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Impact of Gasoline RON on Engine Vibration, Knock and Sound Level in a Single-Cylinder SI Engine

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ABSTRACT

Engine vibration is critical toward overall engine performance, engine lifespan and passenger comfort. Engine sound level is critical toward the environment by increasing the noise polution. An experimental investigation on cylinder block vibration of engine, knock intensity and sound level with research octane number (RON) 95, 97 and 100 was carried out on a spark ignition (SI) engine under different engine speeds (1600, 2000, 2400, 2800 and 3200 RPM). The experiment was conducted in a proper experimental setup with all the equipment and materials. Multiple sensors were used in this experiment to obtain the following data such as accelerometer sensor, knock sensor and microphone. This experiment proved that cylinder block vibration and knock intensity with RON 100 had the lowest reading data compare to RON 95 and RON 97. The sound level (Pa) for RON 100 is the highest compared with RON 95 and RON 97 due to this fuel is able to produce more power and this affected the sound level of RON 100. In conclusion, RON 100 is better in every aspect and suitable for car's engine which are able to draw out all the fuel performance.

Keywords:
Vibration, RON, knock

1. Introduction

Vehicles are mobile bodies that carry and transport people or goods. There are few categories for vehicles such submarines, space vehicles, trains, airplanes, and others. Every vehicle that moves on the road will have an engine build into it. Once the engine starts to operate, it will create sound and movements in the whole vehicle. Vibration is the vehicle's engine in operation and the vehicle or a part of it perform oscillatory motion [1, 2]. The sound is the adjacent air which exhibits vibration. An operating engine will produce a pinging or knocking sound. This process is called engine knocking. Vehicle sound includes wanted and unwanted sounds. Therefore, the unwanted sound is noise. Vibration and noise can affect passenger discomfort and can be harmful to the customer's perception of vehicle quality [3]. Comfort of riding, driving stability and drivability are important factors in the performance of a vehicle and are affected by the engine vibrations [4, 5]. Vibration and sound quality

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are also the important vehicle's attributes. Both of these are the top attributes of any vehicle type. For a vehicle, vibration and sound are major qualities that customers consider when they purchase a new vehicle. Engine vibrations are caused due to the rotating masses and reciprocating of the engine. Because of the environmental considerations, as well as changes in consumer preferences, vibrations induced must be reduced [6]. In a typical engine, a portion of fuel-air mixture undergoes combustion in single cylinder generates a local pressure pulse which leads to pressure oscillation spread across the single spark cylinder. This process is called internal combustion (IC). The pressure oscillation creates noise outside the engine which is called "knock" [7]. Vibration behaviour of an IC engine is related to unbalanced reciprocating and rotating parts, cyclic variation in gas pressure, shaking forces due to the reciprocating parts and structural characteristics of the mounts. During the operation, the compression differences of the piston cylinder arrangement and the combustion produce variations of inertial forces. The engine inertial forces leads to the unbalanced forces of the engine and they are quiet varying with respect to speed, fuel supply and combustion characteristics of the fuel [5, 8]. Besides, there are some of the bad effects such as specific fuel consumption (SFC) rise in the engine, engine pollution increases and engine efficiency decreases when the knocking happens in the engine. Vibration analyses had been used in many ways. Main events such as valve impact, injector pulses and engine knocking are the application of Short Time Fourier Transform (STFT) to measure the vibrational acceleration of gasoline engine [9]. Automotive sound and vibrations have received much attention by researchers over the last two decades [10]. In the automotive community, the term NVH (noise, vibration, and harshness) has been widely used to describe unwanted vibration and sound in an automobile [11]. NVH is a generic term that covers the section of engineering related to vehicle refinement in terms of vibration and sound experienced by the occupants when the vehicle is in service. The term has been used mainly in connection with road vehicles, but almost the same techniques are used in air and rail vehicles to provide refinement.

