STUDIUL AMESTECULUI CARBURANT ÎN FUNCȚIE DE CALITATEA COMBUSTIBILULUI BENZINĂ - BIOETANOL E10

Phd. Eng. Adrian IRIMESCU,
„Politehnica" University – Timişoara

Faculty of Mechanics graduate, Department of Thermal Machinery and Equipment in 2004, phd. student from October 2006, at the TMTAR Department, with Phd. Eng. Dănilă Iorga as coordinator.

Prof. Phd. Eng. Dănilă IORGA
„Politehnica" University – Timişoara

Absolvent al Facultății de Mecanică, în anul 1964, doctor inginer din 1985. Actualmente profesor consultant la Catedra de Termotehnică Maşini Termice şi Autovehicule Rutiere, conducător de doctorat din anul 2001.

Phd. Eng. Laurențiu CĂLIN,
„Politehnica" University – Timişoara

Faculty of Mechanics graduate, Department of Food Industry Technology in 2004, phd. student from October 2005, at the TMTAR Department, with Phd. Eng. Jădăneanț Mihai as coordinator, AGIR member from 2005.

Phd. Eng. Nicolae LONTIŞ,
„Politehnica" University – Timişoara

Faculty of Mechanics graduate, Department of Automotive Vehicles in 2004, phd. student from October 2005, at the TMTAR Department, with Phd. Eng. Habil Ioana Ionel as coordinator.

REZUMAT. Biocombustibilii sunt una din principalele mijloace prin care se ţinteşte o reducere a emisiei de gaze cu efect de seră. Utilizarea bioetanolului pentru alimentarea motoarelor cu aprindere prin scânteie ridică o serie de probleme specifice în domeniul producției, transportului şi exploatării acestui tip combustibil. Pentru a limita efectele negative pe care le are etanolul asupra componentelor din motoarele construite special pentru a fi alimentate cu benzină, etanolul se foloseşte în amestec cu benzina în diferite proporții, limita superioară fiind de 10% (combustibil cu denumirea comercială E10). Una din problemele majore ale utilizării bioetanolului este faptul că acest alcool este foarte hidrofil, iar în unele cazuri poate provoca separarea alcoolului şi a apei de benzină, ceea ce duce la apariția unui strat distinct în rezervoarele unde este depozitat combustibilul. Lucrarea de față tratează aspecte legate de formarea amestecului carburant şi comportarea motoarelor alimentate cu E10. Astfel, se constată o reducere a temperaturii amestecului la alimentarea cu E10 față de cazul alimentării exclusiv cu benzină, ceea ce se traduce printr-o îmbunătățire a gradului de umplere. Un alt aspect important este modificarea raportului stoechiometric, ceea ce determină o creştere a consumului de carburant. Performanțele motorului nu sunt semnificativ influențate în regimuri tranzitorii, iar la funcționare cu amestec stoechiometric puterea dezvoltată este aproximativ aceeaşi ca şi la alimentarea cu benzină.

Cuvinte cheie: Biocombustibili, etanol. performanțele motorului, benzină.

ABSTRACT. Biofuels are a major factor of green house gas emission reduction. Using bioethanol for fueling spark ignition engines raises an array of problems în the fields of fuel production, transport and other applications. în order to limit engine components damage due to the use of ethanol, different blending proportions of gasoline and alcohol are used, with the maximum limit of ethanol content being 10% (commercially known as E10) for use în engines build to run on gasoline only. One of the major issues with ethanol is that it attracts water easily and can cause phase separation, thus forming a distinct layer on the bottom of the tank. The present paper shows aspects of mixture formation and engine behaviour when fueled with E10. Thus, a reduction of mixture temperature is observed when using E10 compared to straight gasoline, which means an improvement în volumetric efficiency. Another important aspect is the increase of fuel consumption due to the change în air-fuel ratio. Engine performance is not significantly influenced în transitory states, and when running on steichiometric air-fuel ratios, engine power is about the same with E10 compared to straight gasoline.

Keywords: Biofuels, ethanol, engine performance, gasoline.

1. INTRODUCTION

As biodiesel has become the main biofuel for compression ignition (CI) engine, bioethanol seems to be the fuel most likely to be used as an alternative for spark ignition (SI) engines. Bioethanol is a renewable energy source as it is obtained from biomass, and using it as a fuel produces less pollutant emissions.

