p-ISSN 1693-1246
e-ISSN 2355-3812
July 2017

Jurnal Pendidikan Fisika Indonesia 13 (2) (2017) 119-126
DOI: 10.15294/jpfi.v13i2.10152

http://journal.unnes.ac.id/nju/index.php/jpfi

THE EFFECT OF ELECTRO MAGNETIC FIELD INTENSITY TO BIODIESEL CHARACTERISTICS

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Received: 16 April 2017. Accepted: 27 June 2017. Published: 1 July 2017

ABSTRACT

Various studies of diesel fuel optimization have been done, one of them by using a permanent magnet on the fuel line, the lack of magnetic field intensity decreases along with time increasing by using an electromagnetic field. The purpose of this study is to analyse the biodiesel fuel characteristics due to exposure of electromagnetic fields in terms of the viscosity and vibration of these fuel molecules. Electromagnetic field is generated from wire coil of 5000-9000 on galvanum pipe with diameter of 1.5 cm and length of 10 cm and connected to 12 V batteries. Here, biodiesel fuel is inserted in a galvanum tube, magnetized for 1200 s, and tested its viscosity of the falling ball system by viscometer. Fuel functional groups as well as vibrations between fuel molecules are tested with FTIR. The results show that the magnetized fuel changes. The viscosity of fuels from 2933 to 2478 and an increasing in the absorption of fuel molecules ranges from 13-58%. Therefore, the increasing of vibrating fuel molecules decreases its molecular attraction tug. These indicate that the magnetized fuel molecule causes a changing in the fuel molecule, cluster becomes de-clustered. It is a potential method to clarify the phenomenon of fuel magnetization due to its efficient combustion process.

ABSTRAK

Berbagai penelitian tentang pengoptimalisasian bahan bakar motor diesel telah banyak dilakukan, salah satunya dengan menggunakan magnet permanen yang dipasang pada saluran bahan bakar, kekurangannya adalah intensitas medan magnetnya berkurang seiring dengan bertambahnya waktu. Untuk mengatasi hal tersebut digunakan medan elektromagnet. Tujuan penelitian ini adalah menganalisis karakteristik bahan bakar biosolar akibat paparan medan elektromagnet ditinjau dari viskositas dan vibrasi molekul bahan bakar tersebut. Medan elektromagnet dihasilkan dari lilitan kawat sebanyak 5000-9000 pada pipa galvanum yang berdiameter 1.5 cm dan panjang 10 cm serta dihubungkan ke baterei sebesar 12 Volt. Selanjutnya bahan bakar biosolar dimasukkan dalam tabung galvanum untuk dimagnetisasi selama 1200 detik dan diuji viskositasnya dengan viscometer sistem bola jatuh. Gugus fungsi bahan bakar serta vibrasi antar molekul bahan bakar diuji dengan FTIR. Hasil penelitian menunjukkan bahwa bahan bakar yang dimagnetisasi memberikan perubahan karakteristik biosolar. viskositas bahan bakar menurun dari 2.933 menjadi 2.478 dan peningkatan intensitsas absorbsi molekul bahan bakar berkisar 13-58%. Ini berarti, dengan bertambahnya molekul bahan bakar yang bervibrasi menyebabkan makin meningkatnya molekul bahan bakar yang memiliki gaya tarik antar molekulnya rendah. Dua hal ini menunjukkan bahwa molekul bahan bakar yang dimagnetisasi menyebabkan perubahan molekul bahan bakar yang awalnya menggumpal (*cluster*) menjadi tidak menggumpal (*de cluster*). Informasi ini berguna untuk penelitian lebih lanjut agar secara jelas dapat mengklarifikasi fenomena magnetisasi bahan bakar terhadap proses pembakaran yang efisien.

Keywords: Biodiesel; Electromagnet; The magnetization fuel; Viscosity; The functional froup

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INTRODUCTION

Nowdays, energy becomes an absolute necessity. Almost all of the facilities and infrastructure supporting human life is driven by energy. The used energy sources, oil sources, can not be renewed so that the supply is getting thinner. Ussualy, we just look for someway to save and reduse in consuming the fuel, also improve the fuel quality and find some renewable energy sources. Several studies have been done in order to save energy through improved combustion efficiency, *e.g.* adding certain additives into fuel which results in the *octane* value and *cetana* rising, better combustion process, and higher engine power (Fayyazbakhsh & Pirouzfar, 2015; Samoilov et al., 2016).

