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MAGNETIZATION OF BIOETHANOL-GASOLINE FUEL BLENDS FOR DEVELOPMENT COMBUSTION ENERGY AND REDUCING EXHAUST GAS EMISSIONS

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The effect of the magnetization field on molecular interactions of the bioethanol-gasoline fuel blends was investigated. This technique was promoted to escalate both the increase in combustion energy and reduce emissions in the internal combustion engine. The bioethanol and gasoline fuel are used for the single-cylinder four-stroke engine with different mixtures, namely E0, E10, E20, and E30, serially. Distinguish of electromagnetic field strength with various intensity was given into the fuel by lower than 1,500 Gauss. The absorption intensity and the functional groups of the fuel molecules are characterized in detail by Fourier Transform Infra-Red (FTIR) spectroscopy. The exhaust gas emission and the fuel blends energy are performed using a gas analyzer and calorimeter bomb. By increasing the magnetic field, the de-clustering of the fuel molecules is demonstrated by growing the absorption intensity to be advanced. There is no change in the chemical composition of the fuel as the magnetic induction was enforced. Reduction of namely Carbon monoxide (CO), Nitrogen monoxide (NO), Nitrogen oxides (NO_x), and Sulphur Dioxide (SO_2) gas emissions was attained to be 29 %, 25 %, 26 %, and 31 % using a magnetic field of 1,419.57 Gauss, respectively, compared to gasoline fuel without magnetic condition. The greater reduction occurs by employing E30 fuel with the same magnetic intensity, achieved up to 38 %, 42 %, 70 %, and 63 %, regularly. The magnetization treatment leads to improved combustion quality with efficiency increases up to 11.32 %. It contributes to perfect combustion in a single-cylinder four-stroke engine system. Reducing gas emissions can also bring a good environmental impact in the life, although the heat energy gradually deteriorated as the fuel utilized more bioethanol blends

Keywords: magnetization fuel blends, mixtures of bioethanol-gasoline, reduction exhaust emission, combustion energy

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1. Introduction

The exhaustion of fossil fuels and environmental contaminants is considered a major issue responsible for the tendency to accelerate both global warming and national safety of energy. There were around 23 % of the total CO_2 emissions which are issued by the transport sector mentioned by The United Nations Economic Commission for Europe [1]. Therefore, greenhouse gas emissions originating from transportation are the most important parts for taking attention to be reduced from the air pollutants [2]. In the last decade, the problem of gas emissions from a motorcycle has been intensively addressed and become a serious concern [3]. A few strategies from both fuel system technology and fuel blend modification were developed to reduce the issues [4]. Some studies reported continually the handling progress to solve air pollution control by the addition of bioethanol into gasoline (gasoline-bioethanol) as a fuel blend. The studies focused on reducing the exhaust emission using oxygenates-gasoline blended fuels in gasoline-powered vehicles [5]. The bioethanol-gasoline blend can be used as an alternative fuel in reducing hydrocarbon and carbon monoxide emissions [6]. Another strategy is to develop fuel system technology to produce a perfect combustion process. Therefore, study on the development of combustion energy and reducing exhaust emissions is relevant to be environmentally friendly.

2. Literature review and problem statement

The gasoline-bioethanol mixture has been considered as one of the best alternative fuels when oil and natural reserves are running low. It is known that compared with gasoline, bioethanol has a higher-octane number [7]. Bioethanol can be added to gasoline which can increase the octane value, where the octane number for 98 % ethanol is 115. Besides, the mixture of ethanol-gasoline with the bioethanol containing 30 % oxygen can be categorized as high-octane gasoline (HOG). So, it can decrease gas emissions up to 50 % compared to fossil fuels [8]. Moreover, compared to traditional gasoline, the advantages of bioethanol are due to flammability, heat evaporation, higher oxygen content, and higher-octane values [9, 10]. Thus, they can degrade the temperature of the cylinder, thereby reducing NOx emissions and producing less CO_2. It can also reduce arranged gaseous emissions, such as carbon monoxide (CO), greenhouse gas (GHGs) and total hydrocarbons emissions (THC) [11]. So, the handling related to the emission problem was done by mixing gasoline with bioethanol at certain levels. However, a lower calorific value of bioethanol has been an obstacle to generating reliable engine power. It occurs due to lower heat combustion associated with per unit mole of mass and volume than petroleum [12]. Study of particulate and gaseous emissions from fueled with bioethanol and gasoline blends at ultra-high injection pressure reported that increasing bioethanol contents on bioethanol-gasoline blend reduce the production energy from the fuel combustion even though the total THC and NOx emission could be decreased [13]. However, bioethanol has some drawbacks due to its high viscosity and octane number where the combustion process on standard gasoline engines cannot run completely.

An excellent fuel structure for the internal combustion engines is the most challenging approach to reach better energy combustion and lower gas emissions. Therefore, some researchers have made efforts to modify the fuel characteristic for improving the combustion efficiency and decreasing the pollutants product using magnetic field. Among the fuel structure modification method, utilizing electromagnetic fields is one of the powerful techniques that has been employed to generate better fuel conditioning [14]. Its strategy facilitated the turn of fuel properties with an alteration molecule structure. The magnetic fuel treatment influences better atomization that reduces the amount of HC, CO, NOx in the exhaust gas [15]. The effects of magnetic field permanent with the intensity of 9,000 G on performance, combustion, and emission characteristics of a spark ignition engine was investigated. They reported that the reduction of 4–12 % in fuel consumption and reduction in 11, 10, 18, and 10 % for CO, CO_2, HC, and NO_x emissions, respectively, compared to gasoline fuel without magnetic condition [16]. Another study on the magnetic fuel treatment on Engine's performance showed a reduction of fuel consumption up to 15.5 % and a reduction in the engine pollutants [17]. Therefore, promising results were obtained evidenced by the reduction in engine fuel consumption and main pollutants. Furthermore, the combustion process becomes more complete, and hydrocarbons decrease after being magnetized on different intensities of 2000, 4000, 6000, 9000 Gauss without retention time [18]. In addition, studied benzene combustion behavior in exposure to the magnetic field that activates new vibrational modes in exposure to strong enough magnetic fields for molecules of hydrocarbons, improving in average kinetic energy and then free energy of fuel [19]. However, the studies of magnetic fields on the fossil fuel blends (bioethanol-gasoline) are rare up to now. In addition, the investigation is carried out by the high intensities magnetization which uses the big magnet equipment requiring a large space.

