Comparative Study of Biofuel and Biodiesel Blend with Mineral Diesel Using One-Dimensional Simulation

To cite this article: Rafidah Rahim *et al* 2012 *IOP Conf. Ser.: Mater. Sci. Eng.* **36** 012009

View the article online for updates and enhancements.

IOP **ebooks**™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

Comparative Study of Biofuel and Biodiesel Blend with Mineral Diesel Using One-Dimensional Simulation

Rafidah Rahim, Rizalman Mamat, Mohd Yusof Taib

Faculty of Mechanical Engineering, Universiti Malaysia Pahang,
26600 UMP, Pekan, Pahang, Malaysia.
Phone: +6094242303 Fax: +6094242202

E-mail: rafidah.rahim@yahoo.com

Abstract - This study is intended to perform one-dimensional simulation for four cylinders diesel engine by using various type of fuels and blend. The testing of biofuels properties conducted according to ASTM standards. The physical properties of the fuel are investigated in chemical laboratory which comprises of flash point, kinematic viscosity, density, cloud & pour point, acid value and moisture content. There are three types of fuels used throughout the study, which are straight vegetable oil (SVO), biodiesel 20% blend (B20) and biodiesel 5% blend (B5). Then, the properties data from the experiment will be used in the simulation GT Power software. Simulation tests have been run with the aim of obtaining comparative measures of torque, power, specific fuel consumption and volumetric efficiency. The results is use to evaluate and analyze the performance of diesel engine running with the mentioned fuels above. The comparison performances for each fuel have been discussed. There is no significant difference in the engine performance when fueled with B5 and diesel. There is only about one percent lower of B5 and four percent higher of B20 and SVO compare to diesel fuel.

Keywords: Biodiesel, diesel, simulation

1. Introduction

Global warming and green house effects nowadays give a high impact to environmental problem. Due to the environmental policies to reduce carbon dioxide emission, taking of biodiesel as an alternative and renewable source to replace fossil diesel becomes increasingly important. Palm oil has been reported to be the most interesting option instead of consideration various oil sources to be the feedstock to biodiesel production plants. All fuels have properties that we can use to identify them. The more properties that we can identify, the better we know the fuel. To faithfully predict alternative fuel combustion, accurate prediction of the physical properties of alternatives fuels is critical in the representation of identification for each fuel.

Biodiesel is the general word for all types of fatty acid methyl esters (FAMEs) or ethyl ester made from different raw materials and used as fuels. It is produced from transesterification process of vegetables oils or animal fats with the addition of methanol [1]. The transesterification (alcoholysis) process is a probable method for biodiesel production. This process is a chemical reaction between triglycerides and alcohol in the presence of alkaline liquid catalyst, usually sodium or potassium methoxide. The alcohol reacts with the fatty acids to form the methyl ester (biodiesel) and glycerol [2].

Physically and chemically, all vegetable oils can be used to produce [3]. Commonly, the liquid has similar composition and characteristics such as cetane number, energy content, phase changes and viscosity compare to petroleum-derived diesel. So it can be used in any CI diesel engine without any modification when it blended together with petroleum-derived diesel. Biodiesel have enabled to become one of the most familiar biofuels in the world compare to petroleum-derived diesel because some of its distinct benefits such as lower greenhouse gases emissions, higher lubricity and cetane ignition rating [1].

Malaysia and Indonesia are respectively largest and second largest producers of palm oil in the world, jointly they produces 85% of world's palm oil [4]. Progressively growing domestic palm-oil production will provide the basis for a rapid growth of the biofuel industry during the coming decade. Production is expected to increase at a rate of about 10 percent annually, reaching 1.1 billion litres by 2017. In Southeast Asia (SE Asia) biodiesel production is drastically growing due to its high potentiality and yield factor of palm [4]. Tropical climate and cheap man power of this region is another beneficial point for growing of this plant [5]. The industry will be predominantly export oriented, with the EU as its target market [6].