Another way to improve the combustion efficiency is fuel magnetization. This process is done by putting a permanent magnet on the fuel line of the combustion chamber. Some researchers have reported that the magnetization of fuel resulting in a reduction of fuel consumption (9-30%) and the reduction of exhaust emission levels of HC (5-32%) and decreasing in CO (5-34.3%) (Faris et al., 2012; Kumar et al., 2014; Ugare, Dhoble, Lutade & Mudafale, 20 14). However, both of them have the disadvantage that almost all the chemical additives that are widely circulated and used by the community contain metals that harm to human health. On the other hand, the use of permanent magnets, its power will be reduced over time.

One way to reduce the negative effects of those problems by making an instrument that is capable of functioning as a substitute for fuel chemical additives and permanent magnets. The nature of this instrument is non-chemical and uses the physical energy of a magnet generated by an electric current (electromagnetic field). This instrument when installed on petrol and diesel engines can minimize fuel consumption of up to 12.8-30% and lower levels of HC exhaust emissions by 44-58% and CO decreased by 35-80% (Okoronkwo et al., 2010; Fatih & Gad, 2010; Patel et al, 2014; Chaware, 2015). The electromagnet field generated by this instrument reacts by weakening the hydrocarbon molecular bond structure inside the fuel, so that both hydrogen and carbon in the fuel can react better with oxygen to produce better combustion processes inside the combustion chamber (Guo, Liu, Chen and Yao t, 2011; Attar, Tipole, Bhojwani & Deshmukh, 2013)

Instruments is able to generate an electromagnetic field can be seen in Figure 1. The instrument consists of a cylinder made of pipe galvanum of radius R and length L, tied by copper wire N windings and given electric current i. On this condition will be obtained electromagnet field at P.

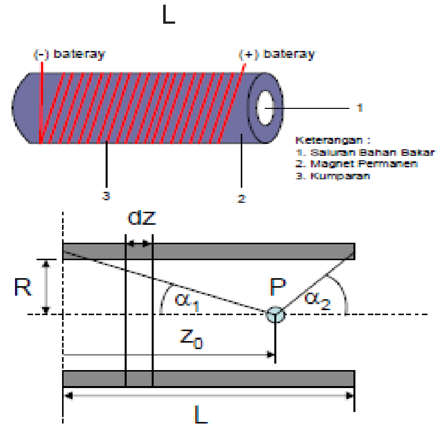

Figure 1. Electromagnetic field instrument (Bachtiar, 2007)

Dividing the length of the cylinder into a long-dz elements, where in each dz containing

$N\frac{dz}{L}$ coil (Halliday & Resnic, 2000). (1)

$$B_z(z_0)=\frac{\mu_o N\ R}{2L}\int_0^L \frac{dz}{\left[(z_0-z)^2+R^2\right]^{3/2}}$$

$$R=z_0\tan\alpha_1$$

$$R=(L-z_0)\tan\alpha_2$$

$$z-z_0=R\cot\alpha$$

$$dz=\frac{R}{\sin^2\alpha}d\alpha$$

$$\left[(z_0-z)^2+R^2\right]^{3/2}=\left(\frac{R}{\sin\alpha}\right)^3$$

Then the magnetic induction at point P

$$B_z(z_0)=-\frac{\mu_o N\ R^2}{2L}\int_{\pi-\alpha 1}^{\alpha 2}\frac{(R/\sin^2\alpha)}{(R/\sin^2\alpha)^3}d\alpha \quad (2)$$

$$=\frac{\mu_o N}{2L}\int_{\alpha 2}^{\pi-\alpha 1}\sin\alpha d\alpha$$

$$=\frac{\mu_o N}{2L}\left[-\cos(\pi-\alpha_1)+\cos\alpha_2\right]$$

$$B_z(z_0) = \frac{\mu_o N}{L}\left[\frac{\cos\alpha_1 + \cos\alpha_2}{2}\right] \quad (3)$$

If the length of the solenoid bigger than its radius and z_o not close to zero or L, then the angle of α_1 and α_2 is small and it can be approximated by:

$$\alpha_1 = \frac{R}{z_0}; \alpha_2 = \frac{R}{L - z_0}$$

So that

$$B\ (z0) = \frac{\mu_o N}{L}\left[1 - \frac{R^2}{4{z_0}^2} - \frac{R^2}{4(L - z_0)^2}\right] \quad (4)$$

