Effect of magnetized ethanol-gasoline blends on vibration and sound emissions of a single cylinder SI engine

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Abstract

The purpose of the present study was to investigate the effects of magnetized ethanol-gasoline fuel blends on the vibration and sound status of a single-cylinder gasoline engine. Totally 36 tests were conducted including two factors: ethanol (with share of 0, 5, 10 and 20% blended with gasoline) and magnetic field intensity (0, 5300 and 7000 G) at three replications as factorial experiment based on completely randomized design. The sound signals of the engine at 10 cm distance from the driver's ear were recorded and its vibration was measured in Z direction. The results of statistical analysis of engine vibration and sound data showed a significant difference at 1% probability level between various fuel blends in all studied magnetic levels. The maximum sound pressure level with averages of 88.41 was belonged to pure gasoline and magnetic intensity of 7000 G and minimum value (78.94 dB) was belonged to 10% ethanol-gasoline blend and magnetic intensity of 5300 G. The driver can operate the engine for both 10–20% ethanol shares with all studied magnetic intensities without use of any ear protector. In the presence of magnetic field, vibration decreased by increasing ethanol up to 10%. The maximum amount of vibration in frequency domain obtained without using magnetic field. For 5300 G magnetic intensity, the least amount of vibration was observed at all frequencies.

Introduction

The motorized machines that are used in the field of transportation, industry and agriculture along with high advantages, have some disadvantages such as noise, vibration, and environmental pollutions. Today, reducing the emissions of internal combustion engines is one of the most important environmental concerns. Decrease of fossil fuel sources and increase of environmental pollutions of these fuels encouraged the researchers to conduct more investigations on renewable fuels (Iliev, 2019).

Several techniques have been applied to reduce engine emissions such as improving the engine design and enhancement of fuel characteristics adding biofuels to fossil fuels (Mwangi et al., 2015; Chang et al., 2014a). One of the prerequisites for using a fuel is how it affects the engine. Biofuels will reduce the use of fossil fuels and consequently emissions of greenhouse gases (Gobadian et al, 2009).

Bioethanol, biodiesel and pure vegetable oils have recently been considered as reasonable and promising biofuels. One of the most important of these fuels as alternative fuel is bioethanol which forms a proper fuel when it is blended in gasoline (Zoldy, 2011). Ethanol is a plant-based and renewable fuel with high oxygen content in its molecular structure. Therefore, it requires less oxygen than diesel and gasoline for combustion and therefore has fewer pollutants (Iodice et al, 2017). Also, it has a low octane number and is therefore used as an octane number augementer in spark ignition engines (Saxena and Williams, 2007).

The other technique which recently used to reduce emissions and fuel consumption is magnetizing the inlet fuel to engines using an external magnetic field (Govindasamy and Dhanapani, 2007; Hricak, 1994).

Intermolecular bond lengths and angles in liquid fuels play important roles in determining surface

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 e fuel stream, as the bond angle increases, the surface

tension decreases, which improves fuel evaporation resulting in more complete combustion. Also, internal energy of the fuel molecules increases and they are more easily separated and their tendency to react with oxygen cause to have better combustion process (Chen et al, 2017; Pramodkumar et al, 2017).

Investigating the sound emission and vibration resulting from the combustion process in internal combustion engines has always been of interest to researchers. The vibration directly has a destructive effect on the engine parts and operators as well as the noise that causes an adverse impact on the operators (Jahanbakhshi et al, 2017; Melemez and Tunay, 2010; Carlucci et al, 2006).

Many researchers have studied the relationship among gasoline and ethanol fuel mixtures and performance, vibration, and noise parameters of SI engines. Experimental results showed that with increasing ethanol in the fuel mixture, the engine performance increased while the environmental pollutions, vibration and noise of the engine decreased (Hasan, 2002; Salles et al, 2008; Keskin, 2010; Tibaquira et al, 2018).

In the literatures, effect of the magnetic field on fuel characteristics (Govindasamy and Dhanapani, 2007), engine performance (Patel, et al, 2014; Habbo et al, 2011) and engine exhaust emissions (Aydin and Ogut, 2017; Mane and Sawant, 2015; Khalil, 2012) have been reported. The results showed that the magnetic field could improve combustion and ultimately enhance the engine performance.

