition of a combustion blend when gasoline and blend M25 are supplied to the vehicle. In all cases, leaning of gasoline-methanol blend by 13...17 % can be observed. When this occurs, the engine power and the amount of pollutants in the exhaust (e.g. CO and HC) as well as fuel consumption decrease, increasing the efficiency of the engine.

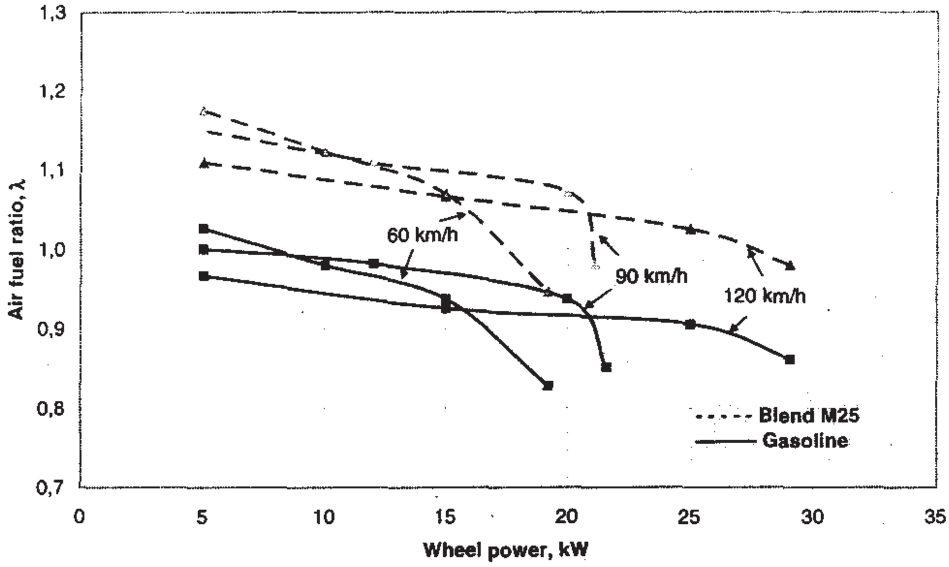

Fig. 3. The effect of loading on air-fuel ratio of a vehicle running at different speed

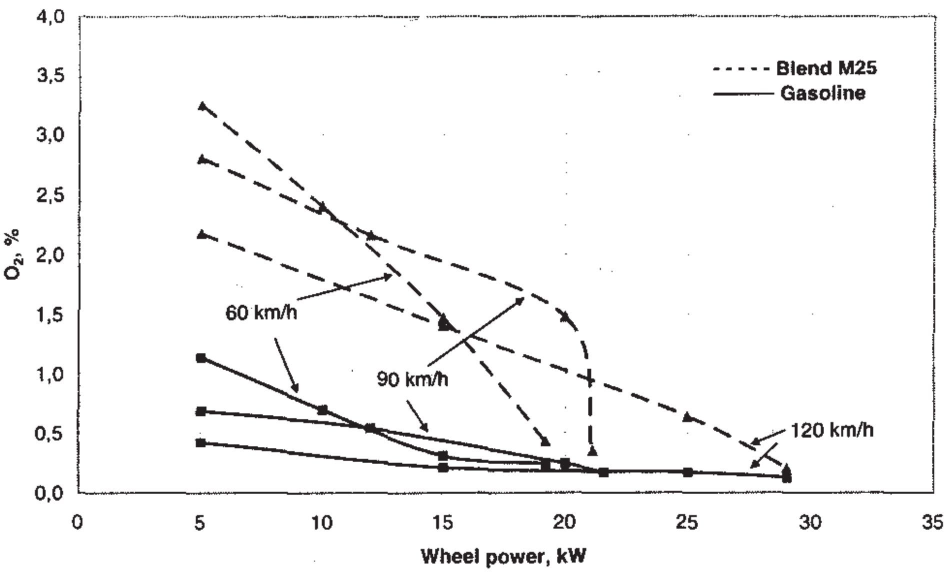

Fig. 4. The effect of loading on the amount of oxygen (O_2) in the exhaust of a vehicle running at different speed

The data on the measured amount of oxygen in the exhaust are presented. When the blend M25 is used, the amount of oxygen in the exhaust is by 3...4 times higher than in the case of using pure gasoline. This is easy to explain because methanol molecules contain 49.9 % (m/m) of oxygen. Though oxygen reduces heating value it improves combustion as well as reducing the release of CO gases.

