ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1138643

BMD ECOFUEL FOR DIESEL ENGINES

Mieczysław Struś, Lech Sitnik

Wroclaw University of Technology
Mechanical Faculty, Institute of Machine Construction and Exploitation
Łukasiewicza Street 5, 50-370 Wroclaw
tel.: 071 320 20 75, fax: 071 320 42 02

Andrzej Piętak

University of Warmia and Mazury
Technical Sciences Faculty
Słoneczna Street 16A, 10-710 Olsztyn, Poland
tel.: +48 89 5245101, fax: +48 89 5245150
e-mail: apietak@uwm.edu.pl

Abstract

The World is strongly dependent on crude oil for its transport needs. In order to diminish this dependence, we need to introduce clean, CO_2-efficient, secure and affordable transportation fuels. The current production of liquid biofuels in the EU25 is less than 1% of the market. Recent assessments have concluded that the 2010 targets, 18 Mtoe used in the transport sector, are unlikely to be achieved. There can be three basic possibilities of accomplishing this target: i) use of alcohols (first of all ethanol) and their mixing with petrol; ii) use of fatty acids esters (methyl or ethyl) of vegetable oils and their mixing with diesel fuel, iii) use of synthetic hydrocarbons of the synthetic gas coming from biomass resources and eventually their mixing with other "classical" hydrocarbons.

This paper presents a novel way of utilizing alcohols as fuels for a diesel engine. It is proposed to use heavy alcohols as a mix with vegetable oils and conventional diesel fuel. It is presented the way to use alcohols. Namely, the use of heavy alcohols as a solvent for vegetable oil (named the biomix or BM) and after the obtainment of the thickness, which would be approximate to diesel fuel, mixing the biomix with diesel fuel to obtained biomixdiesel (BMD). This solution will be shown for example with butanol as heavy alcohol, rape oil as vegetable oil and conventional diesel fuel. The investigations are carried out with a simple diesel engine on the engine test bed. Main parameters of engine (power output, torque, specifically fuel consumption) and the main exhaust gas component (in this case CO, NO_x, PM) will be investigated. There were better results achieved than one expected. Opposed to existing experiences, the maximum of power output and the torque of engine are higher in the whole range of the rotational speed of the engine crankshaft when the engine biomixdiesel (BMD) is reinforced. The addition of the component biomix to fuel influences the specific fuel consumption. Generally, with the larger part of the component biomix the specific fuel consumption grows. Because the power of engine also grows up one should expect that in exploitation the specific fuel consumption should not increase. Very important is that this fuel could be used to reinforce old, existing now and the future diesel engines. The production of butanol is known (from biomass and in other way with electrolysis of ethanol). The possibility to get butanol from ethanol gives a very good perspective for the use of ethanol from today's overproduction and moreover without the essential change of infrastructure.

All this leads to the conclusion that fulfilling of the expected requirements of European Union regarding the ecofuels is fully possible.

Keywords: *ecofuels, biomixdiesel, BMD, engines, diesel engines*

1. Introduction

In 2011, it had been 125 years since the car was designed and by 2013, it will have been 125 years since it first came into use. This period in the history of motorization has been marked by a constant increase in the demand for oil derivative fuels. Although in the 1970s of the 20th century people realized that the natural resources of these fuels had been depleting (which led to a temporary decline in the use of oil derivatives), this has been seen as less important while new deposits have been found. The basic factors behind the decrease in the use of oil derivatives are economic and, more importantly, ecological considerations.

To address the need for limiting the greenhouse effect very strict norms were implemented to limit acceptable emissions of toxic fuel components, particularly carbon dioxide, which is in direct proportion to the level of fuel consumption. These norms have been subsequently tightened, which has led to a growing demand for alternative fuels. It is worth remembering that Henry Ford, who was the first to introduce mass production of cars, built a network of distilleries, which were designed to provide ethanol for car engines. This might be seen as the first step in the development of fuels derived from renewable resources for motorization. As yet, however, no significant progress has been made in this respect. For instance, in the European Union, biofuels, which are regarded as alternative to oil derivatives, constitute approximately 1% of annual fuel consumption [1]. In the light of these limitations, the 3x20 principle has been introduced in the UE, namely:

- By 2020,
- Energy consumption is to lower by 20%,
- 20% of fuel is to be derived from renewable resources (with regard to engine fuels in transport this indicator shall be 10%).

The attempts made so far towards meeting these criteria include some particular directions:

- introducing hydrogen as fuel,
- deriving hydrocarbon liquid fuels from biomass (which includes deriving liquid fuels by way of gasification of biomass to synthetic gas and from synthetic gas, through Fisscher Tropsch synthesis, to liquid fuels),
- using raw vegetable oil as fuel,
- using processed vegetable oil as fuel (higher fatty acids) for their methyl and ethyl esters,
- using alcohols derived from biomass fermentation (so far mostly ethanol),
- composing fuels as blends of the elements enumerated above or as blends of oil derivatives.