Four methods to reduce the high viscosity of vegetable oils to enable their use in common diesel engine without operational problem such as engine deposits have been investigated: blending with petro diesel, pyrolisis, micro emulsification (co solvent blending), and transesterification [7]. In the early phases of starting biodiesel projects, it can be observed that simple process technologies and basic purification do not achieve the required high quality needed for the modern diesel engine [8]. This paper highlighted the new data of biodiesel in GT-Power that do not have in any other analysis of engine performance instead of commonly used the diesel data. The objective of this research is to study the effect of temperature of biodiesel fuel as an alternative fuel for the same diesel engine specification. The properties of diesel fuel are varied significantly with the properties of biodiesel fuel. The vapor of diesel and biodiesel fuel properties from GT-POWER is shown in Table 1. The performance of brake power, brake torque, brake specific fuel consumption (BSFC), brake mean effective pressure (BMEP), volumetric efficiency, and brake efficiency were being discussed in this research.

Table 1: Vapor fuel properties of diesel and biodiesel

Vapor Fuel Properties	Density (g/cm^3)	Energy content (MJ/kg)
D2	0.837	49.9618
B5	0.839	49.8964
B100	0.878	39.9161
SVO	0.917	39.8887

2. Model Setup

In general, a one dimensional (1D) simulation of an engine model consists of intake system, exhaust system, compressor and variable geometry turbocharger system (VGT), common rail fuel injection systems, exhaust gas recirculation systems, engine cylinders and valve train. The development of the four cylinder modeling in one-dimensional simulation for four-stroke direct-injection (DI) diesel engine was presented in this paper. Figure 1 below shows the diesel engine modeling using GT-POWER software.

Optional of the first step of building engine model in GT-POWER is to modeling the intake system. For the selected diesel engine, the intake system has a few components, size and different data. The system is started from environment till the intake valve. The intake system components in the GT-POWER model are environment, intrunner, inport, intvalve. Figure 1 shows the intake system components for one cylinder only. The other three cylinders have the same configurations of the intake system as for the one cylinder. The components in this system require a few data to complete the data form before running the model.
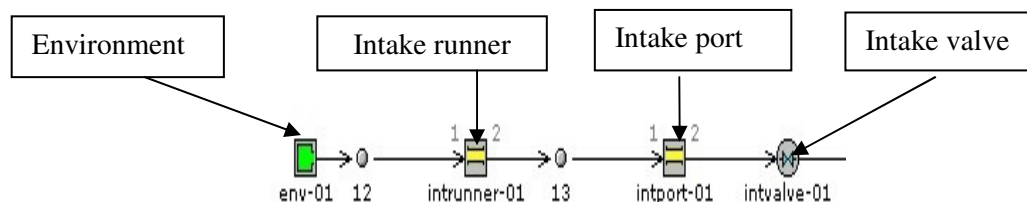
Figure 1. Intake system components

Data in environment panel are pressure, temperature, pressure flag and composition. For this study, the environment pressure is at standard atmospheric pressure which is 1 bar. The same goes for environment temperature, which is assumed to be 298 K. Initial fluid compositions is assumed to be fresh air and by neglecting the existing of NO, NO_2 and CO concentration.

The engine cylinder and fuel injection system are focused in the engine cylinder performance supports diesel fuel from fuel injection system, fresh air intake system and exhaust gas to exhaust system. There are many components in the engine cylinder and fuel injection system of the diesel engine. However the basic for all diesel engines are the same components. Then the components, size and data must be recorded and inserted into the GT-POWER form.

The engine cylinder and fuel injection system component are injector, cylinder and engine. Every component in this system needs any data to complete the data form and running the model. Figure 2 shows the engine cylinder and fuel injection system components for the selected diesel engine. It shows only for one cylinder and the rest three cylinders share the same configuration instead of engine. Engine is only one, which represents overall of the cylinders.
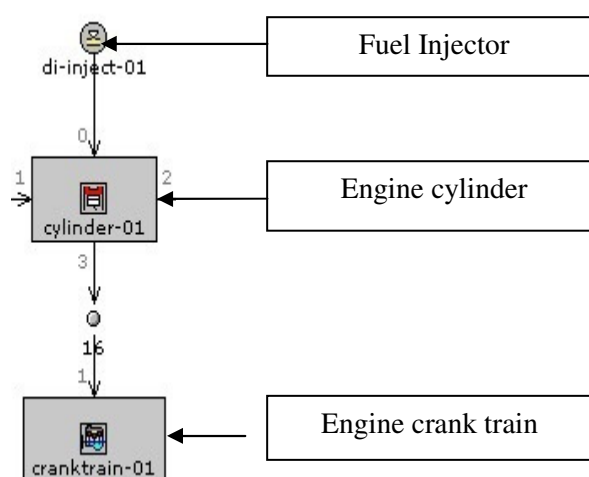