While most studies report engine performance under ethanol-gasoline blends or operate magnetic field on the fuel separately, an analytical experiment is required to explore effect of these conditions simultaneously on vibration and sound emission of engine. Therefore, this work focuses on the blending ethanol with gasoline in proportions ranging from 0 to 20% (V/V) and then a magnetic field applied on the fueling system line to assess the impact of magnetic field on vibration and noise emissions of single-cylinder four-stroke SI engine.

Material And Methods

Experimental equipment and data acquisition

In this work, the vibration and noise pollution of a single-cylinder direct-injection gasoline engine of a lawnmower (Model 53 PO, Italy) with maximum power output of 2.6 kW and a constant speed of 2850 rpm were studied.

Ethanol fuel was used to make fuel blends based on volumetric ratio. Different mixtures of ethanol-gasoline fuels were prepared by volumetric ratio of 0 (E0G100, pure gasoline), 5 (E5G95), 10 (E10G90) and 20% (E20G80).

To magnetize the fuel blends, six neodymium magnet blocks with $50 \times 40 \times 20$ dimensions were used. This magnet is one of the strongest and most popular types of magnets and is known as a mineral magnet because of its elements such as neodymium.

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The two boxes with inner diameters of 40×150 mm were provided to mount the magnets in the fueling line systems. The intensity of magnetic field has a reverse relation with the distance of the magnets from each other. So, to provide the magnetic intensities of 5300 and 7000 G, two intervals were considered as 10 and 5 cm, respectively.

The magnet was installed between the fuel tank and engine. A non-magnet fuel line were provided and implemented on the studied engine (Fig. 1).

In order to reach steady state during the tests, the engine warmed up for 10 min with pure gasoline and there were about 10 min intervals between two consecutive experiments. Then the different prepared of ethanol-gasoline blends were poured into the fuel tank. To create the magnetized blend, the magnet blocks put on both sides of the fuel pipe line to create the desired magnetic field. Then sound and vibration of the engine were measured.

To measure the vibration of the lawnmower engine according to IEC 1010, CE and ISO 9001 standards, a accelerometer (VB-8203, Lutron, Taiwan) with accuracy of 0.1 m.s^{-2} and the frequency range of 0.01-10 kHz was used. This accelerometer has a magnetic base to enables fast and constant connection to the surface of the object that was positioned perpendicular to the engine body (Z direction).

A sound level meter (SL 4013, Lutron, Taiwan) with accuracy of 0.1 dB and frequency range of 31.5–8000 dB was applied. The device has two outputs, AC Voltage Output and RS232 Computer Interface Output. The microphone connected to the sound level meter senses sound pressure changes and converts them to voltage changes. To record the vibration and acoustic data, the device software, Lutron 801 model SW-U801-WIN, was used.

The characteristics of the test site for measuring the noise of the lawnmower engine selected in according with the standards of the International Organization and the Society of Automotive Engineers (ISO 5131, 1996; ISO 7216, 1992), so that the measurement area should be a flat and open land without cover and large reflective surfaces at a distance of at least 50 meters from the test site.

Measurements were carried out under ambient conditions with no precipitation and wind speeds lower than 5 m.s^{-1} . Therefore, the conditions of the test site environment such as background noise level, wind speed and ambient air temperature were measured during the tests.

In this study, the sound level was measured in the driver's ear position so that the microphone was located 10 cm away from the driver's ear. The test was carried out with an ambient temperature of 12°C and a wind speed of 1.8 m.s^{-1} .

Analysis Of Engine Vibro-acoustic Emissions

In this study, statistical analysis of data in time domain was performed as factorial experiment based

Loading [MathJax]/jax/output/CommonHTML/jax.js¹ Software. The main factors in this study included fuel (four

levels) and magnetic field intensity (three levels). The measured attributes were vibration and sound signals. Experiments were performed at constant engine speed and in three replications (Table 1).

Table 1
Experimental conditions to measure engine sound and vibration.