The introduction of these fuels requires:

- creating new infrastructure (hydrogen) and implementing new energy sources (new combustion engines or fuel cells),
- implementing entirely new energy sources (e.g. a self-ignition engine designed by ELSBETT company, which can be powered directly with raw vegetable oil, or a self-ignition engine designed by SCANIA company, which can be powered with ethanol,
- elaborating new varieties of eco-fuels (biofuels) whose application will not require significant changes in the infrastructure. These fuels could be applied to power both the engines, which are currently in operation and those, which will appear as the technology advances in the future.

The last direction seems particularly worthy of attention. With no more than 8 years left until 2020, the time, notwithstanding the expenses, is in short supply.

It is believed that adequate solutions may appear halfway through this period, namely around the year 2016, which is definitely too late to expect the application of the new infrastructure for production and distribution of bio (eco) fuels in the UE and the implementation of new powering technologies [1, 2, 3, 4, 5, 6].

Recently the price of diesel oil has drawn level with or even exceeded the price of petroleum, which proves that the cars running on self-ignition engines outnumber other vehicles, causing “excessive” consumption of diesel fuel and inadequate consumption of petroleum. This tendency will become stronger along with the development of gas applications, with natural gas in particular. While it is believed that the percentage of vehicles powered with natural gas will not exceed 60% of the total number of vehicles, this share of the market is significant enough to exacerbate the problem of excessive supply of petroleum. It is inconceivable that these tendencies may have changed by 2020. With petroleum and diesel fuel at equal prices, it is still economical to exploit the diesel engine, as its efficiency is approximately 30% higher, which lowers the quantity of the consumed fuel. The consumption of petroleum for land vehicles should grow in proportion to the growing consumption of diesel fuel, which obviously cannot be produced without a simultaneous growth in the production of petroleum. Thus, the suggestions of the growing presence of ethanol in petroleum appear to be impractical, as it disturbs the balance in the fuel market [7, 8, 9, 10, 11 , 12, 13, 14].

By way of digression, it is worth observing that the increase in the consumption of gas fuels based on oil or natural gas derivatives exploiting non-renewable resources does not contribute to the EU objectives, unless biogas is added to these gases.

What remains to be done is therefore the design of new varieties of fuel, which could be applied, in the existing infrastructure for their extraction and utilization.

None of the known studies stipulate the shortage of petroleum by 2020 and further by 2050, even with the steep increase in its consumption in Asian and, in the near future, African economies. Therefore, bio (eco) fuels will constitute additives to oil derivatives. It remains to be seen what kind of additives these will be. [15, 16, 17, 18, 19, 20, 21, 22, 23]. Overall, there are three possibilities:

- synthetic hydrocarbons from biomass,
- vegetable oils, higher fatty acids and their esters,
- alcohols, mainly those derived from the lignin of plants,
- blends of the above.

The latter constitute the subject of this paper.

2. BMD fuel

The present paper discusses the use of heavy alcohols used as solvents for vegetable oils (the biomix blend – BM) of density close to that of diesel oil (including synthetic oil from biomass), which is mixed in to obtain the biomixdiesel – BMD.

One of the simplest heavy alcohols used as a component in the BMD is butyl alcohol (butanol) [5, 6], which contains 4 atoms of carbon of the formula C_4H_9OH. Today it is primarily used as a solvent or an intermediate product in chemical reactions.

The table below shows some of its parameters.

Tab. 1. Comparison of selected parameters of butanol and petroleum and its standard components

Fuel	Calorific value	Vaporization heat
Petroleum	32.0 MJ/l	0.36 MJ/kg
Butanol	29.2 MJ/l	0.43 MJ/kg
Ethanol	19.6 MJ/l	0.92 MJ/kg
Methanol	16.0 MJ/l	1.20 MJ/kg

Butanol can be utilized as a fuel for engines of inner combustion, but exclusively in the engines of spark ignition, as it has been noticed that butanol is more similar to petroleum than ethanol. The calorific value of butanol and its vaporization heat are close to the calorific value of petroleum [8]. As yet, butanol as a fuel or an additive to fuel for self-ignition engines has not been utilized.

Since the 1950s, butanol has been produced mainly from fossil fuels. It is important though, in the light of the guidelines set by the EU, that it can be produced from biomass by means of fermentation with the use of *Clostridium acetobutylicum* bacterium (since the 1950s this has been the main manner of butanol production). Over the last several years, other bacteria capable of producing butanol have been discovered and currently the research on the new bacteria has begun in earnest. The main objective is to obtain butanol also from cellulose.