Figure 2. Engine cylinder and fuel injection system components

Engine cylinder input panel consists of various attributes such as the start of cycle, cylinder geometry object and initial state name. Figure 2 showed the input panel for it. Start of the cycle is also known as crank angle at intake valve close. Crank angle is at which each cylinder's cycle begins. This value does not affect the simulation predictions; it only specifies the starting and ending angle within a cycle over which integrated and averaged predictions are measured. This attribute should usually be set to "def"

which sets the value to be equal to the value specified in 'Engine Crank Train' for Start of Cycle (CA at IVC). The dimension of bore, stroke and connecting rod which are measured corresponding to the real engine were inputted in this general engine panel. Other components, size and data must be recorded and inserted to the GT-POWER template library input panels. Data in the engine cylinder geometry are bore, stroke, and wrist pin to crank offset, compression ratio, TDC clearance height and connecting rod length.

The input panel for the template of engine crank train consists of number of cylinders, configuration of cylinder and engine type. For the selected diesel engine, the exhaust system has a few components, size and different data. The system is started from the intake valve till environment. The exhaust system components in the GT-POWER model are environment, exhrunner, exhport, and exhvalve. Figure 3 showed the exhaust system components configuration for the four cylinders. The components in this system require a few data to complete the data form before running the model.
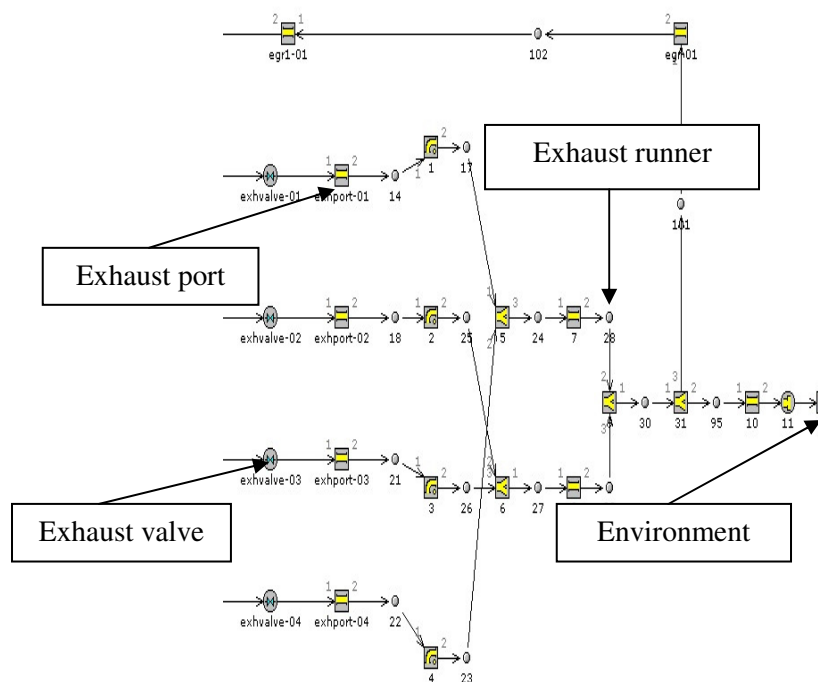

