



THE FUTURE OF ALTERNATIVE FUELS FOR INTERNAL COMBUSTION ENGINES APPLICATIONS

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Abstract

The European Union 2009/28WE directive treating promotion and using of energy from alternative sources assumes that bio-components addition to conventional fuel should account for 7 % for diesel oil and 10 % for petroleum. The aim of this study is finding answer for a question if that numbers are reasonable in aspect of contemporary internal combustion engines operation and development.

The problem of alternative fuels application in combustion engines should be discussed in two aspects: adjusting new fuel parameters for engine properties and adjusting an engine to be fuelled with new fuel. Taking into consideration the possible ways of renewable fuels applications it is important to consider costs of the researches of the engines adjustment. The expenditures are reasonable if the alternative fuels supplies will be at the same level as crude oil exploitation these days. The fuel of the future seems to be the hydrogen, fuel for temporary period – natural gas and partly, methane from biomass and dimethylether (DME) as a fuels which can be used in contemporary engine after insignificant modifications.

Keywords: renewable energy sources, engine fuel, DME, SynFuel, hydrogen, Biodiesel

1. Introduction

The worldwide energy consumption in 2005 accounted for over 10,5 Gtoe (ton of oil equivalent). The 88% of that value came from fossil fuels: crude oil (36,5%), coal (28%) and natural gas (23,5%). If in next few years velocity of increase in fuel consumption will be higher than new sources discovering, the supplies of crude oil will be exhausted after 40 years of exploitation, natural gas after 60 years of exploitation and coal after 200 years of exploitation [1].

The coal is used directly for electric and heat energy production, natural gas for mainly in industry sector for energy production and as a fuel in automotive industry. Crude oil is used almost only as an engine fuel: petroleum, diesel oil, turbine fuels and shipping fuels.

During the fuel combustion processes the exhaust gases are produced. The exhausts consist environment harmless compounds: CO, CO₂, SO₂, NO_x, particle matter (PM) and unburned hydrocarbons. Some of that chemical invidious have mutagenic and carcinogenic properties (mainly hydrocarbons like aromatic and polyaromatic compounds). Some of them (especially carbon dioxide and some hydrocarbons) are responsible for Green House effect.

According the recent researches 25 mld Mg of CO₂ is emitted every year and in each year the emission increase about 3 ppm. The CO₂ concentration in atmosphere in 2008 accounts for 385

ppm. The forecasts says that in 50 years the carbon dioxide concentration achieve very dangerous level of 560 ppm.

The anthropogenic sources of CO₂ is approximately 28 Gt per year and in 18 % is generated by automotive industry, mainly by car vehicles fuelled by fossil fuels [3].

The worldwide exploitation of crude oil probably achieve a culmination point in one decade. The history of the exploitation and its forecast is presented in figure 1 [3]

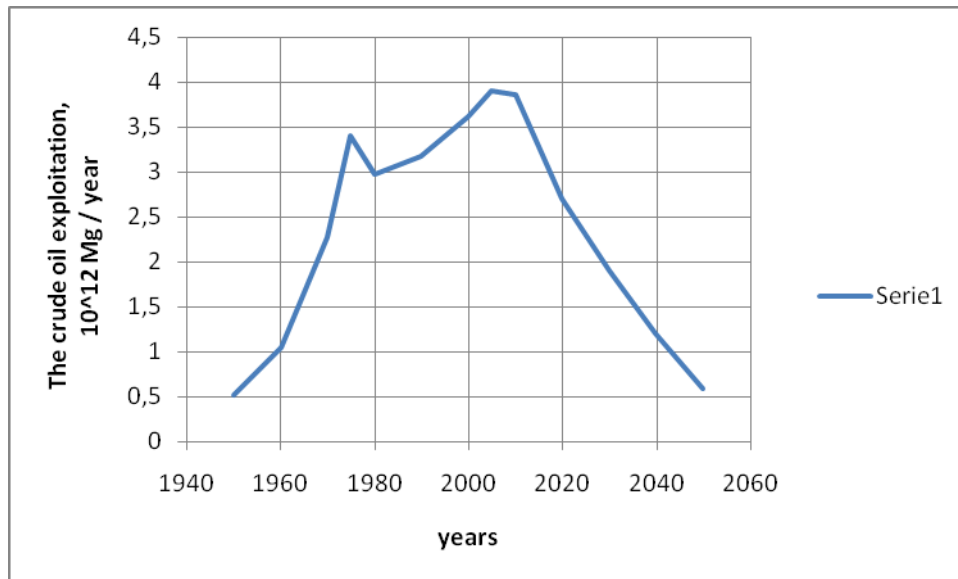


Fig 1. Real Worldwide crude oil exploitation and its forecast in years

Rudolf Diesel (in 1912) emphasised the vegetable oil's role as a alternative for crude oil and coal: "The vegetable oil usage as a fuel today may seems insignificant. But these kind of energy source may became in time as important as crude oil and its products nowadays".

