ON THE EFFICIENCY OF BIOETHANOL OBTAINING METHODS AND ON ITS FURTHER USE

Alexandru RACOVITZĂ[+], Laurenţiu FARA[++], Gheorghe NICULAE[+], Iulian VOICU[+]

[+]UNIVERSITY POLITEHNICA BUCHAREST, Faculty of Mechanical Engineering
[++]UNIVERSITY POLITEHNICA BUCHAREST, Faculty of Applied Sciences

Rezumat. Articolul de faţă prezintă principalele aspecte privind eficienţa metodelor clasice şi neconvenţionale de obţinere a bioetanolului din biomasa lemnoasă provenită de la anumite clone de plopi, precum şi perspectivele certe de utilizare a acestui tip de combustibil în alimentarea motoarelor şi în funcţionarea celulelor de combustibili.
Cuvinte cheie: bioetanol, eficienţă, combustie, celule de combustibil, biomasă lemnoasă, zero-emisii.

Abstract. The paper should highlight the main aspects regarding the conventional and unconventional methods of bioethanol production from specific poplar clones wooden biomass and also the use of this kind of fuel in thermal engines supplying and in the use of direct ethanol fuel cells.
Keywords: bioethanol, efficiency, combustion, fuel cells, wooden biomass, zero-emissions.

1. INTRODUCTION

Ethanol and especially bioethanol proves to be an efficient agent to be used as an alternative fuel in thermal engines fueling as well as primary source-fuel in the modern fuel cells [1]. Bioethanol could be obtained by applying a multitude of methods, depending on the primary sources used, therefore the paper could not emphasize them all but the ones which refer to the use of wooden biomass, among which a great interest is shown by the biomass extracted from some special poplar clones. These species are representative for what our country is able to offer to the fuels manufacturers. Three were these species chosen, as it will be further detailed and concerning these options, some comparative results applying different methods of bioethanol extraction will be highlighted [2]. The methods to be discussed are only the fermentation methods applied to the sucrated compounds of the lignocellulose: the chemical fermentation through strong or weak concentrated acids, as classic methods and the enzymatic fermentation which provides to be a promising unconventional new method [3]. The obtained bioethanol corresponds to all requests in order to be an appropriate alternative fuel mainly for Spark Ignition Engines (SI Engines) but also for Diesel Engines. Bioethanol has the standard specified low heating value, viscosity, octane and cetane numbers, boiling temperature etc. Due to its high octane number and to its good miscibility, bioethanol could form with gasoline mixtures with good results concerning SI engine performances and emissions. Meanwhile, ethanol could be also used in diesel engines supplying using Diesel-Carburetor Method (DC). This consists in air-ethanol vapors mixture formation through a carburetion device in the engine inlet combined with the classic diesel injection system. The optimum ethanol substitution rate between different engine types remains to be discussed on further investigations on the basis of engines performances and their emissions levels. In what concerns the bioethanol use in modern ethanol fuel cells, a new and revolutionary type of fuel cell principle and design is revealed by the **Direct Ethanol Fuel Cell** (DEFC) (see Figure 1) [4, 5].

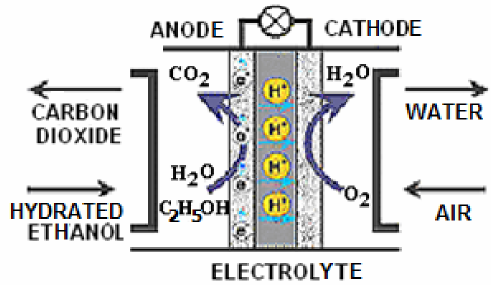

Fig.1. The scheme of Direct Ethanol Fuel Cell (DEFC) operation.

2. BIOETHANOL PRODUCTION

As it has been mentioned, a study has been conducted in order to get results on bioethanol production applying three different fermentation methods of the lignocellulose extracted from three different poplar clones trees [2] [6]. The chosen sorts of the wooden biomass characterize the possibilities offered by the Romanian trees cultures in the process of bioethanol production. These sorts are coded with the names: A-F8, 3 years-Turcoaia and Sacrau-79.

First two applied methods are chemical fermentation methods and the third one is an enzymatic fermentation method of the cellulose coming from the raw used material. The comparative results are shown in Table 1 under percentage values expressing alcohol obtained grams on 100 gr. of used biomass.