Figure 3. Exhaust system components

Figure 4 shows complete model of the engine. After completing the simulation model, Plot Options requesting were made. Plot Options are plots of results over the course of a single engine cycle (the last engine cycle in multi-cycle simulations) which indicated which interesting parameters of the study that are going to be observed. Plot Options may be requested by selecting the appropriate plot from the plot panel within each part. If the model is ready for simulation, GT-POWER simulation may be started and this will start the simulation running. By running the solver, a shell will open, noting the version of the solver being used. Windows will show the progress of simulation in the form of scrolling text. Once the input has been read successfully, it is all set to create the requested data for post-processing in GT-POST.
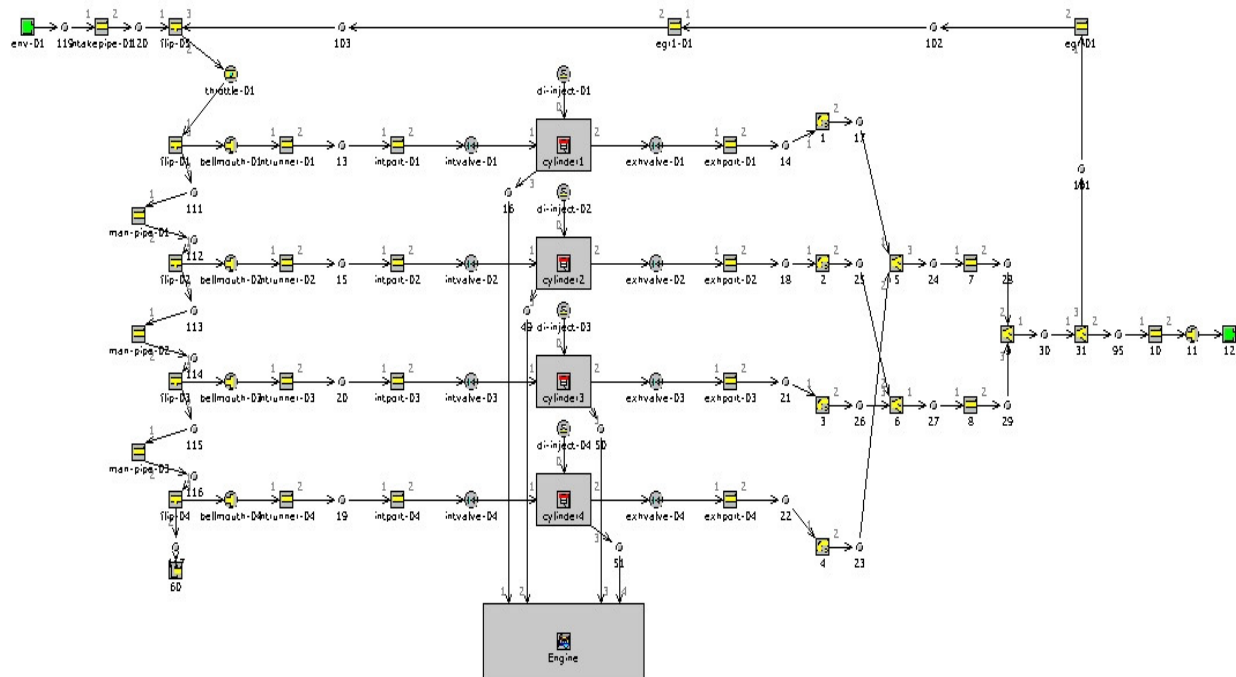
Figure 4. Four cylinders diesel engine modeling using GT-POWER

In GT-POWER, there is no biodiesel fuel in its Fuel Properties panel. In GT-POWER, a gas reference object is commonly described by its C: H: O: N compositions. For incompressible liquid properties, information about density, vapor fluid object and heat of vaporization are the necessary input to GT-POWER. Typically every liquid reference object must be associated with a gas reference object so that the properties of the liquid will be known if the fluid evaporates. Then, the gas/vapor properties of biodiesel need to be determined which it consists of molecular weight, lower heating value, and number of atoms per molecule which is carbon, hydrogen, nitrogen and oxygen.

In the selected diesel engine, the intake system has a few component, size and different data. The system is started from environment till the intake valve. All of the intake system components in the GT-POWER model are environment, intake runner air filter, air filter, intake runner, intake port, intake valve. The components in this system need a few data to complete the data form and running the model.
Engine cylinder and fuel injection system that focused in engine cylinder performance support diesel fuel from fuel injection system, fresh air intake system and exhaust gas to exhaust system. The components, size and data must be recorded and inserted to the GT-POWER form.

All of the engine cylinder and fuel injection system component are injector, cylinder and engine. Exhaust system is the last system in the diesel engine. The system starts from exhaust valve and finishes in the environment. The GT-POWER components in the exhaust system are exhaust valve, exhaust port, exhaust runner, muffler, exhaust runner exit, and environment. The details of the engine parameters used in this model are described in Table 2 below.