The problems of crude oil products demand, the realistic forecast of its exhaust and Green House effect progress stimulate researches on alternative and environmental friendly substances for fuel production.

The European Union 2009/28WE Directive about promotion and using of energy from alternative sources assumes that bio-components addition to conventional fuel should account for 7 % for diesel oil and 10 % for petroleum [2].

The aim of this study is finding answer for a question if that numbers are reasonable in aspect of contemporary internal combustion engines operating and development.

2. The technical and logistic problems of renewable fuels usage

The problem of alternative fuels application in combustion engines should be discussed in two aspects:

- adjusting new fuel parameters for engine properties,
- adjusting an engine to be fuelled with new fuel.

Because of advance in engines technology, a scale of their production, the number of engines which are currently in exploitation and condition of engine's steering systems the preferable direction is the first one. Even in that direction of the researches some important problems need to be solved in technical aspect:

- decrease in engine effectiveness in comparison to conventional fuel,
- disadvantageous impact of fuel on engine fuelling system and its components,
- problems with fuel-air mixture formation because of difference in viscosity, density and surface tension of bio-based fuels and the problems with combustion process caused by that facts,
- need of engine's control systems modification because of previous facts,
- nitric oxides emission increase,
- discursive scale of other exhaust toxic compounds decrease,
- problems with current exhausts toxicity standards abiding,
- a scale of fuel available compare to crude oil products,
- no compatible, with alternative fuel demand, engine development

logistic aspect:

- oil plants harvesting one time per year,
- dependence of fuel quantity on environment condition (climate, soil, pollution),
- unstable fuel parameters (quantity),
- demand on infrastructure for bio-based fuel production,
- fuel stability and its ageing,
- necessity of using areas assigned for food production for biomass production,
- increase in food prices,
- organisation of fuel distributing net,

ecologic aspect:

- change in culture structures (so called: monoculture),
- demand on chemical substances for disease prevention,
- soil demineralisation.

Taking into consideration the direction of alternative fuels application also engine adaptation to new fuel parameters is needed. The main engine parameters should be investigated to achieve the engine effectiveness comparable to the effectiveness with engine fuelled with conventional fuel.

That is why the question about alternative fuels should be answered only in context of the engine assigned for concrete fuel usage (in aspect of thermodynamic machine). Typically, for that kind of situations, the arguments are divided according to the author's background.

3. The VOLVO AB strategy

The VOLVO AB Company, as a producer of heavy-vehicles and buses, consistently believes diesel engines as a drive unit for next 20 years [3]. The main advantageous of compression-ignition engine usage is high effectiveness – even at maximum 45 % level.

The others diesel engine advantageous are:

- Low toxic compounds emission – contemporary compression-ignition engine equipped with exhaust gases purification system is very profitable for environment in toxic emission aspect especially particle matter (PM) and NO_x; According to the forecast in next few years the emission will be 100 times lower than in 1980.
- The fuel flexibility – the compression-ignition engine can be fuelled with various alternative fuels like synthetic diesel oil, dimethylethers (DME), alcohols and gas fuel.

- The possibility of assembling with other systems – it is possible to connect the diesel engine with electric one and the intelligent controlling system what cause very effective and environmental friendly drive unit (low specific fuel consumption, low CO₂ and toxic emissions).
- The reliability, profitability, and competitiveness – because of wide applications of compression-ignition engines, especially in service sector it is very important to achieve reliability drive unit, characterized by low fuel consumption what effects with profitability and competitiveness on the market.
- The proper technology for the future standards – to achieve more and more restrict emission standards the engine and vehicle producers offer the solutions proper for each national market.

In USA where very strict standards of nitric oxides emissions are implemented (US 07) special series of diesel engines is offered. Those engines are equipped with exhausts gases recirculation system (EGR) and diesel particle filters (DPF).

In Europe most of the offered engines are equipped with selective catalytic reduction systems (SCR). The basic principal of the method is catalytic conversion of NO_x in exhaust gases to atmospheric nitrogen simultaneously with fuel consumption reduction what effects in CO₂ emission decrease. VOLVO has carried out the researches on exhaust gases treatment system based on EGR and SCR on the same time.