Table 1

Comparison of results concerning bioethanol production methods

Method	Bioethanol (gr/100 gr biomass)		
	A-F8	3-years Turcoaia	Sacrau-79
Enzymatic Method	21	22.3	21.9
Chemical Method I	22.6	20.72	20.96
Chemical Method II	21.28	21.64	23.44

Table 2

Ethanol standard characteristics

Characteristic	Ethanol
Molecular mass	46.070
Melting point (at normal pressure) [deg C]	-114.6
Melting heat [kJ/kg]	109
Boiling heat (at normal pressure) [deg C]	78.5
Vaporization heat [kJ/kg]	854
Critic temperature [deg C]	243.15
Critic pressure [MPa]	6.30
Lower /Higher Heating Value [kJ/kg]	28037 / 30973
Normal density [kg/dm^3]	0.794
Specific heat [J/kgK]	2.369
Dynamic viscosity [Ns/mp]*1000	1.2
Refractive Index at 20 dec.C	1.361
Reid vapor's pressure [daN/cm^2]	0.14
Temperature decrease when vaporizing a theoretical mixture [deg C]	96.5

The results are comparable speaking in terms of effective quantities. Both chemical methods use for the hydrolysis process diluted amounts of sulphuric acid. Also, the energy consumption during the chemical processes is high. Enzymatic hydrolysis process of the lignocellulose materials is very complex. The use of enzymes eliminates the use of polluting chemical products used in chemical hydrolysis. Although the enzymatic process is more expensive, this method is non-polluting and could become economically viable by further researches. The products from the enzymatic hydrolysis are not toxic therefore they could be used as animal food or fertilizers [3].

Table 2 shows the assembly of the 99.5% purity ethanol characteristics, taken out from the standards. The values in case of the produced bioethanol are similar to these ones within an error range of maximum 1%.

3. BIOETHANOL USED AS ENGINES FUEL

Since its first use at the beginning of the years 1970, ethanol has been continuously considered an appropriate alternative fuel basically for SI engines. Its high octane number and its good miscibility make it easy to form blends with gasoline, these mixtures being well known and used as E fuel mixtures [7]. It doesn't mean that ethanol could not be used as a single fuel through carburetion or either injection but the lack of lubrication capacity diminishes the fueling system reliability. Thus, rather than using it separately or in addition with expensive lubricating additives ethanol has been commonly used in mixtures with gasoline.

More interesting appear the opportunities to use ethanol (bioethanol) in Diesel engines. There are three methods to be applied in order to combine diesel fuel and ethanol supplies and to not give up to the basic principle of engine compression ignition:

1. The Mixtures method. This could be used only in case of relative small to medium amounts of ethanol due to the limited miscibility of the alcohol with classic fuel. The method has been successfully tested in case of methanol and since ethanol mixes better with diesel fuel than methanol it is expectable to be able to use bioethanol rates greater than 35…37% [8].

2. Diesel-Carburetor method. This method has been also tested in case of methanol. The alcohol is brought in the engine inlet through a carburetor, forming a homogenous mixture with air and diesel fueling injection system is kept as usually [9]. Problems to occur are connected to the rough engine operation when mass alcohol used ratios overpass 50%. Despite the fact that ethanol has a lower specific vaporization heat than methanol, special components designated to accelerate the preheating and vaporization of ethanol, electrical or whatever heat transfer devices, are to be insert into the air-ethanol carburetion system. In order to control the combined air-fuel formation and its combustion an adjustable percentage of exhaust gas recirculation (EGR) is also recommendable to be applied.

3. Double Injection method. This method allows the highest amounts of alcohol to be used in order to replace diesel fuel. The method has been tested both for methanol [10] and ethanol [11]. The maximum amount of diesel fuel mass substitution was around 90% under the condition of preserving the pilot-injection of the remaining diesel fuel quantity as a condition to have engine ignition followed by alcohol injection and subsequent combustion. The main construction problem is that of having separate fuels circuits (tanks, pumps, injection pumps, filters, high-pressure pipes, injectors) being although possible to maintain the same cylinder injector for both fuels [12]. Again, the lubrification problem has to be solved by using coat-protection to the alcohol injection pump pistons or by using special additives in the fuel.

4. BIOETHANOL USE IN FUEL CELLS

The development of the ethanol fuel cells allows new solutions in automotive propulsion to be identified. The bioethanol obtained from wooden or vegetable waste biomass represents a renewable energy source, including the on-board hydrogen formation.

The fuel cell based on bioethanol will convert the chemical energy into electrical energy under a higher rate than using internal combustion engines.