3. The aim and objectives of the study

The studies w set the aim to analyze the influence of magnetization on the bioethanol-gasoline blends on the increasing combustion energy and reducing exhaust gas emissions. The design of the magnetic utilizing system is simpler for creating a significant change in the spectrum and it produces the energy combustion.

To achieve the set aim, the following objectives have been solved:

– to determine effects of fuel magnetization on molecular interactions of the bioethanol-gasoline blends on the increasing combustion energy;

– to specify effects of fuel magnetization on the reducing exhaust gas emissions;

– to establish the production energy on magnetized mixed fuel (bioethanol-gasoline) combustion.

4. Materials and methods of research

This research uses experimental methods and is supported by relevant theories. Table 1 presents the main properties of the modeled gasoline-ethanol fuel mixture. Bioethanol was made from fermented cassava peels and purity was 99 % by volume. EX shows a mixture of gasoline and bioethanol where X represents the percentage by volume of bioethanol in the mixture. The samples tested consisted of gasoline with octane 88 (E0), bioethanol (E100), 10 % bioethanol and 90 % gasoline (E10), 15 % bioethanol and 85 % gasoline (E15), and 20 % bioethanol and 80 % gasoline (E20). Each 5 ml fuel is placed in a metal tube, and controlling samples are placed at room temperature. The exposure system consists of a metal tube surrounded by magnets, the magnetic intensity varies 647.15 Gauss, 847.25 Gauss, and 1068.29 Gauss, and 1419.29 Gauss for 20 minutes. This design is different from that done by previous researchers who used a Helmholtz coil, with a parallel spherical pole and a 2000 Gauss magnet for 1–2 hours [9]. The advantages of this design are simpler and produce a significant change in spectrum.

Table 1

Properties of gasoline and bioethanol

Fuel type	Gasoline	Bioethanol
Chemical Formula	C_4–C_{12}	CH_3CH_2OH
Stoichiometric Air/fuel ratio	14.7	9.0
Density at 15 °C (gr/ml)	0.747	0.79
Research Octane Number	88	102
Lower heating value (MJ/kg)	44.0	26.78
Boiling temperature at 1 atm (°C)	40–210	78.4

Moreover, the fuel combustion process uses the single-cylinder four-stroke engine. Table 2 presents the engine specification which is employed for the experimental conditions.

Table 2

Engine specification for operation condition

Parameter	Value
Engine type	Single cylinder
Number of cylinders	Four-stroke
Fuel system	Injection
Engine capacity	125.00 cc
Bore×Stroke	52.4×57.9 mm
Compression Ratio	9.5:1
Camshaft Valve Train Configuration	Single Overhead Cams (SOHC)
Maximum power	9.39 HP (6.9 kW)) @ 8000 RPM
Maximum torque	9.60 Nm (1.0 kgf-m or 7.1 ft.lbs) @ 5500 RPM

The experimental setup is illustrated in more detail on the schematic diagram in Fig. 1. The fuel blend flows from storage to engine by passing the magnetic field. Before and after magnetization treatment, the absorption intensity and the functional groups of the fuel molecules were investigated using IRPrestige-21 Shimadzu FTIR spectroscopy.

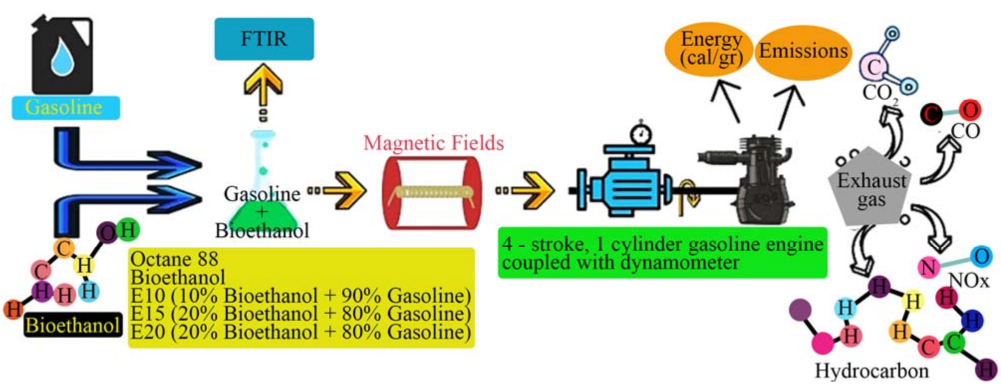


Fig. 1. Schematic diagram of the experimental setup

The fuel sample of 1 μl mixed with 0.5 g KBr was required for this test. The working principle of an FTIR spectrophotometer is based on the interaction between light energy and matter, where the energy emitted comes from infrared radiation with a wavelength of 400–4000 cm^{-1}. When infrared radiation is passed through a sample, the molecules can absorb energy and there is a transition from a basic vibration level (ground state) to an excited state [20]. The mixed fuel energy output is also characterized using Calorimeter Bomb by following the ASTM D4809 standard. Five different samples namely gasoline, bioethanol, E10, E20, E30 were measured, and exposed repeatedly for 3 times. Analysis was carried out using exposed and unexposed samples for comparisons. Finally, the gaseous emissions namely CO_2, NO, NOx, and SO_2 is measured by using a gas analyzer (ANOVA 2000).