Among the topics discussed above, many previous studies have reported that engine vibration is critical toward overall engine performance, engine lifespan and passenger comfort. Engine vibration will be transmitted through all the supporting structure of a vehicle and transfer to passengers in the vehicle. Engine vibrations are exhibited in all direction in a vehicle with some variations such as ignition order, type of engine support and type of fuels used (i.e. Research Octane Number (RON) of gasoline fuel). Consequently, there is a strong motivation to investigate the impact of different RON of commercially avaliable gasoline fuels in a single cylinder engine, and to analyse the effects of this RON on engine vibration, knock and sound level characteristics. This experiment was performed under five different engine speeds (1600, 2000, 2400, 2800 and 3200) and at a full load condition. Parameters including cylinder block vibration, knock intensity and sound level analysis were investigated and evaluated.

2. Methodology

2.1 Experimental Setup

A single cylinder spark ignition engine is used for this experiment and the model for the engine is Mitsubishi-GM131P. In addition, few sensors was mounted on the engine such as Kistler Spark Plug adapter with pressure sensor, accelerometer (603C01), index pulse sensor, knock sensor (Denso 89615-20090) and crank angle pulse sensor. A microphone (BSWA Tech MA211) was placed straight above the engine to record the sound level. The pressure sensor, accelerometer and microphone are all connected to a 3-channel signal conditioner (480B21) before connecting to the DAQ System (DEWE-43 USB). Therefore, the result obtained is transfer to the computer via USB connection. The overall experiment setup is shown in the Fig. 1 and the schematic diagram of the setup is shown in Fig. 2.