The use of ethanol in SI engines is widely known on local levels in countries like Brazil for several decades. Only recently the interest for this biofuel has become a general issue [1]. Ethanol can be used in pure form E100 or as a blend with different proportions (E10 – 10% ethanol blend with 90% gasoline, E85 – 85% ethanol blend with 15% gasoline). One aspect of gasoline-ethanol blends is that they require a very high purity of ethanol (maximum water content is 1% in the US and 0.2% in Europe) compared to E100 which may contain up to 4.4% water, a product that can be obtained by classic distillation, with far lower cost [2]. Bioethanol is used in CI engines blended with diesel fuel (Scania uses E95 – a blend of 95% bioethanol and 5% diesel – for fueling buses equipped with diesel engines [3]), but only at an experimental level.

Ethanol is an alcohol with a molar mass of 46.0684 kg/kmol [4], it contains two carbon atoms, six hydrogen and one oxygen atom, with the chemical formula of C_2H_5OH (figure 1). Energy density is lower compared to gasoline, however the energy contained in stoechiometric air-fuel mixtures is very close for both fuels (table 1). One important property of ethanol is its high enthalpy of vaporization, much higher then that of gasoline. This makes cold start during winter very difficult. A positive aspect is that using ethanol increases engine volumetric efficiency due to lower mixture temperatures. Another advantage of ethanol use in SI engines is that spark advance can be optimized, given the higher octane rating compared to gasoline, with an increase of combustion efficiency. In the US ethanol is frequently used as an additive to improve gasoline octane rating (table 2).

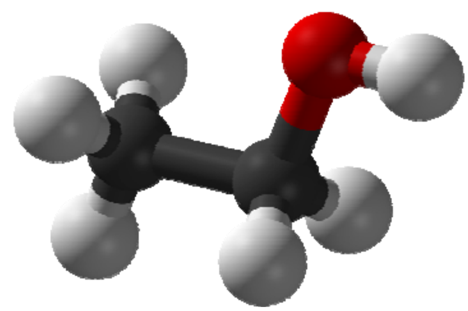

Fig. 1. Ethanol molecular structure [5].

Table 1. **Fuel properties [4, 6]**

Fuel	Density [kg/m^3]	Energy density [MJ/l]	Stoechiometric mixture energy density [MJ/kg]	Stoechiometric air-fuel ratio [kg_{air}/kg_{fuel}]	Vaporization enthalpy at 20°C [kJ/kg]
Gasoline	0.72 – 0.78	30.2 – 33.95	2.67 – 2.77	14.7	360
Ethanol	0.79	21.15	2.68	9	930
E10	0.73 – 0.78	29.30 – 32.67	2.67 – 2.77	14.10	420

Table 2. **Fuel octane rating [6]**

Fuel	MON [-]	RON [-]	Sensibility [-]
Gasoline	82	92	10
Ethanol	96	129	33
E10	83.4	95.7	12.3

An important property of ethanol is that it is fully miscible with water. By classic distillation 95,6% grade alcohol can be obtained, concentration level at which water and ethanol evaporate and condense together. Even if standard purity is assured, ethanol can be contaminated with water even from air contained humidity. Thus an azeotropic solution forms inside the storage tanks that can separate from gasoline in a distinct layer at the bottom of the tank. Research on this issue showed that in ethanol-gasoline blends with more then 15% ethanol content phase separation does not occur and corrosive activity is greatly reduced [2].

2. E10 FUEL *I-X* DIAGRAM

Mixture formation in port fuel injection SI engines is a complex heat and mass exchange process between intake air and injected fuel, with droplet size being the most important factor. The fuel droplets gradually evaporate in contact with air, a process very similar with water evaporation. Thus, the idea of using an i-x diagram for air-fuel mixtures came about, like the humid air Mollier diagram [7].

When plotting the air-fuel ix- diagram (figure 2) several hypothesizes were used. Humid air was considered a mixture of ideal gases, given the low vapor partial pressure. Thus, ideal gas mixture laws like the Dalton and Amagat laws can be applied. Gasoline is a mixture of hydrocarbons with different boiling points at a given pressure level. For the i-x diagram plotting the fuel was replaced with a mixture of three paraffin components, hexane-heptane-octane, a mixture with a distillation curve very close to that of gasoline. Ethanol and water was added to these three components with the corresponding volumetric participations of a gasoline-ethanol blend E10 that may contain water (up to 4.4% water volume).