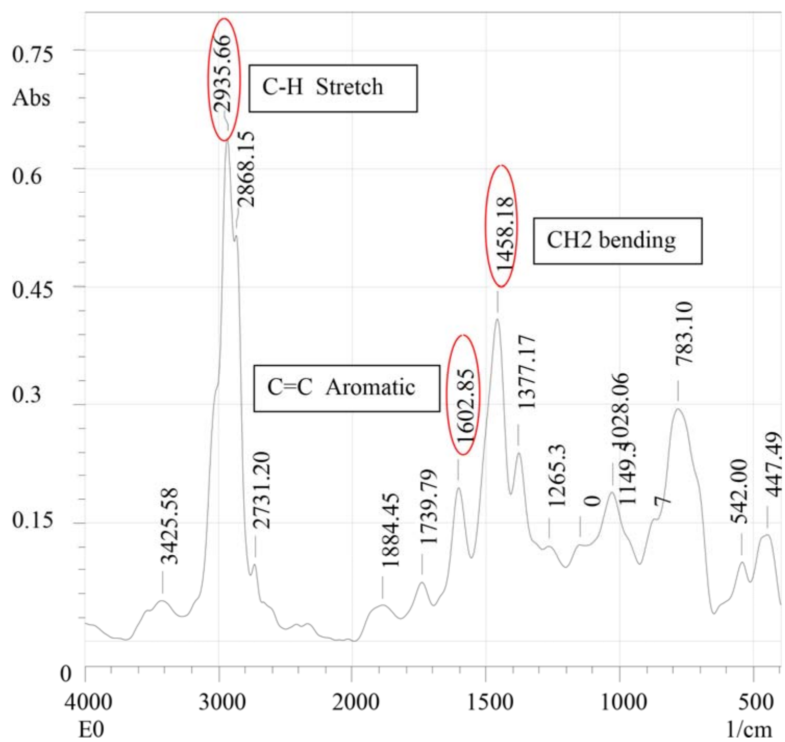
5. Results of influence the magnetization of bioethanol-gasoline fuel blends

5. 1. Studied effects of fuel magnetization on molecular interactions

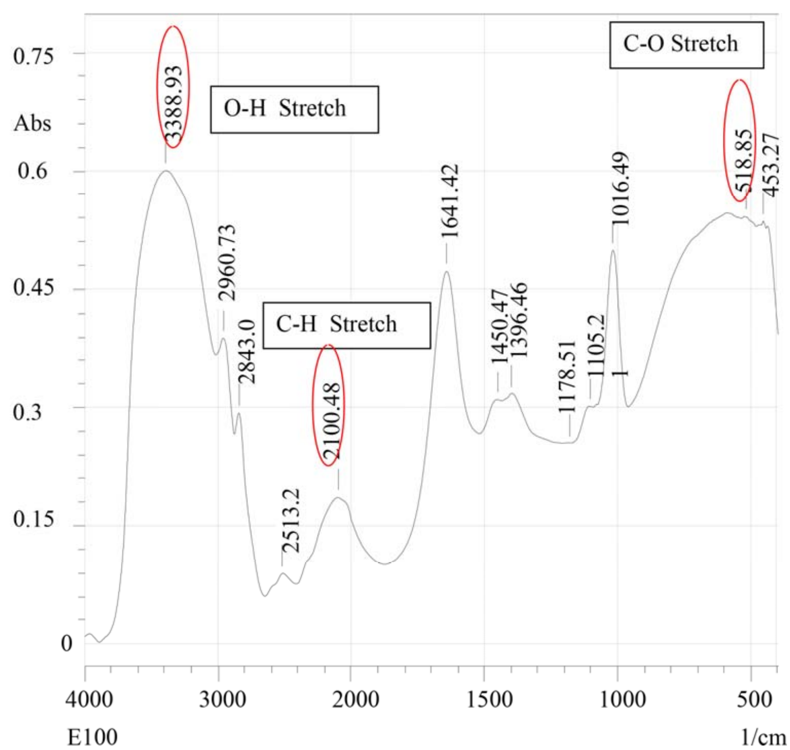
Fig. 2 displays the FTIR fuel results related to both E0 (pure gasoline) and E100 (pure Bioethanol). In gasoline fuel, there is a compound composed of hydrocarbon chains ranging from C7 to C11 which can have a straight or aromatic chain arrangement. One of the constituents of gasoline straight-chain hydrocarbons is n-Heptane (CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3). The formula of n-Heptane is possible for vibration that can occur is C-H stretch. Meanwhile, the aromatic group contained in E0 will give the possibility of vibration C=C aromatic stretch. Detail of the straight-chain hydrocarbon of E0 is displayed in Fig. 2, *a*. The CH stretch vibration peaks appear at wavenumbers 2868.15 cm^{-1} and 2935.66 cm^{-1}, and vibrational peak C=C aromatic stretch at wavenumbers 1602.85 cm^{-1}. The presence of a methylene group (CH_3-) as support for absorption at wavenumber 2935.66 cm^{-1} can be seen with the emergence of very sharp peaks at wavenumber 1458.18 cm^{-1}. The peak arises from the absorption of the CH_2 group by bending CH_2 symmetry vibrations.

Furthermore, Fig. 2, *b*, demonstrates the structure properties of bioethanol (E100) associated with FTIR. Bioethanol is ethanol processed biologically using natural raw materials. The chemical structure of bioethanol is the same as ethanol that is C_2H_5OH. The formula is also possible for vibrations that can occur in C-H stretch, C-O stretch, and O-H stretch. According to the results shown in Fig. 2, *b*, the emergence of the OH stretch vibration peak is located at wavenumbers of 3388.93 cm^{-1}. The vibration peak of CH stretch position is at wavenumbers both 2843.07 cm^{-1} and 2960.73 cm^{-1}. While CO vibrations peak is positioned at wavenumbers both of 1016.49 cm^{-1} and 1105.21 cm^{-1} as well.

