Although the results of spark ignition and emission performance exploitation of alcohol-based fuels like (ethanol and methanol) have been conjointly investigated, studies on the effects of vibration characteristics on ignition engines moreover noise emissions exploitation of grain alcohol fuel and alcohol do not seem to widely be reported. The investigations created by different studies[25–28] on engine vibrations used different fuels like gas, kerosene, methanol, oil, and blends of wood spirit and fuel employing a smooth turbine shaft with the utilization of a free turbine driver measuring instrument. Vibration patterns were obtained throughout numerous operative conditions with the employment of a period time spectrum instrument. The oscillation movement was found at the time of multiplied combustion with the carbon-hydrogen quantitative relation of the fuel. As the load will increase, it mechanically decreases the frequency and primary harmonic amplitude. Therefore, the engine vibration level is foretold for fuel speed once the induction of combustion during a machine is on the far side style, the purpose of the look and medical specialty performed are helpful. The investigation of variations in idle diesel motor vibrations caused by entirely different fuel compositions has been performed, and the results showed a contribution to the difference in vibration on the handwheel.[29,30] To obtain the specific results of the vibration knowledge from the transient and periodic yields of the idle four-cylinder engine at totally different fuel conditions, it will use the technique of continuous-time moving ridge transformation (CWT) and time-changing variance (TV-AutoCov). Several studies[31–33] have investigated the consequences of liquified petroleum gas (LPG) and hydrocarbon for pressure and vibration throughout the combustion of spark-ignition engines. Increased vibration acceleration within the casting is because of excessive load and engine speed; the variation of fuel used is 22.1 to 100.5 m/s^2 and 4.1 to 95.5 m/s^2 for LPG operation. In such cases,[34–37] they are available on the relationship between the use of fuel-ethanol-oil intermixture with the vibration characteristics of spark ignition engines and conjointly for noise emissions. The experiments showed the amplitude of vibration, and sound emissions on the engine showed an inclination to extend significantly once exploitation mixed fuel for engine speeds of 1500 and 2500 rpm. The higher oxygen content, yet as higher heat than alcohol evaporation, has caused this result to extend. Thus, pressure rate and pressure price are magnified once the height within the cylinder increase throughout the combustion method.

This study aims to analyze the results of vibration characteristics on SI engines response to petrol fuel mixed with wood spirit. Vibration measurements are carried out during the experimental process with different engine speeds. The examination was carried out to measure the characteristics of engine vibrations triggered by a mixture of methanol and gasoline, then compared before and after blend. The test uses 15% and 20% engine load with four speeds (1000, 1200, 1400, and 1600 rpm). This research is only to test the methanol-gasoline fuel mixture in two engine load conditions with different engine speeds. The methanol-gasoline fuel blend was applied because the previous research was still little done, especially for SI engine vibration measurements. The variables defined in this work are the latest in this article.

Experimental Setup

Experiments were conducted on pure gasoline and varied fuel blends of wood alcohol and ethanol, with different levels of various fuel blends between 5% and 10% respectively. Before the experiment, some fuel combination tests were determined by preventing fermentation alcohol reaction with vapor. The engine was initially heated for 20 to 30 minutes before being allowed to begin the experiment. Before the fresh fuel mix was loaded into the engine, the engine was left on for some moment to be able to consume the remaining fuel from previous tests. This experiment was performed with all fuel combinations prepared with distinct load circumstances and engine speeds. This experiment was performed until the maximum rotation was achieved, in particular by beginning the speeds of 1000, 1200, 1400, and 1600 rpm. The dynamometer controls the required engine load is acquired.

There is a wide variety of characteristics in the engine in response to combustion of each fuel. The fuel's properties can change engine efficiency, vibration, and emission features. Considering the fuel properties associated with the burning, each fuel was evaluated in the laboratory using conventional ASTM tests. Fuel characteristics were determined for various combinations of methanol and ethanol fuels, as shown in Table 1.