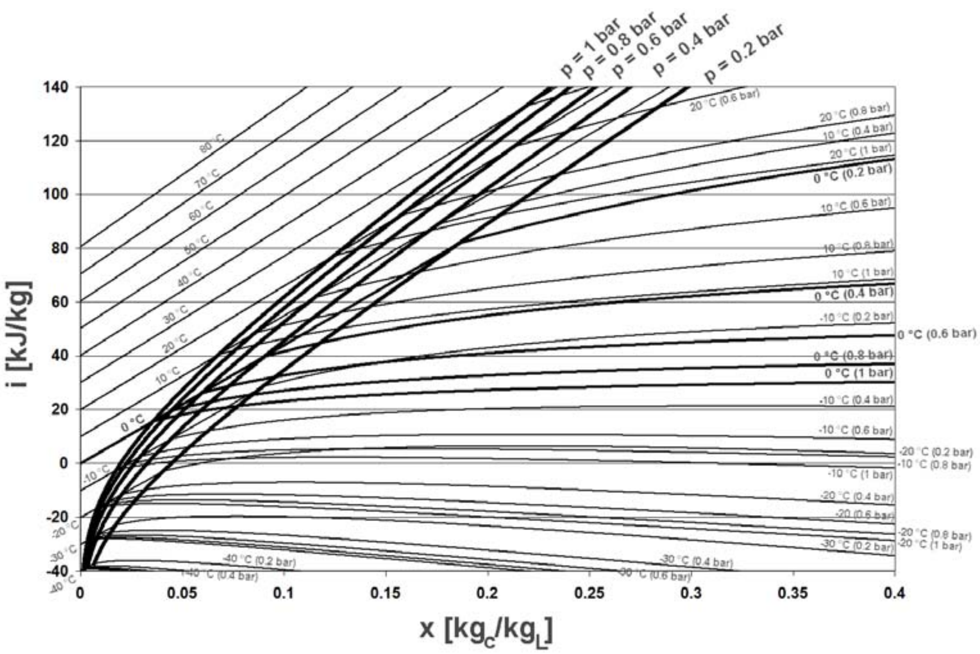

Fig. 2. Air-fuel i-x diagram for gasoline-bioethanol blend E10 (*i* [kJ/kg] enthalpy – *x* participation [kgfuel/kgair]).

3. MIXTURE STATE AND INFLUNECES ON ENGINE OPERATION FUELED WITH E10

Air-fuel mixture state can be determined using the graphical or numerical method [8]. By calculating the mixture temperature after fuel evaporation, the ratio of fuel vapor to total injected fuel can be evaluated. Mixture temperature calculated values for manifold absolute pressure of 1 bar and stoechiometric air-fuel ratio are presented in figure 3. The temperature drops slightly when E10 is used, compared with straight gasoline. The influence of fuel evaporation is dependent on ambient conditions, like temperature, pressure and relative humidity (φ) [9]. When the engine is operated at low humidity and high temperature levels, the mixture temperature drop is greater.

Figure 4 shows how the evaporated fuel to total injected fuel ratio is influenced. A lower ratio is observed when E10 is used for ambient temperatures below 40°C. If lower mixture temperature means higher volumetric efficiency, low evaporated fuel ratio can increase cold start unburned hydrocarbons (HC) emissions.

One problem of using alcohols as a fuel for SI engines is that they make very difficult starting up the engine at low temperature levels. Experimental trials conducted by the author have shown that a way around this issue is increasing the gasoline content in fuel blends (confirmed by fuel providers practice that deliver the E85 blend with 75% ethanol and 25% gasoline during winter). Low ethanol content in the fuel blend of up to 10% should not make cold starting the engine during winter any more problematic compared to straight gasoline.

Given the high miscibility of ethanol with water, a theoretical study was undertaken to evaluate mixture temperature and evaporated fuel ratio when using E10 with pure ethanol or an azeotropic solution (95.6% ethanol and 4.4% water). As the results of this study show (table 3), the presence of water in ethanol has little influence on air-fuel mixture state.

