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THE CHANGES OF BURNING EFFICIENCY, EMISSION AND POWER OUTPUT OF A DIESEL ENGINE FUELED BY BIOETHANOL – BIODIESEL-DIESEL OIL MIXTURES

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ABSTRACT - The environmental pollution and the decrease of the oil based fuels are the greatest problems of the automotive-industry at the start of the 21st century. There were and certainly there are a number of experiments to aiming substitute the petrol and the diesel oil with other fuels. One group of these substitutable fuels is the bioethanol – biodiesel – diesel oil mixtures. These mixtures are very similar to the fuels used today, as it can be used in the engines without any structural changes.

At the Technical University of Budapest investigations have been made to explore the possibility of using bioethanol – biodiesel – diesel oil mixtures in vehicles and agricultural engines. The main aspects of the researches was find blends that are substitutable for diesel oil consisting of the most renewable part as possible, reaching the same or similar power output and lower the emissions.

The experimentations were based on mixing bioethanol and biodiesel with diesel oil. Our idea was, when the biofuels are mixed they supplement each other, cutting the negative effect of each and increasing the renewable component rate in the fuel. During the researches the two main requirements of the fuel were: the maximal possible renewable part with which the engine does not need any changes, yet meets the prerequisites set by diesel oil and to have the same power and better emissions with the blend. The low (up to 20%) biofuel rate was important, while the first step of introduction is possible with low rates.

The experiments were maid at engine benches with different engines, one-cylinder measurements, cetin-number determination, viscosity determination, life cycle analysis and cost benefit analysis.

In conclusion of the research it could be established that the use of bioethanol-biodiesel-diesel oil emulsion in agricultural engines is in technicality already solved, as no changes are needed on the engine, and it also reduces the emissions and is economically justified.

INTRODUCTION

The Department of Automobiles at the Technical University of Budapest has been searching the possibilities of using alternative fuels for a long time (1,2). The target vehicle of this investigation, a flexible fueled vehicle (FFV) has a single fuel tank, fuel system, and engine. The vehicle is designed to run on diesel oil and a mixture of bioalcohol, biodiesel and diesel oil, containing up 20% of biofuel. The engine and fuel system in a flex-fuel vehicle must be slightly adapted to run on bioethanol-biodiesel-diesel oil blends, as the biofuels are more corrosive. The vehicle running with the investigated blends offers its owner an environmentally beneficial option whenever the alternative fuel is available.

MAIN GOALS OF THE INVESTIGATION

The main goal of our investigation was to increase the renewable part in the bioethanol-biodiesel-diesel oil mixture. The most important point we wanted to fulfill the standard requirements of diesel oil with the mixtures. The most significant parameters were the viscosity and the cetane number in the burnings point of view. Our idea was if these parameters can be met, than there is not or a very little need of madding any changes in the engines. It means that the mixture could be used in the normal everyday engines without major reconstruction in the engine.

With the help of the investigated mixtures the EU directives and recommendations are to match. The EU Directive 2003/30/EC recommends for the EU member states to increase the biofuel proportion in the total amount of used fuels. It states that increased use of biofuels for transport is one of the tools by which the European Union can reduce its dependence on imported energy sources, as diesel oil or gasoline. The Directive 2003/30/EC determines the two following steps for the member states:

- „A reference value for these targets shall be 2 %, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2005.” (3)
- „A reference value for these targets shall be 5,75 %, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2010.” (3)

INVESTIGATED FUELS

Diesel oil is produced from petroleum. As a hydrocarbon mixture, it is obtained in the fractional distillation of crude oil between 250 °C and 350 °C at atmospheric pressure. It is considered to be a fuel oil and is about 18% denser than gasoline. The density of diesel oil is about 850 grams per liter whereas gasoline has a density of about 720 g/l, or about 15% less. When burnt, diesel oil typically releases about 40.9 megajoules (MJ) per liter, whereas gasoline releases 34.8 MJ/L, also about 15% less. Diesel oil is generally more simple refinable than gasoline and often costs less (although price fluctuations often mean that the inverse is true; for example, the cost of diesel traditionally rises during colder months as demand for heating oil, which is refined in much the same way, rises). Diesel fuel, however, often contains higher quantities of sulphur. In Europe, emission standards and preferential taxation have both forced oil refineries to dramatically reduce the level of sulfur in diesel fuels (4).