The experiments carried out in the study were carried out eight times. Experimental tests were applied to engine loads of 15% and 20%. In the first experiment, it was tested with an engine load of 15% for each engine speed (1000 rpm, 1200 rpm, 1400 rpm, and 1600 rpm). Furthermore, the second test was applied to the engine load of 20% for the same engine speed.

This research utilizes some of the required instruments such as motors, vibration analytics instruments, and dynamometers as shown in Fig. 1, the schematic diagram setup experimentally. The requirements of the four-cylinder engine used in this research are shown in Table 2. The engine used in studies is Mitsubishi 4G93 SOHC type, four-cylinder fuel injection, maximum power of 86 kW, maximum torque of 161 mm bore stroke of 81.0 mm × 89.0 mm. An elastic coupling connects a dynamometer device to a machine. This dynamometer is used for monitoring and measuring torque, as well as an instrument panel fitted for remote control of load or engine velocity.

The mechanical vibrations obtained from the engine cylinder block were evaluated using the domestic instruments (NI), as shown in Fig. 1 and Fig. 2, at the moment of engine operation utilizing the combination

Table 1 — Properties of various fuels[38]

Property	Lower heating value (MJ/kg)	Kinematic Viscosity, 40°C (mm^2/s (cSt))	Research octane number	Density, 15.5 ºC (kg/l)
Gasoline	44.106	0.55	95	0.748
Methanol	(M5) 0.7688 (M10) 0.7702	(M5) 0.5269 (M10) 0.5286	(M5) 91.3 (M10) 88.2	(M5) 0.8222 (M10) 0.8466
Test Method	ASTM D340	ASTM D445	ASTM D2699	ASTM D455

Fuel properties	Gasoline	Methanol
Density @ 20 °C (g/cm^3)	0.745	0.796
Kinematic viscosity (mm^2/s at 40 °C)	0.494	0.596
Oxygen content (% wt.)	< 0.05	50
Research octane number	95	108.7
Stoichiometric air/fuel ratio	14.7	6.49
Viscosity @40 °C (mm^2/s)	0.4–0.8	0.59
Surface tension @ 27 °C (10^{-3} N/m)	18.93	22.18
Latent heat of vaporization @ 25 °C (kJ/kg)	305	1103