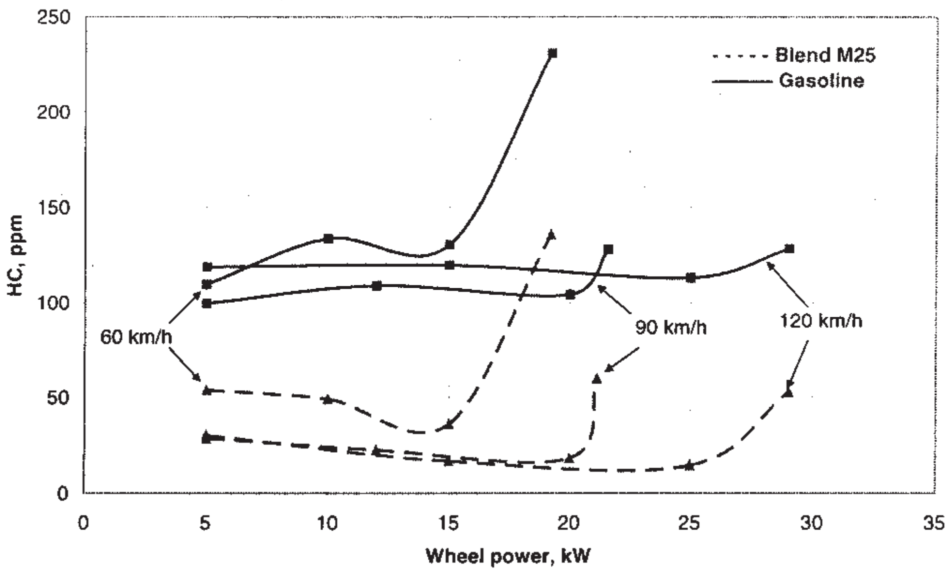

Fig. 5. The effect of loading on the amount of hydrocarbon HC in the exhaust of a vehicle running at different speed

In Fig.5, the data obtained in measuring the amount of hydrocarbon HC in the exhaust of a vehicle are shown. It has been found that when using the blend M25, the amount of HC is reduced by 40...90 % compared to burning pure gasoline.

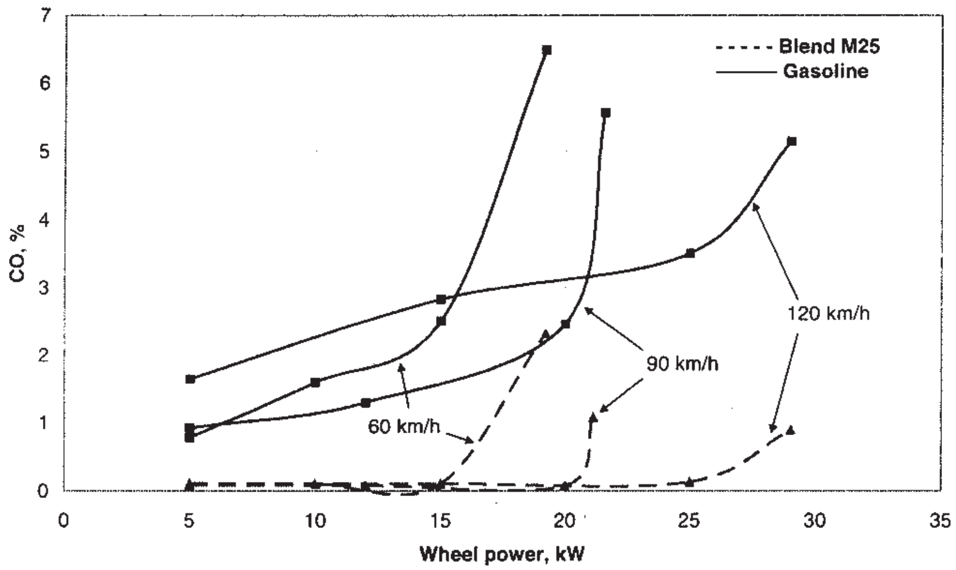

Fig. 6. The relationship between the amount of carbon oxide (CO) in the exhaust and the loading of a vehicle running at different speed

In Fig. 6, the results obtained in measuring the amount of carbon oxide (CO) in the exhaust are given. It can be observed that the amount of CO is by about 15 times reduced when the blend M25 is used compared with the results obtained for gasoline.