Variables Level	1	2	3	4
Fuel blends (% ethanol)	0	5	10	20
Magnetic field (Gauss)	0	5300	7000	
Engine rotational speed	2850 rpm			
Sound level meter position	10 cm from away from driver's ear			
Accelerometer position	On the engine at Z direction			

Time-domain analysis of signals shows the general trend of data changes due to variables, but it is necessary to convert the signals frequency domain to obtain further information. Often the time response function does not provide much useful information, while the frequency response represents one or more separate frequencies where their energy is concentrated (Ahmadian et al, 2013). There are two main reasons for obtaining frequency content, 1) the response of human organs and mechanical systems depends on frequency and 2) the physical processes of propagation, transmission, and energy content of vibrational and acoustic signals depend on their frequency. So it is necessary to convert the signals from the time to the frequency domain. The result of the conversion of the signals from the time to the frequency domain is achieving the narrow band spectrum of sound and vibration acceleration. Figure 2 shows the procedure of analyzing of sound and vibration signals

To calculate the one-third octave band, the values of the narrow band data are logarithmically summed over the specified frequency bands and therefore high and low peaks and sudden fluctuations in the narrow band signals are deleted (Heidary et al, 2013).

By definition, one-third octave band is equal to a range of frequencies where the ratio of high frequency (f_2) to low frequency band is equal to $2^{1/3}(f_1)$. Frequency center value (f_c) of the one-third octave band are defined as the geometric mean of the upper and lower frequencies. Thus for the one-third octave band there will be

$$f_c = \sqrt{f_1 f_2} \quad \text{and} \quad \frac{f_2}{f_1} = 2^{\frac{1}{3}}.$$

Fast Fourier Transform (FFT) was applied to convert data to frequency domain and to calculate 1/3 octave band in MATLAB R2010b Software environment.

Results And Dissolution

Variance Analysis

In the present study, the effect of four types of fuel in three intensities of magnetic field with 3 replications on vibration and noise emission of gasoline engine was investigated.

The effect of the magnetic field and different combinations of gasoline and ethanol fuel blends on the root mean square (RMS) vibration amplitude and sound emission of the engine were analyzed by statistical comparison in a factorial experiment based on completely randomized design. The results of the analysis of variance showed the significant effects of the main factors and their interaction on the engine vibration amplitudes and sound level at 1% probability level (Tables 2 and 3).

Table 2
The effects of the studied factors on the engine vibration.

SOV	DOF	SS	MS	F Value
Magnetic field	2	29.6966	14.8483	9.93*
Ethanol	3	200.2393	66.7464	44.64*
Magnetic field × Ethanol	6	12.3344	2.055	1.37*
Error	24	35.8861	1.4952	-
Total	35	278.1564	-	-
*Significant at 1% probability level.				

Table 3
The effects of the studied factors on the engine sound emission.

SOV	DOF	SS	MS	F Value
Magnetic field	2	14.05	7.02	5.77*
Ethanol	3	392.77	130.92	107.48*
Magnetic field × Ethanol	6	22.32	3.72	3.05*
Error	24	29.23	1.21	-
Total	35	458.45	-	-
*Significant at 1% probability level.				

According to the significant effects of the main factors and their interaction, Duncan's multiple range test was performed to compare the vibration (in the Z direction) and sound averages of the engine for different field intensities and fuel combinations (Tables 4 and 5). There was a significant difference Loading [MathJax]/jax/output/CommonHTML/jax.js three magnetic intensities (0, 5300 and 7000 Gauss) in

vibration and sound levels. But there was no significant difference between E5 and E10 in all magnetic intensities and between E0 and E5 at 5300 G on engine vibration. There was a significant difference between the mean noise for E0 and E5 blended fuels when using magnetic field with intensities of 5300 and 7000 G but no significant difference was observed between E10 and E20 blends.

Table 4
Compare mean results of the tested treatments on engine vibration.