Table 2: Detail parameters of a four cylinder diesel engine

Parameter	Value
Bore (mm)	82.7
Stroke (mm)	93
Compression ratio	22.4
Displacement (cc)	500
Number of Cylinder	4
Connecting Rod Length (mm)	150
Piston Pin Offset (mm)	1
Intake Valve Open (°CA)	351
Intake Valve Close	-96
Exhaust Valve Open	125
Exhaust Valve Close	398

In this section, some basic parameters that are commonly used to characterize engine operation are developed. These include the mechanical output parameters of work, torque, and power; the input requirement of air, fuel and combustion; efficiencies; and emission measurement of engine exhaust [9-10].

4. Results and Discussion

Biodiesel operates in compression ignition engines with little or no modification just like petroleum diesel. Figure 5 below shows the variation fuels for brake mean effective pressure. The mean effective pressure is quite often used to calculate the performance of an internal combustion engine. The maximum brake mean effective pressure is essentially for well establish a good engine designs. The diesel fuel and B5 shows the highest BMEP compare to other two fuels, B100 and SVO. As shown, B100 and SVO significantly similar value, while trend for D2 quite similar to B5
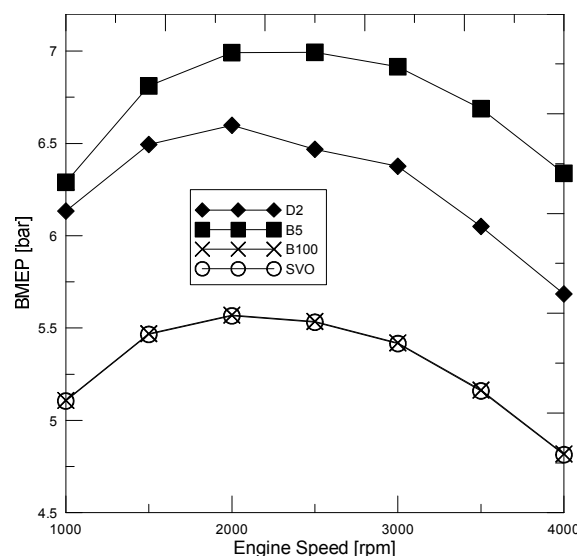
Figure 5. Effect of engine speed variation on BMEP

Brake specific fuel consumption is measured as a flow rate-mass flow per unit time. From figure 6 below, the analysis results for brake specific fuel consumption are well in good agreement. As shown in

figure, B5 and D2 shows the lowest BSFC while B100 and SVO shows the highest BSFC. For compression ignition engines, the best performance for BSFC is lowest value, it is obviously desirable [9]. The higher BSFC value in the case of SVO and B100 is due to the lower energy content as depicted in Table 1 above. This results cause the engine to inject more fuel to gain equal brake torque.
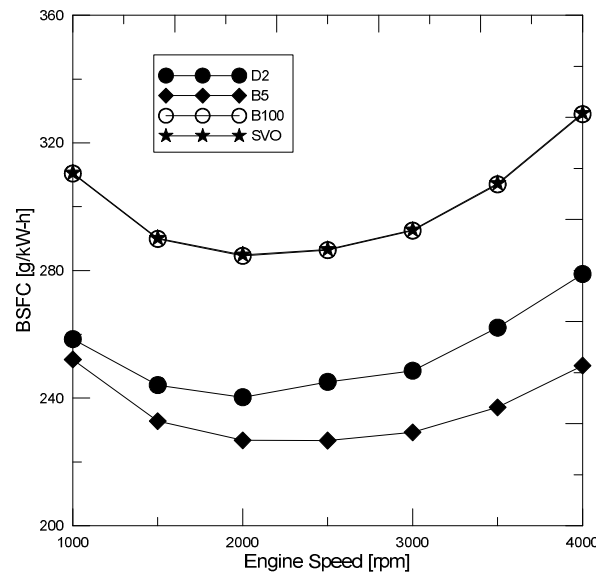