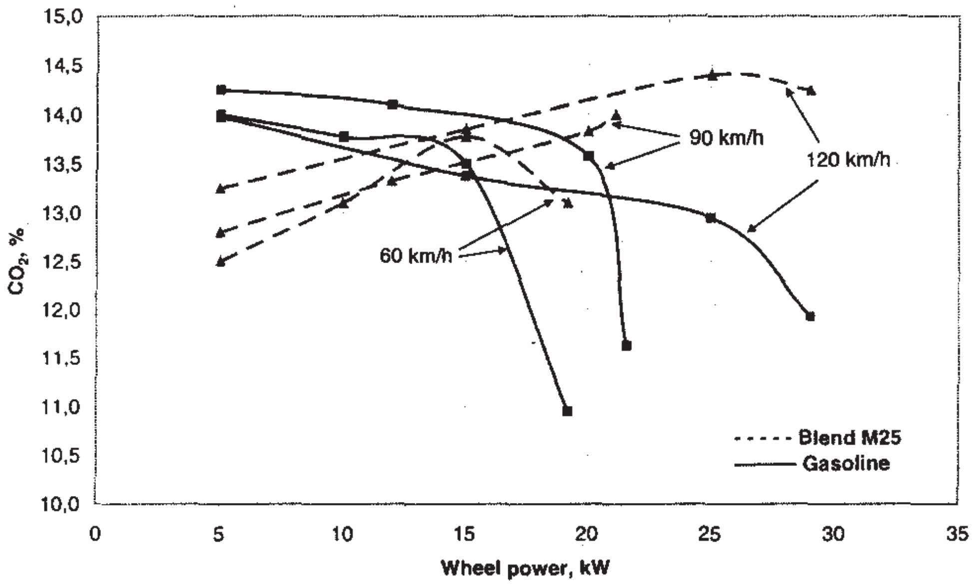

Fig. 7. The relationship between the amount of carbon dioxide (CO_2) and the loading of a vehicle running at various speed

The amount of carbon dioxide in the exhaust is reduced at low or medium vehicle loading and increased at the maximum load. It is affected by more efficient combustion in the engine's cylinders. The better the combustion, the lower is the amount of the products of incomplete burning in the exhaust and the higher the amount of completely burnt materials. In this case, the added methanol causes the leaning of the combustion mix, because it has about 50 % of oxygen thus improving the combining of oxygen molecules with the fuel molecules in combustion. This leads to the decrease of the amounts of CO and HC, while increasing the relative amount of CO_2.

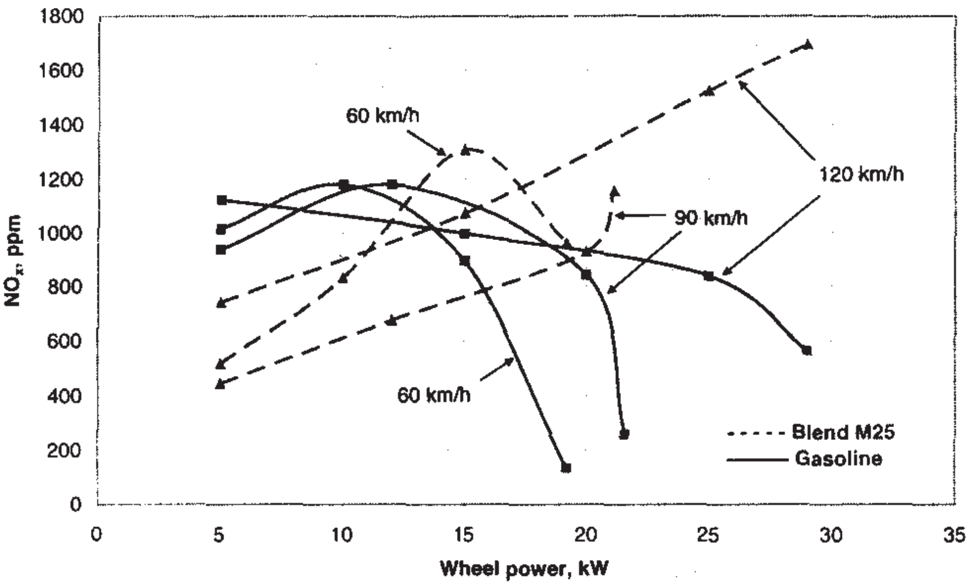

Fig. 8. The relationship between the amount of nitrogen oxides NO_x and the loading of a vehicle running at various speed

In Fig. 8, the results of measuring the amount of nitrogen oxides NO_x in the exhaust are given. It can be observed that when the blend M25 is used, the amount of NO_x decreases in all cases except for maximum loading. In all engine operational modes the amount of NO_x is decreased by about 25 %.