If the solenoid radius is small, then the magnetic field becomes:

$$B = \frac{\mu_o \mu N\ i}{L} \quad (5)$$

Permeability μ of any other material expressed as multiples μ_o multiplier is called *the relative permeability* μ_r, so that

$$B = \frac{\mu_o \mu N\ i}{L} \quad (6)$$

$$B = \frac{\mu_r N\ i}{L} \quad (7)$$

Notes :
B: Magnetic field (Tesla)
μ: permeability core material (core) = 31, 76
μ_o:permeability of air vacuum = 1, 256 G cm / A
N: number of inductor coils
A: cross sectional area of the inductor (m^2)
L: length of the inductor (m)

In this research, fuel used is biodiesel derived from Pertamina. Biodiesel fuel is mixed fuel for diesel engines consisting of non-fossil biological oil by 10% which has been formed into *fatty acid methyl ester* (FAME) and 90% pure diesel subsidy. This fuel will gradually reduce role of solar. Non-fossil bio-oil added in diesel is known as biodiesel. The addition of biodiesel to diesel fuel is done because biodiesel has several advantages. According to Canakci and Van Gerpen (2001), the advantages of biodiesel include higher cetane number than diesel fuel, contains no aromatic compounds, barely contains sulfur, and has a 10-11% oxygen content. In addition, emissions of carbon monoxide (CO), hydrocarbons (HC), and compounds of particulate matter (PM) in the exhaust gas generated less than that of petroleum diesel. Chemical structures of biodiesel fuel is shown in Figure 2.

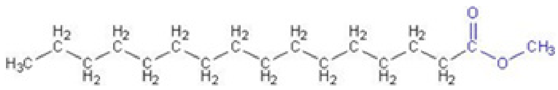

Figure 2. Chemical structure of biodiesel.

The atomic theory illustrates the phenomenon that the negative electrons that rotate around the atom's nucleus influence whether or not a substance can be influenced by a magnetic field. As the elements contained in the hydrocarbon fuel which comprises (H^+) and (C^-) where the number of electrons is not the same, then the substance can be influenced magnetic field.

In physics, the cause of magnetism in the object is atomic magnetic moments associated with the electron movement, the electron moves in its orbit around the nucleus and the electron spins on its axis (spin), so it has a spin angular momentum, *i.e.* the spin up (+1/2) and spin down (-1/2) as presented in Figure 3. Thus, fuel is a substance that can be affected by a magnetic field.

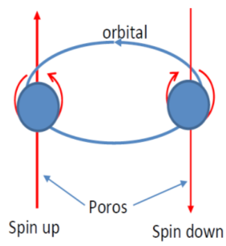

Figure 3. The magnetic moment associated with orbital and spin of electrons.

Based on the theory of the bonding moment when a polar bond such as OH is left in a magnetic field, the bond will experience a number of back forces. This force simply pushes the magnetic field to free the bond in the field. The more polar bonds experience a greater force than the less polar ones. HC including non-polar bond that is forming a major element in the fuel, because the value of the bond moment simply by 0.4 D *(Debye).* However a strong magnetic field can interfere with and affect the HC bond. Although the bonds between HC atoms are not released from each other, but at least the bond strength will weaken slightly.

Provision of an electromagnetic field in the fuel molecules also cause adverse reactions between molecules *(de-clustering)* to form the optimal distance between the molecules of fuel. Molecular activity increased as a result of this magnetic field will also cause a molecular collection was split so that it becomes smaller molecules and cause fuel viscosity decreases (Rosensweig, 1989; Marques *et al* 1997).

The purpose of this study was to analyze the characteristics of biodiesel fuel as a result of exposure to electromagnetic fields in terms of viscosity and molecular vibration of the fuel.

METHOD

Electromagnetic fields generated by wrapping the wire diameter 0, 2 0 mm on the tube galvanum with the number of windings 5000, 7000 and 9000, then given a DC voltage of 12 volts.

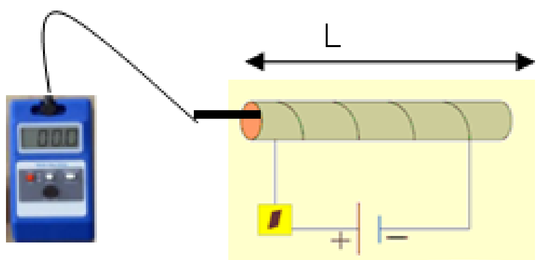

Figure 4. A series of strong electromagnetic fields gauges.