The results of the FTIR characterization on the fuel (E0, E10, E20, E30, and E100) are shown in detail in Fig. 3. Distinguish of peak color demonstrates the different magnetic strength employed to expose the fuel blends. It could be seen that an increase in the magnetic field has generated the enhancement of peak intensity.



a



b

Fig. 2. Characterization results of Fourier transform infra-red fuels: *a* — Gasoline; *b* — Bioethanol

Thus, the magnetization treatment improves absorption intensity which influences an escalating number of molecules vibration of fuel. This vibration happens due to chemical bonds on that molecule absorbing the energy from electromagnetic waves, which then weakens the chemical bonds. So, the kinetic energy and free energy of fuel molecules increase to be higher for which optimize the combustion enthalpy [19]. The greatness of magnetization treatment was not changing the composition of the chemical structure of the fuel (no peak shift and no emergence of new peaks).

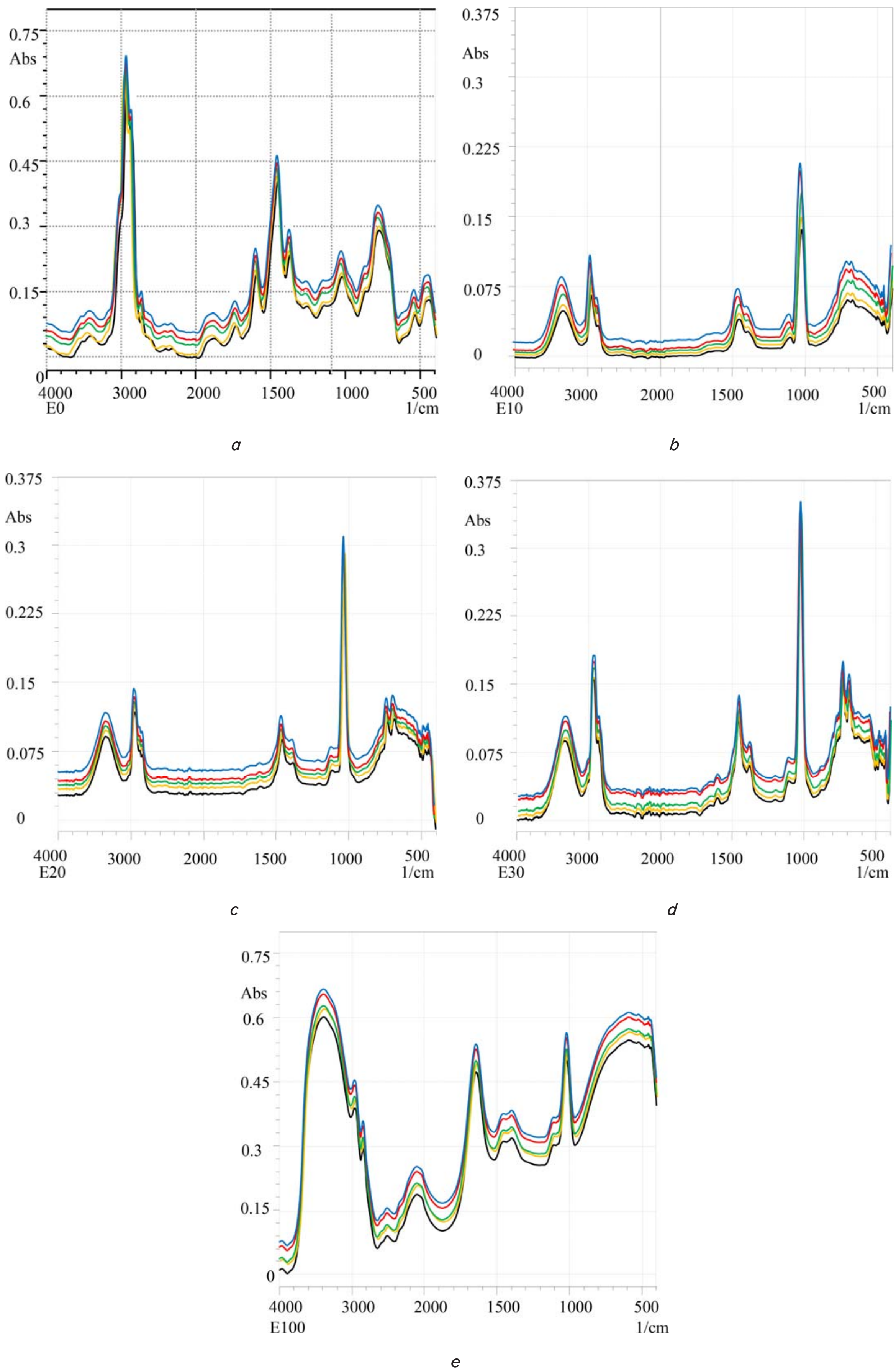


Fig. 3. Fourier transform infra-red fuels characterization without magnets to magnetic exposure: *a* – E0; *b* – E10; *c* – E20; *d* – E30; *e* – E100

5. 2. Studied effects of fuel magnetization on the emissions amount

Fig. 4 show the magnetic field process which is carried out in the fuel to enhance the heat energy. The fuel flows from the fuel tank to the combustion chamber. The magnetic field is put in the fuel line, and it modify the hydrocarbon cluster to be the dispersed fuel.

Clusters in hydrocarbons (due to non-polar) cause the phenomenon of incomplete combustion associated with the difficulty of oxygen entering the hydrocarbons. Thus, it produces CO gas and carbon residues both in the exhaust gas and in the combustion chamber walls. So, de-clusterization of hydrocarbon molecules is carried out because of magnetic induction which could lead to reduction in exhaust emissions from incomplete combustion, such as (CO, SO_2, NO, and NO_X) [21].