The possibility of producing butanol from ethanol through electrolysis is also being considered:

$$2C_2H_5OH + 2C_2H_5OH \rightarrow 2C_4H_9OH + 2H_2 + O_2.$$

This method is very promising at the time of ethanol overproduction in Europe as a whole and in almost every European country. The possibility of utilizing this excess would have become the easiest way of obtaining this fuel component, as it would have released the full capacity of the existing infrastructure, while the expenses towards its adjustment for electrolysis are relatively low.

Butanol produced from biomass used to be known as biobutanol.

Bearing in mind the properties of heavy alcohols, particularly those used as solvents, it has been stipulated that they could serve as solvents for vegetable oils. The trials have been made mixing rapeseed oil with butyl alcohol in such proportions as to obtain a blend of the standard diesel oil density (in this example 840 kg/m^3)

Butyl alcohol has been found to be an efficient solvent for rapeseed oil. The blend is homogenous and it does not separate even after a 9-month period.

Research has been conducted on the fuelling propertied of the BMD blend.

In the research commercial diesel, oil has been used of low methyl ester content as well as commercial rapeseed oil. A pure, n-butyl alcohol produced by POCH company has been selected as a co-solvent. The diesel oil applied for composing biofuel has met all the quality guidelines set in the norm PN-EN 590 [9]. The Tab. 1 below presents its basic properties. For comparison, Tab. 2 presents the properties of n-butyl alcohol.

Tab. 2. Basic physical and chemical properties of diesel oil

No.	Property	Result
1.	Cetane number	53.0
2.	Density at 15^{o}C, kg/m^3	836.2
3.	Ignition temperature, ^{o}C	63
4.	Carbonization residue (of 10% rem. dest.), %(m/m)	<0.10
5.	Fuel distillation range below 250^{o}C distills, %(v/v) below 350^{o}C distills, %(v/v) 95%(v/v) distills . to temp., ^{o}C end, ^{o}C	 39.5 94.9 350.5 362.4

Tab. 3. Properties of n-butyl alcohol

No.	Property	N-butyl alcohol
1.	Density at 20^{o}C, kg/m^3	810
2.	Boiling temperature, ^{o}C	117
3.	Ignition temperature ^{o}C	30

In order to assess the quality of the biofuel containing such components as higher alcohol and rapeseed oil experimental blends have been made. Conventional diesel oil constituted the basic component of the blend (80% of the capacity), added to which was a composition of two biocomponents in the congregate amount of 20% of the total capacity. First, a biomixture was made containing heavy alcohol and rapeseed oil, which was next introduced into diesel oil. The samples were marked B2O (containing n-butanol). The B2O blends were clear and free of turbidity or residue. They did not show any separation after a few days in room temperature.

The biofuel samples have been assessed for the requirements set in the norm PN-EN 590. The results of the assessment are presented in Tab. 3 and 4

Tab. 4. Comparison of assessment results of B2O biofuel against the PN-EN 590 norm

No.	Property	Assessment method	Assessment result B2O	PN-EN 590 requirements
1	Cetane number	PN-EN ISO 5165	44.4	min 51.0
2	Cetane rating	PN-EN ISO 4264	46.8	min 46.0
3	Density at 15°C, kg/m^3	PN-EN ISO 12185	837.9	820.0 – 845.0
4	Content of polynuclear aromatic hydrocarbons, %(m/m)	PN-EN 12916	1.9	max 11
5	Sulphur content, mg/kg	PN-EN ISO 20846	5.7	max 10.0
6	Ignition temperature, ^{o}C	PN-EN ISO 2719	< 40.0	more than 55
7	Carbonization residue (of 10% rem. dist.), %(m/m)	PN-EN ISO 10370	0.48	max 0.30
8	Cineration residue, %(m/m)	PN-EN ISO 6245	< 0.001	max 0.01
9	Water content, mg/kg	PN-EN ISO 12937	110	max 200
10	Contamination content, mg/kg	PN-EN 12662	<6.0	max 24
11	Assessment of corrosion effect on copper (3 h, 50^{0}C)	PN-EN ISO 2160	class 1	class 1
12	lubricity, corrected diameter of wear mark (WS 1,4) at 60°C , μm	PN-EN ISO 12156-1	281	max 460
13	Kinematic viscosity at 40°C, mm^2/s	PN-EN ISO 3104	2.710	2.00 – 4.50
14	Fuel distillation range below 250^{o}C distills, %(v/v) below 350^{o}C distills, %(v/v) 95%(v/v) distills . to temp., ^{o}C end, ^{o}C	PN-EN ISO 3405	 47.3 -- -- 349.9	 < 65 min 85 max 360 --
15	Methyl esters of fatty acids FAME	PN-EN 14078	< 1.6	max 7.0
16	Resistance to oxidation, g/m^3	PN-ISO 12205	66	max 25