Magnetic field/Ethanol	E0	E5	E10	E20
0 G	11.2974 ^{b*}	8.3746 ^{dc}	8.8116 ^{dc}	14.6799 ^a
5300 G	8.5619 ^{dc}	7.7931 ^{dc}	6.7090 ^d	11.3116 ^b
7000 G	9.9386 ^{bc}	6.8349 ^d	6.8339 ^d	13.9481 ^a
*Non-common letters show significant difference at 1% probability level.				

Table 5
Compare mean results of the tested treatments on engine noise.

Magnetic field/ Ethanol	E0	E5	E10	E20
0 G	87.8799 ^{ab*}	85.2222 ^c	81.2825 ^{ed}	82.5725 ^d
5300 G	86.5402 ^{abc}	86.1037 ^{bc}	78.9439 ^f	79.2656 ^f
7000 G	88.4132 ^a	85.9058 ^{bc}	79.8153 ^{ef}	79.3836 ^{ef}
*Non-common letters show significant difference at 1% probability level.				

Figure 2(A) shows the mean of the 3 replicates for vibration acceleration values of the lawnmower engine in the Z direction. The results showed that the highest vibration was related by E20 in all magnetic fields (0, 5300 and 7000 G) and the lowest vibration was for E5 at 7000 G.

As shown in Fig. 2(A), with increasing ethanol, the engine vibration decreased and the lowest vibration released by the E5 mixture with mean value of 8.37 m.s^{-2} . But with increasing ethanol content, E5-20, due to the high viscosity and density and low thermal value of ethanol compared to gasoline (Rakopoloulos et al., 2008; Li et al., 2007), the engine vibration increased, and the highest vibration was related to the E20 blend with mean value of 14.68 m.s^{-2} .

Similarly, the results showed that by exerting magnetic field on the fuel compounds, the vibration value in all fuel blends decreased and the lowest vibration was observed as 6.71 m.s^{-2} for E10 with magnetic field of 5300 G.

Also, the values of the sound pressure level at the driver's ear position, Fig. 2(B), showed that the highest sound pressure level occurred in pure gasoline (E0) and 7000 G of magnetic field intensity with average

of 8.41dB. The lowest noise level was observed for E10 blend with a magnetic field intensity of 5300G with average of 78.94 dB. In the case of E10 and E20 blends in both non-magnetized and magnetized fuels, the mean sound pressure level was below the standard limit of 85dB(A).

The 1/3 octave band analysis

The 1/3 octave band spectrum of the engine vibration and sound pressure level were obtained. For example, Fig. 3 showed the effect of the magnetic field on E20 blend fuel in frequency domain using 1/3 octave band spectrum. The 1/3 octave band analysis for all treatments showed that the vibration increased at frequencies between 31.5 and 100 Hz and the maximum vibration was reached at frequency 100 Hz and then declined steeply. At higher frequencies, the vibration decreased with greater slope, which may be due to the absence of acceleration components at higher engine frequencies (Salokhe et al. 1995).

Generally, the one-third octave band of the engine vibration showed that the vibration in all blended fuels had decreasing trend with increasing the magnetic field intensities. The 5300 G of field has the lowest vibration.

The vibration values corresponding to 5300 G magnetic field intensity was lowest for all the studied fuel blends and the highest amount of vibration released to pure gasoline fuel and it decreased by increasing ethanol percentage.

By investigation the 1/3 octave diagrams, it was observed that the highest sound pressure level for all blended fuel samples and in all magnetic field intensities were in the frequency range of 31.5 to 200 Hz. The frequencies corresponding to the maximum sound levels also changed by alteration the percentage of fuel blends and using the magnetic field and these variations were mostly between the frequencies of 250 to 800 Hz.

The results showed that the maximum amount of SPL was related to pure gasoline for all studied magnetic intensities and the magnetic intensity of the 5300 G had the greatest effect on decreasing of engine sound level. Also, by increasing ethanol percentage up to 10% in the studied fuel blends, the SPL values decreased for all magnetic intensities.

Conclusion

In the present study the effect of two essential variables, namely ethanol-gasoline blends and magnetic field on vibration and acoustic emission of gasoline engine were analyzed.