Internal combustion engines are more efficient when operated with lean air-fuel mixtures. One major disadvantage of this operating strategy is the increase of nitrous oxides (NO_x) emissions. Thus, in SI engines the air-fuel ratio is maintained as close to stoechiometric as possible by employing oxygen sensors. Given the presence of oxygen in ethanol, operating the engine on E10, increases fuel consumption at stoechiometric air-fuel mixture. The reduction of fuel consumption when E10 with ethanol that contains water is used, is given by the fact that the presence of water decreases ethanol content, thus increasing the stoechiometric air-fuel ratio (table 4).

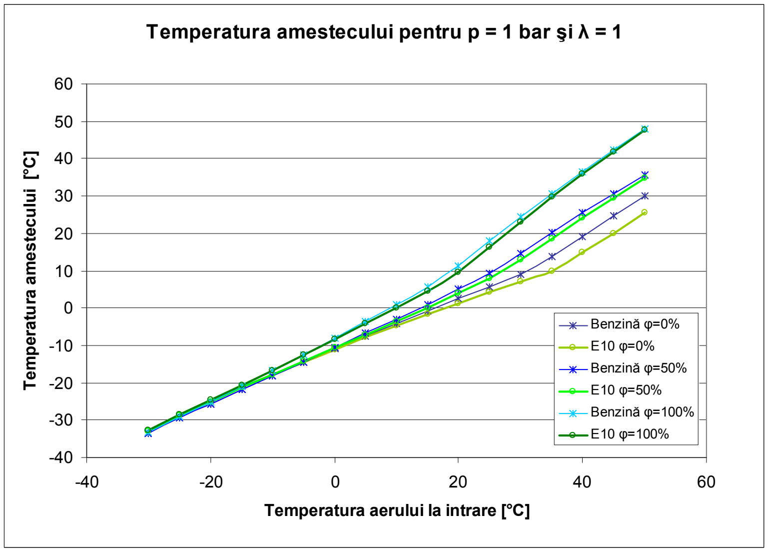

Fig. 3. Variaţia temperaturii amestecului carburant.

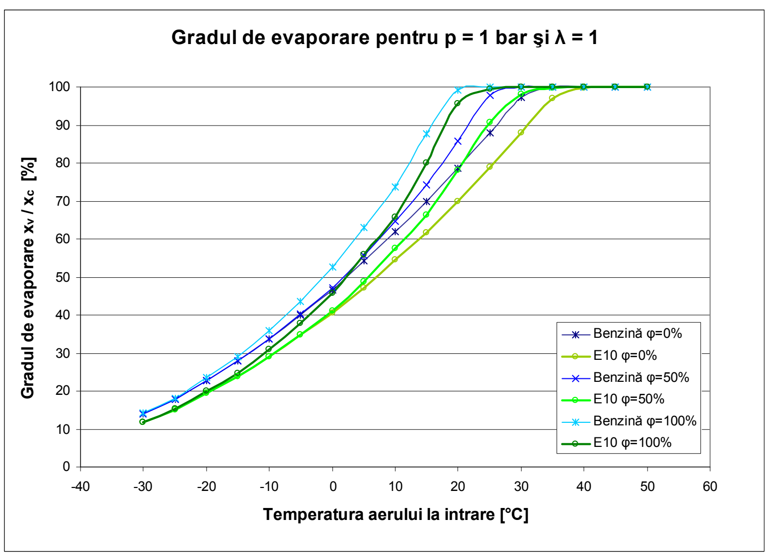

Fig. 4. Variaţia gradului de evaporare.

Fuel consumption can be reduced further by advancing spark ignition timing. The electronic command unit adjusts the timing so that detonation does not occur, thus the engine is operating with less advanced timing away from the optimum point. Due to the higher octane rating of ethanol, the engine can be operated with advanced timing without detonation occurring. Port fuel injection engines have a detonation sensor or an octane coding plug that can be used to take advantage of ethanol's higher octane number, without other modifications to the control system. Another aspect of advanced timing is higher combustion temperature levels that lead to an increase in NO_x emissions. Due to the use of ethanol lower combustion temperatures are obtained, at roughly the same indicated pressure. The presence of water in the fuel, has a similar effect [10].

A further fuel consumption reduction is obtained when the engines operate in acceleration mode, when the injection system delivers the same volume of fuel, no matter what the air-fuel ratio. The presence of ethanol in the fuel makes the mixture leaner, increasing efficiency, with a slight reduction in performance (3-4% power loss).