Fig. 5 demonstrates the effect of fuel blends and magnetic fields on the gaseous emission produced from the combustion process. It has tested exhaust gas emissions using a gas analyzer like the one used in this study [10, 11]. There are four kinds of gasses observed from exhaust gas namely CO_2, NO, NO_x, and SO_2 displayed in Fig. 5. By increasing the bioethanol content on the gasoline fuel, the gas emission gradually decreases to be lower.

In this case, bioethanol successfully reduces the exhaust gas emission from the internal combustion engine. Reducing gas emission from pure gasoline (E0) is achieved by about 31, 30, 55, and 59 % using the E30 fuel blends. However, the reducing value is followed by decreasing heat energy when bioethanol is added to be more in the gasoline fuel shown in Fig. 6.

5. 3. The studied energy test on magnetized mixed fuel (bioethanol-gasoline) combustion

Fig. 6 displays the fuel-burning energy employed in different fuel blends of E0, E10, E20, and E30 using various magnetic field strengths. It has conducted a combustion energy test using a bomb calorimeter like the one used in this study [22]. The trend line of energy produced by the fuel seems to be enhanced as magnetic field was added.

Tests with calorimeter bombs show the amount of combustion energy released. It appears in Fig. 6 that for all types of fuels, an increase in the amount of combustion heat released due to the magnetization effect. However, the addition of bioethanol content on the gasoline reduced the energy releasing from the fuel.

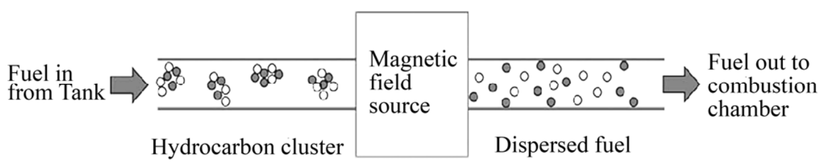


Fig. 4. Fuel magnetization process in the combustion chamber [18]

