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The Effects of Using a Biofuel on the Performance of a Marine Diesel Engine

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ABSTRACT

For many years, the design of diesel engines has changed profoundly. Currently, the main challenges launched concern the respect of emissions standards more stringent and improve efficiency. To meet these expectations, must develop better simulation models of diesel engines.
Thus, the aim of the present work is the study the effects of using a bio-fuel on the performance of a marine diesel engine. We used the thermodynamic model of zero-dimensional (0D) of CHEMKIN software.
We compared some parameters physical of engine for evaluating effects of substitution the diesel by bio-fuel (SME), we noticed that the difference is not enough large for most parameters (cylinder pressure, temperature, heat produced and specific fuel consumption), but the difference is in the NOx emissions which is much higher with SME than with the gasoil, this is explained by the fact that the SME is more oxygenated.

Keywords: Diesel engine, CHEMKIN, Bio-fuel.

1. INTRODUCTION

High power diesel engines are widely used in marine propulsion because of their reliability and significant performance. However, more restrictive legislation, aimed at limiting emissions of pollutants from exhaust gases generated by the engines, tend to question their supremacy [1, 2].

Most studies on the different approaches to estimate the emission rate are carried out by many established models, such as:

- The direct models which lead to the numerical resolution of the Navier-Stokes equations (CONCHAS, KIVA, and KIVA II codes);
- Phenomenological models that simulate combustion, using different formulations based on physical and chemical phenomena that have been experimentally observed and described;
- Empirical models.

Many studies were conducted at the experimental level as well as on the level of analysis, in order to study the mechanisms of the formation of the different pollutants. The study of the analysis of pollutant emissions and their reduction in exhaust gases from semi-fast turbo diesel engines is the main objective of this study.

2. MODELING AND KINETIC MECHANISM

A zero-dimensional (0D) model is used to study the performance of the diesel engine fueled by Soy Methyl Ester (SME) fuel, because of its simplicity and its ability to predict the characteristics and has been developed for the closed cycle with complete chemical kinetic considerations both in the process of compression and relaxation. The following assumptions are considered for this model in the single zone:

- All the chemical species are considered to be gas.
- The mixture is considered to be homogeneous; the spatial gradient is zero throughout the combustion chamber.
- The homogeneous mixture of fuel and air is formed just before IVC (closing of the intake valve).

For this system, the law of conservation of energy in differential form is:

$$\delta Q - \delta W = dU \tag{1}$$

Considering of this work, the heat transfer and the mass fraction of each species, the form of the differential equation of the first law of thermodynamics with respect to time is as follows:

$$\dot{Q} - p\,\frac{dV}{dt} = \sum_{i=1}^{s} \bar{u}_k \frac{dn_k}{dt} + n\sum_{i=1}^{s} n_k \frac{d\bar{u}_k}{dt} \tag{2}$$

The results are obtained after the resolution of these equations in a system of ordinary differential equations (EDO).

The initial concentration and temperature are specified in the input file. The variation of the overall volume of the load in the engine cylinder is a function of the crank angle. In the formula (3) called the crank-rod formula, Vc, rc, R and θ represent the volumetric ratio, the compression ratio, the radius of the crankshaft and the instantaneous angle of crankshaft respectively:

$$V=V_c\left[1+\frac{r_c-1}{2}\left(R+1-\cos\theta-\sqrt{R^2-\sin^2\theta}\right)\right] \qquad (3)$$

All equations for the heat engine are taken from the CHEMKIN theory manual [3]. The reaction mechanism of SME is composed of 354 reactions and 82 species [4].

The results of this work represent a comparison by numerical simulation, based on the CHEMKIN 4.1 code [5], the influence of diesel and bio-fuel SME (Soy methyl ester) on the operating parameters and pollutant emissions NOx of a marine diesel engine. The characteristics of the engine are detailed in Table 1.