The experts from VOLVO claim that diesel oil will be basic engine fuel for next 20 years but emphasizes the problem of new energy sources development. The values of energetic effectiveness in cycle “well to wheel” for different, conventional and alternative, fuels are presented in figure 2.

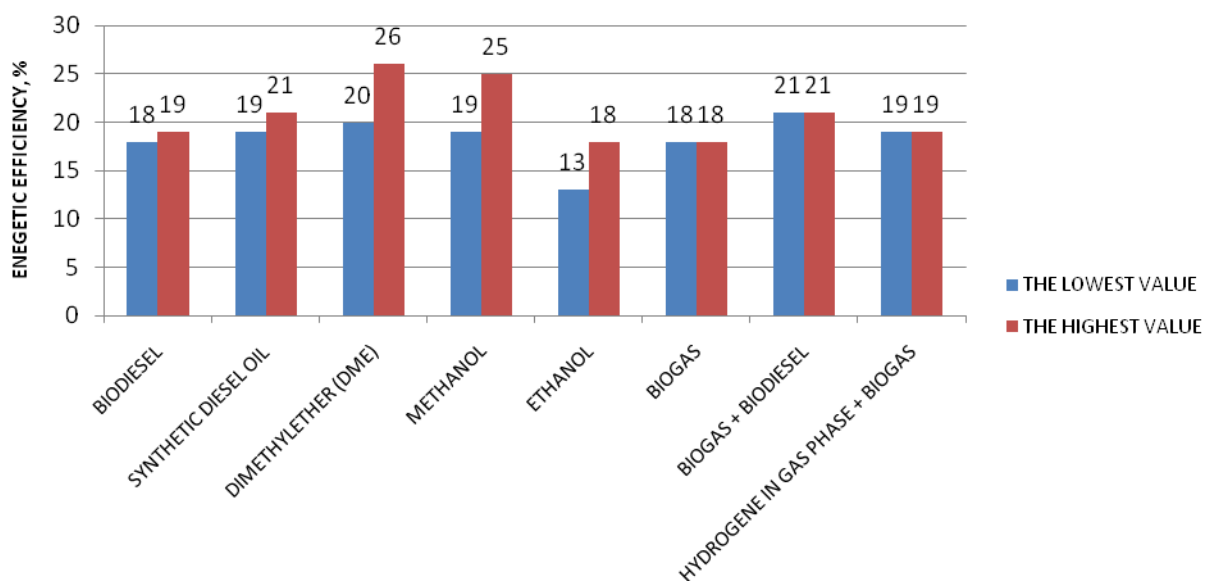


Fig 2. Energetic effectiveness for different fuels [3]

The method for bio-based fuels comparison is analysis of distance, in kilometres, which vehicle can achieve fuelled with fuel produced from 1 ha of cultivation. The values of this parameter are shown in figure 3.

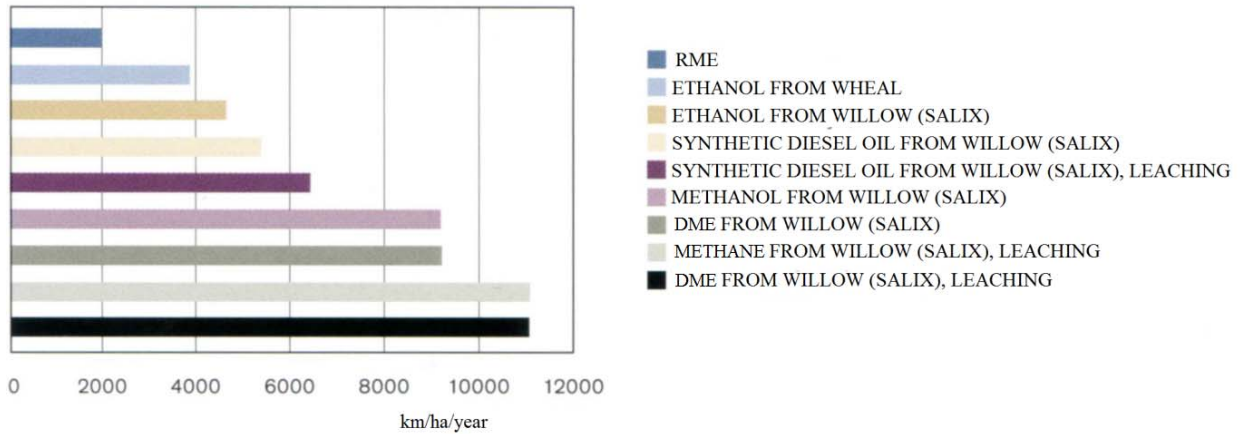


Fig 3. The distance, in kilometers, which vehicle can achieve fuelled with fuel produced from 1 ha of cultivation

The energy source which is the most perspective seems to be syngas (dimethylether, DME). DME may be produced from biomass but also from coal and natural gas. The most profitable is the production from biomass sources.