Figure 6. Variation of brake specific fuel consumption against engine speed

The effect of variation fuels on brake engine torque for various speeds is shown in figure 7 below. The torque is a function of engine speed [11]. At low speed, torque increases as the engine speed increase, reaches a maximum and then, as engine speed increase further, torque decreases as shown in figure below. The torque decreases because the engine is unable to ingest a full charge of air at the higher speed. Figure 8 below clearly shows the gap between D2 & B5 and B100 & SVO. The maximum reduction brake engine torque recorded between these fuels when engine speed achieved at 2000 rpm. The performance of the fuels same with other performance whereas B15 and B20 is the highest value of brake torque while the lowest value are SVO and B100 fuels.
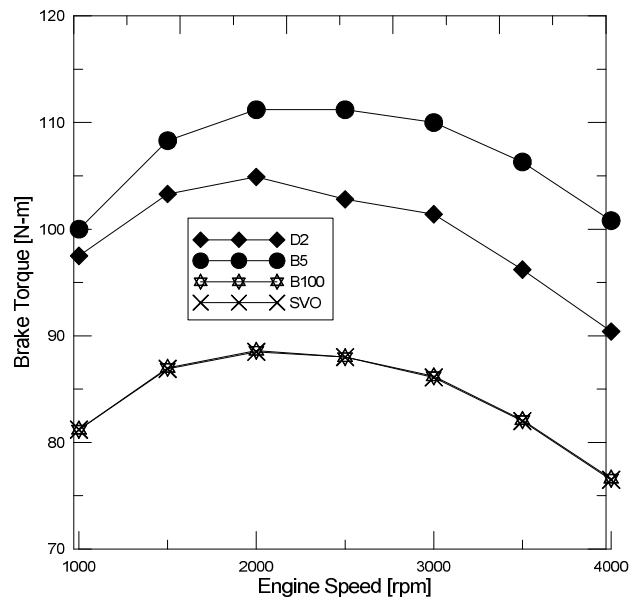
Figure 7. Variation of brake torque against engine speed

Brake power is defined as power that developed at the crankshaft or flywheel. Figure 8 below shows that SVO and B100 have a lower value of brake power compare to B5 and D2. It is resulting due to the lower energy level of fuel that causes some reduction in the engine power when it is used in diesel engine without any modification [12]. A close resemblance occurred at low speed representing small discrepancy in output between the fuels. The maximum brake power is 42.2 kW for B5 while the minimum value is 8.5 kW posses by B100 and SVO. It is well known that the heating value of the fuel affects the power of an engine. The lower energy level of the B100 and SVO fuel causes some reductions in the engine power when it is used in diesel engines without any modifications [12].
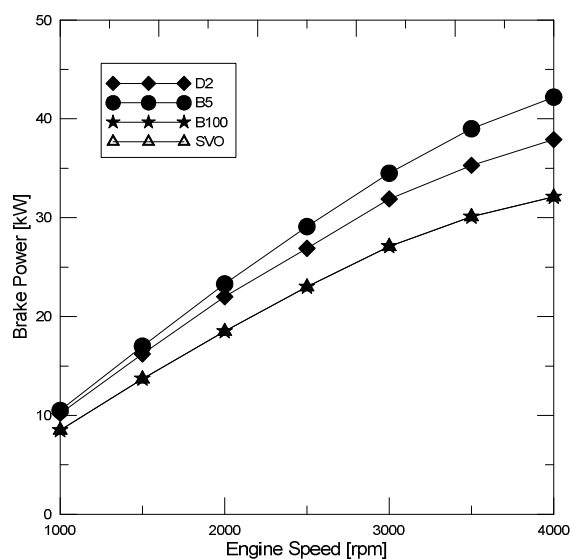