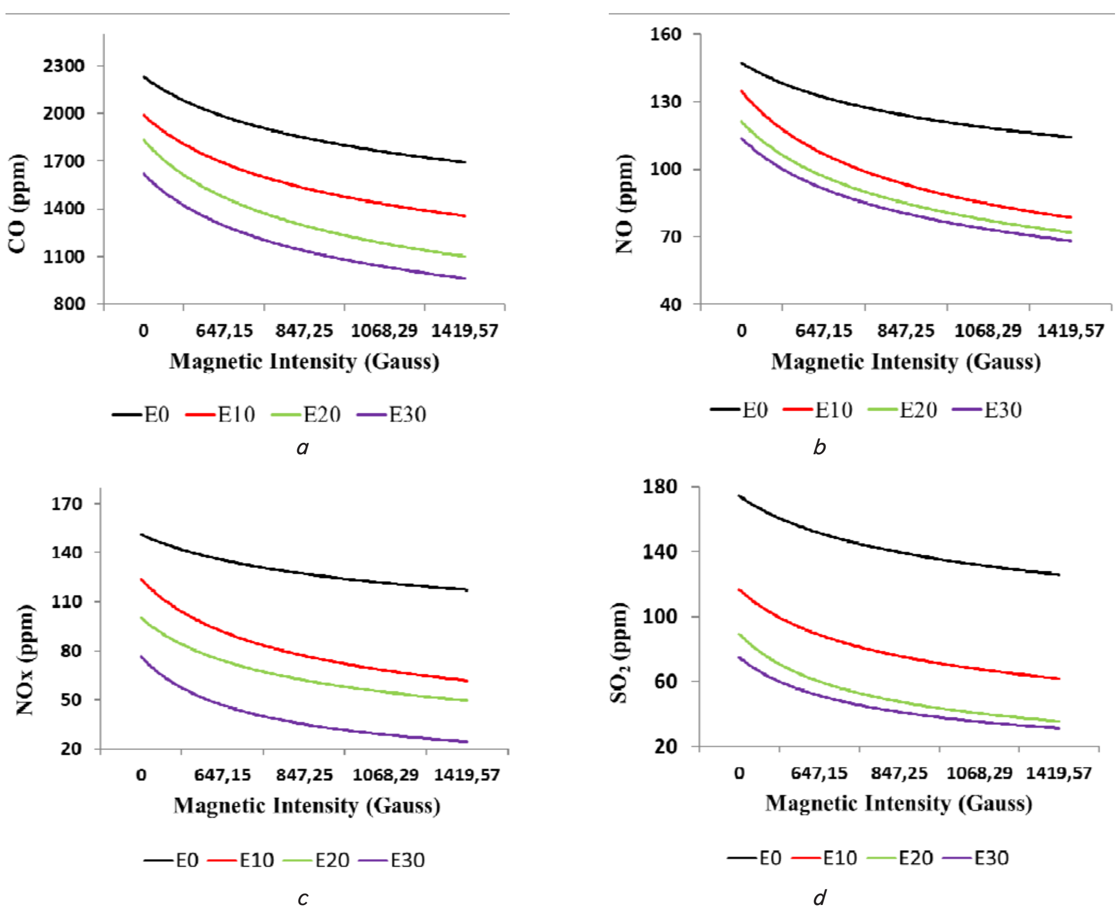


Fig. 5. Emissions testing result: *a* – CO; *b* – NO; *c* – NO_X; *d* – SO_2

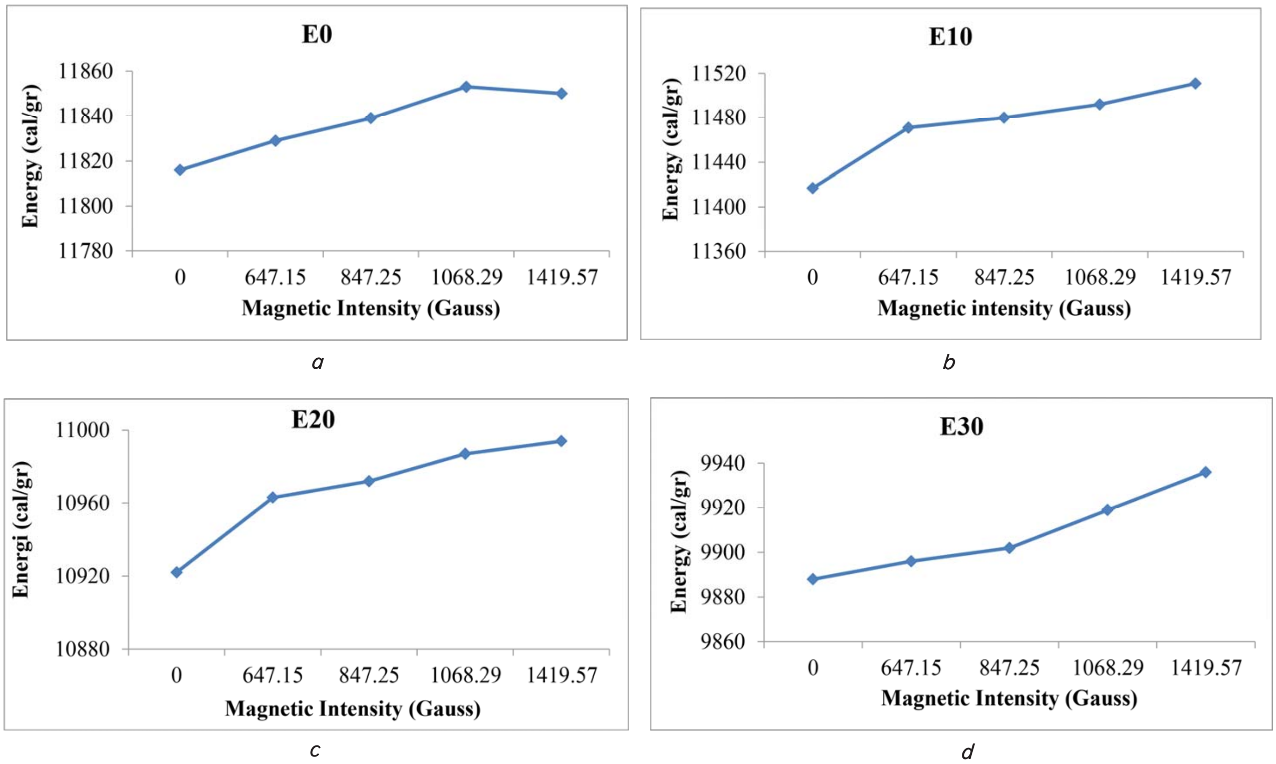


Fig. 6. Fuel burning energy test results: *a* – E0; *b* – E10; *c* – E20; *d* – E30

6. Discussion of results of influence the magnetization of bioethanol-gasoline fuel blends

The magnetization effect on the fuel is created from a moment originated by action of outermost electrons in the hydrocarbon chain [23]. It forces the electrons into states of higher principal quantum number, ionized and realigned the hydrocarbon molecules of fuel. De-clustering of hydrocarbon structure is done by weakening of their Vander Waal's bonds. Increasing the strength of the magnet will also increase the intensity of IR absorption of a composition. The highest magnetic strength gives the highest peak intensity absorption effect. Based on the FTIR results, the stronger magnetic exposure to the fuel, the higher vibrational received on the molecules, increasing the IR absorption intensity as well.

By the magnetic fields employed in the fuel, the gas emission decreases to be lower, and its values reduce continually with increasing the strength of the magnetic fields shown in Fig. 5. It is well known that the hydrocarbon molecule is a diamagnetic molecule. So, the existence of a magnetic field on hydrocarbon molecules can interfere and affect the H–C bond. It can pull away and stretch the bond between molecules, even though the bonds between H–C atoms are not separated from each other. The strength of the bonds will be slightly weakened due to stretching the bond so that the hydrogen and carbon atoms will be more easily attracted to oxygen in the combustion process [24]. Further, gasoline fuel is composed by molecules bonded to each other which is a long hydrocarbon chain. For this reaction to take place simultaneously in the combustion chamber, the first thing that must be done is to break the chemical bonds in the hydrocarbons [25]. Therefore, a spark is needed by the spark plug as an external energy source to break the chemical bonds. The chemical bond in gasoline fuel molecules plays an important part in creating energy. Every time a new chemical bond is formed, the energy is released. This exothermic bond-making energy will be used to heat up the air in the combustion chamber. Further, the hot air then will expand its volume in the combustion chamber which can be used to move pistons.

To form combustion products, namely CO_2 and H_2O, the hydrocarbon in the fuel must be cut off first to react with O_2. In real conditions, the hydrocarbon chain in fuel tends to form a cluster which can inhibit O_2 to react with ionized hydrocarbons. So, the exposure to external magnetic fields is used to polarize the hydrocarbons [26]. Subsequently, it generates in the active interlocking both of fuel and oxygen molecules, obtaining better completion of the combustion process [23]. The resulting test demonstrates in Fig. 5, suggesting more complete combustion and reducing levels of effective exhaust emissions. The influence of the fuel magnetization phenomenon on the combustion chamber causes polarization (due to magnetic induction) on hydrocarbon molecules, so that what used to be a cluster (non-polar) becomes a de-cluster.

There is a decrease in gas emissions in the emission test results on the use of fuels (E0, E10, E20, and E30) which are given magnetization treatment with a varying magnitude of the magnetic field. The reduction in exhaust emissions shows linear results in their respective applications fuel to the magnetizing effect which can be seen in detail in Fig. 5. By using different fuel blends between E0 to E30, reduction of gas emissions of CO, SO_2, NO, and NO_X occurred to be 31, 30, 55, and 59 %, respectively. While a decrease of gas emission of E0 gasoline using a magnetic field to 1,419,57 Gauss are 29, 25, 26, and 31 % for CO, SO_2, NO, and NO_X, serially. Moreover, the greater reduction occurs as using E30 fuel after magnetic treatment using similar magnetic intensity was achieved up to 38, 42, 70 and 63 % in gas emission of CO, SO_2, NO, and NO_X, regularly. According to the emission testing results, not only the content of bioethanol mixed with the gasoline fuel led to reduced gas emission but also the magnetic field strength employed to fuel blends.