4. The strategy of VOLKSVAGEN AG

The VW company as a worldwide producer of internal combustion engines (gasoline and diesel), discuss the possibility of alternative fuels applications, especially on synthetic fuels(SynFuels) field and biofuels (SunFuel: SunDiesel and SunEthanol). Hydrogen and its usage in fuel cells is an electrotraction stage [4]. The VW fuel and powertrain strategy is presented in figure 4.

Fig 4. The Volkswagen fuel and powertrain strategy: SynFuel – Synthetic fuel, SunFuel – fuel derived from biomass, CCS – Combined Combustion System [4]

Implementation of alternative fuels for engine applications causes series of consequences. The basic problem is change in caloric value and its changing in time. The phenomena is presented in figure 5.

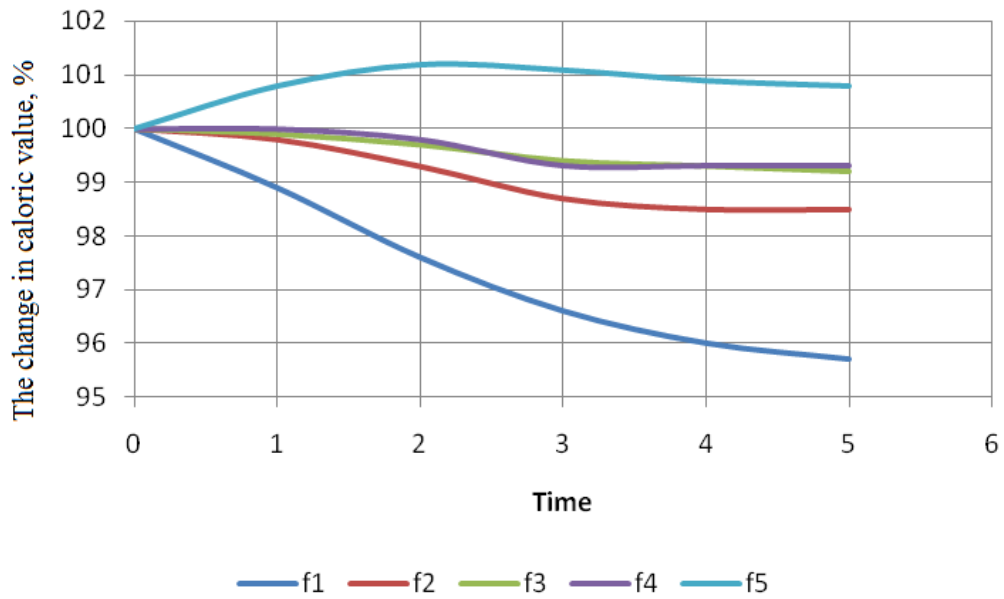


Fig. 5. The change in caloric value of alternative fuel in time [4]: f1 – diesel oil, f2 – biodiesel, f3 – diesel with commercial additions, f4 – diesel oil with 5% of bio-component and commercial additions, f5 – diesel with special additions

The changes in combustion process on example of indicator diagram of engine fueled with diesel oil and rape oil methyl ester (RME) is presented in figure 6.

