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STUDY REGARDING THE EFFECT OF BIODIESEL ON DIESEL ENGINE EMISSION

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ABSTRACT: This paper analyzes effect of biodiesel on engine power, fuel consumption, emissions: nitrogen oxides (NOx) and particulate matter (PM) while the effective power is maintain constant. Biodiesel is a renewable, alternative diesel fuel of domestic origin derived from a variety of fats and oils by a transesterification reaction. Considering global energy policies, more and more governments try to increase the usability of biodiesel for powering motor vehicles. Cars manufacturing companies and private users are reluctant in using biodiesel, especially in current engines. Because of this, it is difficult to achieve the targets of increases the usage of biodiesel in ICE. There is a lack of knowledge on emissions of an engine what is fueled with biodiesel. An advantage of biodiesel is its potential to significantly reduce most regulated exhaust emissions, including particulate matter (PM), with the exception of nitrogen oxides (NO_x).
KEYWORDS: diesel engine, biofuel, emission, NO_x, particulate matter

INTRODUCTION

The fuel used for motor vehicles are subject to regulation EN-590. One of the most important restrictions is sulfur content (max 0.001% since 1 January 2009) and it had economical consequence for oil companies and on final fuel price. Together with the fluctuating price of oil price and with reducing of taxes for biofuels has opened the way for the use of biodiesel and a way to reduce the price of transport.
The technical definition of biodiesel is a fuel suitable for use in compression ignition (diesel) engines that is made of fatty acid monoalkyl esters derived from biologically produced oils or fats including vegetable oils, animal fats and microalgal oils.
When biodiesel is produced from these types of oil using methanol fatty acid methyl esters (FAME) are produced. Biodiesel fuels can also be produced using other alcohols, for example using ethanol to produce fatty acid ethyl esters, however these types of biodiesel are not covered by EN 14214 which applies only to methyl esters i.e. biodiesel produced using methanol. [1]
Considering global energy policies, more and more governments try to increase the usability of biodiesel for powering motor vehicles. Cars manufacturing companies and private users are reluctant in using biodiesel, especially in current engines. Because of this, it is difficult to achieve the targets of increases the usage of biodiesel in ICE. There is a lack of knowledge on emissions of an engine what is fueled with biodiesel.
Biodiesel fuels have a higher lubricity than conventional fuels, but they can contribute to the formation of deposits, the degradation of filters materials, depending on their degradability, their glycerol content, and their cold flow properties and on other quality specifications [2].
Biodiesel fuels also have a potential to reduce chemical emissions. The effect depends on the engine's type, engine speed, load, ambient condition. According Euro 5 emissions standard, NOx and PM emissions were reduced to 0.18 g/km and 0.005 g/km. Use of biodiesel can help to meet these limits. For this, automakers would have to adapt their engines for operation with biodiesel, which involve additional cost.

Table 1 - Ranges of the specifications of the fuels

Specifications	Biodiesel	Diesel
Density (15^0C) (kg/m^3)	870 - 895	810 - 860
Visosity (40^0C)(cSt)	3.5 - 5.5	2 - 3.5
Cetane number	45 - 65	40 - 55
Cloud point (^0C)	-5 - 10	-20 - 0
Lower heating value (MJ/kg)	36.5 - 38	42.5 - 44
Water content (mg/kg)	0 - 500	0
Sulfur content (mg/kg)	0	15 - 500

Engine performance

At partial loads, the output power of an engine fueled with biodiesel is the same as for diesel fuel.
The driver press more the accelerator to obtain the same power.

At full load or for the same pedal position of accelerator, the output power is lower.
Kaplan et al. [3] compared sunflower-oil biodiesel and diesel fuels at full and partial load. After tests they determined that power and torque values fall between 5 and 10%. Cetinkaya at al. [4] compared pure waste-oil biodiesel and diesel fuels and achieved a decrease of power and torque by 3 - 5%.
Other authors report an increase of power and torque when using biodiesel. Altiparmak et al [5] obtain a increase of torque by 6.1% when used a blend with 70% tall-oil biodiesel. They explained this by high cetane number, high values of density and viscosity of biodiesel fuel (922 kg/m^3, 7.1cSt at 40^{0}C).
In the literature are offered several reasons to explain the difference between lost of power and torque compared with calorific value, most related to viscosity.