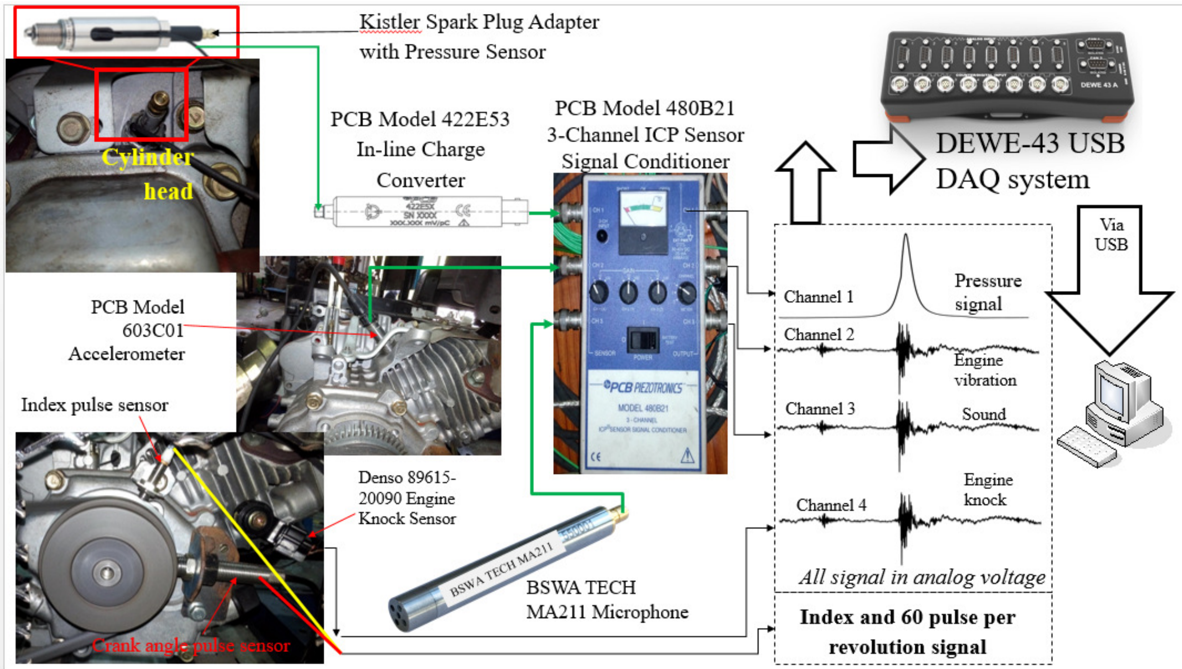

Fig. 1. Experiment setup

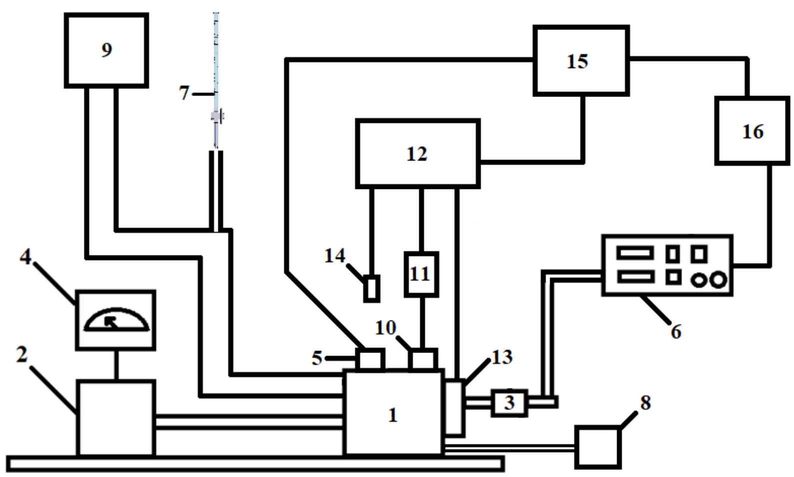

Fig. 2. The schematic diagram of the experimental setup. 1) SI Engine, 2) Dynamometer, 3) Exhaust pipe, 4) Dynamometer control unit, 5) Knock Sensor, 6) Gas analyzer and 7) Burette, 8) Surge Tank, 9) Fuel Tank, 10) Spark Plug with Pressure Sensor, 11) In-line Charge converter, 12) Sensor Signal Conditioner 13) Accelerometer, 14) Microphone 15) DAQ System 16) Computer.

2.2 Test Procedure

The test fuels were prepared in the laboratory prior to the engine test. The initial step is to switch on all the devices (i.e. computer, data acquisition system, gas emission analyser and exhaust ventilation system). This was followed by filling the fuel tank with the test fuel. After that, the in-line valve was opened to allow gasoline flow to the burette and test engine. No modifications were made to the test engine for all tests and the tests were performed under steady-state condition with sufficiently warmed up exhaust gas temperature. For improved accuracy, each test point was repeated twice to obtain the average reading. The repeatability is matched over 95% for each test. This indicates that effects on cylinder block vibration, knock intensity and sound level characteristics can be reliably analysed from this test system. Besides, for performance test, the engine is set to operate under full load with engine speed vary in between 1600 to 3200 rpm and with 400 rpm increments. Besides, a volumetric type fuel flow meter was used to determine the quantity of fuel supply to the engine. Furthermore, K-type thermocouples was employed to measure the temperature of exhaust gas.

2.3 Calculation Method

In the present study, the engine vibration, knock intensity and sound level of different RONs of gasoline fuels were compared with the baseline RON 95 fuel at different engine speeds. The averaged RMS of the corresponding signal was determined using the following equation [12, 13]

$$a_{rms} = \sqrt{\left(\sum_{i=1}^{N} a_i^2\right)/N} \tag{1}$$

where a_{rms} is the average RMS value for the signal, a_i is the instantaneous value in the angle domain signal at point i and N is the total sample number within 10 consecutive cycles.

3. Results and Discussion

3.1 Cycle-to-cycle Analysis

Figure 3 shows the variation of combustion pressure over 10 consecutive of firing cycle for all fuels at full load condition. Here, the horizontal axis of the plot is represented number of firing cycle rather than in seconds as the engine was running at a constant speed of 1600 rpm. The combustion of test fuel in the engine combustion chamber leads to a rapid pressure rise. This pressure gets exerted on internal walls of the chamber and piston, and is primarily responsible for engine vibrations. From the results, it can be seen that a certain amount of cycle-to-cycle variation is inevitable as ignition depends strongly on the actual fuel/air ratio at the spark plug tips, which is affected by non-repeatable flow patterns inside the cylinder. Besides, it can be observed that the correlation between the magnitude of pressure rise rate and engine vibrations, knock intensity and sound level is very strong. This is shown in Fig. 4, Fig. 5, Fig. 6, and Fig. 7 which depicts combustion pressure rise rate, cylinder block vibration signal, knock intensity and sound level over 10 consecutive of firing cycle, respectively, for all fuels at 1600 rpm.