Tab. 5. Comparison of low temperature properties of B2O and B2O-2 biofuels against climate requirements set in the PN-EN 590 norm

No.	Property	Method	Assessment result B20	PN-EN 590 requirements		
				Summer time	Transitional time	Winter time
1	Cold filter plugging point, ^{o}C	PN-EN 116	-21	max 0	max -10	max -20
2	Cloud point, ^{o}C	PN-ISO 3015	-6	only for Arctic climate		

Comparing the results obtained for biofuel B20 against the quality requirements set for diesel oil, it must be stressed that most of the properties meets the criteria; however, there are properties that diverge from the standard requirements.

Due to the 20% content of biocomponents, the cetane number of biofuel B20 is 44,4 units and is lower than the level required by norms, which is at least 51 units. Rapeseed oil has the cetane number in the range of 40-50 units [10, 11], and added in small amount to diesel oil it should not considerably lower its cetane number. However, alcohols of characteristically high octane number, which renders them favourable in the process of petroleum composition, when added to diesel oil worsen the parameters of the engine start in self-ignition engines.

The process of engine start and work is also affected by the fuel distillation range, in particular by the temperature of distilling off the volumetric 50% of the fuel, $T_{50.}$ The lower the T_{50}, the easier to start the engine, although in low temperatures the ignition properties of the engine deteriorate, as the cetane number decreases.

Figure 1 presents the process of distillation of composed biofuel against diesel oil.

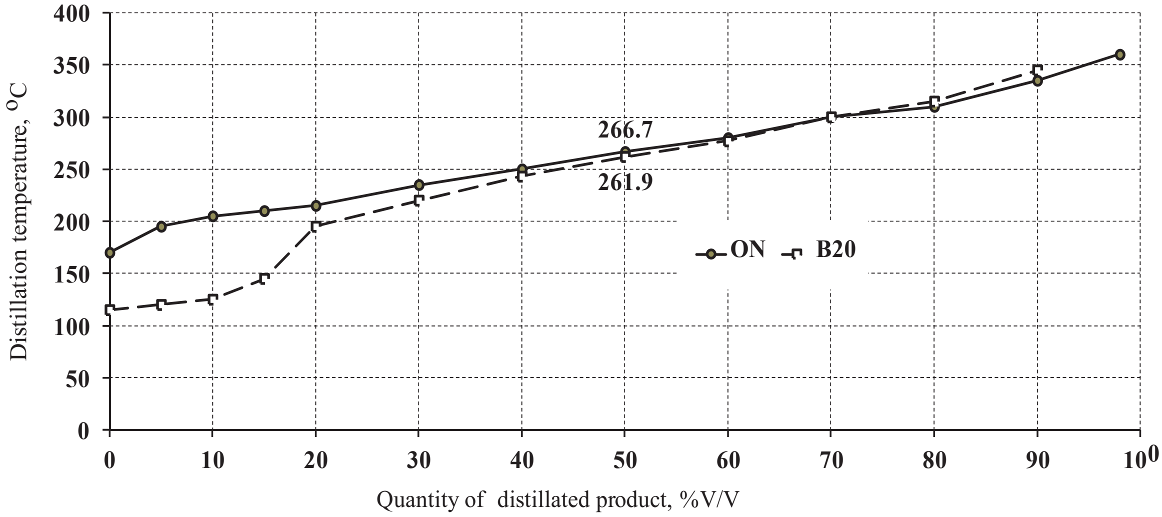

Fig. 1. Comparison of distillation process of diesel oil (ON) and biofuel B2O-1

The temperature T50 in the analyzed samples of B20 biofuel and diesel oil ON was similar. (261.9 and 266.7°C). In the range of temperatures from approximately 250°C to 340°C, the process of biofuel and diesel oil distillation is similar. However, the beginning of distillation is untypical; the B20 sample begins to boil at 114°C. In the initial phase, it is mainly alcohol that distills off; the diesel oil and rapeseed oil distill off at a later stage. The course of the distillation process suggests that the process of biofuel combustion in the engine may be nonuniform.

The content of alcohol in biofuel lowers the temperature of ignition. The ignition temperature of the biofuel blend is conditioned by the ignition temperature of its lightest component, which in this case is n-butyl alcohol. The analyzed B20 biofuel has ignition temperature of 37°C. The safety of transporting and storing diesel oil requires the ignition temperature to be higher than 25°C. Therefore, the fuel of lower ignition temperature may not be marketed and sold without adequate additives. Alternatively, such fuel may be applied to power selected fleets of vehicles.