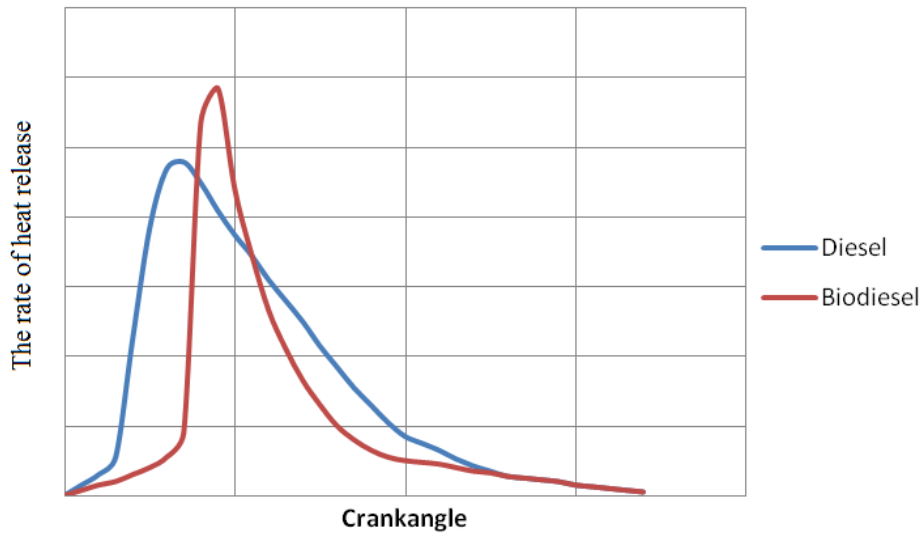


Fig 6. The indicator diagram for diesel fuel and biodiesel [4]

The change in fuel-air mixture combustion process in compression-ignition engine has significant impact on exhaust quality (toxic compounds concentration). The impact of fuel change from diesel fuel to biodiesel on emission of HC, CO, NO_x and smoke matter is shown in figure 7.

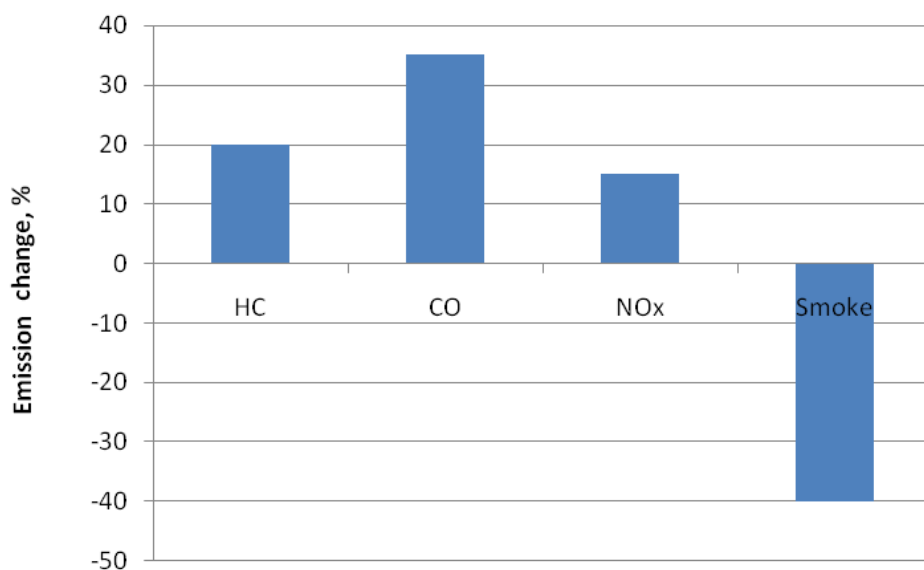


Fig. 6. The change in emission of chosen exhaust compounds from diesel engine fueled with biodiesel in comparison to conventional fuel [4]

The “zero emission” of toxic compounds and high heat efficiency ensure hydrogen usage as an engine fuel. The disadvantageous of hydrogen fuel is insufficient caloric value and high energy-consuming factor of its production process.

4. Conclusions:

Nowadays the trends of alternative fuels production are very difficult to estimate.

The wide international cooperation is needed for finding alternative for diesel oil for engines application.

Taking into consideration the possible ways of renewable fuels application it is important to consider costs of the researches on engines adjustment. The expenditures are reasonable if an alternative fuel supplies will be at the same level like crude oil exploitation these days.

The fuel of the future seems to be the hydrogen fuel for temporary period – natural gas and partly methane from biomass sources and dimethylether (DME) as a fuel which can be used in contemporary engines after insignificant modifications.

References:

- [1] Surygała J.: Wodór jako paliwo. WNT Warszawa 2008
- [2] Dyrektywa UE 2009/28/ WE w sprawie promowania stosowania energii ze źródeł odnawialnych
- [3] Volvo trucks i środowisko. RSP 20100070017.0710
- [4] SunFuel® – The Way to Sustainable Mobility. Materiały informacyjne Volkswagen AG
- [5] UNEP Report on the Automotive Industry as a Partner for Sustainable Development; 2002
- [6] ACEA Communication – vehicles and biofuels towards 2020 [7] Girolamo G.D., Blasi C., Schioppa M., Tapfer L.: *Structure and thermal properties of heat treated plasma sprayed ceria–yttria co-stabilized zirconia coatings*, *Ceramics International* 36 (2010) 961–968