Fortunately, with the enhancement of the magnetic field strength, the energy-burning of fuel can be increased to be higher. While the results of emission tests in Fig. 5 reinforce that a reduction in exhaust emissions of CO, SO_2, NO, and NO_X indicates a combustion efficiency. The reducing incomplete combustion due to the hydrocarbon molecules has been exposed to the effects of magnetic induction in the combustion chamber. Perfect combustion will produce more heat compared to incomplete combustion. While incomplete combustion causes reduced combustion efficiency because it produces less heat. The data in Fig. 6, b shows that burning E10 type fuel without the effect of magnetization releases heat of 11417 cal/gr, whereas if its type of fuel is given a magnetic exposure of 1419.57 Gauss will cause an increase in heat/heat released to 11511 cal/gr. The average combustion efficiency also increases up to 11.32 % due to the increasing energy generated during the combustion process. This shows that the application of the magnetizing effect causes the combustion efficiency shown by the heat generated to increase and the number of incomplete combustion emissions to decrease. Based on the fuel-burning energy related to the various magnetic fields, the increase of combustion energy is affected by the magnetic treatment given on the fuel blends. The better fuel energy generated on the system could be obtained by the optimum of the magnetic field created in it. The higher the magnetic intensity, the greater the interaction effect on the fuel molecules. However, it greatly affects the number of turns and the dimensions of the magnet become larger, making it aesthetically less comfortable. A small dimension of magnet equipment with a high intensity field is required as its method will be applied to motorcycle engines on public transportation. Moreover, low electrical energy to activate magnetic equipment at high intensity becomes an interesting study for the perfection of this system. In the future study, it could be necessary to analyze the effect of fuel magnetization on the fuel droplet size and its fogging distribution. They could be promoted for more complete combustion with both less gas emission and higer fuel burning energy.

7. Conclusions

1. The research determines effects of fuel magnetization on molecular interactions of the bioethanol-gasoline blends on the increasing combustion energy. Based on this, it can be argued that fuel exposed to a strong magnetic field below 1500 Gauss with a magnetization time of 20 minutes leads to a change in the chemical composition of the fuel. There is no peak shift, and no new peaks appear in the hydrocarbon molecule structure after the magnetic treatment. It could be seen that an increase in the magnetic field has generated the enhancement of peak intensity. The magnetization also improves absorption intensity which influences an escalating number of molecules vibration of fuel. Its process was not changing the composition of the chemical structure of the fuel (no peak shift and no emergence of new peaks).

2. The specify effects of fuel magnetization on the reducing exhaust gas emissions are following: the decreasing of gas emission of gasoline fuel using the magnetic field of 1,419,57 Gauss are obtained to be 29, 25, 26, and 31 % for CO, SO_2, NO, and NOX, serially. The greater reduction occurs as using E30 fuel after magnetic treatment using similar magnetic intensity was achieved up to 38, 42, 70, and 63 %, regularly. According to the emission testing results, not only the content of bioethanol mixed with the gasoline fuel led to reduced gas emission but also the magnetic field strength employed to fuel blends.

3. The results also establish the production energy on magnetized mixed fuel (bioethanol-gasoline) combustion. It can be proven that magnetized treatment significantly affect the combustion efficiency increases up to 11.32 % due to the increasing energy generated during the combustion process. The magnetization effect contributes to perfect combustion in a single-cylinder four-stroke engine system.

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References

1. Jhang, S.-R., Lin, Y.-C., Chen, K.-S., Lin, S.-L., Batterman, S. (2020). Evaluation of fuel consumption, pollutant emissions and well-to-wheel GHGs assessment from a vehicle operation fueled with bioethanol, gasoline and hydrogen. Energy, 209, 118436. doi: https://doi.org/10.1016/j.energy.2020.118436
2. Rahman, S. M., Khondaker, A. N., Hasan, M. A., Reza, I. (2017). Greenhouse gas emissions from road transportation in Saudi Arabia - a challenging frontier. Renewable and Sustainable Energy Reviews, 69, 812–821. doi: https://doi.org/10.1016/j.rser.2016.11.047
3. Li, L., Ge, Y., Wang, M., Peng, Z., Song, Y., Zhang, L., Yuan, W. (2015). Exhaust and evaporative emissions from motorcycles fueled with ethanol gasoline blends. Science of The Total Environment, 502, 627–631. doi: https://doi.org/10.1016/j.scitotenv.2014.09.068
4. Yao, Y.-C., Tsai, J.-H., Wang, I.-T. (2013). Emissions of gaseous pollutant from motorcycle powered by ethanol-gasoline blend. Applied Energy, 102, 93–100.doi: https://doi.org/10.1016/j.apenergy.2012.07.041
5. Lim, C.-S., Lim, J.-H., Cha, J.-S., Lim, J.-Y. (2019). Comparative effects of oxygenates-gasoline blended fuels on the exhaust emissions in gasoline-powered vehicles. Journal of Environmental Management, 239, 103–113. doi: https://doi.org/10.1016/j.jenvman.2019.03.039
6. Dhande, D. Y., Sinaga, N., Dahe, K. B. (2021). Study on combustion, performance and exhaust emissions of bioethanol-gasoline blended spark ignition engine. Heliyon, 7 (3), e06380.doi: https://doi.org/10.1016/j.heliyon.2021.e06380
7. Anderson, J. E., DiCicco, D. M., Ginder, J. M., Kramer, U., Leone, T. G., Raney-Pablo, H. E., Wallington, T. J. (2012). High octane number ethanol–gasoline blends: Quantifying the potential benefits in the United States. Fuel, 97, 585–594. doi: https://doi.org/10.1016/j.fuel.2012.03.017