Nitric oxides

FEV report [6] concludes NOx emission increases with biodiesel content until maximum 8% for B100. Schumaher at al. [7] tested a 200 kW engine with B10, B20, B30 and B40 soybean-oil biodiesel. They observed an increase in NOx emissions with 15% for B40.
An explanation for the increase in NOx emissions can be higher cetane number for biodiesel.
After laboratory experiment with different heavy-duty engines (without EGR) US EPA [8] has determined an equation with an accuracy of 95%.

$$\frac{NO_x}{NO_{xD}} = e^{0.0009794\%B} \qquad (1)$$

An explanation for the increase of NO_x when using biodiesel is advancing combustion process due to physical defining characteristics (viscosity, density, compressibility).

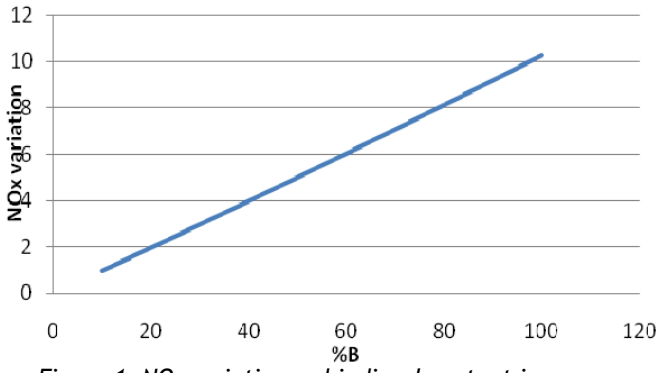

Figure 1. NO_x variation as biodiesel content increases

Effect of physical properties on the advance injection can be seen on mechanical injection pumps. When biodiesel is injected, the pressure increase is faster because smaller compressibility and also propagation speed is higher. Due to the high viscosity, the pressure losses are lower injection pump, resulting in a linear increase in pressure.
As a result, the injector needle rises faster, achieving a higher injection advance.
And tests that remained at the start of fuel injection were observed an increase in NO_x emissions. One reason is due to higher flame temperature adiabatic temperature increase, either due to reduced heat dissipation by radiation as a consequence of low particulate emissions.
Other explanations for the increase in NO_x emissions: high cetane number and greater availability of oxygen when using biodiesel.
To reduce NO_x emissions when replace diesel with biodiesel fuels is necessary to modify the law injection, to delay the moment when injection start. It prefers a delay in injection to maintain the NO_x emissions at the diesel limits, although the advantage of lower soot emissions disappears.

Particulate matter and smoke opacity

Using biodiesel instead of diesel fuel a decrease of PM emissions is observed.
The results of several tests were collected by EPA [8] who has determined an equation with 95% accuracy.

$$\frac{PM}{PM_D} = e^{-0.006384\%B} \qquad (2)$$

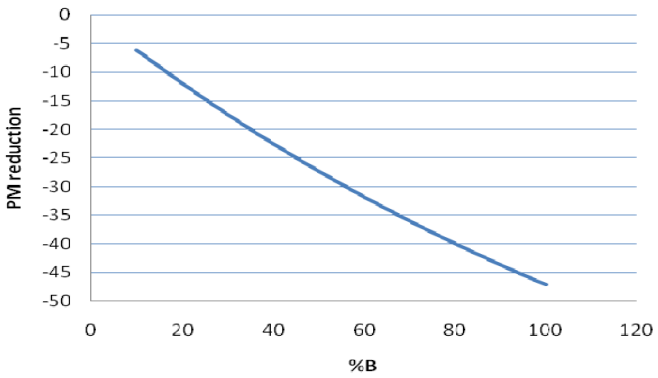

Figure 2. Mean reduction in PM emissions as the biodiesel content increases

There are several ways to explain the reduction when biofuels is used:

- *Oxygen content from biofuels molecule ensuring more complete combustion and oxidation of PM already formed;*
- *Biodiesel need a lower stoichiometric ratio, which reduces the likelihood of a rich mixture;*
- *Absence of aromatics in biofuels, which are considered precursors to soot;*
- *Because larger injection advance, the soot spend a long time in the presence of oxygen and high temperature, which contributes to their oxidation;*
- *The different structure of soot between diesel and biodiesel fuels;*
- *Biofules have 0 sulfur content and prevent sulfate formation which is a significant component of PM.*

Hydrocarbons

The EPA review [8] shows a 70% reduction with pure biodiesel according with equation (3).

$$\frac{HC}{HC_D} = e^{-0.011195\%B} \qquad (3)$$

Several reasons have been proposed to explain the decrease in HC emissions when is used biofuels:

- *Oxygen content from biofuels molecule ensuring more complete and cleaner combustion;*
- *Higher cetane number of biodiesel reduces the auto ignition delay;*