The next step is to measure the magnitude of the electromagnetic field strength by using Digital Teslameter Figure 4. These results were compared using Biot Savart formula as in equation 6.

Biodiesel fuel is exposed to electromagnetic fields which have a strong magnetic field intensity of 900-1500 Gauss (5000-9000 loops) during 0-1200 s. This is done by inserting the fuel in a galvanized tube that has been tied copper wire. The viscosity test was performed using a modification of the falling ball measurement system. This device consists of a sensor coil which is connected with computers and *adobe audition* 1.5 program as a translator signal from the sensor coil. The advantage of this method is its accuracy to detect until 1/1000 in a second. The series of gauges viscosity is shown in Figure 5.

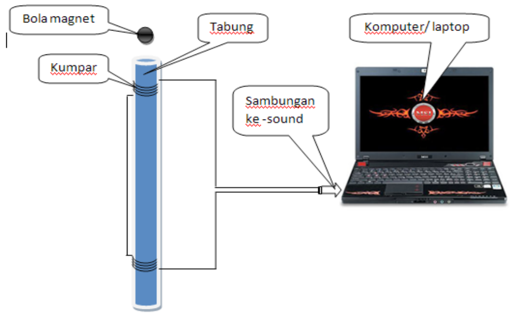

Figure 5. Series of Viscosity Gauges (Salim, 2012)

How the viscosity test kit works: the magnetic ball is dropped into the tube. When the magnetic ball moves through the coil at points A and B there will be a current on the wire. The current will be read by the existing sound card on the computer in waveform with decibels (dB) on y axis and time (seconds) on the x axis. When the magnet ball passes through the first coil and the second coil, then for the reading the time is taken as the ball passes through the initial and final coils. This data is recorded by software as in Figure 6.)

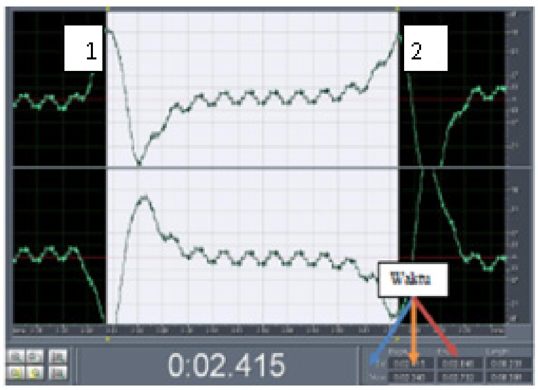

Figure 6. Biodiesel viscosity test results recorded on a computer.

At the beginning peak of wave 1 and wave 2. Time window shows the time data in numerical format. This data is presented in standard time display format (Minutes: second: per-thousand-second). The amount of viscosity can be calculated by the following equation.

$$\eta = \frac{2r^2 g\,(\rho_b - \rho_f)}{9L} \quad (7)$$

Notes:
η : fuel viscosity (cSt)
r : radius of the sphere (0.00215 m)
t : travel time ball in a fluid (s)

g : gravity (9.8 $m/s^{2)}$
L : length of trajectory in the travel
ρ_b : Desitas ball (27638.475 $kg/m^{3)}$
ρ_f : Density of fuel (879 $kg/m^{3)}$

Viscocity test has been done repeatedly, each five times for one sample. It has been done for biodiesel before passing through the magnetic field and after passing through a magnetic field.

Molecule vibration measured using FTIR *spectroscopy IR Prestige-21 Shimadzu Co. Ltd.* The working principle of this tool is based on the number of *infrared* rays frequency are absorbed by certain energy level passes a compound under investigation, then the energy of these frequencies will be transferred to the compound that causes amplitude changes molecular vibration. There are two kinds of vibration, namely stretching vibration and bending (Figure 7), stretching vibration is a rhythmic movement along the axis of the bond so that the distance between atoms is increased or decreased. Bending vibration occurs because of the change of bond angles between the bonds on an atom.

