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COMPARATIVE STUDY ON DIESEL ENGINE PERFORMANCE OPERATING WITH BIODIESEL AND DIESEL FUEL

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ABSTRACT

The main objective of this research is to compare the performance of direct injection diesel engine operating with biodiesel and diesel fuel. Based on GT-Power simulation, the effects of using biodiesel fuel had been analyzed. The specifications of engine follow the diesel engine Mitsubishi 4D68, four cylinders, four stroke, and 50-kW power capacity. These comparison studies were conducted on both engine power and characteristics of each fuel. The simulation results showed that torque and power outputs for biodiesel fuel were generally lower than those for diesel fuel.

Keywords: Biodiesel, diesel, simulation, performance

INTRODUCTION

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 (Lim and Teong, 2010). The transesterification (alcoholysis) process is a probable method for biodiesel production. This process is the 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 (Mamat, 2009). Physically and chemically, all vegetable oils can be used to produce (Abdullah et al., 2009).

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 (Lim and Teong, 2010).

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 (Knothe et al., 2005). 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 (Korbitza et al., 2003).

The study focus on the comparative performance effect of diesel fuel substituted to biodiesel fuel as an alternative fuel for the same diesel engine specification. The properties of diesel fuel are varying 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, volumetric efficiency, and brake efficiency were being discussed in this research.

Table 1: Vapor fuel properties of diesel and biodiesel

Vapor Fuel Properties	Diesel	Biodiesel
Carbon Atom per Molecule	13.5	18.82
Hydrogen Atom per Molecule	23.6	34.39
Oxygen Atom per Molecule	0	2
Nitrogen Atom per Molecule	0	0
Lower Heating Value (J/kg)	4.325e+007	3.715E7
Critical Temperature (K)	569.4	785.87
Critical Pressure (bar)	24.6	12.07
Min. Valid Temperature (K)	200	100
Max. Valid Temperature (K)	1200	1200
Min. Valid Pressure (bar)	0.01	0.01
Max. Valid Pressure (bar)	2000	300

The objective of this study was to investigate the effects of used biodiesel fuel on engine performance using engine 4D68, four cylinders, four stroke, and 50-kW power capacity diesel engine specifications. Comparative measurements with diesel fuel were done on both, engine power and characteristics of each fuel.

MATERIALS AND METHOD

The development of the four cylinder modeling in one-dimensional simulation for four-stroke direct-injection (DI) diesel engine was presented in this paper. The details of the engine parameters used in this model are described in Table 2 below. The research start on developed the GT-POWER of four cylinder four stroke direct-injection diesel engine modeling to simulate the engine performance. Figure 1 shows the diesel engine modeling using GT-POWER software. The biodiesel as an alternative fuel for four stroke diesel engine modeling was developed from the real diesel engine using GT-POWER computational model with measure all of engine components size.

The results from this research show that biodiesel fuel and diesel fuel can comparable engine performance parameters such as torque (T), brake specific fuel consumption (BSFC) and thermal efficiency. Engine exhausts gas emissions of Total Hydrocarbon (THC). Carbon Monoxide (CO) and smoke emissions reduce significantly when engine was run with biodiesel fuel. Meanwhile the using of biodiesel cause slightly increase Nitrogen Oxide (NOx) emission (Reksowardojo et al., 2007).