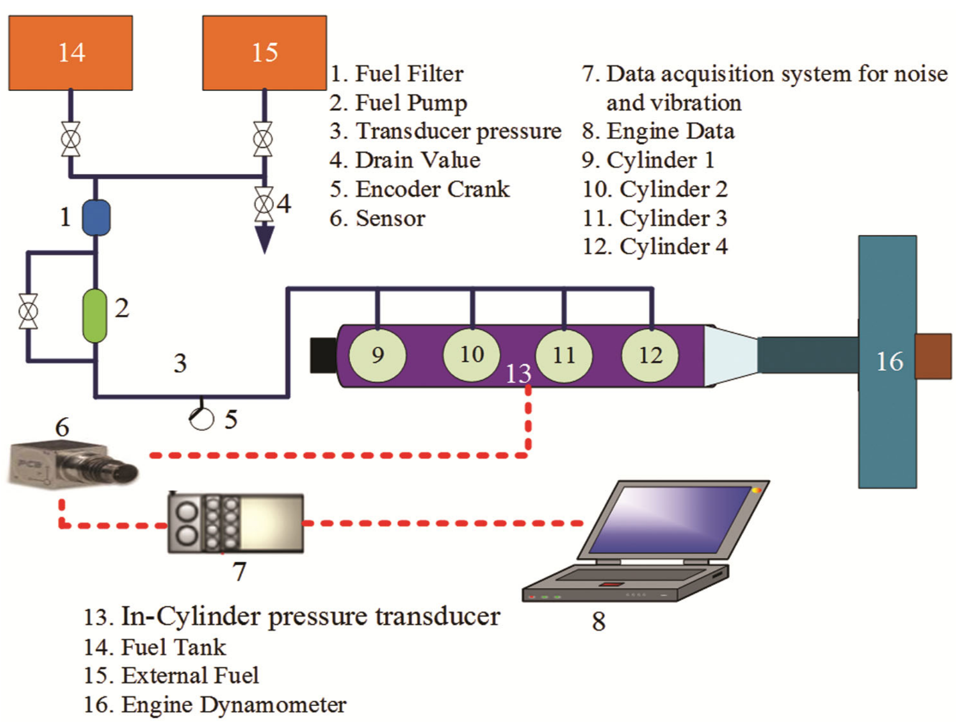

Fig. 1 — Schematic engine setup

of the mixed gas with the alcohol-based fuel. This accelerometer was positioned on the motor surface adjacent to the head of the car. Besides, the signal from the captured voltage accelerometer was registered in a computer linked to the accelerometer: the sound and vibration analysis were performed with the assistance of 'ME'ScopeVES software. Control was carried out while the experiment was in progress. All information samples were registered depending on the velocity and fuel used to make the evaluation simpler.

Table 2 — Specifications of engine

	Engine Specifications
Engine type	Mitsubishi 4G93 SOHC
Bore stroke	81.0 mm × 89.0 mm
Number of cylinders	4 (1st cylinder is instrumented)
Fuel injection type	MCI-Multi (Electronically Controlled Multi-pint) fuel injection
Piston displacement	1.834 L
CR	9.5:1
Max power	86 kw @ 5500 rpm
Max torque	161 nm @ 4500 rpm

Fig. 2 — NI acoustic and vibration data logger and cable uni-axial

Results and Discussion

Unit of internal combustion engine vibration signals manages PC communication, while accelerometer measurements are standard multi-harmonic signals localized in short time intervals and spread over the cycle duration. Structures cause the frequency cycle during engine combustion and non-harmonic constant frequency response at natural frequencies that have a relationship between frequency harmonic answers integrally to machine structure.[39] The spectrum on the Z-axis shows 0–3000 Hz, and 0–1000 Hz is the vibration from the surface at a certain point when the engine was triggered by a blend of methanol-gasoline fuel at maximum load with a speed of 1000 rpm, as shown in Fig. 3. The spectrum was plotted into a scale linear frequency and not planned in the form of a frequency logarithm function. Thus, the most prominent component was at 153 Hz and 160 Hz. Another exciting spectrum measurement result for the spectrum in Fig. 4 is that the center of the highest level was significantly recorded as 68.21 Hz, the middle peak was 424.4 Hz, and the height peak was 804.4 Hz. The results above are the peak of the harmonic indication of the cycle frequency

The experimental results analyzed the frequency of the Z-axis because analysis of results for the X, Y,