The analyzed biofuel exhibits high propensity for producing residue and fouling, regarded as residue of carbonization. In case of the B20 sample, the amount of residue after carbonization exceeds the 60% required by norms. The fuel of such high carbonization residue may cause the residue to remain in the combustion chamber of the engine, on the valves, piston rings, and injector parts. Additionally, the particulate matter originating in the combustion of such fuel may lead to an excess use of the components of the system of pistons, rings and cylinders. The residue and fouling may also alter the conditions of the heat exchange process and lower the quality of fuel distribution. It must be emphasized, however, that these adverse parameters result from the use of commercial rapeseed oil. It is not impossible to customize such oil; besides, rapeseed oil is not the only vegetable oil, which can possibly be applied.

Biofuel has good low temperature properties (Tab. 4). The cold filter plugging point has been marked at -21°C and the cloud point at -6°C, which diverges slightly from the equivalent parameters of diesel oil. The assessment of low temperature stability have proven that biofuel stored for a few days in room temperature muddles, but does not separate and retains its liquidity. The kinematic viscosity of the fuel is appropriate and amounts to 2.710 mm2/s. the appropriate viscosity of fuel is a crucial parameter as it affects its distribution and the quality of combustion.

The other quality properties of biofuels do not diverge from the norms. The content of sulphur, water, polynuclear aromatic hydrocarbons, solid contamination, cineration residue, density and lubricity are all appropriate. The only alarming parameter is the resistance to oxidation. The amount of residue after a period of accelerated ageing is approximately twice as high as the normative requirements. It must be pointed out, however, that this kind of biofuel will not be intended for long term storage.

3. Test bench assessment of the BMD powered engine

Biofuels BMD have been mixed in the following proportions:

– Diesel fuel 90% v/v, biomix 10% v/v (marked ON B10),
– Diesel fuel 80% v/v, biomix 20% v/v/ (marked ON B20),
– Diesel fuel 50% v/v, biomix 50% v/v/ (marked ON B50).

Standard diesel fuel has been used in the norm PN EN 590.

The assessment was made [12] with the use of a PERKINS self-ignition engine type AD 3.152.UR. This "classic" engine of conventional fuel system was set for diesel oil. The settings remained unchanged both when the engine was powered with a blend of diesel oil and butanol and when it was powered with a blend of diesel oil and a blend of rapeseed oil and butanol.

The assessment on an appropriately equipped test bench was made to determine the external characteristics of the engine powered with a blend of diesel oil and a blend of rapeseed oil and butanol.

Basic parameters of the engine were determined, such as the power, torque, fuel consumption per unit; besides, preliminary measurements were taken of the toxic tailpipe emissions; carbon monoxide (CO), nitric oxide (NO) and particulate emission (PM).

In every case, the determined quantities were equivalent to external characteristics, indicating the changes caused by powering the engine with a new type of fuel as opposed to standard, mineral diesel oil. Those changes have been presented on a percentage scale.

The engine settings remained unchanged – the manufacturer's settings were left intact – designed for ON.

Figure 2 presents the changes in the parameters when the engine was powered with a 10% biomix.

It is indisputable that the addition of the 10% biomix to mineral diesel oil caused the increase in the engine torque, without simultaneously changing the fuel consumption per unit. However, the emission of nitric oxide decreases by 30 to 60%. At the range of engine crankshaft rotation speed in which the engine is usually used, the emissions of carbon dioxide and particulates also decrease.

The changes in the engine performance powered with the fuel mixed with biofuel at the level of 20% are of similar nature.

Undoubtedly, the positive changes in the engine parameters are most explicitly seen when the engine is powered with a 50% "bio" blend. Here the engine power and torque increase along with the fuel consumption per unit. Generally, the increase in the fuel consumption per unit occurs in the range of higher engine crankshaft rotation speed. The increase is similar to the rise in the engine torque, which, in turn, occurs in the whole range of its crankshaft rotation speed. On the other hand, the decrease in both carbon monoxide and nitric oxides emission is remarkable.

