INFLUENCE OF BIODIESEL ON COMPRESSION IGNITION ENGINE PERFORMANCE

Simeon Iliev & Emil Mitev

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Abstract

In the simulation study, the four-cylinder, four-stroke, direct injection compression ignition engine with an electronically controlled injection system was used. The results obtained from the use of biodiesel were compared to those of pure diesel fuel. The characteristic of maximum power, torque, temperature and pressure were compared. One-dimensional simulation of a four-cylinder diesel engine with the help of the AVL Boost software has been done. Comparison of simulated power and torque results in use of biofuel showed that the use of biodiesel causes a drop in power and torque at maximum power 3750 min^{-1} up to 6.5%. At maximum engine torque 1900 min^{-1} , there is a very small drop in power and torque of 0.15%. Power drop and the torque of using biodiesel is within the expected range of 8 to 10%.

Keywords: Biofuel; Diesel Engine; Engine Performance; Engine Simulation; AVL

1. Introduction

The fossil fuel resources are dwindling day by day. Oil is becoming increasingly scarce and soon will not be able to meet the numerous demands, arising mainly from the transport sector. Decline of available oil reserves and more stringent environmental regulations have motivated the global interest in other energy sources. Environmental legislation has demanded lower emissions of harmful products over the last decade combustion that the internal combustion engine may release into the environment. One way reduction of environmental pollution is also the use of alternative fuels [1], [2]. If transport fleets operated completely with biofuels, it would strengthen the sustainable energy system. The current tendency in energy consumption will create an energy crisis in the near future. Renewable and carbon-neutral biodiesel is the way to achieve economic sustainability and environmental protection.

The primary alternate to fossil fuels is biodiesel. Biodiesel is an alternate energy source for numerous reasons: being renewable, the molecular structure is highly biodegradable with minimal combustion toxicity; compared to diesel, it gives off negligible emissions of sulphates, aromatic hydrocarbons along with minute quantities of smoke containing carbon dioxide (CO_2), carbon monoxide (CO) and particulates; it can be used in diesel engines without any modifications [3], [4], [5], it contains more oxygen which aids the complete combustion of the fuel, leading to decrease in emissions [6], it is suitable for use in modern diesel engines (blended with diesel or pure biodiesel) [7], it has better lubricating properties and reduces engine wear [8], its cetane number is higher than that of conventional diesel, biodiesel is rapidly

The characteristics of the diesel engine used in the study are shown in Table 1. The results of the numerical simulation for diesel in AVL Boost were compared with the basic engine information given in the engine manual and Table 1 (maximum engine power 47 kW at 3750 min⁻¹, maximum torque of 160 Nm at 1900 min⁻¹).

Description	Value
Fuel	Diesel
Engine type	Four cylinder
Piston diameter [mm]	76
Piston stroke [mm]	80,5
Volume [cc]	1461
Compression ratio	18,25:1
Power [kW]	47 at 3750 min ⁻¹
Maximum torque [Nm]	160 at 1900 min ⁻¹
Fuel injection system	Common rail
Number of valves per cylinder	2
Charging system	Turbocharger
Connection Rod Length [mm]	4,5

Table 1. Characteristics of the diesel engine

In the table. 2 are given some of the basic properties of diesel fuel and biodiesel.

Fuel properties	Diesel	Biodiesel
Density at 15 °C, kg/l	0,82 – 0,86	0,885
Boiling point, °C	180 - 360	322
Viscosity at 40°C, mm ² /s	2 – 4,5	4,58
Flash point, °C	> 55	>110
Temperature of self-ignition, °C	200 - 300	167
Ignition delay (ms)	8,7	9,99
Ash, %	< 0,01	<0,02
Acidity, mg KOH/100cm ³	< 5	0,23
Sulfur content, %	< 0,001	0,01
Temperature of freezing, °C	- 5 to -25	-8 to -20
Ester content	-	98
Cetane number	> 51	52-65
Lower combustion heat, MJ/kg	42,5	36-68
Elementary analysis	-	-
C, %	76,6 - 78	86 - 86,4
H, %	12,1	13,4 - 14
O, %	10 - 11	-

Table 2. Essential properties of diesel and biodiesel

Figure 2 shows the comparison of the engine power from the manual with numerical simulation for diesel fuel at maximum torque 1900 min⁻¹ shows equal values. Value power from the manual is 32 kW at 1900 min⁻¹, while the result

of numerical simulation is 31.3 kW. The difference is thus 0.7 kW or 2.2%. The torque tolerance is slightly larger 3750 min^{-1} : in the numerical simulation for diesel, the value of the engine power is 44.9 kW, while the manual states a power of 47 kW. The difference is thus 2.1 kW or 4.5%.