With analysis of the obtained data, it was revealed that adding ethanol into gasoline from 0 to 20% (v/v ethanol content) causes to reduce vibration and acoustic emissions, so that the E5 and E10 blends had greatest decrementing impact on vibration and sound emissions, respectively. Such test fuels, by applying the magnetic field with 0, 5300 and 7000 G intensities, would lead to a significant reduction in

vibro-acoustic emissions in comparison with commercial gasoline (E0), and 5300 G intensity revealed the greatest effect on the emissions decreasing among the other intensities.

It can be concluded that by creating a magnetic field, the required force is gradually provided to overcome the hydrocarbon clusters of the fuel structure and the breakdown of these clusters allows more oxygen to bond to the intermediate carbons. Also, the decreasing of vibro-acoustic emissions is related to the high oxygen content in the ethanol molecules which enhances fuel oxidation. Therefore, the combustion process becomes uniform and eventually produces less vibration and noise pollution. But it is noticeable that the effect of ethanol percentage on the emission reduction was higher than that of magnetic intensity.

Declarations

Availability of data and materials: Not applicable

Competing interests: The authors have declared no conflict of interest.

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Authors' contributions:

Hosna Faraji: Acquisition of data, Writing - Original Draft.

Kobra Heidarbeigi: Conceptualization, Supervision, Data analysis, Writing- Reviewing and Editing.

Sadegh Samadi: Acquisition of data.

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References

1. Ahmadian, H., Hassan-Beygi, S.R., Ghobadian, B. 2013. Power tiller vibration acceleration envelope curves on transportation mode. *Journal of Vibroengineering*, 15(3): 1431–1441.
2. Aydın, F., Ogut, H. 2017. Effects of using ethanol-biodiesel-diesel fuel in single cylinder diesel engine to engine performance and emissions. *Renewable energy*, 103: 688–694.
3. Carlucci, A. P., Chiara, F F., Laforgia, D. 2006. Analysis of the relation between injection parameter variation and block vibration of an internal combustion diesel engine. *Journal of Sound and Vibration*, 295: 141–164.
4. Chang, Y.C., Lee, W.J., Wang, L.C., Yang, H.H., Cheng, M.T., Lu, J.H., Tsai, Y.I. and Young, L.H. 2014.

- engine. *Applied Energy*, 113: 631–638.
5. Chen, C.Y., Lee, W.J., Mwangi, J.K., Wang, L.C., Lu, J.H. 2017. Impact of magnetic tube on pollutant emissions from the diesel engine. *Aerosol and Air Quality Research*, 17: 1097–1104.
 6. Ghobadian, B., Rahimi, H., Nikbakht, A.M., Najafi, G., Yusaf, T. 2009. Diesel engine performance and exhaust emission analysis using waste cooking biodiesel fuel with an artificial neural network. *Renewable Energy*, 34 (4): 976–982.
 7. Govindasamy, P., Dhandapani, S. 2007. Experimental investigation of cyclic vibration of combustion parameters in catalytically activated and magnetically energized two-stroke SI engine. *Journal of Energy and Environment*, 6: 46–50.
 8. Habbo, A. R. A., Khalil, R. A., Hammoodi, H.S. 2011. Effect of magnetizing the fuel on the performance of an SI engine. *AL Rafdain Engineering Journal*, 19(6): 84–90.
 9. Hasan, M. 2002. Effect of ethanol-unleaded gasoline blends on engine performance and exhaust emission. *Energy Conversion and Management*, 44: 1547–1561.
 10. Heidary, B., Hassan-beygi, S.R., Ghobadian, B., Taghizadeh, A. 2013. Vibration analysis of a small diesel engine using diesel-biodiesel fuel blends. *Agric Eng Int: CIGR Journal*, 15(3): 117–126.
 11. Hricak, R.Z. (1994). Air fuel magnetizer. U.S. Patent No. 5: 331–807.
 12. 10.5772/intechopen.81776
Iliev, S. 2019. Comparison of Ethanol and Methanol Blending with Gasoline Using Engine Simulation, *Biofuels - Challenges and opportunities*, Mansour Al Qubeissi, IntechOpen (Eds), DOI: 10.5772/intechopen.81776.
 13. Iodice, P., Langella, G., & Amoresano, A. 2018. Ethanol in gasoline fuel blends: Effect on fuel consumption and engine out emissions of SI engines in cold operating conditions. *Applied Thermal Engineering*, 130: 1081–1089.
 14. Jahanbakhshi, A., Ghamari, B., Heidarbeigi, K. 2017. Assessing acoustic emission in 1055I John Deere combine harvester using statistical and artificial intelligence methods. *International Journal of Vehicle Noise and Vibration*, 13(2): 105–117.
 15. Keskin, A. 2010. The influence of ethanol-gasoline blends on spark ignition engine vibration characteristics and noise emissions. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 32: 1851–1860.
 16. Khalil, R.A. 2012. Reduction of Pollutant Emission in Ethanol-Gasoline Blends Engines with Magnetic Fuel Conditioning. *Al-Rafidain Engineering*; 20(3): 148–154.
 17. Li, W., Ren. Y., Wang X. B., Miao. H., Huang. Z. H. 2007. Combustion characteristics of a compression ignition engine fuelled with diesel–ethanol blends. *Automobile Engineering*, 222: 265–274.
 18. Mane, D.R., Sawant, V.S. 2015. A Comparative Study of Effect of Magnetic Field on Exhaust Emission in Internal Combustion Engine. *IOSR Journal of Applied Physics (IOSR-JAP)*, 7(6): 38–40.
 19. Melemez, K., Tunay, M. 2010. The investigation of the ergonomic aspects of the noise caused by agricultural tractors used in Turkish forestry. *African Journal of Agricultural Research*, 5(4): 243–249.