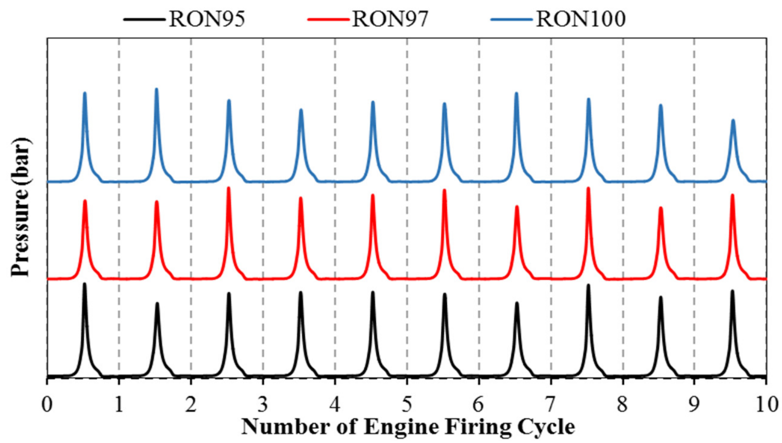

Fig. 3. Cylinder combustion pressure signal for 10 consecutive engine firing cycle at 1600 RPM

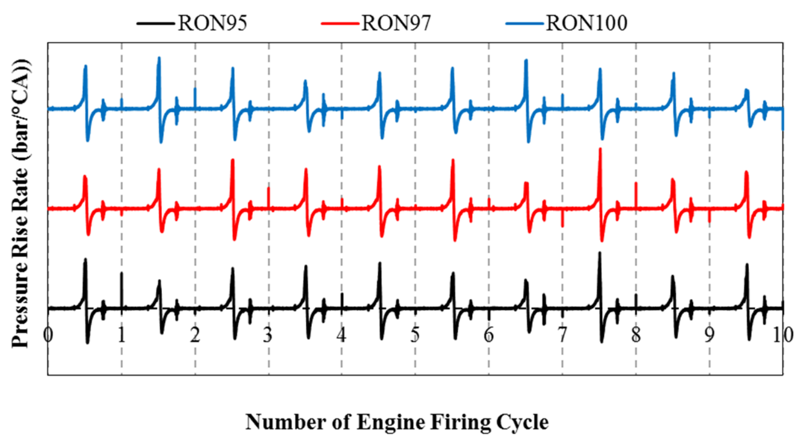

Fig. 4. Cylinder combustion pressure rise rate for 10 consecutive engine firing cycle at 1600 RPM

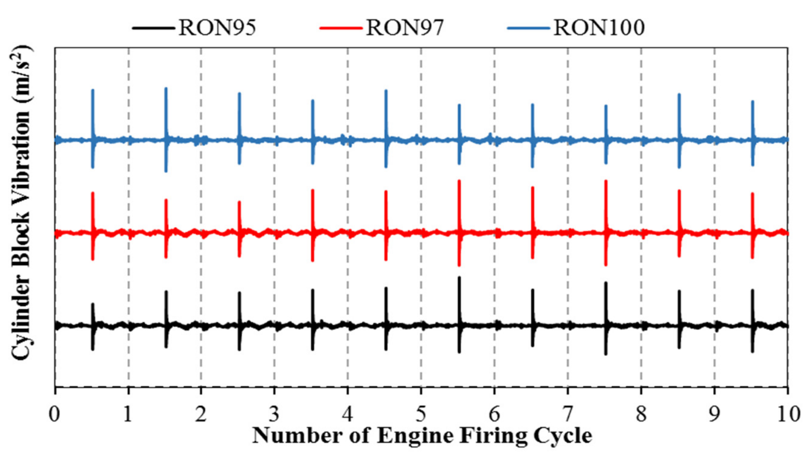

Fig. 5. Cylinder block vibration signal for 10 consecutive engine firing cycle at 1600 RPM

