NUMERICAL INVESTIGATION ON THE COMBUSTION CHARACTERISTICS A DIESEL ENGINE FUELLED BIODIESEL B20

Mohanad Aldhaidhawi [a,b], Radu Chiriac [b], Viorel Badescu [b], A A Alfaryjat [b]

[a]1Applied Thermodynamics, Engines, Thermal and Refrigerant Equipment Department University POLITEHNICA of Bucharest Faculty of Mechanical Engineering and Mechatronics 313 Splaiul Independentei , sector 6, Bucharest, 060042 Romania

[b] Ministry of Higher Education and scientific research, Al-Furat Al-Awsat Technical University, Najaf, Iraq

*Corresponding author: mohanadhamazah@gmail.com

Abstract. The increasing costs and depletion of fossil fuels, as well as increased awareness of the global concern regarding air pollution caused by the extensive use of petroleum fuels in internal combustion engines are prompting researchers to increase their investigations into alternative fuels that should be available and environmentally friendly. Among alternative fuels, Biodiesel is considered as sustainable, and the most promising fuel for compression ignition engines. The objective of this paper is to numerically study the effect of Biodiesel B20 on ignition delay, combustion duration, peak fire pressure and peak fire temperature at engine speeds of 1000 rpm to 2400 rpm, in increments of 200 rpm, and full load condition. A four cylinder, four stroke, direct injection tractor Diesel engine was modelled by using the AVL Boost software. The simulation results revealed that Biodiesel B20 reduces ignition delay time and combustion duration, exhibits lower peak fire pressure and peak fire temperature at low engine speeds, and higher ones at higher engine speeds, compared to Diesel fuel.

Keywords: Biodiesel B20, Diesel engine, Ignition delay, combustion duration .

1. INTRODUCTION

Today there is increased environmental awareness, awareness of the depletion of petroleum resources, oil price increases, and increasing industrialization and modernization of the world have increased investigation on alternative fuels for daily use from renewable resources. Biodiesel is composed of fatty acids which are produced via chemical processes from vegetable oil or animal fat. It is one of a number of promising alternative fuels, which is available, economically viable and environmentally and acceptable replacement to Diesel fuel, contributes to climate, water and soil protection and enables a reduction of greenhouse gas emissions [1].

There is a large volume of published studies describing the advantages of Biodiesel as a substitute to Diesel fuel, such as: free of sulfur content, higher cetane number, higher flash point and lower volatility, all of which make Biodiesel safe to store and handle. In addition it has a lower aromatic compound content, 10–11% oxygen content by weight [2,3,4]. These characteristics contribute to the reduction in carbon dioxide, carbon monoxide, unburned hydrocarbons and soot emissions [5, 6].

There have been several studies in the literature reporting the disadvantages of Biodiesel such as: lower heating value, higher density and higher viscosity [7, 8, 9]. These characteristics contribute to reduced atomization quality, lower spray cone angle, increased average droplet diameter, and longer tip penetration of the sprayed injected fuel, higher brake specific fuel consumption (BSFC), reduction in the rate of heat release during combustion, resistance to flow, especially at lower temperatures, difficulty in initial starting and increased engine carbon deposits [8,9].

During the past 30 years much more information has become available on Biodiesel as fuel used directly in Diesel engines, or blended with Diesel, such as the works of Harch et al [10] who developed a combustion model for a Diesel engine using the computational fluid dynamics (CFD) software and AVL Fire program to predict the engine performance and emission characteristics of second generation Biodiesel produced from the Australian native beauty leaf seed (B and B10) for different injection timings and a variety of compression ratios. The results of the numerical simulation indicate that Biodiesel B5 provides slightly improved performance and efficiency, and moderately reduced emissions compared to Diesel. Biodiesel B10 provides better performance and efficiency, and significantly reduced engine emissions compared to petroleum fuel.

In another study, Rakopoulos et al. [11] examined the effect of using Biodiesel in a six-cylinder, turbocharged heavy-duty, direct injection (DI), Mercedes-Benz Diesel engine at different engine loads and engine speeds (1300 rpm,1500 rpm) experimentally. The results shown a shorter ignition delay at all operation conditions with Biodiesel compared to Diesel, and this is due to the fact that Biodiesel has a small percentage of diglycerides, which have higher boiling points.