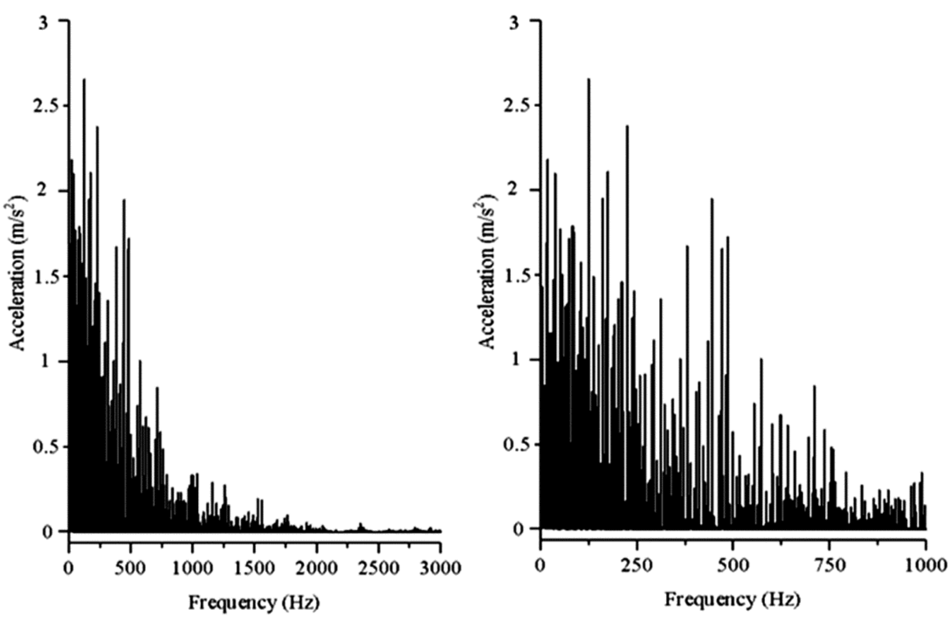

Fig. 3 — Acceleration spectrum Z-axis for the engine using fuel blend, at 1000 rpm

Fig. 7 — Frequency spectra Z-axis for the engine using fuel blends (M5, M10, and Gasoline) at speed 1400 rpm, 1600 rpm, and load 20%

while the M10 fuel combination produced significantly lower values of 3.733 m/s^2 (156 Hz), 3.784 m/s^2 (157 Hz), and 3.431 m/s^2 (156.7 Hz). Tests carried out at a speed of 1600 rpm for 20% engine load showed almost the same vibration level of 156.9–165.2 Hz. Besides, observations made for engine vibration characteristics of mixed fuel M5 and M10 showed amplitude values with the highest acceleration between 7.21 m/s^2 (157 Hz) and 6.705 m/s^2 (156.8 Hz) at 1600 rpm. Therefore, the M5 combination produced vibrations higher than gasoline and increased further compared to the M10 mixture.

The experimental results on the spark ignition engine operated using pure gasoline fuel with a combination of methanol (Methanol 5% and Methanol 10%) showed changes in vibration in the engine. This change is caused by changes in the engine combustion process from the fuel used. Similar research results from several previous studies have also been reported.[40] However, this test was done on different engines and fuels.

Conclusions

The results of the tests showed that the engine triggered by the methanol-gasoline mixture changed significantly by 148–173 Hz. Increased engine speed can reduce the necessary harmonic amplitude acceleration. The peak of engine vibration using gasoline was in a narrow band around 150–155.3 Hz. The methanol-gasoline combination tested showed the most stable vibration acceleration level. The introduction of mixed fuels to measure engine vibration spectra can apply at engine speeds of 1600 rpm. The changes in the combustion process of the machine can explain the results caused by the properties of mixed fuels. These results can be used as a comparison for future work in measuring vibration waves using the process against vibration signals.

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Nomenclature

RPM	Revolutions per minute
λ	Lambda
SI	Spark-ignition
LPG	Liquified petroleum gas
MJ/kg	Megajoules per kilogram
kW	Kilowatt
ASTM	American society for testing and materials
M5	Methanol 5%
M10	Methanol 10%
ºC	Degree celsius
Hz	Frequency

References

1 Bharathiraja B, Sridharan S, Sowmya V, Yuvaraj, D & Praveenkumar R, Microbial oil–a plausible alternate resource for food and fuel application, *Bioresour Technol*, **233** (2017) 423–432.

2 Gutiérrez-Antonio C, Gómez-Castro F I, de Lira-Flores J A & Hernández S, A review on the production processes of renewable jet fuel, *Renew Sust Energ Rev*, **79** (2017) 709–729.

3 Naqvi S R, Jamshaid S, Naqvi M, Farooq W, Niazi M B K, Aman Z & Afzal, W, Potential of biomass for bioenergy in Pakistan based on the present case and future perspectives, *Renew Sust Energ Rev*, **81** (2018) 1247–1258.

4 Erdiwansyah, Sani M S M, Mamat R, Zikri J M & Razak N F D, Experimental investigation of vibrations and noise characterization for spark-ignition engine, *J Phy Conf Ser*, **1262(1)** (2019) IOP Publishing.

5 Bennertz R & Rip A, The evolving Brazilian automotive-energy infrastructure: Entanglements of national developmentalism, sugar and ethanol production, automobility and gasoline, *Energy Res Soc Sci*, **41** (2018) 109–117.