Biodiesel refers to a diesel substitutable fuel, produced from biological sources. It is a processed fuel that can be used in diesel engine vehicles, which feature distinguishes biodiesel from the straight vegetable oils or waste vegetable oils used as fuels in some modified diesel vehicles. Biodiesel is a light to dark yellow liquid. It is practically immiscible with water, has a high boiling point and low vapor pressure. Typical biodiesel has a flash point of ~ 150 °C, making it rather non-flammable. Biodiesel has a density of ~ 0.8, less than that of water. Biodiesel, when uncontaminated with starting material, is regarded as non-toxic substance.

Biodiesel has a viscosity similar to diesel oil, the industry term for diesel produced from petroleum. It can be used as an additive in formulations of diesel to increase the lubricity of pure ultra-low sulfur diesel fuel. Much of the world uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix, in contrast to the "E" system used for bioalcohol mixtures. For example, fuel containing 20 % biodiesel is labeled B20. Pure biodiesel is referred to as B100. It has a very high cetane number, up to 56 CN.

Bioethanol has less than two-thirds of the energy density of diesel oil, and has the same limitations as alcohol vehicles. The lower energy density implies that at equivalent engine efficiency, a pure-alcohol-fueled vehicle would travel half to two-thirds as far as a diesel oil-fueled vehicle using the same size tank. The 1999 model year flexible fueled vehicles using E-85 have a driving range of 200-300 miles. The range for these vehicles when using diesel oil is 320-440 miles. These energy density disadvantages can be compensated by certain improvements in efficiency. These can be carried out in spark ignition engines using alcohols, unlike with diesel oil. Pure ethanol can also cause starting problems in cold weather.
The ethanol has a cetane number 8, much lower than the diesel oil's 50-55. The air need of the ethanol is app. 9 kg air pro kg of ethanol (8.4 kg for the E93 ethanol and 7% water content fuel), and this rate is lower than diesel oil, which has an air need of 14.5 kg. The lower air need means a possibility to increase the measure of the ethanol without change the value of the lambda namely the engine optimizing.

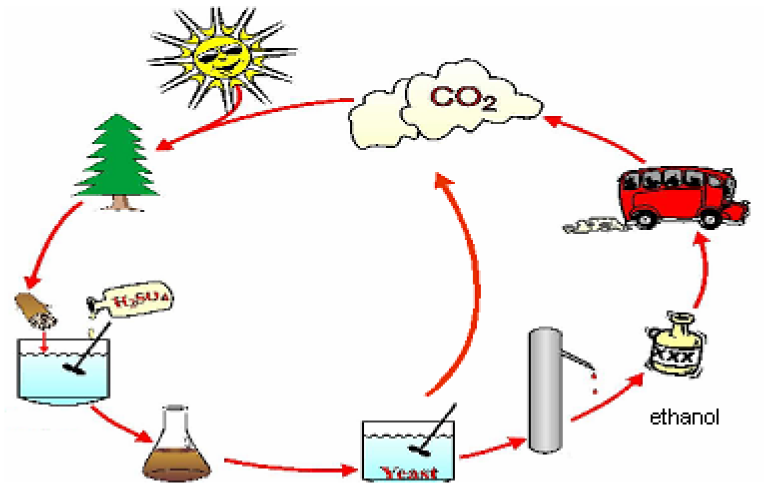


Fig. 1. The closed CO2 cycle of the biologically produced ethanol (5)