3. RESULTS

Figures 1 and 2 shows the variation of the pressure in the cylinder and the combustion temperature for the two fuels (gas oil and bio-fuel (SME)) as a function of the angle of rotation of the crankshaft. We note that they are in perfect agreement, especially in the Top dead center (TDC) region.

Table 1. Diesel Engine characteristics

Mark	WARTSILA NSD type 6R32 LNE
Ignition order	1-5-3-6-2-4
Speed	750 tr/mn
Piston speed	8.4-8.8 m/s
Bore	32 cm
Stroke	35 cm
Maximum ignition pressure	165 Bar
Compression ratio	12
Injection pressure	450 Bar

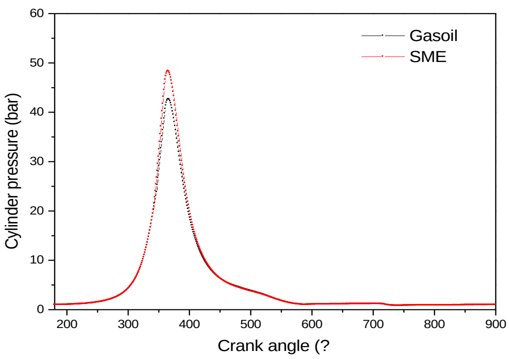

Figure 1. Variation of the cylinder pressure as a function of the crankshaft angle for the two fuels: gasoil and SME

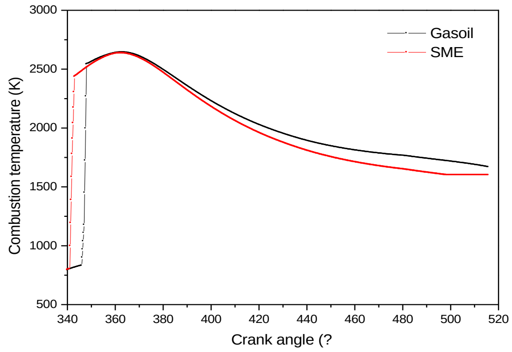

Figure 2. Variation of the combustion temperature as a function of the crankshaft angle for the two fuels: gasoil and SME

In Figure 3, the variation of the heat quantity produced by gasoil and SME bio-fuel was presented. This figure shows that combustion is faster with the SME bio-fuel than gas oil, but the combustion rate is lower at the beginning of the combustion process.

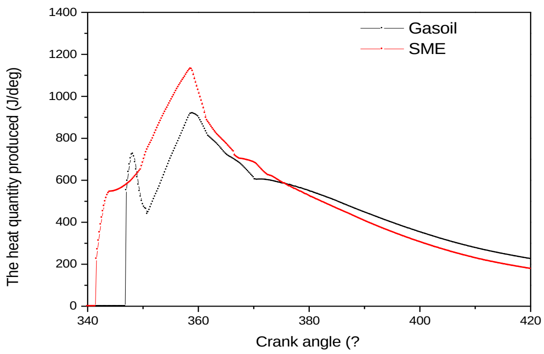

Figure 3. Variation of heat quantity as a function of the crankshaft angle for the two fuels: gasoil and SME

The cause of the early start of combustion is the advancement of the injection and a shorter firing time. When the combustion rate is lower, is that the energy released is low in the premixed phase and also probably the lower volatility of biodiesel. In the diffusion phases, the SME biodiesel has a rapid combustion because most fuels are vaporized during this phase.