6 Archer M & Szklo A, Can increasing gasoline supply in the United States affect ethanol production in Brazil?, *Renew Energy*, **95** (2016) 586–596.

7 Debnath D, Whistance J, Thompson W & Binfield J, Complement or substitute: Ethanol's uncertain relationship with gasoline under alternative petroleum price and policy scenarios, *Appl Energy*, **191** (2017) 385–397.

8 Monaco F, Lanzini A & Santarelli M, Making synthetic fuels for the road transportation sector via solid oxide electrolysis

and catalytic upgrade using recovered carbon dioxide and residual biomass, *J Clean Prod*, **170** (2018) 160–173.

9 Ail S S & Dasappa S, Biomass to liquid transportation fuel via Fischer Tropsch synthesis–Technology review and current scenario, *Renew Sust Energ Rev*, **58** (2016) 267–286.

10 Ben-Iwo J, Manovic V & Longhurst P, Biomass resources and biofuels potential for the production of transportation fuels in Nigeria." *Renew Sust Energ Rev*, **63** (2016) 172–192.

11 Röder M & Thornley P, Waste wood as bioenergy feedstock. Climate change impacts and related emission uncertainties from waste wood-based energy systems in the UK, *Waste Management* **74** (2018) 241–252.

12 Hamawand I, Sandell G, Pittaway P, Chakrabarty S, Yusaf T, Chen G & Hopf J, Bioenergy from cotton industry wastes: A review and potential" *Renew Sust Energ Rev*, **66** (2016) 435–448.

13 De Clercq D, Wen Z, Gottfried O, Schmidt F & Fei F, A review of global strategies promoting the conversion of food waste to bioenergy via anaerobic digestion, *Renew Sust Energ Rev*, **79** (2017) 204–221.

14 Sakai S, & Rothamer D, Effect of ethanol blending on particulate formation from premixed combustion in spark-ignition engines, *Fuel*, **196** (2017) 154–168.

15 Thakur A K, Kaviti A K, Mehra R & Mer K K S, Progress in performance analysis of ethanol-gasoline blends on SI engine, *Renew Sust Energ Rev* **69** (2017) 324–340.

16 Najafi G, Ghobadian B, Moosavian A, Yusaf T, Mamat R, Kettner M & Azmi W H, SVM and ANFIS for prediction of performance and exhaust emissions of a SI engine with gasoline–ethanol-blended fuels, *Appl Therm Eng*, **95** (2016) 186–203.

17 Doğan B, Erol D, Yaman H & Kodanli E, The effect of ethanol-gasoline blends on performance and exhaust emissions of a spark-ignition engine through exergy analysis, *Appl Therm Eng*, **120** (2017) 433–443.

18 Iodice P, Senatore A, Langella G & Amoresano A, Effect of ethanol-gasoline blends on CO and HC emissions in last generation SI engines within the cold-start transient: An experimental investigation, *Appl Energy*, **179** (2016) 182–190.

19 Iodice P, Langella G & Amoresano A, Ethanol in gasoline fuel blends: Effect on fuel consumption and engine-out emissions of SI engines in cold operating conditions, *Appl Therm Eng*, **130** (2018) 1081–1089.

20 Elfasakhany A, Engine performance evaluation and pollutant emissions analysis using ternary bio-ethanol–iso-butanol–gasoline blends in gasoline engines, *J Clean Prod*, **139** (2016) 1057–1067.

21 Deng X, Chen Z, Wang X, Zhen H & Xie R, Exhaust noise, performance and emission characteristics of spark ignition engine fuelled with pure gasoline and hydrous ethanol-gasoline blends, *Case Stud Therm Eng*, **12** (2018) 55–63.

22 Sharudin H, Abdullah NR, Najafi G, Mamat R & Masjuki HH, Investigation of the effects of iso-butanol additives on spark-ignition engine fuelled with methanol-gasoline blends, *Appl Therm Eng*, **114** (2017) 593–600.

23 Awad O I, Mamat R, Ali O M, Sidik N A C, Yusaf T, Kadirgama K & Kettner M, Alcohol and ether as alternative fuels in spark ignition engine: A review, *Renew Sust Energ Rev*, **82** (2018) 2586–2605.