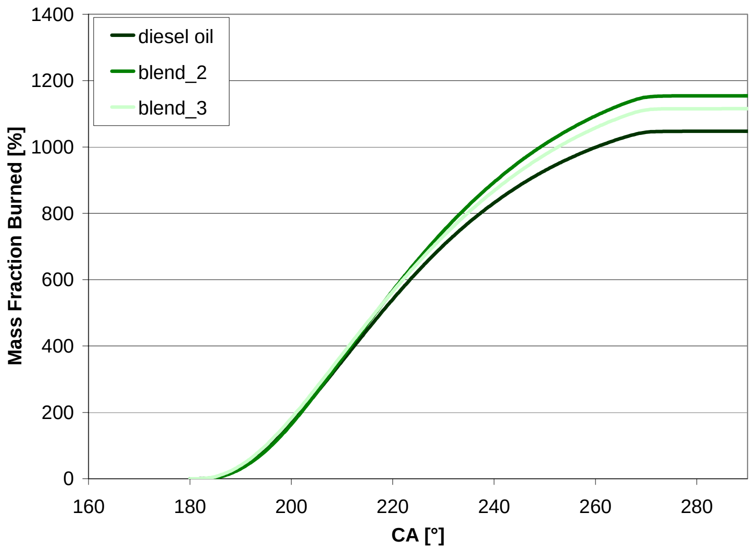
Ethanol, as noted above, is a renewable resource that contributes nothing in itself to global warming concerns (Fig. 1). Ethanol doesn't contains sulphur, which means it doesn't emit any sulphur dioxide. The NO_x emission is lower on the grounds of the ethanol's higher vapor heat, which cools the combustion temperature. Ethanol vehicles require lines, hoses and valves to be resistant to the corrosion that alcohol can induce. Alcohol corrodes lead-plated fuel tanks; magnesium, copper, lead, zinc, and aluminum parts; and some synthetic gaskets (6). There are no additional changes needed in the distribution network for gasoline, diesel, and natural gas. The ethanol is denatured, to prevent any misuse from ingestion.

During the investigation no burning additives have been used. Our speculation was, that the abilities two of the renewable material are compensating each other. Another important factor was that we wanted to have the simplest mixture. 10 different mixtures have been investigated.

BURNING EFFICIENCY

The researches of the blend's burning efficiency have given information about the real burning process. The main goal of the experiments was to select blends that have same burning abilities as the diesel oil with the highest biofuel content. The mass fraction burned in the function of the camshaft angle is shown in Diagram 1.

Blend 2 with the lower biofuel content has faster burning. It based on the ethanol's low vaporization heat. The rate of the ethanol increases the burning speed of the blend. On the others hand, with increasing the biofuel ratio with the 1:2 bioethanol: biodiesel ratio slows the blends burning speed. But it does not reach the burning level of the diesel oil.



EMISSIONS

The emission results have been confirmed by our previous assumptions. In the following six main gas emissions are described regarding by as function of mixtures consistence. The consistence of the three presented blends is described in the table 1.

table 1.
Consistence of the presented blends

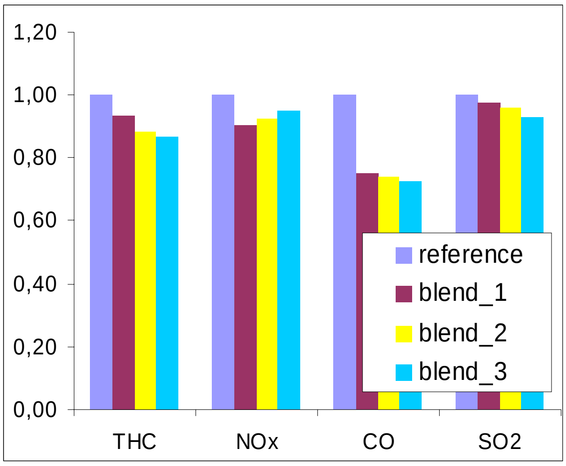
	blend_1	blend_2	blend_3
ethanol	2,5%	2%	4%
biodiesel	2,5%	4%	8%
diesel oil	95%	94%	88%

Blend one was the first investigated mixture with equilibrant ratio of bioethanol and biodiesel. We have increased by turns the bioethanol- and biodiesel ratio of the blend. The optimal ratio of to renewable part according to the investigations is near to the 1:2 bioethanol: biodiesel ratio. That helps to hold the bioethanol in blend with diesel oil. The low (up to 20%) ratio of the renewable fuels was based on the easy market introduction. During the analysis we have investigated more emissions, six main emitted gases are presented in the Diagram 2.

