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Emissions of Pollutant Gases (CO and CO_2) when Using Fuel Mixtures (Ethanol-Petrol) in Internal Combustion Engines

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ABSTRACT

The objective of the study is to evaluate the emissions of pollutant gases (CO and CO2) when using fuel mixtures (ethanol-petrol) in internal combustion engines. The experiments were carried out in the Engine Laboratory of the Faculty of Engineering Sciences of Agrarian University of Havana (AUH) using JACTO engine. To obtain the amount of toxic gases emitted into the atmosphere (CO2 and CO), the balance of the combustion equations was proposed for the different mixtures estimated taking into account the established coefficients of excess air. The analysis of the combustion process based on 10, 20 and 30 percent ethanol mixtures with hydration (80%; 85%; 90 %; 95%) and conventional petrol of category B-85 for rich mixtures (α = 0,85) and for lean mixtures (α = 1,15) showed that CO2 and CO emissions to the atmosphere are reduced to 17% for considered mixtures as compared to petrol. Despite higher relative fuel consumption as compared to petrol, there is a significant positive environmental effect.

Keywords: *road transport, internal combustion engine, pollutant gases, petrol, mixtures, ethanol, fuel, combustion.*

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INTRODUCTION

One of the most important tasks today is to reduce emissions of harmful substances into the atmosphere during fuel combustion, including in vehicles.

Currently, 40 % of total energy consumption comes from fossil fuels, and more than 90 % of this consumption comes from the transport sector [1; 2]. Therefore, it is necessary to improve the environmental efficiency of units and devices based on the burning of these fuels and reduce their harmful effects [3].

The analysis showed that when an internal combustion engine (ICE) runs on natural gas, CO_2 emissions are reduced by 23–38 %. By running on natural gas mixed with synthesis gas derived from the main fuel, CO_2 emissions into the atmosphere can be reduced by 52 % by reducing the toxicity of exhaust gases to the required level [4–7].

Another way to approach the problem of reducing emissions into the atmosphere is the use of biofuels, whose main practical advantage is that, within certain volume limits, it can be combined with traditional fossil fuels and used in existing energy systems, such as engines of passenger cars and freight vehicles [8].

Following the research *objective* to determine the amount of toxic gas emissions into the atmosphere when using fuel mixtures (ethanol-petrol), the authors carried out the study that allowed quantifying the toxic gases (CO_2 and CO) and subsequently comparing them with similar values obtained during the use of conventional fuel (petrol).

RESULTS

Research Methodology

To determine the amount of CO_2 and CO emitted after combustion of different mixtures, a methodology based on the works of several authors [9, pp. 351–399; 10; 11, pp. 232–282; 12; 13] was used that necessitated:

– To establish the coefficients of excess air used (quantity α of air supplied) in the different tested mixtures.

• To determine the amount of substance in the fuel mixture (ethanol-petrol or pure petrol) involved in the combustion process, this can be determined by the expression (1).

• To balance the chemical combustion equation for different mixtures tested taking into account the established excess air (α) coefficients, for example:

for α=1,5,

$$xC_7H_{17} + yO_2 + zN_2 \leftrightarrow mH_2O + nCO_2 + wO_2 + lN_2;$$

for α=0,85,

$$xC_7H_{17} + yO_2 + zN_2 \leftrightarrow mH_2O + nCO_2 + wCO + lN_2,$$

where x, y, z, n, m and w and l are the amount of substance in each substance (kmol).

• After balancing the chemical equation for cases where the coefficient of excess air differs from the unit α = 1, such a coefficient is multiplied by the amount of substance in the air components in the reactants (O_2; N_2), changing the amount of substance released in the combustion products.

The amount of substance in the fuel mixture (n) was determined by the formula:

$$n = \frac{M}{\mu_c} \text{ кmol,} \qquad (1)$$

where: μ_c – molecular weight of the fuel, kg/kmol (Table. 1);

M – is the fuel mass, kg, which is defined by the expression (2):

$$M = \rho * G_h \text{, kg,} \qquad (2)$$

where: p – density of the fuel mixture, kg/l (Table 2);

G_h – consumption per hour of the fuel mixture, l/h.

To determine the fuel consumption, one litre of each mixture was used and a stopwatch with an accuracy of ±0.01 s (Fig.1) determined the time during which this litre was spent.

Table 1

Molecular weight of the substances involved in the combustion process

Substances	Nomenclature	Molecular weight, kg/kmol
Petrol	C_7H_{17}	101
Ethanol-Petrol	$C_9H_{23}O$	147
Dioxygen	O_2	32
Water	H_2O	18
Dinitrogen	N_2	28
Carbon monoxide	CO	28
Carbon dioxide	CO_2	44

PLANETCALC: Online calculators. Molecular weight of mixtures. Copyright © PlanetCalc. Version: 3.0.4240.0; 2023. https://planetcalc.ru/329/?language_select=ru.