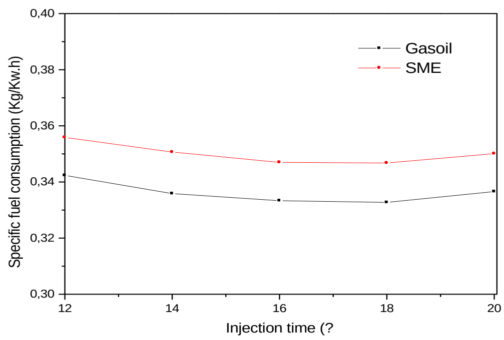

Figure 4. Variation of the specific fuel consumption as a function of the injection time for the two fuels: gasoil and SME

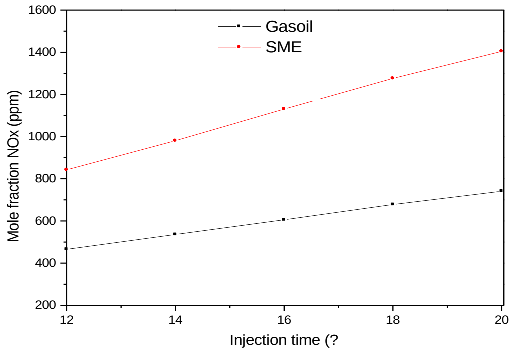

Figure 5. Variation of NOx level as a function of the crankshaft angle for the two fuels: gasoil and SME.

Figures 4 and 5 show the influence of the two fuels on the specific fuel consumption (SFC) and the nitrogen oxides (NOx) as a function of the injection time expressed as a function of the angle of rotation of the crankshaft ranging from 12 to 20 ° before the TDC. There is no significant change with the advancement of injection time on SFC. Therefore, the ignition delay period is longer.

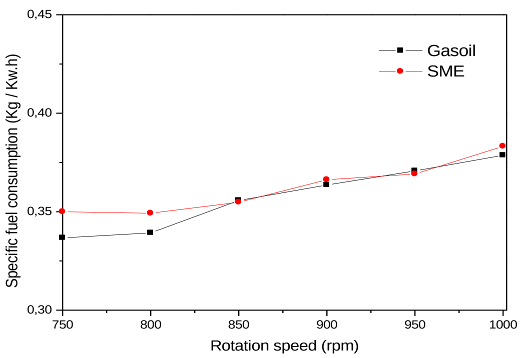

Figure 6. Variation of the specific fuel consumption as a function of the speed of rotation of the engine for the two fuels: gasoil and SME.

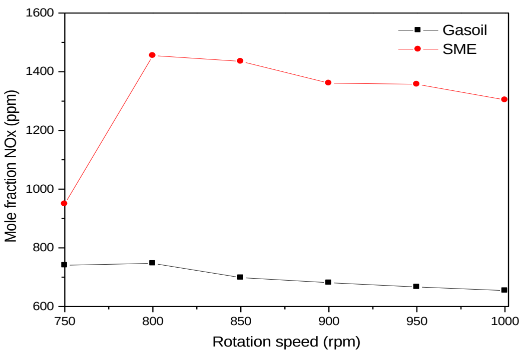

Figure 7. Variation of NOx as a function of the speed of rotation of the engine for the two fuels: gasoil and SME.

Figures 6 and 7 show the influence of the rotation speed of the engine on the fuel consumption and the NOx emissions for the two fuels studied.

For fuel consumption, the same tendency is observed for both types of fuel with a certain difference for the low rotational speeds.

With the increase in the speed of rotation of the engine, the consumption increases. On the other hand, in the case of NOx emissions, bio-fuel emits much more NOx than gasoil at the same speed.

3. CONCLUSION

To solve the problems of global air pollution due to the emission of pollutants from the combustion engine, it is necessary to understand the mechanisms of formation of the pollutants in the various combustion processes.

The main conclusions of this work:

- The use of SME bio-fuel has allowed obtaining a slightly faster combustion compared to gas oil.
- SME bio-fuel increases the formation of NOx more than gasoil, because bio-fuels are products containing a greater quantity of oxygen and their combustion is at a higher combustion temperature than that of gasoil.
- In general, the delay of the injection time is an effective way to reduce NOx emissions.

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NOMENCLATURE

Q	Quantity of heat	[J]
W	Work provided	[J]
U	Quantity of energy received	[J]
n	Number of mole	
i	Number of chemical species	