Figure 8. Variation of brake power against engine speed

Volumetric efficiency is one of the most important parameters which determine the performance level of a four-stroke engine. VE is the measure of success with which air supply is inducted into an engine. Figure 9 shows the effect of volumetric efficiency with respect to engine speed. It can be seen that the maximum efficiency achieved at 1000rpm of engine speed. Engine with higher volumetric efficiency will generally be able to run at higher speeds and produce more overall power due to less parasitic power loss moving air in and out of the engine. Volumetric efficiency was decreasing sharply as the engine speed increase further. The sharp decrease happens because of higher speed is accompanied by some phenomenon that have negative influence on η_v. These phenomenon's include the charge heating in the manifold and higher friction flow losses which increase as the square of engine speed [13].
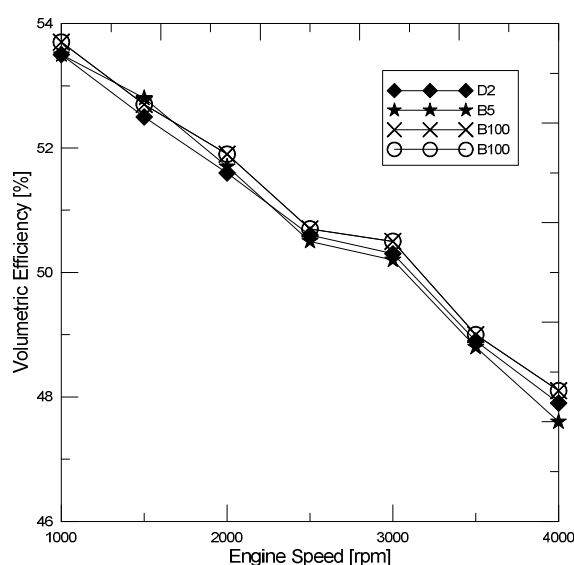

Figure 9. Effect of engine speed variation on volumetric efficiency

5.0 Conclusion

The performance of power, torque, specific fuel consumption, brake mean effective pressure and volumetric efficiency are compared. Analyzing results shows that the performance of diesel engine running with B5 and Diesel fuel has no significant difference in the engine performance. Inversely with the biodiesel fuel blended 100% (B100), it shows slightly difference performance for diesel engine. It highlights a lower performance and need some modification of engine to level up the performance as equal to B5 and diesel fuel.

References

1.   Lim, S. and L.K. Teong, *Recent trends, opportunities and challenges of biodiesel in Malaysia: An overview.* Renewable and Sustainable Energy Reviews, 2010. **14**: p. 938-954.
2.   Mamat, R., *Performance and Emission Characteristics of an Automotive Diesel Engine Using Biodiesel Fuel with The Influence of Air Intake Variables*, in *School of Mechanical Engineering.* 2009, The University of Birmingham Birmingham.
3.   A.Z.Abdullah, et al., *Current status and policies on biodiesel industry in Malaysia as the world's leading producer of palmoil.* Energy Policy, 2009. **37**: p. 5440-5448.

4.   Jayed, M.H., et al., *Environmental aspects and challenges of oilseed produced biodiesel in Southeast Asia.* Renewable and Sustainable Energy Reviews, 2009. **13**: p. 2452-2462.

5.   Tan, K., et al., *Palm oil: addressing issues and towards sustainable development.* Renewable and Sustainable Energy Reviews, 2009. **13**(2): p. 420-427.

6.   Wiebe, K.A., et al., *The State of Food and Agriculture.* Rome: FAO Publications, 2008.

7.   Knothe, G., J.V. Gerpen, and J. Krahl, *The Biodiesel Handbook*, ed. L.o.C.C.-i.-P. Data. 2005.

8.   Korbitza, W., et al., *Worldwide review on biodiesel production.* IEA Bioenergy Task 39, Subtask „Biodiesel", 2003.

9.   Heywood, J.B., *Internal Combustion Engine Fundamentals* 1988: McGraw-Hill 930.

10.   Pulkrabek, W.W., *Engineering Fundamentals of the Internal Combustion Engine.* Second ed. 2004: Pearson-Prentice Hall. 478.

11.   Abu-Zaid, M., *Performance of single cylinder, direct injection Diesel engine using water fuel emulsions.* Energy Conversion & Management, 2004. **45**: p. 697-705.

12.   Can, Ö., I. Çelikten, and N. Usta, *Effects of ethanol addition on performance and emissions of a turbocharged indirect injection Diesel engine running at different injection pressures.* Energy Conversion and Management, 2004. **45**(15-16): p. 2429-2440.

13.   Rahman, M.M., M.K. Mohammed, and R.A. Bakar, *Effects of Air Fuel Ratio and Engine Speed on Engine Performance of Hydrogen Fueled Port Injection Engine.* American Journal of Scientific Research, 2009(1): p. 23-33.