24 Elfasakhany A & Mahrous A F, Performance and emissions assessment of n-butanol–methanol–gasoline blends as a fuel in spark-ignition engines, *Alexandria Eng J*, **55(3)** (2016) 3015–3024.

25 Ahirrao N S, Bhosle S P & Nehete D V, Dynamics and vibration measurements in engines, *Procedia Manuf*, 20 (2018) 434–439.

26 Gravalos I, Loutridis S, Moshou D, Gialamas T, Kateris D, Tsiropoulos Z & Xyradakis P, Detection of fuel type on a spark-ignition engine from engine vibration behavior, *Appl Therm Eng*, **54(1)** (2013) 171–175.

27 Cantu L M, Grohmann J, Meier W & Aigner M, Temperature measurements in confined swirling spray flames by vibrational coherent anti-stokes Raman spectroscopy, *Exp Therm Fluid Sci*, **95** (2018) 52–59.

28 Erdiwansyah, Sani M S, Mamat R, Khoerunnisa F, Rajkumar A R, Razak N F D & Sardjono R E, Vibration Analysis of the Engine Using Biofuel Blends: A Review, *MATEC Web Conf*, **225** (2018) EDP Sciences.

29 Omar F K, Selim M Y & Emam S A, Time and frequency analyses of dual-fuel engine block vibration, *Fuel*, **203** (2017) 884–893.

30 Taghizadeh-Alisaraei A & Rezaei-Asl A, The effect of added ethanol to diesel fuel on performance, vibration, combustion, and knocking of a CI engine, *Fuel*, **185** (2016) 718–733.

31 Taghizadeh-Alisaraei A & Rezaei-Asl A, Knock detection in si engines by using the discrete wavelet transform of the engine block vibrational signals, *Energy Procedia*, **81** (2015) 673–688.

32 Jafarian K, Mobin M, Jafari-Marandi R & Rabiei E, Misfire and valve clearance faults detection in the combustion engines based on a multi-sensor vibration signal monitoring, *Measurement*, **128** (2018) 527–536.

33 Antoni J, Griffaton J, André H, Avendaño-Valencia L D, Bonnardot F, Cardona-Morales O & Sierra-Alonso E F, Feedback on the Surveillance 8 challenge: Vibration-based diagnosis of a Safran aircraft engine, *Mech Syst Signal Process*, **97** (2017) 112–144.

34 Lee J, Lee S & Lee S, Experimental investigation on the performance and emissions characteristics of ethanol/diesel dual-fuel combustion, *Fuel*, **220** (2018) 72–79.

35 Çelebi K, Uludamar E, Tosun E, Yıldızhan Ş, Aydın K & Özcanlı M, Experimental and artificial neural network approach of noise and vibration characteristic of an unmodified diesel engine fuelled with conventional diesel, and biodiesel blends with natural gas addition, *Fuel*, **197** (2017) 159–173.

36 Corsetti S, McGloin D & Kiefer J, Comparison of Raman and IR spectroscopy for quantitative analysis of gasoline/ethanol blends, *Fuel*, **166** (2016) 488–494.

37 Javed S, Murthy Y S, Baig R U & Rao T N, Vibration analysis of a diesel engine using biodiesel fuel blended with nanoparticles by dual fueling of hydrogen, *J Nat Gas Sci Eng*, **33** (2016) 217–230.

38 Sharma N, Patel C, Tiwari N & Agarwal A K, Experimental investigations of noise and vibration characteristics of gasoline-methanol blend fuelled gasoline direct injection engine and their relationship with combustion characteristics, *Appl Therm Eng*, **158** (2019) 113754.

39 Marples V, On the frequency content of the surface vibration of a diesel engine, *J Sound Vib* **52(3)** (1977) 365–386.

40 Othman M, Najjar Y S H & Abou-Arab T W, Fuel effect on induced vibration in gas turbine engines, *Fuel*, **67(3)** (1988) 321–326.