More recently, Belymen et al. [12] experimentally investigated the influence of palm oil Biodiesel at different percentages (B2, B5, B7, and B10) on the performance and engine exhaust of a generator Diesel engine at an engine speed of 3000 rpm and a variety of compression ratios and different engine load conditions. Experimental results indicated that Palm oil methyl ester produces a better output when the engine operates with variable compression ratio, increases fuel consumption by 1.26%, increases NOx emissions by 1.18, while carbon monoxide is reduced by 29.1% when using Biodiesel, and found similar results to those obtained by [13].

The main objective of this paper is to numerically study the effect of Biodiesel B20 on ignition delay, combustion duration, peak fire pressure, peak fire temperature of Diesel engine at full load and varied engine speeds by using the AVL- Boost program.

2. ENGINE SPECIFICATIONS

The compression ignition engine is much more efficient, achieves better fuel economy and ispreferable when compared to all current types of internal combustion engines due to the high compression ratio used with this kind of engine. The Diesel engine that was used in this study for modeling is a four cylinder, four stroke, natural aspiration, direct injection tractor engine. The technical specifications of the engine include a displacement volume of 3759 cm3, a bore of 115 mm, a stroke of 102 mm and a compression ratio of 17.6:1. The engine was coupled to an eddy-current dynamometer located at the internal combustion laboratory of Politehnica University (Romania), is shown in Fig. 1 [14].

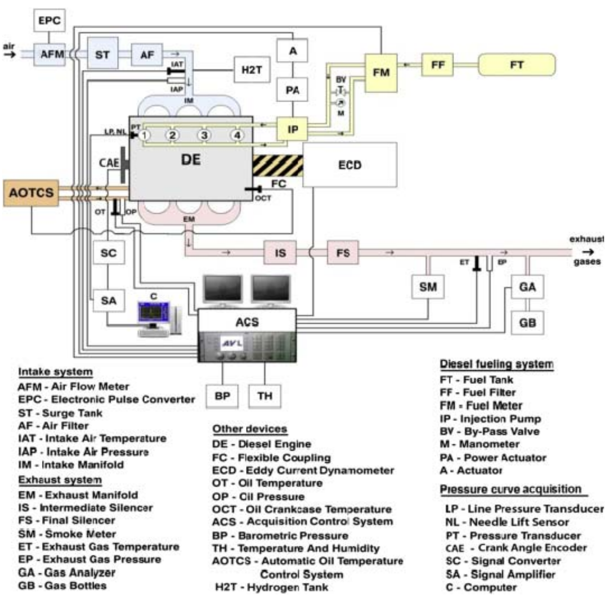

Fig. 1. Schematic of the test bed

3. Simulation Procedures

The AVL BOOST program was used in the present work to predicate the engine performance, combustion characteristics and exhaust gas emissions of a Diesel engine. The most important engine specifications are presented in section (2). The AVL- MCC combustion model and the Woschni 1990 heat transfer model were chosen in this modeling. The initial simulation was performed to compare Biodiesel B20 produced from Rapeseed oil to petroleum Diesel fuel at different engine speeds, of 1000 rpm to 2400 rpm in 200 rpm increments, at full load condition. All the test engine components, such as: cylinder geometry, intake and exhaust manifolds, air filter, system boundaries, catalyst, are linked together by pipes, as shown in (Fig. 2) [14].

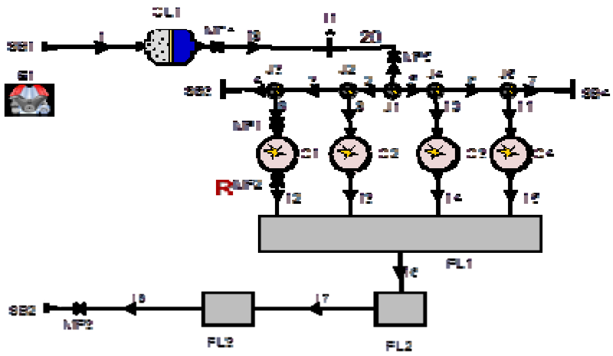

Fig. 2.Schematic of the engine symbolic model (AVL BOOST Theory and AVL BOOST Users Guide)[14]

4. RESULT AND DISCUSSION

In this part of the study, a numerical result related to cylinder pressure was validated with the experimental result in order to investigate the usefulness of the AVL Boost model. The effect of Biodiesel B20 fuel on ignition delay, combustion duration, and peak fire pressure and peak fire temperature are presented and compared with Diesel fuel at engine speeds of 1000 rpm to 2400rpm in increments of 200 rpm, at full applied loads.