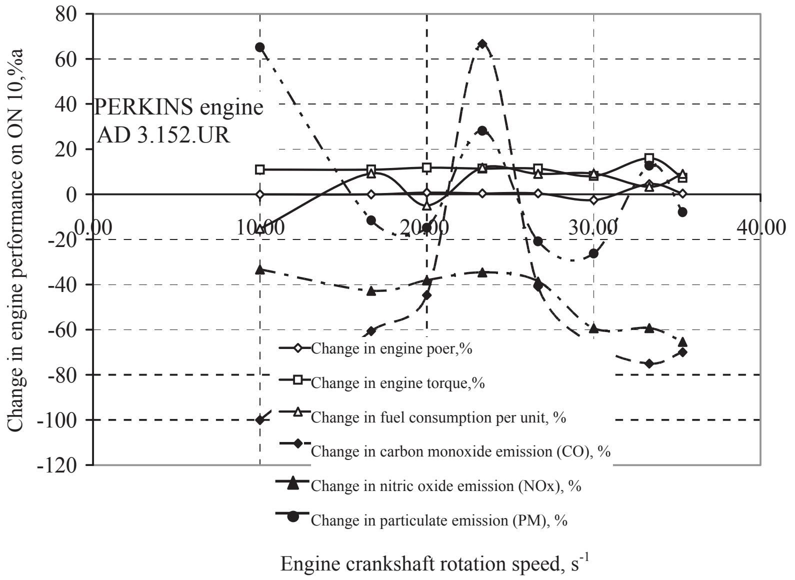

Fig. 2. Performance change in PERKINS AD.3.152.UR engine powered with a blend of diesel oil and a blend of ON B10 of diesel oil (90%) and a blend of butyl alcohol and rapeseed oil (10% v/v)

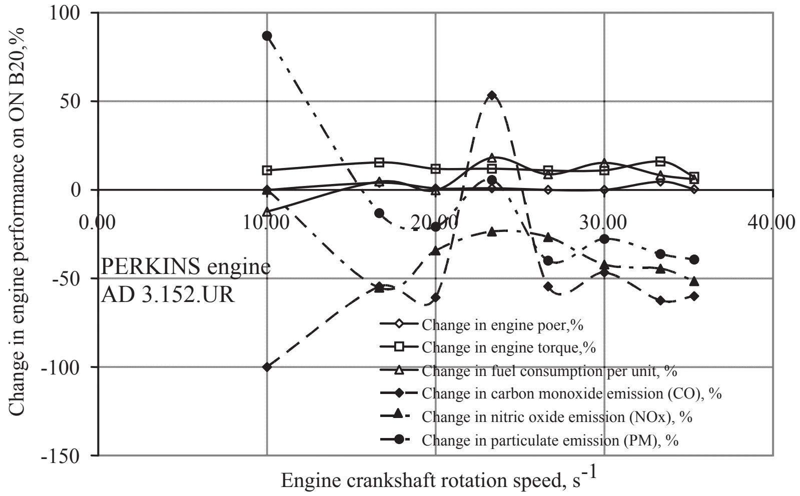

Fig. 3. Change in PERKINS AD.3.152.UR engine powered with diesel oil and biomix ON B20 of diesel oil (80%v/v) and a blend of butyl alcohol and rapeseed oil (20% v/v)

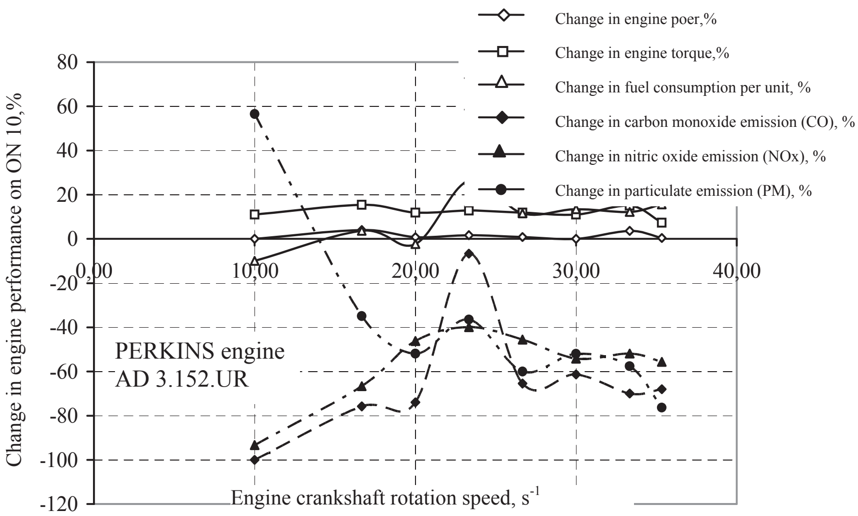

Fig. 4. Change in PERKINS AD.3.152.UR performance powered with diesel oil and a blend of ON B50 of diesel oil (50% v/v) and a blend of butyl alcohol and rapeseed oil (50% v/v)

4. Conclusion

The discussions as presented above and the preliminary results of evaluation can be summarized as follows:

