Magnetization of Biodiesel (Cooking Oil Waste) to Temperature and Pressure Combustion in Diesel Engine

T H Nufus1, S Lestari2, A Ulfiana*, and M Manawan1

1Mechanical Engineering, Politeknik Negeri Jakarta, Prof. Dr. G.A Siwabessy Street, Kampus UI, Depok, Jawa Barat 16424, Indonesia.
2Electrical Engineering Politeknik Negeri Jakarta, Prof. Dr. G.A Siwabessy Street, Kampus UI, Depok, Jawa Barat 16424, Indonesia.

*andi.ulfiana@mesin.pnj.ac.id

Abstract. Research related to the provision of magnetic field strength in the flow of fuel that can cause more complete combustion has been reported by many researchers and most of these observations were carried out by measuring machine performance using a dynamometer. Given the dynamometer prices are very expensive then another way to prove the occurrence of complete combustion is through the combustion chamber indicator. The hypothesis is the greater magnetic field passed by fuel, the more perfect the combustion is. In addition, the combustion chamber temperature also increases and thermal efficiency increases. The fuel used is biodiesel derived from cooking oil waste, biodiesel 100% (denoted as B0), a blend of biodiesel (20%)-diesel (80%) (denoted as B20), a blend of biodiesel (40%)-diesel (60%) (denoted as B40), a blend of biodiesel (30%)-diesel (30%) (denoted as B70), and diesel 100% (denoted as B100). The magnetic field used is 500 Gauss, 900 Gauss and 1500 Gauss. Measurement of combustion temperature is using R type temperature sensor, which is connected to the NI USB interface to computer and LabVIEW for data acquisition. 13 HP capacity of diesel engine was used. The results obtained is 13 % temperature increase in the combustion chamber of the engine and 7 - 12% thermal efficiency increase equipped with a magnet compared to a non-magnetic engine.

Keywords: cooking oil waste, temperature, magnetic field, engine performance.

1. Introduction
Fuel oil is a non-renewable energy source that will eventually run out in the future. Efforts to overcome this situation are by saving fuel use or finding alternative energy sources. Several studies have been carried out in order to save energy through increasing combustion efficiency, including mixing additives in fuels which increase octave and cetane values, effective combustion processes and increased engine power [1]. Fuel magnetization, by installing a permanent magnet on the fuel line to the combustion chamber, decrease 9% to 30% of fuel consumption, reduced 5% to 32% of HC exhaust emissions and reduce 5 to 34.3% of CO exhaust emissions [2-9]. However, both emissions produce chemical additives that contain metal elements that are harmful for human health. Other studies tried using installed electromagnetic fields on gasoline or diesel engines to minimize fuel consumption by 12.8% to 30% and reduce levels of HC exhaust emissions by 44-58% and CO decrease by 35-80% [10-12]. This electromagnetic field does not contain harmful element and safe to used in diesel engine vehicles [7,8,13,14].
The hypothesis is based on the theory of electric magnets by Bio-Savart, where when the magnetic field is given to a substance, its atoms will be oriented parallel to the direction of the magnetic field, and the vibration produced by this electromagnetic field causes wide distance between molecules hence fuel and oxygen will react easily, therefore a more perfect combustion occurs. The purpose of this study is to analyze the effect of temperature and pressure on a diesel engine performance.

2. Experimental Methods

2.1. Materials
The data was obtained by direct observation and measurement in the field. The experiment was conducted in the Energy Conversion and Heavy Equipment Laboratory, Jakarta State Polytechnic, on June 2018-August 2018. Instruments were calibrated and installed as shown in Figure 1. A 3-cylinder generator (Perkin 403D-15) with a power of 13.5 HP. The independent variables in this test are fuel composition (B0, B10, B30, B50, and B100 type) and variations in electromagnetic field (500 Gauss, 900 Gauss and 1500 Gauss). The dependent variable for this performance test is fuel consumption, temperature, and combustion chamber pressure.

![Figure 1](image-url) 

Figure 1. Flowchart of the generator set testing with load bank.

2.2. Sample preparation
The magnitude of fuel consumption, temperature, pressure and exhaust emissions was observed. Diesel engine rotation was measured with a Digital Tachometer. Temperature and pressure sensors were positioned to insert into the combustion chamber. Data result from temperature and pressure sensors were stored in data bases through NI USB 6009 and NI USB 9213 interface. The results were displayed on a laptop equipped with LabVIEW program. The test was started by turning on Perkin P135-4 diesel engine at 1550 rpm and left for ± 10 minutes to get the engine's normal working temperature.