Table 3. **E10 with pure cu ethanol and ethanol with 4.4% water content compared for p = 1 bar, λ = 1, φ = 50%**

t_{air} [°C]	Temperature		Evaporated fuel ratio	
	$t_{mixture}$ [°C]		x_v / x_c [%]	
-30	-32.92	-32.88	-30	-32.92
-25	-28.88	-28.82	-25	-28.88
-20	-25.1	-25.03	-20	-25.1
-15	-21.32	-21.23	-15	-21.32
-10	-17.8	-17.69	-10	-17.8
-5	-14.33	-14.22	-5	-14.33
0	-10.68	-10.56	0	-10.68
5	-7.17	-7.05	5	-7.17
10	-3.54	-3.43	10	-3.54
15	0.09	0.21	15	0.09
20	3.87	3.96	20	3.87
25	7.88	7.95	25	7.88
30	12.88	12.87	30	12.88
35	18.58	18.42	35	18.58
40	24.17	24.01	40	24.17
45	29.59	29.46	45	29.59

Table 4. **Consumption change when fueling the engine with E10**

Fuel	Gasoline	E10 pure ethanol	E10 ethanol with 4.4% water content
Consumption increase [%]	-	3,6	3,3
Stoechiometric ratio [kg_{air}/kg_{fuel}]	14,7	14,10	14,12

4. CONCLUSIONS

Using the numerical method for determining mixture temperature, a theoretical study was developed for evaluating air-fuel mixture formation when SI engines are fueled with a E10 gasoline-bioethanol blend.

Temperature and evaporated fuel ratio are lower as the ethanol content increases. While the lower mixture temperature is beneficial as it increases volumetric efficiency, less evaporated fuel means difficult cold start during winter and an increase in hydrocarbons emissions.

The presence of water in the fuel blend, due to the properties of ethanol, does not influence mixture state significantly.

When operating the engine in a steady state, with stoechiometric air-fuel ratio, another effect of using E10 is an increase of 3.6% in fuel consumption when the ethanol is pure and 3.3% if the ethanol contains 4.4% water. One way of reducing fuel consumption is adjusting the spark ignition timing. An increase in conversion efficiency by advancing the timing is possible due to the higher octane rating of E10 compared to gasoline.

BIBLIOGRAPHY

[1] **** http://www.ethanolstatistics.com

[2] *Biofuels International*, September 2008, Issue 4, Volume 2, pag. 67-71.

[3] *Automotive Engineer*, May 2008, Volume 33, No 5, pag. 41.

[4] **** http://webbook.nist.gov/chemistry – National Institute of Standard and Technology – Chemistry Webbook.

[5] **** http://en.wikipedia.org/wiki/Ethanol.

[6] *Fuel specifications and fuel property issues and their potential impact on the use of ethanol as a transportation fue*l, Oak Ridge National Laboratory Ethanol Project, Subcontract No. 4500010570 – December 16, 2002.

[7] **D. Iorga**, *Contribuţii la studiul schimbului de căldură şi de substanţă în procesul de formare al amestecului la motoarele cu aprindere prin scânteie*, Institutul Politehnic „Traian Vuia", Timişoara, Facultatea de Mecanică, 1985.

[8] **D. Iorga, A. Irimescu, L. Mihon, I. Vrabie**, *L'Utilisation d'une méthode numérique de calcul basée sur les équations du diagramme i-x air-combustible, pour la détermination des paramètres du mélange carburant d'un moteur à injection de l'essence à l'extérieur de cylindre*, COFRET '08, 11-13 juin 2008, Nantes, France.

[9] **A. Irimescu, D. Iorga, L. Mihon** – *Study of the Intake Air Properties Influence on the Fuel Injected Mixture Formation în a Spark Ignition Engine Using the i-x Air-Gasoline Diagram*, International Congress Automotive, Environment and Farm Machinery, AMMA 2007, 11-13 October, 2007, Cluj-Napoca, România, Acta Technica Napocensis, Series: Applied Mathematics and Mechanics, 50, Vol. IV.

[10] **Lars Eriksson** – Spark Advance Modeling and Control, Division of Vehicular Systems, Department of Electrical Engineering, SE-581 83 Linköping, Sweden, 1999.