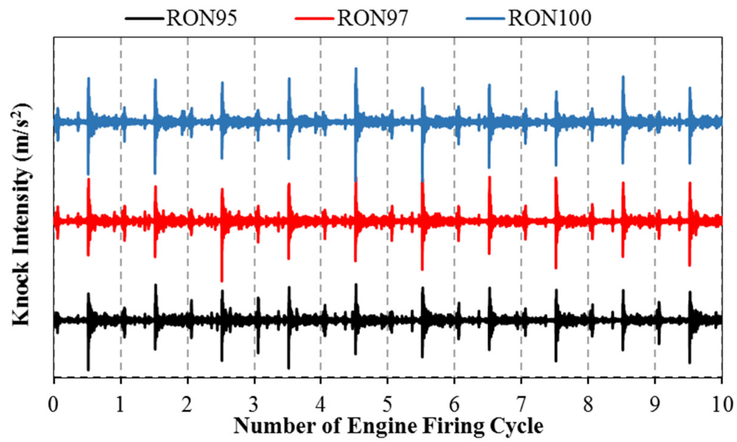

Fig. 6. Knock intensity for 10 consecutive engine firing cycle at 1600 RPM

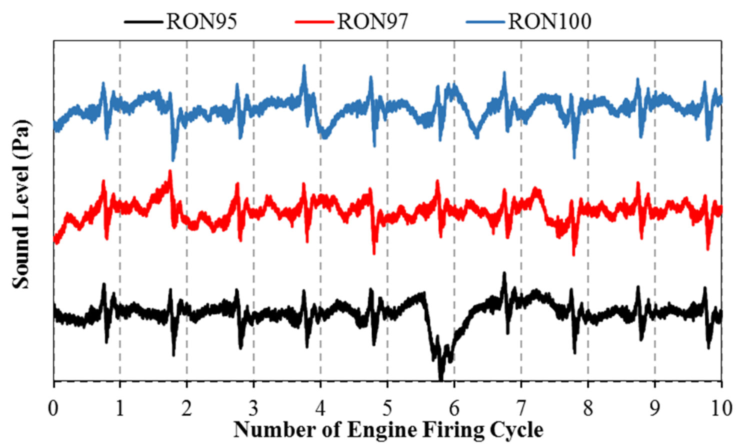

Fig. 7. Sound level signal for 10 consecutive engine firing cycle at 1600 RPM

3.2 Variation in RMS Result

Figure 8 to Fig. 10 shows the variation in RMS in cylinder block vibration, knock intensity and sound level against the engine speed (RPM) by using RON 95, RON 97 and RON 100. The averaged RMS of the corresponding signal was determined using the Eq. 1.

Figure 8 shows the RMS of cylinder block vibration against engine speed for all fuels. Generally, the magnitude for cylinder block vibration was marginally increased between 1600 to 2400 rpm. However, there are major increase in magnitude when the engine speed is at 2800 rpm. With higher engine speed of 3200 rpm, the magnitude of cylinder block vibration for all fuels was reduced. Besides, the results also indicated that the cylinder vibration for RON 100 were consistently lower than that of RON 97 and RON 95 fuels across all engine speeds. This can be associated to the better ignition quality of RON 100 than RON 97 and 95 fuels, consequently reduced the engine cylinder vibration by smoothing the combustion process [14, 15].