Fuel consumption is calculated based on the difference in the fuel level on measuring cup that connected to the fuel tank, per time unit. Measurement and recording of fuel consumption was carried out five times, on each time fuel and electromagnetic field changes. The temperature and pressure of the combustion chamber are observed through a pressure sensor capable of measuring up to 750 Psi and a R type temperature sensor capable of measuring up to 1750°C. Both sensors are connected to the data logger for pressure and temperature on each NI USB 6009 and NI USB 9213 interface. The data sampling is 400 data/second. The results of temperature (T) and pressure measurement data are used to calculate the thermal efficiency of the engine using Equation (1).
\[ H_{th} = 1 - \frac{1}{k} \left( \frac{T_4 - T_1}{T_3 - T_2} \right) \]  

where:

- \( \eta_{th} \) is the thermal efficiency;
- \( T_1 \) is the temperature at point 1 (K);
- \( T_2 \) is the temperature at point 2 (K);
- \( T_3 \) is the temperature at point 3 (K);
- \( T_4 \) is the temperature at point 4 (K);
- \( C_p \) is the heat capacity at constant pressure (kJ/kg.K);
- \( C_v \) is the heat capacity at constant volume (kJ/kg.K);
- \( k = \frac{C_p}{C_v} \) is the specific heat ratio.

Thermal efficiency is the amount of utilization of heat energy stored in fuel to be converted into effective power by an internal combustion motor. Thermal efficiency is calculated using P-V and T-S diagrams.

Figure 2. (a) P–V and (b) T–S Diagram.

Fuel condition data results were compared before and after magnetization. The data then processed quantitatively in the form of several graphs, namely the graph of thermal efficiency of the load, graph of the temperature of the combustion chamber against time, and graph of combustion pressure against time.

3. Results and discussion

Diesel engine performance is indicated by fuel consumption, specific fuel consumption, thermal efficiency and exhaust emissions. Therefore, research data leads to these indicators. Every data is presented and analyzed in graphical form. Pressure and Temperature in the combustion chamber will make an oxidation reaction between fuel and air (oxygen) which produce heat. The fuel will burn perfectly when there is sufficient oxygen supply (O\(_2\)). The amount of oxygen reaches 20.9% of the air, 79% is nitrogen (N\(_2\)) and the rest are other elements such as argon, helium, neon, krypton, carbon dioxide, hydrogen, xenon, and others. Complete combustion of hydrocarbon compounds will form carbon dioxide and water vapor, while incomplete combustion forms carbon monoxide.

Figure 3. Relationship between pressure in the combustion chamber and time at 2200 rpm.
The measurement of combustion chamber pressure was done to calculate thermal efficiency which is one of the engine performance indicators. Figure 3 shows the relationship between pressure in a combustion chamber and time for diesel fuel without magnetization. The graph data is obtained at 2200 rpm engine speed or equal to 36.67 rps, considering that 1 combustion cycle = 2 revolutions, for the engine speed of 2200 rpm there are 19 cycles in one second, hence the time of each cycle is 0.05 seconds and pressure of 525 Psi.

**Figure 4.** Relationship between pressure in the combustion chamber and the crank shaft angle on various types of fuel (a) B0 (b) B10 (c) B20 (d) B40 & (e) B100.
Figure 4 shows the relationship between pressure in the combustion chamber and the crank shaft angle on various types of fuel. This graph is obtained by converting Figure 3, which is on the x-axis from time to angle of the crank shaft. It shows that the greater the magnetic field exerted on the fuel the greater pressure that occurs in the combustion chamber. This is caused by the magnetized fuel causing the fuel molecule to vibrate and becomes unstable. This has an effect on the reduced attraction between the atoms causes the molecular affinity energy to be smaller, then the fuel molecule is more and easier to react with oxygen, and finally the combustion process becomes more homogeneous and the fuel burns more as a result the pressure becomes greater. More bioethanol mixture in gasoline causes the pressure to decrease, because although bioethanol has a high octane value, the power produced by the engine is getting smaller.

At the compression pressure there is a slight turn. This shows that at the time of the spraying of fuel has a lower pressure than the compressed air so that the pressure at that time did not rise and the time is very fast

Figure 5 presents a graph of the relationship between temperature in the combustion chamber and time, the same as in Figure 2 that the graph is obtained at engine speed of 2200 rpm or equal to 36.67 rps, given that 1 combustion cycle = 2 cycles, so for 2200 rpm engine speed there are 19 cycles in one second, and each cycle takes about 0.05 seconds and a temperature of 1050°C.

![Figure 5. Relationship between temperature in the combustion chamber and time.](image)

Figure 6 presents a graph of the relationship between the temperature in the combustion chamber and the crank shaft angle, this graph is obtained by converting Figure 5 is on the x-axis of time into the crank shaft angle. The greater the magnetic field applied to the fuel, the greater the temperature that occurs in the combustion chamber. This is caused by the magnetized fuel which causes the fuel molecule to vibrate more and becomes unstable, this has an effect on the reduced force attraction between atoms which results in smaller energy affinity of molecules, and more fuel molecules and easier to react with oxygen, finally the combustion process becomes more homogeneous and more fuel is burned and the pressure becomes greater. More bioethanol mixture in gasoline causes the temperature to decrease, because although bioethanol has a high octane value, the power produced by the engine is smaller.
Figure 6. Relationship between temperature in the combustion chamber and crank shaft angle with fuel variation, (a) B0 (b) B10 (c) B20 (d) B40 and (e) B100.