Fig. 2. Comparison of engine power with diesel fuel

The torque from engine manual is 160 Nm at 1900 min^{-1} (maximum torque) and 120 Nm at 3750 min^{-1} . It is in Figure 3 presented a comparison between manual data and numerical simulation results for diesel fuel. The manual indicates maximum torque 160 Nm, the result of the numerical simulation is 2.5 Nm lower. The difference is 1.6%. To higher the difference in torque drop occurs at 3750 min^{-1} : Numerical simulation result is 4.7% lower than information in the manual, which states 120 Nm.

Fig. 3. Comparison of engine torque with diesel fuel

Figure 4 shows a comparison of engine torque when using biodiesel and diesel fuel at 1900 min^{-1} and 3750 min^{-1} . Based on the results presented, it can be confirmed that a very small difference in the drop is observed of torque at 1900 min^{-1} for both types of fuel. The difference is 0.24 Nm or 0.15%. Numerical simulations, when comparing biodiesel and diesel, showed that at 3750 min^{-1} the diesel engine achieves 7.3 Nm more torque than if it had been driven fuel used biodiesel. The engine torque is thus 6.5% higher when using diesel fuel. The drop is not so great due to higher cetane biodiesel and higher injected masses of fuel that offset the lower fuel value of biodiesel.

Fig. 4. Comparison of engine torque when using different fuel

Figure 5 and Figure 6 show the in-cylinder pressure variation with biodiesel and diesel fuels at 1900 min^{-1} and 3750 min^{-1} engine speed. As can be seen from Figure 5, no major changes were observed in the use of biodiesel in-cylinder pressure variation compared to diesel fuel. At engine speed 1900 min^{-1} it can be observed that the combustion pressure of biodiesel fuel in range between 360 and 390 degrees of crankshaft rotation is higher on average by 0,5 MPa or 6% of the combustion pressure of the diesel fuel. From Figure 6, which shows the in-cylinder pressure variation at engine speed 3750 min^{-1} , there are no major changes in the use of diesel or biodiesel and range from 0,1 MPa to 1%. This can be explained by the higher density, kinematic viscosity and cetane number compared to diesel. Low cetane number of diesel fuel means longer ignition delay, taking more time for fuel to vaporize before combustion starts, which causes a reduction in maximum pressure rise.

Fig. 5. In-cylinder pressure variation depending on the crankshaft angle, with biodiesel and diesel at 1900 min^{-1}

Fig. 6. In-cylinder pressure variation depending on the crankshaft angle, with biodiesel and diesel at 3750 min⁻¹

Various simplifications are used to approximate the heat release characteristic heat release models. For the diesel engine, the model was used in our case Woschni 1978 [13]. Figure 7 shows the amount of heat released at 1900 min⁻¹. From figure we can see that they are maximum the amount of heat released for both compared fuels is relatively the same and does not produce large deviations. The maximum value of 73 J/° RG is reached at 370 degrees of crankshafts rotation. The use of biodiesel results in a faster increase of the released heat, which is reflected at a higher maximum pressure in the combustion chamber.

Fig. 7. Amount of heat released depending on the crankshaft angle, with biodiesel and diesel at 1900 min⁻¹

Maximum amount of heat released at 3750 min^{-1} is reached at 370 degrees of crankshaft rotation and for diesel fuel $53 \text{ J/}^\circ \text{ RG}$ and for biodiesel $51 \text{ J/}^\circ \text{ RG}$ (Figure 8).

Fig. 8. Amount of heat released depending on the crankshaft angle, with biodiesel and diesel at 3750 min^{-1}

3. Conclusion

The main purpose of this study is to investigate the effect of using biodiesel and its influence on compression ignition engine performance. According to the simulation results, it can be concluded that:

1. At engine speed 1900 min^{-1} it can be observed that the combustion pressure of biodiesel fuel in range between 360 and 390 degrees of crankshaft rotation is higher on average by 0,5 MPa or 6% of the combustion pressure of the diesel fuel biodiesel fuel. For engine speed 3750 min^{-1} , there are no major changes in the use of diesel or biodiesel and range from 0,1 MPa to 1%. This can be explained by the higher density, kinematic viscosity and cetane number compared to diesel. Low cetane number of diesel fuel means longer ignition delay, taking more time for fuel to vaporize before combustion starts, which causes a reduction in maximum pressure rise.

2. The amount of heat released at 1900 min^{-1} we can see that they are maximum the amount of heat released for both compared fuels is relatively the same and does not produce large deviations. The maximum value of $73 \text{ J/}^\circ \text{ RG}$ is reached at 370 degrees of crankshafts rotation. The use of biodiesel results in a faster increase of the released heat, which is reflected at a higher maximum pressure in the combustion chamber.

3. Maximum amount of heat released at 3750 min^{-1} is reached at 370 degrees of crankshaft rotation and for diesel fuel $53 \text{ J/}^\circ \text{ RG}$ and for biodiesel $51 \text{ J/}^\circ \text{ RG}$

As the future plan of the experiment team will investigate the influence of biodiesel on compression ignition engine exhaust emissions.

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