Table 2: Diesel Engine Specification

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

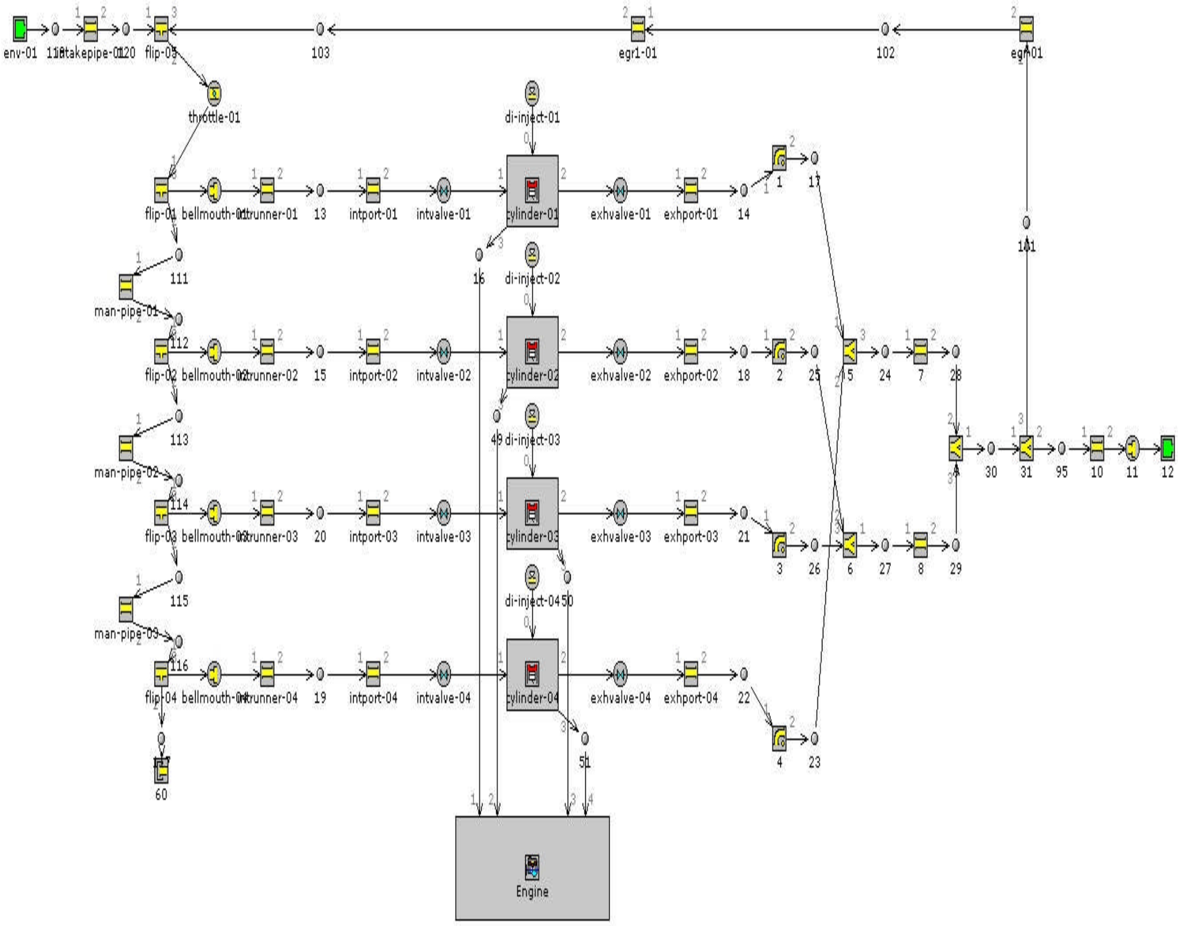

Figure 1: Four cylinder direct injection diesel engine model using GT-POWER

RESULTS AND DISCUSSION

Engine performance is an indication of the level of accomplishment with which it does its assigned job i.e., conversion of chemical energy contained in the fuel into the useful mechanical work. Certain basic parameters are selected and the effects of various operating conditions, concepts and modifications on these parameters are studied in the analysis of engine performance (Rajput, 2005).

The simulation results for performance comparative of diesel engine using diesel fuel and biodiesel fuel are shown in Fig. 2, Fig. 3, Fig. 4, Fig. 5 and Fig. 6. The tests were performed by varying the engine speed starting from 1000rpm until 4000rpm with the increment of 500rpm. The trends output for each fuels temperature give the reason for their circumstances.