Figure 7 presents a graph of the relationship between pressure and temperature with respect to crank shaft angle. The temperature value is determined with the help of the intersection of the temperature graph with respect to time and dashed lines. One cycle has 4 steps, therefore one cycle in Figure 7 is divided by 4 equal dashes line hence the T1 (°C) value is the lowest temperature because air from outside enters the combustion chamber. Under these conditions both temperature and pressure are at the lowest value. T2 (°C) is the compression temperature where all valves are closed, so T2 > T1. Furthermore T3 (°C) is the combustion temperature at the pressure and the temperature is at the highest position and T4 (°C) is the exhaust temperature, where at this position the pressure will start to fall, while the temperature is higher than the temperature T1. Furthermore, the value of k is calculated using equation (1).
Figure 7. (a) Graph of 1 diesel cycle expressed by (a) pressure with respect to crank angle (b) temperature with respect to crank angle and (c) PV & TS graphs.

Figure 8 shows the relationship between thermal efficiency and the types of fuels that are magnetized and non-magnetized. The magnetized fuel has a higher thermal efficiency than non-magnetized fuel. Fuel magnetization functions to break down clumping fuel molecules into non-clumping and polarize fuel molecules. This has the effect of mixing the fuel and air more homogeneously therefore the fuel that burns more and combustion becomes perfect, and thermal efficiency increases.

Figure 8. Relationship between thermal efficiency with fuels.

The increase of the percentage of biodiesel mixture in diesel fuel causes a decrease in the value of thermal efficiency. The decrease in the value of thermal efficiency due to the high viscosity value of biodiesel makes its ability to form a homogeneous mixtures with air to be low. This causes
Combustion to be less perfect and thermal efficiency becomes lower. The increased in thermal efficiency ranges from 7 to 12%. The addition of the percentage of biodiesel mixture in diesel fuel causes a decrease in the value of thermal efficiency. The decrease in the value of thermal efficiency due to the high value of biodiesel viscosity makes its ability to form a homogeneous mixture with air to be low. This causes combustion to be less than perfect and the thermal efficiency becomes lower. The increase in thermal efficiency ranges from 9.2-18.3%. The results of the thermal efficiency calculation are shown in Figure 8.

4. Conclusion
Fuel magnetization causes an increase in temperature and pressure in the combustion chamber increase by 13% and in thermal efficiency by of 7 to 12%. In conclusion, fuel magnetization increase engine performance.

Acknowledgment
This research was supported by the Ministry of Research and Technology of Indonesia and Jakarta State Polytechnic

References
[1] Fayyazbakhsh A and Pirouzfar V 2016 Investigating the influence of additives-fuel on diesel engine performance and emissions: Analytical modeling and experimental validation FUEL 171 167-177
[2] Govindasamy P and Dhandapani S 2007 Experimental investigation of cyclic variation of combustion parameters in catalytically activated and magnetically energised two-stroke SI engine Journal of Energy & Environment 6 (4) pp 561-569
[3] Faris AS et al 2012 Effects of magnetic field on fuel consumption and exhaust emissions in two-stroke engine Elsevier Energy Procedia 18 pp 327–338
[4] Jain S and Deshmukh S 2012 Experimental Investigation of Magnetic Fuel Conditioner in I.C. Engine IOSR Journal of Engineering 2 (7) pp 27-31
[5] Singh AK and Solank RM 2013 Investigation of fuel saving in annealing lehr through magnetic material fuel sarver International Journal of Science and Research 6 (14) pp 178-180
[6] Patel P et al 2014 Effect of magnetic field on performance and emission of single cylinder four stroke diesel engine Journal of Engineering (IOSRJEN) 4 (5) pp. 28-34
[7] Kumar PV et al 2014 Experimental study of a novel magnetic fuel ionization method in four stroke diesel engines International Journal of Mechanical Engineering and Robotics Research, 3 (1)
[8] Kolhe AV et al 2014 Performance and combustion characteristic of DI diesel engine fueled with jatropha methyl esters and its blends Jordan Journal of Mechanical and Industrial Engineering 8 (1) pp 7-12
[9] Chaware K 2015 Review on effect of fuel magnetism by varying intensity on performance and emission of single cylinder four stroke diesel engine International Journal of Engineering Research 3 pp 174-178
[10] Okoronkwo C et al 2010 The effect of electromagnetic flux density on the ionization and the combustion of fuel American Journal of Scientific and Industrial Research 1 (3) pp 527-534
[11] Habbo AR et al 2011 Effect of magnetizing the fuel on the performance of an S.I. engine”. Journal Al Rafidain Engineering 6 (19) pp 84-90
[12] Siregar H and Nainggolan R 2012 Electromagnetic fuel saver for enhancing the performance of the diesel engine Global Journal of Research in Engineering Mechanical and Mechanics Engineering, Global Journal Inc (USA) 12 (6) pp 1-4
[13] Gaikwad DR and Dange HM 2014 Experimental investigation of four stroke si engine using oxyrich air energizer for improving its performance International of Technology Enhancement Engineering Research 2 (7) pp 2347-2354.
[14] Salih AM and Al-Rawaf MA 2015 The effect of increasing of diesel fuel temperature upon the engine performance by using two magnetic fields International Journal of Engineering Research and General Science 4 (3) pp 170-185