Table 2

Fuel mixture density [performed by the authors]

Fuel	Ethanol	Petrol	Ethanol 10 %+ Petrol	Ethanol 20 %+ Petrol	Ethanol 30 %+ Petrol
Density, kg/l	0,789	0,680	0,789	0,7018	0,7073

Pic. 1. Digital stopwatch com precision ±0,01 s.

Experimental Research

The experiments were carried out in the Engine Laboratory of the Faculty of Engineering Sciences of Agrarian University of Havana (AUH). A single-cylinder JACTO engine was used. Analysis of the combustion process based on mixtures of 10, 20, 30 % ethanol and conventional petrol of category B-85 (E-10, E-20, E-30). Before combustion, the degree of hydration of ethanol (80 %; 85 %; 90 %; 95 %) and type of mixture were determined. According to the theoretical assumption that stoichiometric fuel mixture is called rich with $\alpha < 1$ and lean with $\alpha > 1$, rich mixture was used with $\alpha = 0,85$ and lean mixture with $\alpha = 1,15$.

The engine used has an effective power of 1,2 kW, rotation speed of 580 rpm, combustion chamber volume of 34 cm^3.

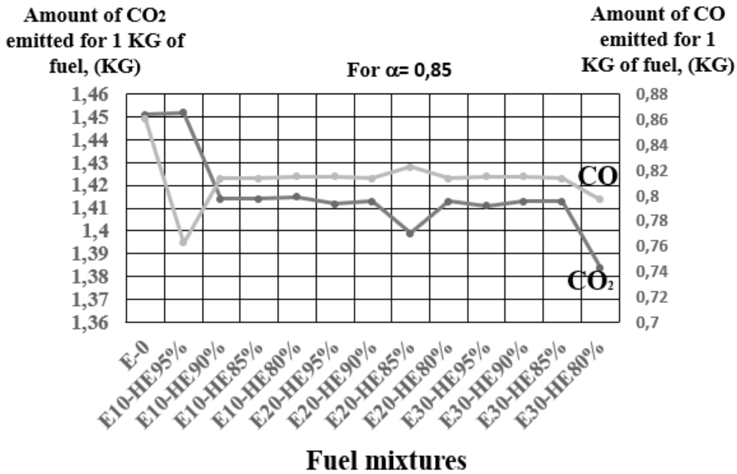
The following mixtures were prepared: 10 % ethanol with 95 % hydration + Petrol (E-10-EH-95 %); 10 % ethanol with 90 % hydration + Petrol (E-10-EH-90 %); 10 % ethanol with 85 % hydration + Petrol (E-10-EH-85 %); 10 % ethanol with 80 % hydration + Petrol (E-10-EH-80 %); 20 % ethanol with 95 % hydration + Petrol (E-20-EH-95 %); 20 % ethanol with 90 % hydration + Petrol (E-20-EH-90 %); 20 % ethanol with 85 % hydration + Petrol (E-20-EH-85 %); 20 % ethanol with 80 % hydration + Petrol (E-20-EH-80 %); 30 % ethanol with 95 % hydration + Petrol (E-30-EH-95 %); 30 % ethanol with 90 % hydration + Petrol (E-30-EH-90 %); ethanol with 85 % hydration + Petrol (E -30-EH-85 %) and 30 % ethanol with 80 % hydration + Petrol (E-30-EH-80 %).

The Table. 3 shows the results of the fuel consumption for each of the mixtures as well as for Petrol (E-0). It is noted that with increase in concentration of ethanol and in its hydration, fuel consumption increases by 0,583 l/h. In addition, in mixtures at $\alpha = 1,15$, fuel consumption increases, since the mixture contains more air, and the fuel burns faster.

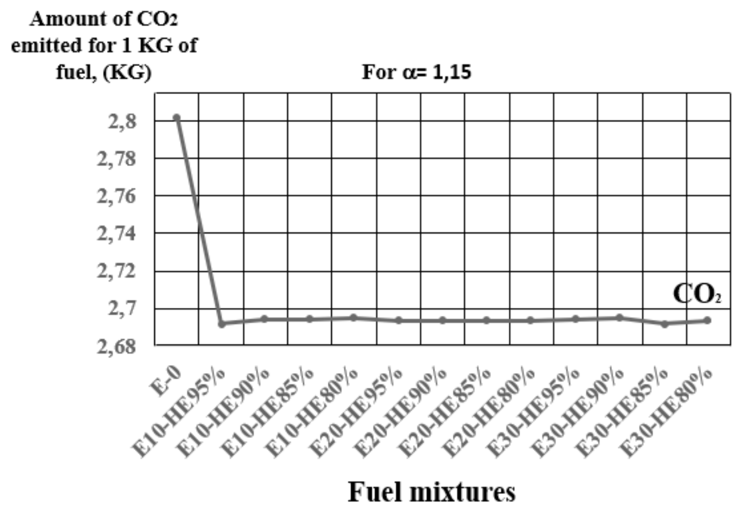
Table 3

Fuel consumption per hour [performed by the authors]