- further growth in the use of liquid engine fuels is expected,
- the present structure of the vehicle fleet in Europe and the tendencies of its development in the nearest future suggest a dynamic increase in the number of vehicles powered with self-ignition engines. On the other hand, spark-ignition engines will be powered with petroleum and gas or solely with gas, particularly with natural gas,
- at present and in the foreseeable future, it seems likely that there will be an excess of petroleum for spark-ignition engines and a shortage of diesel oil for self-ignition engines,
- the requirement laid out in the European Union is to increase the share of engine fuels from renewable resources up to 10% of the total fuel consumption by the year 2020,
- it is possible to meet the above requirement of the European Union either by adding biomass gas to gas fuels or by composing liquid fuels from mineral and synthetic fractions (including those made of renewable resources) or by using liquid components (GTL, vegetable oils and their esters, as well as alcohols),
- the resources of vegetable oils in Europe are limited and, according to global estimates, they may be sufficient to cover only a few per cent of the demand for liquid fuels. In that regard, the esters of these oils can also be introduced instead of vegetable oil, as an additive of a few per cent to liquid fuels,
- there is an overprodution of ethyl alcohol in Europe. The per head consumption of ethyl alcohol is decreasing along with the decreasing population, causing most of the infrastructure for its production to be hardly profitable and some of the infrastructure to be closed down,
- the use of ethyl alcohol as a fuel component is generally possible only with regard to petroleums and only to a limited extent as well as uneconomical on account of the volume proportions of the produced fuels,
- there is a hypothetical possibility of using heavy alcohols ($c>2$) as a component for liquid fuels. These alcohols can be extracted directly from biomass or through converting ethanol to butanol. The latter seems particularly attractive as it is possible to exploit the ethanol production infrastructure and its overcapacity,
- heavy alcohol is characterized by properties equivalent to liquid engine fuels. In particular, the calorific value of such alcohols is similar to that of petroleums. They are also comparable in terms of density and viscosity. It is significant that those alcohols do not absorb water,
- the fuelling properties of the blends of diesel oil with mixes of heavy alcohol and vegetable oil are satisfactory, especially to power vehicle fleets,
- test bench studies have been made of the engine powered with a blend of diesel oil with biomix (rapeseed oil + butanol) in the following proportions:
  - Diesel oil 90% v/v, biomix 10% v/v (marked ON B10),
  - Diesel oil 80% v/v, biomix 20% v/v/ (marked ON B20),
  - Diesel oil 50% v/v, biomix 50% v/v/ (marked ON B50),
- diesel oil is a standard oil within the norm PN EN 590,
- in the evaluation of a blend of diesel oil and “bio” mix consisting of rapeseed oil dissolved in butyl alcohol it has been found that:
  - a homogenous blend of all the components develops regardless of their proportions,
  - the engine powered with blends of any composition from the ingredients discussed above works properly,
  - the engine performance (power, torque) improves (which has not been registered in the studies conducted before with the use of “bio” component),
  - the fuel consumption per unit increases, but not in the whole range of the crankshaft rotation speed,

- generally, the toxic tailpipe emissions decrease both with regard to carbon monoxide and particulate matter (similar results have been obtained also when the engine was powered with other fuels containing "bio" component, for example, when the engine was powered with blends of diesel oil and the ethyl ester of rapeseed oil mixed with ethyl alcohol, and, most importantly, with regard to nitric oxides (the decrease in the nitric oxide emissions has not been registered in any of the already known blends containing biocomponents),
- adding a relatively small (10% v/v) "bio" component (rapeseed oil dissolved in butyl alcohol) leads to a significant reduction in the emissions of nitric oxides (from 35% to 65% in the whole range of the crankshaft rotation speed) and particulate matter (from 40% to 80%; however, not in the whole range of the crankshaft rotation speed) as well as, in certain ranges of the crankshaft rotation speed, a significant decrease in the emissions of carbon monoxide,
- the tendency to decrease the emissions of toxic exhaust components is reinforced by the growth of the "bio: component in diesel oil blends,
- it has been discovered that both the engine performance and the emissions of toxic exhaust components are not linear functions of the crankshaft rotation speed, which calls for elaborating a complete system of adjusting engine settings. Another reason for elaborating such a system is the fact that in the nearest future one vehicle is expected to be powered with various fuels of different "bio" content.

However encouraging, the results of the studies discussed above are merely preliminary and may not be possibly treated as evidence on which to elaborate and implement new varieties of fuel. It is necessary to conduct comprehensive studies, from marking and optimization of fuel parameters to basic studies on the process of fuel combustion in the engine and a field testing validation of the results (in particular field testing in diverse environment).

Simultaneously, studies should be carried out of the methods of extracting and preparing vegetable oil (e.g. in Poland rapeseed oil and saffron oil) and obtaining heavy alcohol, e.g. butyl alcohol (either by way of biological extraction or through electrolysis of ethyl alcohol)

References

[1] *Appendix C, Biofuels and bio-based chemicals (background*). http://www.dni.gov/nic/PDF_GIF_confreports/disruptivetech/appendix_C.