- Even biofuels is less volatile as diesel fuels, diesel fuels has final point of distillation higher. Final fraction of diesel fuels may not vaporize completely, resulting in unburned hydrocarbons;

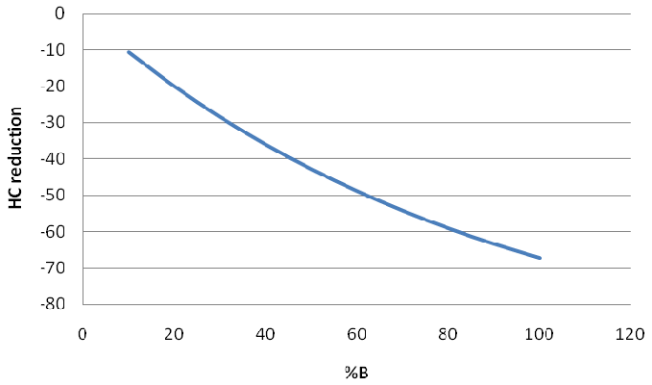

Figure 3. Mean reduction of HC emissions as biodiesel content increases

Carbon monoxide

A decrease in CO emissions when substituting diesel fuel with biodiesel can be observed. After revising several works, EPA [8] proposed equation (4) for general trend.

$$\frac{CO}{CO_D} = e^{-0.006561\%B} \qquad (4)$$

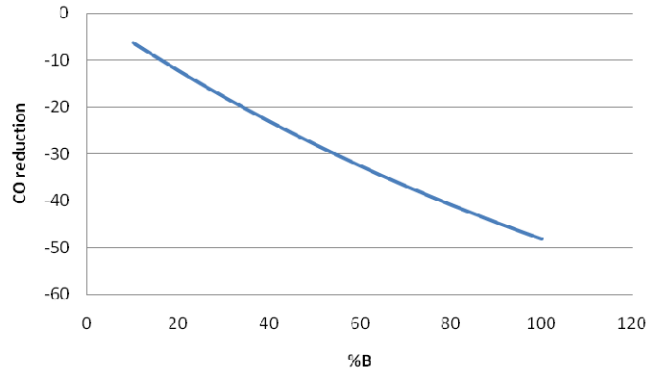

Figure 4. CO reduction as the biodiesel content increases

Several reasons have been proposed to explain the decrease in HC emissions when is used biofuels:

- Oxygen content from biofuels molecule ensuring more complete combustion;
- Higher cetane number of biodiesel reduces the probability of fuel-rich zone formation;
- The advanced injection and combustion when using biofuels may also justify the CO reduction with this fuel.

CONCLUSIONS

The following general conclusions could be proposed:

- At partial loads, the output power is identical, fuel consumption increases to compensate the lower calorific power;
- NO_x emissions increase because the injection process is advanced with biodiesel;
- When biodiesel is used, it is obtained a reduction of soot. Oxygen content and no aromatic substances leading to this decrease;
- HC and CO emissions are significantly reduced by using biodiesel. A more complete combustion caused by the presence of oxygen can cause this reduction.

REFERENCES

[1.] http://en.wikipedia.org/wiki/EN_14214
[2.] Waynick JA. Characterization of biodiesel oxidation and oxidation products. USA SouthWest Research Institute 2005 [Project 08-10721].
[3.] Kaplan C, Arslan R, Surmen A. Performance characteristics of sunflower methyl esters as biodiesel. Energy Sources 2006;Part A 28:751-5.
[4.] Cetinkaya M, Ulusay Y, Tekın Y, Karaosmanoglu F. Engine and winter road test performances of used cooking oil originated biodiesel. Energy Convers Manage 2005;46:1279-91.
[5.] Altiparmak D, Deskin A, Koca A, Guru M. Alternative fuel properties of tall oil fatty acid methyl ester-diesel fuel blends. Bioresource Technol 2007;98:241-6.
[6.] FEV Engine Technology. Emissions and performance characteristics of the Navistar T444E DI engine fuelled with blends of biodiesel and low sulphur diesel. Final report to National Biodiesel Board 1994.
[7.] Schumacher LG, Borgelt SC, Hires WG, Fosseen D, Goetz W. Fueling diesel engines with blends of methyl ester soybean oil and diesel fuel. 1994. Available on line: www.missouri.edu/_pavt0689/ASAED94.htm
[8.] Assessment and Standards Division (Office of Transportation and Air Quality of the US Environmental Protection Agency). A comprehensive analysis of biodiesel impacts on exhaust emissions, 2002; EPA420-P-02-001.

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