fuel	Specific fuel consumption per hour, for different α, l/h	
	α=0.85	α= 1,15
E-0	0,675	0,667
E-10-EH95 %	0,716	0,783
E-10-EH90 %	0,774	0,837
E-10-EH85 %	0,861	1,029
E-10-EH80 %	0,921	0,994
E-20-EH95 %	0,779	0,923
E-20-EH90 %	0,911	0,986
E-20-EH85 %	0,968	1,020
E-20-EH80 %	1,032	1,169
E-30-EH95 %	0,828	0,986
E-30-EH90 %	0,970	1,029
E-30-EH85 %	1,037	1,078
E-30-EH80 %	1,118	1,250



Pic. 2. The amount of CO_2 and CO emitted to the environment during the combustion process for rich mixtures [performed by the authors].



Pic. 3. Amount of CO_2 released into the environment by the combustion of poor mixtures [performed by the authors].

Ecological Analysis of the Results of Experiments

The results obtained for fuel (per each kilogram) used in the combustion process for rich mixtures with an excess air coefficient α= 0,85 are shown in the graph in Pic. 2, which allows to observe the behaviour of CO_2 and CO regarding different mixtures studied.

The graph above shows the amount of carbon dioxide (CO_2) and carbon monoxide (CO) released into the environment by the combustion of the various mixtures tested for α= 0.85. As can be seen, with mixtures of ethanol and petrol, the largest amount of CO_2 is released by E-0-EH-95 % mixture, reaching a value of 1,452 kg per kilogram of fuel burned, which is by 0,001 kg more than with petrol (E-0).

In the remaining mixtures, values lower than for E-0 and E-10-EH-95 % were obtained. For example, values in the range from 1,384 kg (mixture E-30-EH-80 %) to 1,412 kg (mixture E-20-EH-95 %) show results lower than E-0 by 0,067 kg and by 0,039 kg, respectively.

On the other hand, the highest amount of CO emitted per 1 kg of fuel used was recorded with the E-0 petrol with a value of 0,860 kg, followed by the E-20-EH-85 % mixture (value of 0,823 kg). It has been determined that the use of the E10-EH-95 % mixture is the most favourable for the environment since the emissions reach the lowest values (0,762 kg).

If both gases (CO and CO_2) are considered, the mixture with the lowest emissions would be E10-EH95 %.

In the same way, a gas analysis was carried out for the combustion of lean mixtures with an excess air coefficient α = 1,15, the graph presented in Pic. 3 was so obtained.

So, Pic. 3 shows the amount of carbon dioxide (CO_2) emitted to the environment during the combustion of the different mixtures studied for α = 1,15. As can be seen, when ethanol and petrol mixtures are used, the least amount of CO_2 is released by E-10-EH-95 % and E-30-EH-85 % mixtures, reaching a value of 2,692 kg per kilogram of fuel burned, which is 0,11 kg less than in E-0. At the same time, for the other mixtures, the indicators were also lower than for E-0, with values from 2,693 kg to 2,695 kg.

CONCLUSIONS

The study has confirmed that the use of biofuels reduces the release of toxic gases (CO_2 and CO) into the atmosphere, contributing to environmental protection and, therefore, to improving human life, which is consistent with several studies on the subject [5;14].

Particularly:

1. For the rich mixtures, the largest amount of CO_2 is released by E-10-EH-95 % mixture, reaching a value of 1,452 kg per kilogram of fuel burned, which is 0,001 kg more than with Petrol (E-0), for the rest of the mixtures results below E0 were obtained within the range from 0,067 kg to 0,039 kg of difference in the amount of CO_2 emitted.

2. For rich mixtures, the lowest amount of CO emitted per 1 kg of fuel used was achieved using E-10-EH95 % with a value of 0,762 kg.

3. For lean mixtures, the least amount of CO_2 is released by E-10-EH-80 % and E-30-EH-90 % mixtures, reaching a value of 2,692 kg per kilogram of fuel burned, which is by 0,11 kg less than that by E-0, while the values for the rest of the mixtures were lower than for E-0, with values from 2,693 kg to 2,695 kg.

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