Diagram 2. shows the changes in the THC, SO_2, NO_x and CO emissions. The trend of the THC emission was decreased with increasing renewable ratio. The main reason of this is the lower coal chain of bioethanol. It contains proportionately more oxygen than diesel oil, and so its emission contains will have THC. The nitrogen-oxide emission shows the same results, as have been assumed: the portion of biodiesel increases the NO_x emission of the blend, but the bioethanol's decreasing effect is much stronger, so the aggregate NO_x emission will be lower. Bioethanol lowers the nitrogen-oxide emission approximately with double percent the blend containing the same bioethanol-biodiesel level.

Diagram 2.

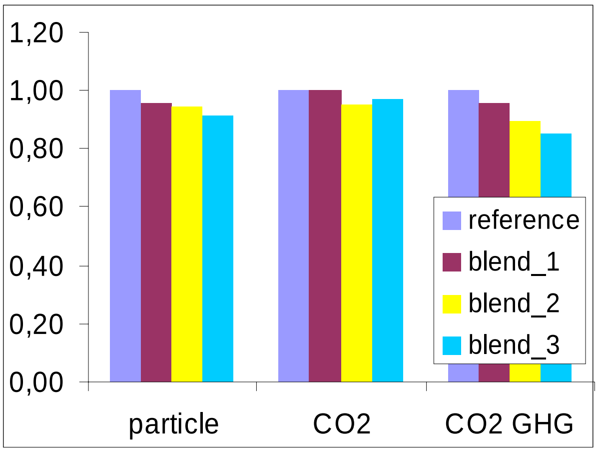
Emission changes 1.



The increasing biodiesel level increases the NO_x emission, but it does not reach the emission level of the diesel oil. The CO emissions have been decreased, as based on the better burning conditions. This awes to biodiesel part of the blend as ethanol increases CO emission. The sulphur-oxide emission has been decreased by the bioethanol and biodiesel. In long-term it is the less relevant, because of the sulphur content of diesel oil is in decrease.

Emission changes 2.

Diagram 3.



The lower particulates emission is in high dependency with the renewable part of the blend. Diagram 3. shows the shrinkage of the particle emission. It was expected, as both additives decreasing the particle emission. The parallel reduction of NO_x and particle emissions is one of the most important questions of the diesel engine improvement to be able hold the newest emission regulations. They could be reduced in the engine blended with each other only. Use of the bioethanol-biodiesel blend gives a possibility to reach it.

The brut carbon-dioxide emission increased with the use of the blends. The main benefits of the biofuels are shown under the title CO_2 GHG (Greenhouse-gas). It is calculated from the brut carbon-dioxide minus the emission of the renewable part of the blend. It shows, that the use of the biofuels contributes to the decreasing of the greenhouse gas emissions more than that of their proportion.

POWER OUTPUT

The power output of the experimented blend was lower as the reference diesel oil. It bases on the blend lower energy content. The reduction at these low biofuel content blends was lesser that in was supposed. It has been based on the changes of the burning process. The engines were run with diesel parameters; with the parameters (injection time, injection length etc.) this reduction could be minimized.

SUMMARY

The exchange of the diesel oil to a 20% bioethanol and biodiesel content blends results the following with investigations supported results:

- The NO_x emission is lesser with 8-12%
- The reduction of greenhouse relevant CO_2 emission is equals to the biofuel content of the blend
- The reduction of particle emissions is equals half of the biofuel content of the blend
- The costs of the new fuel with the internalised external costs is lesser than the diesel oil
- The introduction of the new fuel does not mean any extra costs

The greatest benefit of the emulsion is that is reduces the NO_x and the particle emissions at the same time, which could only be reduced in other cases against each-other. The use of bioethanol-biodiesel-diesel oil mixture can help Hungary in complying with the 2003/30/EC directive issued by the European Parliament and Committee on 8^{th} May 2003 that states the following: "The share of bio-fuels within the whole fuel-consumption should reach 2% by end 2005, 5.75 % by end of 2010

In conclusion of the research it could be established that the use of bioethanol-diesel oil emulsion in agricultural engines is in technicalities already solved, it does not require any changes on the engine, it reduces the emissions and it is economically justified.

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