Figure 2 shows the effect of engine speed variation on brake power. It is observed from the curves that less power output is obtained from the biodiesel fuel compared to the petroleum diesel. A close resemblance occurred at low speed representing small discrepancy in output between fuels. However, at higher speed, a clear gap appeared between the diesel fuel and biodiesel. The maximum brake power for diesel and biodiesel are 26.4 kW and 19.7 kW respectively. By comparison, the maximum brake power of engine will reduce 25% when using biodiesel as fuel. It is well known that the heating value of the fuel affects the power of an engine. The lower energy level of the biodiesel fuel causes some reductions in the engine power when it is used in diesel engines without any modifications (Can et al., 2004).

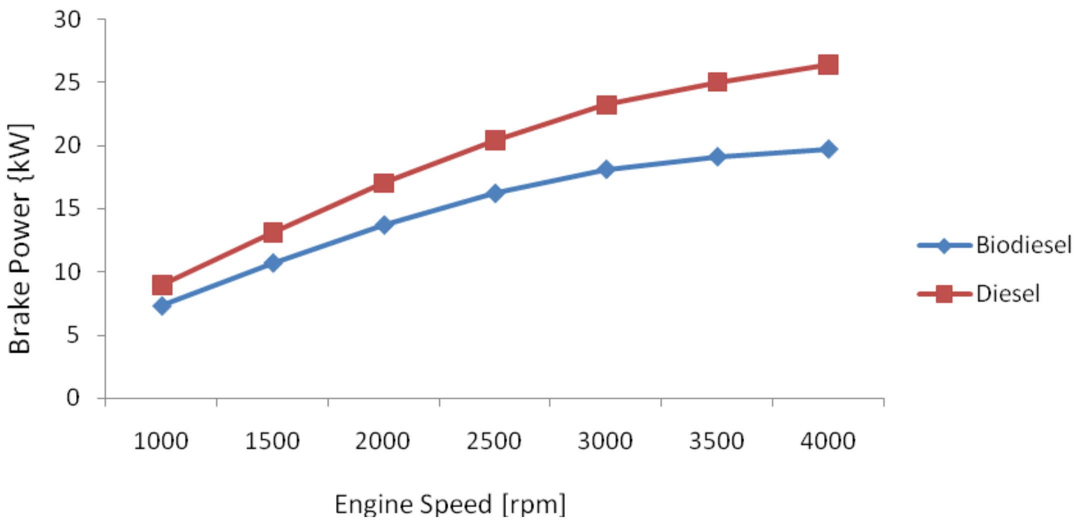

Figure 2: Variation of brake power against engine speed

The brake torque versus engine speed performance of engine fuelled by diesel fuel and biodiesel is shown in Figure 3. The brake torque for diesel fuel is higher than biodiesel fuel. At low speed, the brake torque is higher, as engine speed increase further, torque decreases as shown in Figure 3. The torque decreases because the engine is unable to ingest a full charge of air at the higher speed (Abu-Zaid, 2004). By comparison, the maximum reduction of brake torque occurred at highest speed; reduce by 26% when using biodiesel as fuel.