[2] *Biofuels in the European Union. A vision for 2030 and beyond,* Final report of the Biofuels Research Advisory Council, European Commission, Directorate-General for Research Sustainable Energy Systems, 2006.

[3] Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003, Official Journal of the European Union L 123 of 17 May 2003.

[4] Directive 2003/30/EC of the European Parliament and of the Council of 23 April 2009, Official Journal of the European Union L 140 of 5 June 2009.

[5] http://en.wikipedia.org/wiki/Butanol.

[6] http://en.wikipedia.org/wiki/Biobutanol.

[7] Laza, T., Bereczky, A., *Basic fuel properties of rapeseed oil-higher alcohols blends, Fuel* 90, 803-810, 2011.

[8] PN-EN 228 *Motor vehicle fuels. Unleaded petroleum, Requirements and testing methods.*

[9] PN-EN 590*Motor vehicle fuels..Diesel oil, Requirements and testing methods.*

[10] Collective work, *Report on pure rapeseed oil assessment for fuel in agricultural machines*, 2008.

[11] Sinha, S, Misra, N. C., *Diesel fuel alternative from vegetable oil,* Chem Eng World, 32(10):77-80, 1997.

[12] Sitnik, L. J., *New ecofuel for diesel engines,* Journal of POLISH CIMAC, Science publication of Editoral Advisory Board of POLISH CIMAC, pp. 155-159, Gdansk 2009.

[13] Jankowski, A., Sandel, A., Jankowska-Siemińska, B., Sęczyk, J., *Measurement of drop size distribution in fuel sprays by laser methods,* Journal of KONES, 2001, Vol. 8, No. 3-4, pp.334-345, Warsaw 2001.

[14] Jankowski, A., Sandel, A., *Influence of Fuel Quality on Mixture Preparation and Exhaust Emissions from Diesel Engines with Common Rail System,* Journal of KONES Internal Combustion Engines 2003, Vol. 10, No. 3-4, Warsaw 2003.

[15] Jankowski, A., Sandel, A., Sęczyk, J., Siemińska-Jankowska, B., *Some Problems of Improvement of Fuel Efficiency and Emissions in Internal Combustion Engines,* Journal of KONES Internal Combustion Engines 2002, Vol. 9, 3-4, pp. 333-356 Warsaw 2002.

[16] Jankowski, A., Sandel, A., *Exhaust Emission Reduction Problems of Internal Combustion Engines Fueled With Biofuels*, Journal of KONES Internal Combustion Engines 2003, Vol. 10,.No. 3-4, Warsaw 2003.

[17] Jankowski, A., Baczewski, K., *Aging Processes of Biodiesel and Biodiesel/Diesel Fuel Blends,* Journal of KONES Powertrain and Transport, Vol. 17, No. 2, pp. 167-180, Warsaw 2010.

[18] Jankowski, A., *Heat Transfer in Combustion Chamber of Piston Engines,* Journal of KONES Powertrain and Transport, Vol. 17, No. 1, pp. 187-197, Warsaw 2010.

[19] Jankowski, A., Kruczynski, S. S., *Novel Catalytic Converter Oxide for SI Engines,* Journal of KONES Powertrain and Transport, Vol. 17, No. 1 pp. 177-186, Warsaw 2010.

[20] Jankowski, A., *Reduction Emission Level of Harmful Components Exhaust Gases by Means of Control of Parameters Influencing on Spraying Process of Biofuel Components for Aircraft Engines,* Journal of KONES Powertrain and Transport, Vol. 18, No. 3 pp. 129-134, Warsaw 2011.

[21] Jankowski, A., *Study of the influence of different factors on combustion processes (Part two),* Journal of KONES Internal Combustion Engines, Vol. 16, No. 3, s. 135-140, Warsaw 2009.

[22] Jankowski, A., *Laser research of fuel atomization and combustion processes in the aspect of exhaust gases emission,* Journal of KONES Internal Combustion Engines, Journal of KONES Internal Combustion Engines, Vol. 15, No. 1, pp. 119-126, Warsaw 2008.

[23] Jankowski A., Seczyk J., Zbierski K., *Measurement of the Structure Fuel Spray Produced with Common-Rail System*, Journal of KONES. Vol.7. No.1-2. Warsaw 2000.

STRATEGIC PROGRAMME OF THE NATIONAL CENTRE FOR RESEARCH AND DEVELOPMENT

The research task financed within the framework of the Strategic Research and Development Programme entitled "Advanced Technologies for Energy" carried by The National Centre for Research and Development and electric power holding company ENERGA SA in Poland

Research Task No. 4

DEVELOPMENT OF INTEGRATED TECHNOLOGY OF FUELS AND ENERGY FROM BIOMASS, AGRICULTURAL WASTE AND OTHER