4.1. Cylinder pressure

Figure 3 presents the variations of cylinder pressure with respect to crank angle, both experimental and simulation, for Diesel and Biodiesel B20 at an engine speed of 2400 rpm and full load operation. It is apparent from this figure that the best approach between the two pressure traces - numerical and experimental - for test fuels operation, has been observed. All other results with engine speeds of 1000 to 2200 rpm, in increments, have the same trend and exhibit a good approach between the two pressure traces - numerical and experimental - with acceptable relative variation. Based on the results it is concluded that this model can be used for the prediction of the combustion characteristics of the Diesel engine fueled by Biodiesel fuel.

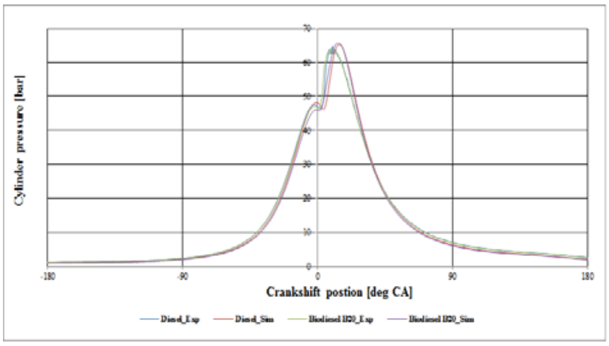

Fig. 3.Comparison between experimental and simulation pressure traces for full load, 2400 rpm speed.

4.2. Ignition delay

The variation of Ignition delay with respect to the engine speed at full load for Diesel and Biodiesel B20 is shown in Figure 4. Ignition delay is defined as the period between the start of fuel injection and the start of combustion. Start of injection is usually taken as the time when the injector needle lifts off while the start of combustion was more difficult to predict. This figure is clearly shows that ignition delay time increases when engine speed increases. It was observed that the ignition delay period of Biodiesel B20 is significantly lower than that of Diesel fuel at all engine speeds, and this is due to the fact that Biodiesel has a higher bulk modulus, higher sound velocity, which lead to an advanced start of fuel injection (SOI), higher density and higher cetane number than for Diesel fuel. Similar results were reported by [15,16].

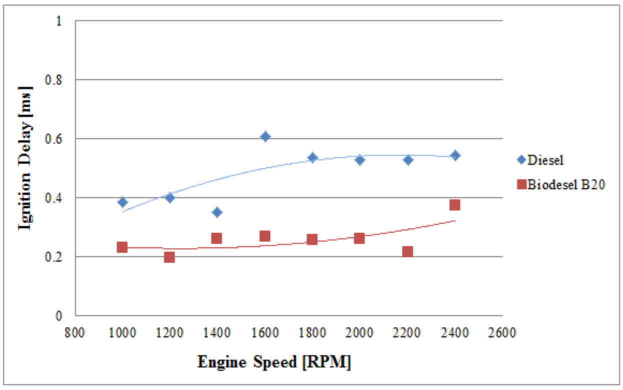

Fig. 4.Ignition delay time .Vs. engine speed

4.3. Combustion duration

Figure (5) presented the variation of combustion duration with respect to engine speed at full load for Diesel and Biodiesel B20. The results of the numerical simulation indicate that the combustion duration of Biodiesel B20 fuel for all engine speeds at full load is shorter than for Diesel fuel, and this may be due to the fact that Biodiesel has 10–11% oxygen content by weight, which will improve combustion, and combined with a shorter ignition delay leads to faster combustion.