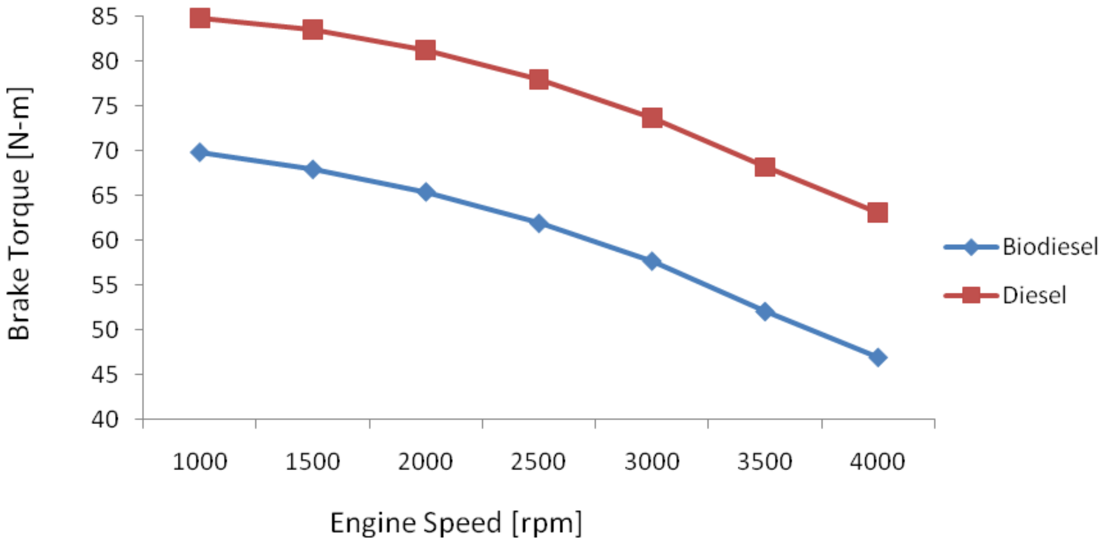

Figure 3: Effect of engine speed variation on brake torque

Figure 4 below shows the variation of brake specific fuel consumption against engine speed. They generally show that brake specific fuel consumption for diesel fuel is lower than biodiesel fuel. This trend representing due to the lower of energy content for biodiesel fuels, thus needs more BSFC to represent at same level of power. The minimum brake specific fuel consumption will increase 18% at lower speed when using biodiesel as fuel tested. As engine speed increase, the percent different between the fuels also increase. The trend represent that BSFC for diesel fuel is lower than biodiesel fuel due to the lower value of energy content for diesel. A low values of specific fuel consumption are obviously desirable (Heywood, 1988).

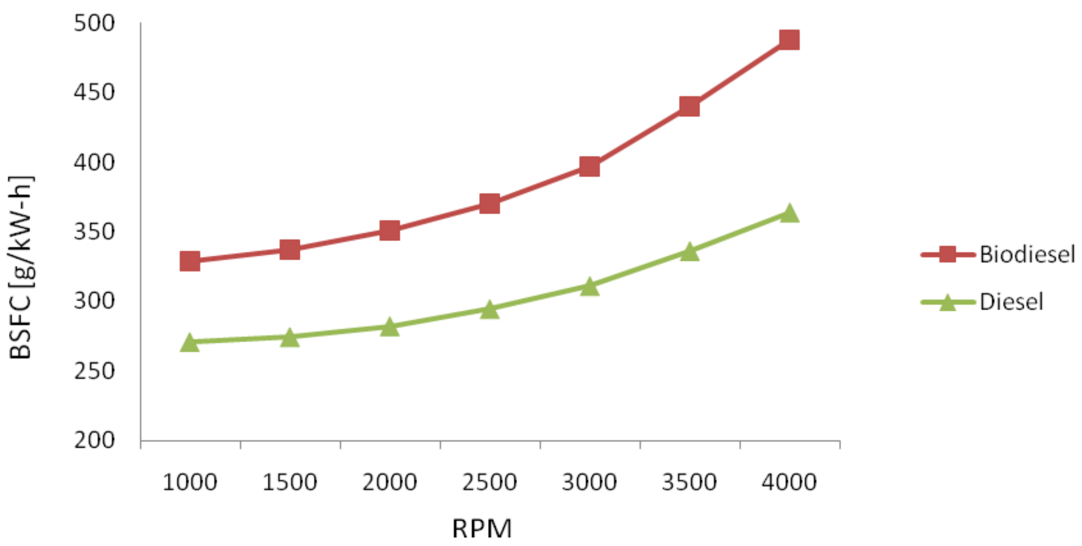

Figure 4: Variation of brake specific fuel consumption against engine speed

The effect of engine speed variation on volumetric efficiency is shown in figure 5. They generally show similar trend and closely resemble on another, thus representing small discrepancy in output between the fuels. It can be seen that the maximum efficiency achieved at 2000rpm 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 (Rahim et al., 2010). The turning point for the volumetric efficiency occurs at the engine speed 2000rpm, so volumetric efficiency decrease 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 (Rahman et al., 2009).