Figure 9 shows the RMS of knock intensity against engine speed for all fuels. As can be observed, the knock intensity for all fuels were consistently increased across all engine speeds. At engine speed of 2800 rpm, the knock intensity magnitude for RON 97 and RON 100 fuels were significantly reduced

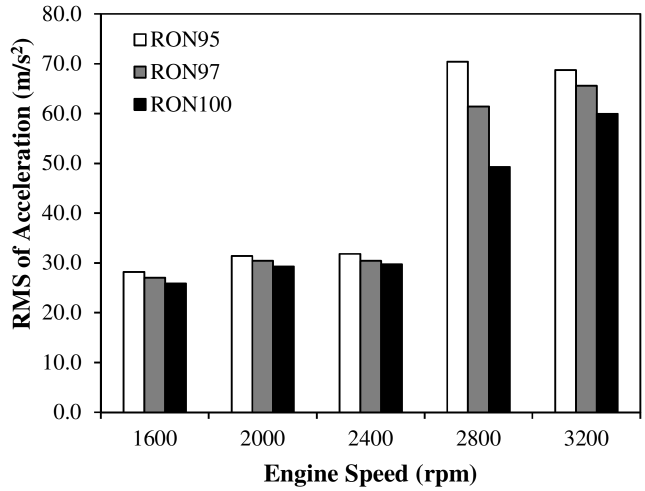

Fig. 8. Variation in RMS of acceleration for all test fuels at different engine speeds

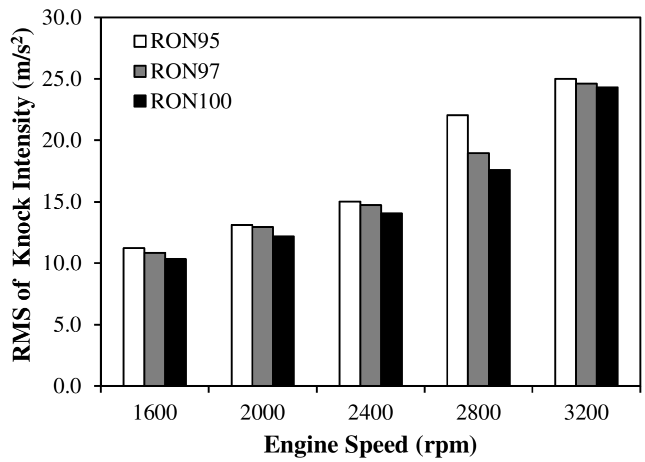

Fig. 9. Variation in RMS of knock intensity for all test fuels at different engine speeds

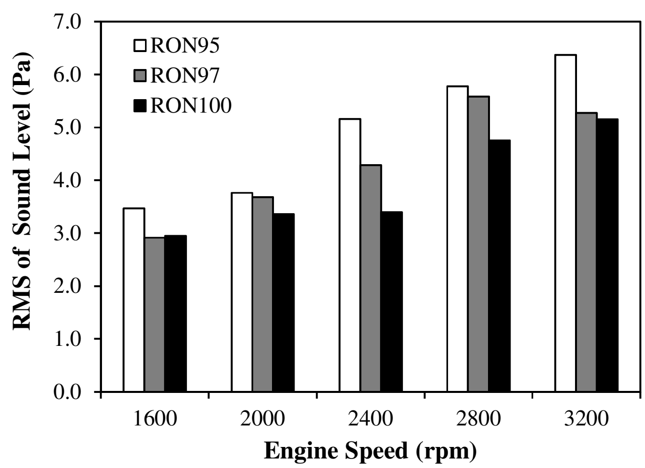

Fig. 10. Variation in RMS of sound level for all test fuels at different engine speeds

as compared with that of baseline RON 95 fuel. This may be explained with the combustion occurs for RON 95 might not be as smooth as RON 97 and RON 100, thus resulting in higher knocking compare to RON 97 and RON 100 fuels.

Another important parameter is the sound level analysis. As can be observed in Fig. 10, the general trend indicated that different type of RON fuels will affect sound level pressure as the speed of the engine increase. Clearly, the RON 100 fuel have the lower sound level pressure compare to RON 95 and RON 97 across all engine speeds. This can be explained with the better resistance to knocking of this fuel as compared to other lower RON fuels of 95 and 97 [16].