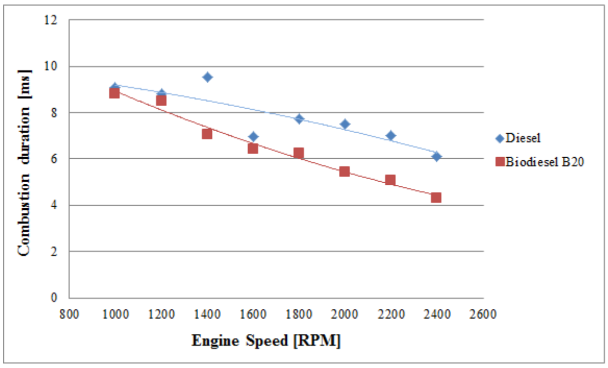

Fig. 5.combustion duration time .Vs. engine speed

4.4. Peak fire pressure

The variation of peak fire pressure with different engine speeds at full load for Diesel and Biodiesel B20 is shown in Figure (6).The results obtained from the simulation indicate that the peak fire pressure of Biodiesel B20 fuel was lower at low engine speeds and higher at high engine speeds than for Diesel fuel. The explanation of this behavior may be due to lower volumetric efficiency at high engine speeds with the natural aspirated engine, and due to the presence of 10–11% oxygen content in Biodiesel, which will be improve fuel combustion and then increase the temperature and pressure inside the cylinder. The finding is consistent with findings of past studies by [17].

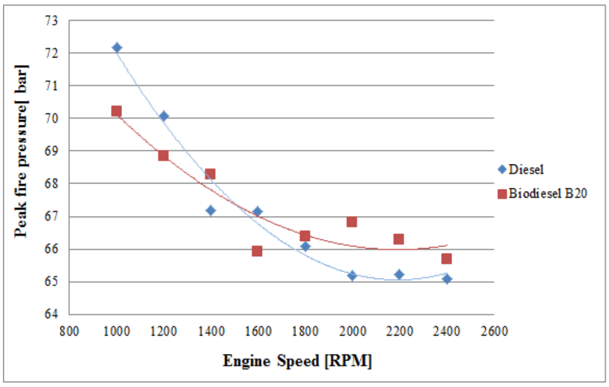

Fig. 6.peak fire pressure .Vs. engine speed

4.5. Peak fire temperature

Figure (7) presented the variation of peak fire temperature with respect to engine speed at full load for Diesel and Biodiesel B20. As shown in the figure, the trend of peak fire temperature of Biodiesel B20 fuel was lower at low engine speeds and higher at high engine speeds than that of Diesel fuel. This may be due to the higher cetane number and the presence of 10–11% oxygen content of Biodiesel, which results in improved fuel combustion and increased temperature.

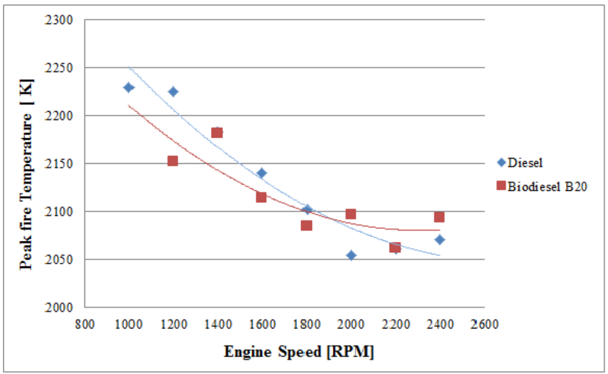

Fig. 7.peak fire temperature .Vs. engine speed

5. CONCLUSION

A numerical investigation was conducted by using the AVL Boost program to explore the effect of Biodiesel B20 on ignition delay time, combustion duration, peak fire pressure and peak fire temperature in a compression ignition engine. The numerical results were validated against experimental data related to cylinder pressure and engine performance. The results were obtained from a four cylinder, four stroke, natural aspirated direct injection Diesel engine which was run on Diesel and Biodiesel B20 at full load conditions and varied engine speeds (1000 rpm to 2400 rpm, in increments of 200 rpm). The results of the simulation indicate that the combustion duration and ignition delay of Biodiesel B20 were shorter than those of Diesel fuel, Biodiesel B20 produces lower peak fire pressure and peak fire temperature at low engine speeds. The lower peak fire pressure and peak fire temperature were higher with Biodiesel B20 at higher engine speeds compared to Diesel fuel.

ACKNOWLEDGEMENT

The authors of this paper acknowledge the AVL Advanced Simulation Technologies team for the significant support they have offered in performing the simulation part of this work. One of author (M.A) thanks the Iraqi government for financial support.