20. Mwangi, J.K., Lee, W.J., Tsai, J.H. and Wu, T.S. 2015. Emission reductions of nitrogen oxides, particulate matter and polycyclic aromatic hydrocarbons by using microalgae biodiesel, butanol and water in diesel engine. *Aerosol and Air Quality Research*, 15: 901–914.
21. Patel, P. M., Rathod, G. P., Patel, T.M. 2014. Effect of magnetic field on performance and emission of single cylinder four stroke diesel engine. *IOSR Journal of Engineering*, 4(5): 28–34.
22. Pramodkumar, G., Naidu, M.K., Sandeep, J.V., Vasupalli, R., Lade, P. 2017. Effect of Magnetic Field on the Emissions of Single Cylinder Four Stroke Petrol Engine. *Advances in Automobile Engineering*, 6 (4): 175.
23. Rakopoloulos, D.C., Kakaras, E.C., Giakoumis, E.G. 2008. Effects of ethanol-diesel fuel blends on the performance and exhaust emissions of heavy duty DI diesel engine. *Energy Conversion and Management*, 49(11): 3155–3162.
24. Salles, E., Zambotti, A., Gouvea, A., Agenor, A. 2008. An experimental study of diesel-ethanol combustion controlled electronically, Robert Bosch Research Manuscript.
25. Salokhe, V. M., Majumder, B., Islam, M. S. 1995. Vibration characteristics of a power tiller. *Journal of Terramechanics*, 32(4): 181–197.
26. Saxena, P., Williams, F. A. 2007. Numerical and experimental studies of ethanol flames. *Proceedings of the Combustion Institute*, 31(1): 1149–1156.
27. Tibaquirá, J.E., Huertas, J.I., Ospina, S., Quirama, L.F., Nino, J.E. 2018. The Effect of Using Ethanol-Gasoline Blends on the Mechanical, Energy and Environmental Performance of In-Use Vehicles. *Energies*, 11(221): 1–17.
28. Zoldy, m. 2011. Ethanol-biodiesel-diesel blends as a diesel extender option on compression ignition engines. *Transport*, 26: 303–309.

Figures

Figure 1

Implementing magnetic block on the fueling system line.

Figure 2

Procedure of sound and vibration signals analysis.

Figure 3

Mean of A) engine vibration in Z direction and B) sound pressure level of engine at drivers ear position.

Figure 4

The 1/3 octave spectrum of A) vibration and B) sound level of engine at E20 fuel blend with different magnetic fields.