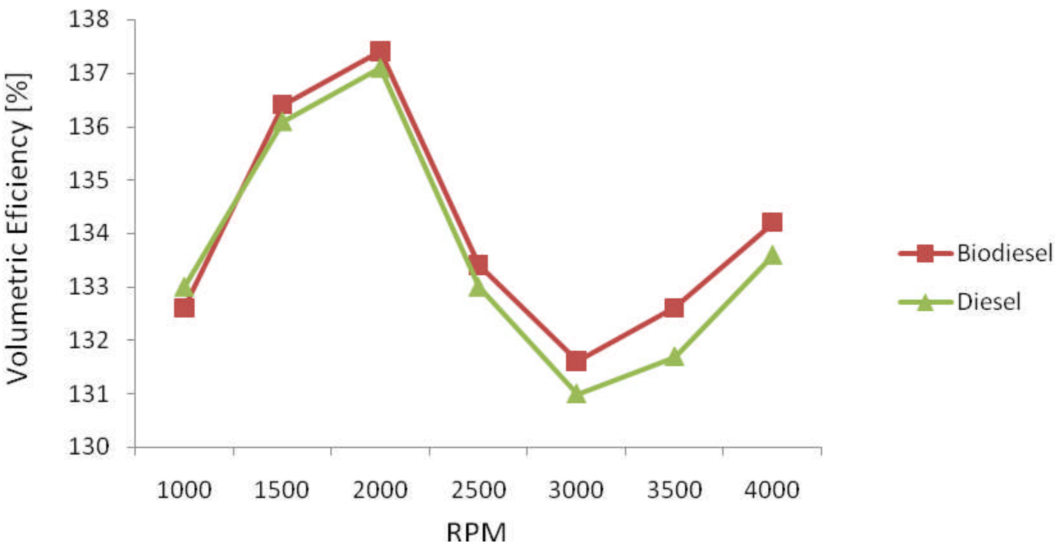

Figure 5: Effect of engine speed variation on volumetric efficiency

Figure 6 below shows that brake efficiency for diesel fuel is higher than biodiesel fuel. This trend was resulted due to the different number of carbon for each fuel. (Brain, 2000) reported that diesel fuel evaporates more slowly because it is heavier. It contains more carbon atom in longer chains than gasoline does (gasoline is typically C_9H_{20}, while diesel fuel is typically $C_{14}H_{30}$). Consequence with this study, biodiesel is heavier than diesel fuel because it contains more carbon atom, thus resulting in low fuel temperature of biodiesel. The brake efficiency is lower as the fuel temperature is low. The efficiency is improved when the fuel temperature increases (Mamat et al., 2009).