REFERENCES

[1] Sheehan J., Camobreco V., Duffield J., Graboski M. , Shapouri H. *An overview of biodiesel and petroleum diesel life cycles*, NREL / TP-580-24772 , Department of Energy's National Renewable Energy Laboratory, U.S. , May 1998.

[2] Khalid A., Syamim M., Mustaffa N., Sapit A., Zaman I., Manshoor B., Samion S. Experimental Investigations on the Use of Preheated Biodiesel as Fuel in Various Load Conditions of Diesel Engine, *Australian Journal of Basic and Applied Sciences*.,**8**, 423-430,2014.

[3] Öztürk E., Performance, emissions, combustion and injection characteristics of a diesel engine fuelled with canola oil–hazelnut soap stock biodiesel mixture , *Fuel Processing Technology*. , **129** 183- 191, 2015.

[4] Subhash L., Subramanian K. , Impact of nozzle holes configuration on fuel spray, wall impingement and NOx emission of a diesel engine for biodiesel diesel blend (B20) ,*Applied Thermal Engineering*. , **64** ,307-314, 2014.

[5] Harch C., Rasul M., Hassan N. , Bhuiya M., Modelling of engine performance fuelled with second generation biodiesel ,Procedia Engineering ., **90** ,459-465,2014.

[6] Lin B., Huang J., Huang D., Experimental study of the effects of vegetable oil methyl ester on DI diesel engine performance characteristics and pollutant emissions, *Fuel*, **88**,1779–6185, 2009.

[7] Dunn R., Shockley M., Bagby M.,Improving the low-temperature properties of alternative diesel fuels: Vegetable oil-derived methyl esters ,*Journal of the American Oil Chemists Society*., **73**,1719- 1728,1996.

[8] Mofijur M., Masjuki H.H., Kalam M.A., Atabani A.E., Arbab M.I., Cheng S.F., Gouk S.W., Properties and use of Moringa oleifera biodiesel and diesel fuel blends in a multi-cylinder diesel engine, *Energy Conversion and Management* .,**82**, 169–176,2014.

[9] Sureshkumar K., Velraj R. Ganesan R., (2008). Performance and exhaust emission characteristics of a CI engine fueled with Pongamia pinnata methyl ester (PPME) and its blends with diesel. *Renew Energy*.,**33**,2294-302,2008.

[10] Harch C. A., Rasul M. G., Hassan N. M. S. Bhuiya, M. M. K., Modelling of Engine Performance Fuelled with Second Generation Biodiesel. *Procedia Engineering*., **90**, 459 – 465 (2014)

[11] Rakopoulos D. C., Heat release analysis of combustion in heavy-duty turbocharged diesel engine operating on blends of diesel fuel with cottonseed or sunflower oils and their bio-diesel,*Fuel.*, **96**,524-534,2012.

[12] Belyamin B. , Noor.A.M , Hussein.M.H , Said M., Characterization of diesel engine generator operating at different compression ratio fuelled with Palm Oil Biodiesel, *Applied Mechanics and Materials.*, **388** , 241-245 ,2013.

[13] Abdul Aziz A , Said M.F, Awang A.M. Performance of Palm Oil-Based Biodiesel Fuels in a Single Cylinder Direct Injection Engine , *Palm Oil Developments*., **42** ,17-25 ,2006.

[14] Chiriac R., Racovitza A., Podevin P., Descombes G.,On the Possibility to Reduce CO2 Emissions of Heat Engines Fueled Partially with Hydrogen Produced by Waste Heat Recovery, *International Journal of Hydrogen Energy*., **40**, 15856-15863,2015.

[15] Ezio Mancaruso E., Luigi Sequino L., Bianca M. Vaglieco., First and second generation biodiesels spray characterization in a diesel engine, *Fuel*. **90**, 2870–2883, 2011.

[16] Buyukkaya E. ,Soyhan H.S.,Gokalp B.,Effects of rapeseed oil addition to a diesel fuel on thermodynamic efficiencies, *International Journal of Exergy*.,**14**, 101-123, 2014.

[17] Tesfa B., Mishra R., Zhang C., Gu F., Ball A. D., Combustion and performance characteristics of CI (compression ignition) engine running with biodiesel, *Energy*., **51**,101-115,2013.