8. Mohammed, M. K., Balla, H. H., Al-Dulaimi, Z. M. H., Kareem, Z. S., Al-Zuhairy, M. S. (2021). Effect of ethanol-gasoline blends on SI engine performance and emissions.Case Studies in Thermal Engineering, 25, 100891.doi: https://doi.org/10.1016/j.csite.2021.100891
9. Yang, H.-H., Liu, T.-C., Chang, C.-F., Lee, E. (2012). Effects of ethanol-blended gasoline on emissions of regulated air pollutants and carbonyls from motorcycles. Applied Energy, 89 (1), 281–286. doi: https://doi.org/10.1016/j.apenergy.2011.07.035
10. Sakthivel, P., Subramanian, K. A., Mathai, R. (2018). Indian scenario of ethanol fuel and its utilization in automotive transportation sector. Resources, Conservation and Recycling, 132, 102–120. doi: https://doi.org/10.1016/j.resconrec.2018.01.012
11. Costagliola, M. A., Prati, M. V., Murena, F. (2016). Bioethanol/gasoline blends for fuelling conventional and hybrid scooter. Regulated and unregulated exhaust emissions. Atmospheric Environment, 132, 133–140. doi: https://doi.org/10.1016/j.atmosenv.2016.02.045
12. Ghadikolaei, M. A. (2016). Effect of alcohol blend and fumigation on regulated and unregulated emissions of IC engines – A review. Renewable and Sustainable Energy Reviews, 57, 1440–1495. doi: https://doi.org/10.1016/j.rser.2015.12.128
13. Lee, Z., Park, S. (2020). Particulate and gaseous emissions from a direct-injection spark ignition engine fueled with bioethanol and gasoline blends at ultra-high injection pressure. Renewable Energy, 149, 80–90. doi: https://doi.org/10.1016/j.renene.2019.12.050
14. Abdul-Wahhab, H. A., Al-Kayiem, H. H., A. Aziz, A. R., Nasif, M. S. (2017). Survey of invest fuel magnetization in developing internal combustion engine characteristics. Renewable and Sustainable Energy Reviews, 79, 1392–1399. doi: https://doi.org/10.1016/j.rser.2017.05.121
15. Jain, S. (2012). Experimental Investigation of Magnetic Fuel Conditioner (M.F.C) in I.C. engine. IOSR Journal of Engineering, 02 (07), 27–31. doi: https://doi.org/10.9790/3021-02712731
16. Niaki, S. R. A., Zadeh, F. G., Niaki, S. B. A., Mouallem, J., Mahdavi, S. (2019). Experimental investigation of effects of magnetic field on performance, combustion, and emission characteristics of a spark ignition engine.Environmental Progress & Sustainable Energy, 39 (2).doi: https://doi.org/10.1002/ep.13317
17. Abdel-Rehim, A. A., Attia, A. A. A. (2014). Does magnetic fuel treatment affect engine's performance? SAE Technical Paper Series. doi: https://doi.org/10.4271/2014-01-1398
18. Faris, A. S., Al-Naseri, S. K., Jamal, N., Isse, R., Abed, M., Fouad, Z. et. al. (2012).Effects of Magnetic Field on Fuel Consumption and Exhaust Emissions in Two-Stroke Engine. Energy Procedia, 18, 327–338. doi: https://doi.org/10.1016/j.egypro.2012.05.044
19. Jalali, M., Ahmadi, M. S., Yadaei, F., Azimi, M. H. Z., Hoseini, H. M. (2013). Enhancement of Benzine Combustion Behavior in Exposure to the Magnetic Field. Journal of Clean Energy Technologies,1 (3), 224–227. doi: https://doi.org/10.7763/jocet.2013.v1.51
20. Stuart, B. H. (2004). Infrared Spectroscopy: Fundamentals and Applications. Analytical Techniques in the Sciences.doi: https://doi.org/10.1002/0470011149
21. Wibowo, N. A., Utami, S. M., Riyanto, C. A., Setiawan, A. (2020). Impact of Magnetic Field Strengthening on Combustion Performance of Low-Octane Fuel in Two-Stroke Engine.JurnalPendidikanFisika Indonesia, 16 (1), 57–62. doi: https://doi.org/10.15294/jpfi.v16i1.17491
22. Shen, J., Zhu, S., Liu, X., Zhang, H., Tan, J. (2012). Measurement of Heating Value of Rice Husk by Using Oxygen Bomb Calorimeter with Benzoic Acid as Combustion Adjuvant. Energy Procedia, 17, 208–213. doi: https://doi.org/10.1016/j.egypro.2012.02.085
23. Oommen, L. P., Kumar, G. N. (2019). A Study on theEffectofMagnetic Field on the Properties andCombustionofHydrocarbon Fuels. International Journal ofMechanicalandProduction Engineering Research and Development, 9 (3), 89–98. doi: https://doi.org/10.24247/ijmperdjun20199
24. Nufus, T. H., Setiawan, R. P. A., Hermawan, W., Tambunan, A. H. (2017). Characterization of biodiesel fuel and its blend after electromagnetic exposure.Cogent Engineering, 4 (1), 1362839.doi: https://doi.org/10.1080/23311916.2017.1362839
25. Chang, R., Goldsby, K. A. (2013). Chemistry.McGraw-Hill Education.
26. Kumar, P. V., Patro, S. K., Pudi, V. (2014). Experimental study of a novel magnetic fuel ionization method in four stroke diesel engines.Int. J. Mech Eng. Rob. Res., 3 (1), 151–159. Available at: http://www.ijmerr.com/v3n1/ijmerr_v3n1_17.pdf