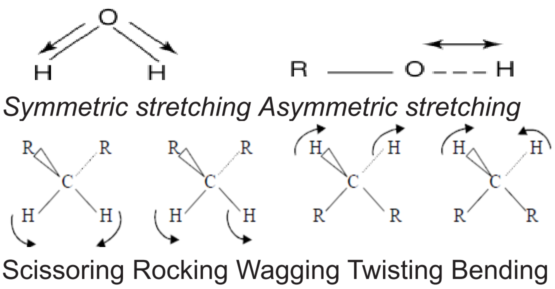

Figure 7. The form of Stretching and Bending vibration

Infrared absorption information generally provided in the form of the spectrum with a wave length or wave number (cm^{-1}) as the abscissa x and the intensity transmittance or percent absorption as ordinate y. This FTIR test serves to identify the functional groups contained in the biodiesel fuel either before or after passing through an electromagnetic field. To change the % transmittance to absorbance using *Lambert-Beer* formula:

$$A = -\log T \quad (7)$$

Notes:
A = Absorption
T = Transmission

RESULTS AND DISCUSSION

Table 1 shows the average of measurement electromagnetic fields as much as five times by using a digital Teslameter as shown in Figure 4 and using the formula t Bio Savart (Equation 6). It appears that the greater its windings the greater the strength of electromagnetic field generated. However, if the windings is too much causes the obstacles becomes large, and small current, so electromagnetic field is small, thus there is a limit to the maximum threshold for the number of windings.

Figure 8 shows a graph of the viscosity with the intensity of the magnetic field, it appears that the higher the magnetic field strength given to biodiesel would result in increasingly lower viscosity values or in other words the magnetic field strength is inversely proportional to viscosity hydrocarbons. On the other hand, exposure to a magnetic field on the fuel also affects the viscosity value, the longer the exposure time of the magnetic field the smaller its viscosity. This shows the effect of *de clustering* tendency in the hydrocarbon molecules that occur due to magnetization.

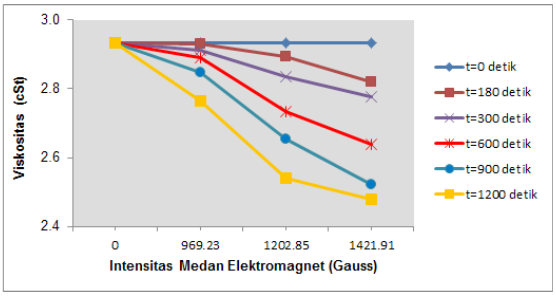

Figure 8. Graph of relation between Intensity of electromagnetic field and viscosity.

Table 1. Data of electromagnetic field measurements

Φ coil (mm)	Number of turns	V (volt)	i (mA)	R (MΩ)	BT (G auss)	BP (Gauss)
0, 2	5000	12	48, 4	251, 7	969, 23	969, 13
0, 2	7000	12	42, 9	283, 3	1202, 85	1201, 39
0, 2	9000	12	39, 5	288, 1	1421, 91	1419, 57

Notes: BT : Electromagnetic field calculated by theory (Bio Savart's formula); BP : electromagnetic field calculated by practice (Teslameter)

Smallest biodiesel viscosity occurs in the magnetic field exposure times for 1200 s. This exposure time is used to detect biosolar vibrations with FTIR.

Figure 9 is a graph of test results for biodiesel FTIR either magnetized or not. The greater the electromagnetic field strength given, the smaller the percentage of transmittance or the greater the percentage of absorbs according to the Lambert-Beer formula, but no changes in the structure of the magnetized biosolar compound. In addition, the results of these tests inform the functional groups contained in the biodiesel, *i.e.* the carbon-hydrogen bond (CH *stretching),* a carbon-oxygen bond (C = O *stretching),* carbon-carbon bond (CC *stretching)* and carbon-oxygen bond (CO *stretching*), the results are consistent with the molecular structure of the biodiesel that has been investigated by Berman et al., 2016.

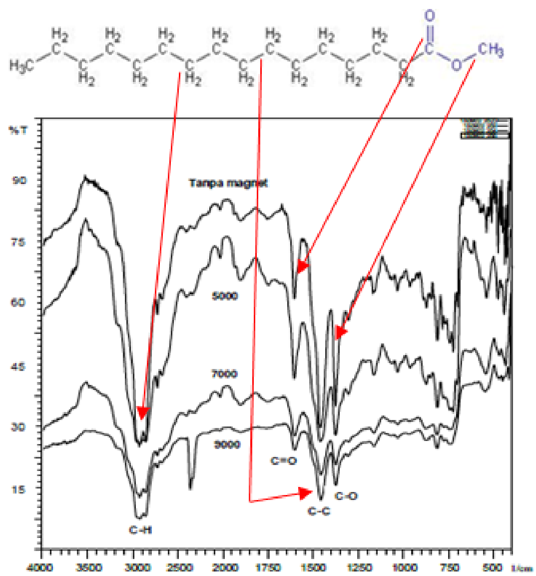

Figure 9. The FTIR spectrum of biodiesel.