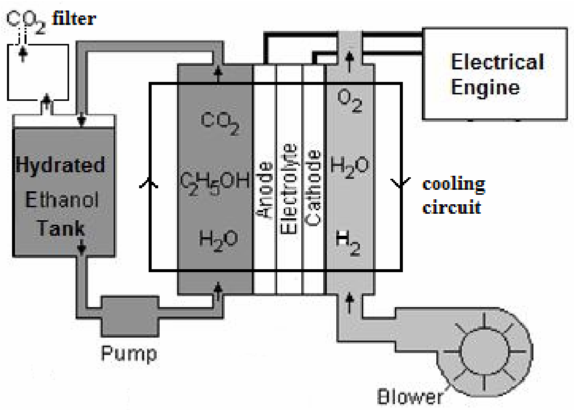

Fig. 2. On board Direct Ethanol Fuel Cell (DEFC).

Ethanol fuel cells could use this fuel as a primary agent even better when hydrated. Energy rate provided by the cells is therefore improved when using bioethanol mixed with small amounts of water comparing to the case when pure-ethanol is used.

Figure 2 is highlighting the basic scheme of a **Direct Ethanol Fuel Cell (DEFC)** mounted on board of the electric vehicle: The scheme presents the structure of the fuel cell consisting in the electrodes separated by the electrolyte. Platinum-based catalysts are expensive, so practical exploitation of ethanol as fuel for PEM (Proton Exchange Membrane) fuel cells requires a new catalyst [13]. New nanostructured electrocatalysts have been developed, which are based on non-noble metals, preferentially mixtures of Fe, Co, Ni at the anode, and Ni, Fe or Co alone at the cathode. A polymer acts exactly like an electrolyte. The electric charge is carried by the hydrogen ions - protons. The hydrated liquid ethanol is oxidized at the anode generating CO_2, hydrogen ions and electrons. Hydrogen ions travel through the electrolyte. They react at the cathode with oxygen from the air and the electrons from the external circuit forming water. The exhaust CO_2 gas is filtered through a filter located on the upper side of the ethanol tank. A secondary water cooling circuit surrounds the structure of the cell, diminishing the thermal operating regime of the assembly.

These types of fuel cells develop up to 40 kW electric power, enough to supply an electric car engine when using it under urban operating regimes. Operating temperatures are below those characterizing a hydrogen fuel cell, but the voltage of the supplying electric energy remains dangerous high, approximately at 500 V; thus, the assembly forming the electric unit has to be very well isolated [14, 15].

Figure 3 shows a comparison between the efficiencies in electrical energy production characterizing several applications, from which it clearly appears the benefits of using fuel cells with or without heat recuperator. Internal combustion engines must evacuate major heat fractions through the cooling and the outlet systems. Fuel cells do not have such constrains. Their operating temperature is significant less than the one existing in the combustion chambers, and there are no heat losses in their outlet system.

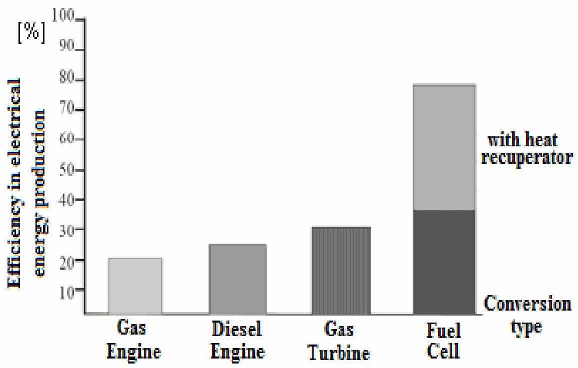

Fig. 3. Efficiency vs. conversion type.

At the same electrical power production, fuel cells have two times less heat losses in their cooling systems comparing to the internal combustion engines. This explains their higher efficiency, not being mentioned, supplementary, the presence of a heat recuperator.

5. CONCLUSIONS

Bioethanol proves to be a significant alternative fuel concerning the use of thermal classic engines as well as a primary agent for ethanol fuel cells.

Regarding the production of bioethanol, poplar clones trees species naturalized in Romania could offer the solution of bioethanol production starting from this kind of wooden raw biomass.

Despite the advance on the research referring to the use of ethanol in fueling the SI engines, new opportunities have occurred consisting in studies of bioethanol use in Diesel engines.

In what concerns the use of bioethanol in the fuel cells, an important advantage of replacing the hydrogen as primary fuel cells agent is based on the fact that alcohol does not need any fuel reformators.

Ethanol fuel cells reach higher operating temperatures, with higher conversion rates of energy. It remains to be solved the problem of weight and displacement together with the one concerning the electric isolation of the assembly, these cells being operated at high voltage. As a primary agent for alcohol fuel cells, bioethanol obtained in a hydrated status through the process of biomass enzymatic fermentation proves to mark a rational choice for the further development of electrical and hybrid automotive transportation.

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