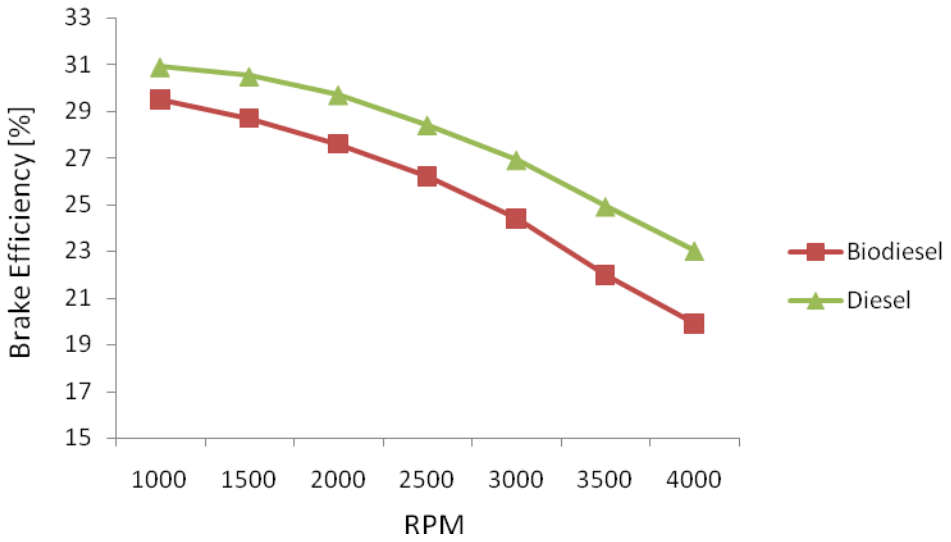

Figure 6: Variation of brake efficiency against engine speed

CONCLUSION

It is observed that at all the engine speed tested, torque output for the biodiesel are generally lower than those for the diesel fuel. Similar observations have been reported (Alamu et al., 2009) for waste French-fry oil and low sulphur No.2 diesel fuel, also for Palm Kernel Oil biodiesel and petroleum diesel tested (Alamu et al., 2009). The limited performance tests carried out showed that biodiesel can successfully fuel a diesel engine. Specifically, the following conclusions can be drawn:

i. Torque and power outputs for biodiesel are generally lowers than diesel fuels at all the engine speed.
ii. Brake specific fuel consumption is obviously desirable for diesel fuels as the value is lower compare to biodiesel fuels.
iii. Biodiesel is heavier than diesel fuel, thus resulting in low brake efficiency for diesel engine.

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REFERENCES

A.Z.Abdullah, B.Salamatinia, H.Mootabadi & S.Bhatia 2009. Current status and policies on biodiesel industry in Malaysia as the world's leading producer of palmoil. Energy Policy, 37**,** 5440-5448.

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

Alamu, O. J., Adeleke, E. A., O, N., Adekunle & Ismaila, S. O. 2009. Power and Torque Characteristics of Diesel Engine Fuelled by Palm-Kernel Oil Biodiesel. Leonardo Jaournal of science**,** 66-73.

Brain, M. 2000. How Diesel Engines Work.
Can, Ö., Çelikten, I. & Usta, N. 2004. Effects of ethanol addition on performance and emissions of a turbocharged indirect injection Diesel engine running at different injection pressures. Energy Conversion and Management, 45, 2429-2440.
Heywood, J. B. 1988. Internal Combustion Engine Fundamentals McGraw-Hill
Knothe, G., Gerpen, J. V. & Krahl, J. 2005. The Biodiesel Handbook.
Korbitza, W., Friedricha, S., Wagingerb, E. & Worgetterc, M. 2003. Worldwide review on biodiesel production. IEA Bioenergy Task 39, Subtask Biodiesel.
Lim, S. & Teong, L. K. 2010. Recent trends, opportunities and challenges of biodiesel in Malaysia: An overview. Renewable and Sustainable Energy Reviews, 14, 938-954.
Mamat, R. 2009. Performance and Emission Characteristics of an Automotive Diesel Engine Using Biodiesel Fuel with The Influence of Air Intake Variables. Doctor of Philosophy, The University of Birmingham
Mamat, R., Abdullah, N. R., Xu, H., Wyszynski, M. L. & Tsolakis, A. 2009. Effect of Fuel Temperature on Performance and Emissions of a Common Rail Diesel Engine Operating with Rapeseed Methyl Ester (RME). SAE International, 01, 1896.
Rahim, R., Mamat, R. & Taib, M. Y. Year. One Dimensional Simulation for Single Cylinder Diesel Engine Operating with Ethanol. In: National Conference in Mechanical Engineering for Research & Postgraduate Studies (NCMER'10), 2010 Universiti Malaysia Pahang.
Rahman, M. M., Mohammed, M. K. & Bakar, R. A. 2009. Effects of Air Fuel Ratio and Engine Speed on Engine Performance of Hydrogen Fueled Port Injection Engine. American Journal of Scientific Research, 23-33.
Rajput, R. K. 2005. A Textbook of Internal Combustion Engines, New Delhi, Laxmi Publications (P) Ltd.
Reksowardojo, I. K., Lubis, I. H., Manggala, W., Brodjonegoro, T. P., Soerawidjaja, T. H., Arismunandar, W., Dung, N. N. & Ogawa, H. 2007. Performance and Exhaust Gas Emissions of Using Biodiesel Fuel from Physic Nut (Jatropha Curcas L.) Oil on a Direct Injection Diesel Engine (DI). SAE International, 2007-01-2025.