In the graph showing the amounts of nitrogen oxides, a considerable growth of these pollutants can be observed at maximum loading when the blend M25 is used. This may be accounted for the following fact: when a certain amount of methanol is added to gasoline, the combustion mix gets leaner. However, it is well-known that the amount of nitrogen oxides is directly proportional to the composition of the combustion mix. When the latter is $\lambda = 1.05...1.1$, the highest amount of NO is formed. When the mix gets leaner or richer, the proportion of NO_x is reduced. When the engine with gasoline was tested, the mix proportions ranged between $\lambda = 1.0...0.83$, while for the blend M25 the range was $\lambda = 1.5...0.95$.

4. Conclusions

The comparative analysis based on the laboratory testing of pure gasoline (OS 95) and methanol-gasoline blend M25 has shown that:

1. When the blend M25 is used, the amount of carbon oxide (CO) in the exhaust is reduced by about 90 % (or more in some cases) compared with pure gasoline toxic exhaust.
2. When the blend M25 is used, the amount of hydrocarbon in the exhaust is reduced by 40...90 % compared with pure gasoline toxic exhaust.
3. When gasoline is blended with methanol the composition of the combustible mix is changed, the latter getting leaner by about 14 %. When the blend M25 is used, the exhaust is by 3...4 times richer in oxygen.
4. When the blend M25 is used at small or medium loading of the engine, the amount of the greenhouse gas (CO_2) is reduced by about 9 % compared with the gasoline exhaust.
5. When the blend M25 is used, the amount of NO_x is reduced except for the cases of high engine loading. The amount of NO_x is smaller by about 25 % in a vehicle tested in various modes of operation.
6. When the blend M25 is used, fuel consumption is increased by about 7 % compared with the case when pure gasoline is used, though heating value by the above blend is by 10 % lower.

References

[1] Auto/Oil Quality Improvement Research Program (1992 a), „Emissions and Air Quality Modeling Results from Methanol/Gasoline Blends in Prototype Flexible/Variable Fuel Vehicle", Technical Bulletin No. 7, January.

[2] Dorn P., Mourao A. M., Herbstman S. The Properties and Performance of Modern Automotive Fuels // Society of Automotive Engineers (SAE), Publication No. 861178 (Warrendale, PA, 1986). 53 p.

[3] Huges P. Personal Transport and the Greenhouse Effect. A Strategy for Sustian Ability. London. Earth Sean Publication Ltd., 1993. 140 p.

[4] Motor vehicle pollution. Reduction Strategies beyond 2010/Organisation for Economic Cooperation and Development. Paris: OECD, 1994. 116 p.

[5] Poulton M. L. (1994). Alternative Fuels for Road Vehicles. Computational Mechanics Publications, Southampton, UK and Boston, USA. – 216 p.

[6] Schoonveld G. A. and Marshall W. F. (1991). The Total Effect of a Reformulated Gasoline on Vehicle Emissions by Technology (1973 to 1989). SAE Technical Paper

Series No. 910380, Society of Automotive Engineers, Inc., Warrendale, Pennsylvania, USA.

[7] US Congress (1990). Replacing gasoline: Alternative fuels for light-duty vehicles, OTA–E–364. US Congress, Office of Technology Assessment, Washington, DC: US Government Printing Office.

[8] Williams D. and Vincent M. W. (1992). Past and anticipated changes in European gasoline octane quality and vehicle performance. Proceedings from the XXIV FISITA Congress „Automotive Technology Serving Society“, 7–11 June 1992, Institution of Mechanical Engineers, London.

[9] Хачиян А. С. Применение спиртов в дизелях // Двигателестроение, 1984. № 8, 30–34 с.