With the help of Figures 9 and Lambert Beer formula at equation 7 obtained data such as the Table 2 indicating that the molecule of biodiesel that does not pass through the magnetic field transmittance percentage relatively larger or the absorption is smaller compared with the fuel molecules pass through a magnetic field.

C-H bonds have the greatest absorption intensity followed by a C-C bond, CO and the smallest C=O bond as presented in Figure 10.

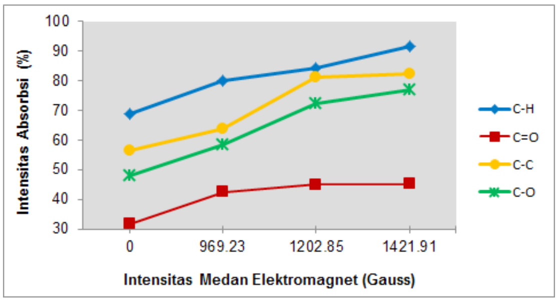

Figure 10. Chart of relationship between electromagnetic field intensity and intensity of absorption

The intensity of absorption can be correlated with the vibration of the functional group. Vibration occurs because the fuel molecule that gains additional energy (magnetic energy) causes the atom to be exited to a higher energy level, the excitation of this atom does not lead to the release of the molecular bond of fuel but merely vibrate. Equation (8) which is famous for Arrhenius equation can be illustrated to explain the phenomenon, on the condition of constant temperature and magnetic energy increases (the energy gap decreases) then the value of N (the number of molecules vibrating) increases. This condition is consistent for all fuels functional groups shown in Figure 10.

$$N = N_{o} \exp\left(\frac{-E}{kT}\right) \qquad (8)$$

Notes:
N : number of molecules after process
No : number of molecules before the process
E : energy
k : Bolzman constant
T : temperature

Table 3 shows changes in the value of

Table 2. Percentage of Biodiesel Absorption Intensity

Group	Wave numbers (cm-[1])	Percentageof absorption			
		No magnets	969.23 Gauss	1202.85 Gauss	1421.91 Gauss
CH	2850-2991	68, 74	80, 05	84, 25	91, 61
C = O	1690-1900	31, 59	42, 47	44, 99	45, 12
CC	1500-1600	56, 54	63, 92	81, 22	82, 36
CO	1080-1350	47, 93	58, 27	72, 33	7 5 85

Table 3. Percentage increase of the number of vibrations of biosolar molecules passing through the magnetic field

Group	Wave numbers ($cm^{-1)}$	Percentage of additions number of vibrations		
		969.13 Gauss	1202.85 Gauss	1421.91 Gauss
CH	2850-2991	16,453	22,563	33.270
C = O	1690-1900	34,441	42.418	42,830
CC	1500-1600	13,053	43,651	45,667
CO	1080-1350	21,573	50,908	58,252

the molecular vibration which are magnetized compared with the fuel molecules are not magnetized. It appears that the greater the electromagnetic fields given to biodiesel then the greater the number of molecules vibrate. The increasing of fuel molecules vibrate led to an increase of fuel molecules that have a low-molecular attractive force means that the lower the energy required for breaking bonds between atoms. It is related to the viscosity and surface tension of fuel decreases. Thus, it can be concluded that the tensile force of the hydrocarbon molecule decreases after it is affected by the magnetic field.

CONCLUSION

Based on this study, it can be concluded that the effect of electromagnetic fields on biosolar characteristics: 1) Electromagnet field on the fuel molecules does not change the molecular structure of biodiesel, but it affects to the absorption intensity, where the higher electromagnetic field strength are given to molecule, the greater amount of fuel molecules to vibrate or more molecules that have the attractive force between fuel molecules is low; 2) Higher strength of the electromagnetic field given to the biosolar molecule, lower viscosity of biodiesel; 3) Both of them amplify the phenomenon where the magnetization of the biodiesel is a product of *de-clustering* effect, this information is useful for further research in order to clearly be able to clarify the phenomenon of magnetization of the fuel-efficient combustion process.

ACKNOWLEDGEMENT

This research was funded by the Ministry of Research and Technology-DIKTI through scholarships and research grants PDD BPPDN 2017.

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