4. Conclusions

Through the present study, the measurement of the vibration, knocking intensity and sound level for spark ignition engine fuelled with different RON fuels have been successfully investigated. Based on the data obtained, it can be concluded that fuel with higher RON will resulted in better performance for engine. Besides, it was observed that a higher RON will produce lower in both of the vibration and knock intensity due to the higher RON fuel of RON 100 is able to resist knocking as compare to RON 95 and RON97 fuels.

Overall, the experimental results suggested that a higher octane number fuel of RON 100 is a good candidate to operate on this engine with consideration is being focused on the balance between engine vibration, knocking intensity and sound emission characteristics.

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References

[1] Sheng, Gang. "Vehicle noise, vibration, and sound quality." (2012).
[2] Satsangi, Dev Prakash, and Nachiketa Tiwari. "Experimental investigation on combustion, noise, vibrations, performance and emissions characteristics of diesel/n-butanol blends driven genset engine." *Fuel*, 221 (2018): 44-60.
[3] Soloiu, Valentin, Jose Moncada, Aliyah Knowles, Tyler Naes, Emerald Simons, Martin Muiños, and Spencer Harp. 2016. "Combustion Performance, Noise, and Vibrations of an IDI Engine Fueled With Carinata Biofuel." ASME 2016 International Mechanical Engineering Congress and Exposition.
[4] Ahirrao, N. S., S. P. Bhosle, and D. V. Nehete. "Dynamics and Vibration Measurements in Engines." *Procedia Manufacturing*, 20 (2018): 434-439.
[5] Ramachandran, T, and KP Padmanaban. "Review on internal combustion engine vibrations and mountings." *Int. J. Eng. Sci. Emerg. Technol*, 3 (1) (2012): 63-73.
[6] Somashekar, V, K Satish, AB Jamuna, and P Ranjitha. "Vibration Signature Analysis of IC Engine." *International Journal of Innovative Research and Development*, 2 (13) (2013).
[7] Heywood, John B. "Internal combustion engine fundamentals." (1988).
[8] Alahmer, Ali, and Wail Aladayleh. "Effect two grades of octane numbers on the performance, exhaust and acoustic emissions of spark ignition engine." *Fuel*, 180 (2016): 80-89.
[9] Omar, Farag K, Mohamed YE Selim, and Samir A Emam. "Time and frequency analyses of dual-fuel engine block vibration." *Fuel*, 203 (2017): 884-893.
[10] Ong, Zhi Chao, Mohd Bakar Mohd Mishani, Wen Tong Chong, Roon Sheng Soon, Hwai Chyuan Ong, and Zubaidah Ismail. "Identification of optimum Calophyllum inophyllum bio-fuel blend in diesel engine using advanced vibration analysis technique." *Renewable Energy*, 109 (2017): 295-304.
[11] Chiatti, Giancarlo, Ornella Chiavola, and Fulvio Palmieri. "Vibration and acoustic characteristics of a city-car engine fueled with biodiesel blends." *Applied energy*, 185 (2017): 664-670.

[12] Taghizadeh-Alisaraei, Ahmad, Barat Ghobadian, Teymour Tavakoli-Hashjin, and Seyed Saeid Mohtasebi. "Vibration analysis of a diesel engine using biodiesel and petrodiesel fuel blends." *fuel*, 102 (2012): 414-422.

[13] How, H. G., H. H. Masjuki, M. A. Kalam, and Y. H. Teoh. "An investigation of the engine performance, emissions and combustion characteristics of coconut biodiesel in a high-pressure common-rail diesel engine." *Energy*, 69 (2014): 749-759.

[14] Binjuwair, Saud, Taib Iskandar Mohamad, Ahmed Almaleki, Abdullah Alkudsi, and Ibrahim Alshunaifi. "The effects of research octane number and fuel systems on the performance and emissions of a spark ignition engine: A study on Saudi Arabian RON91 and RON95 with port injection and direct injection systems." *Fuel*, 158 (2015): 351-360.

[15] Cerri, Tarcisio, Gianluca D'Errico, and Angelo Onorati. "Experimental investigations on high octane number gasoline formulations for internal combustion engines." *Fuel*, 111 (2013): 305-315.

[16] Mohamad, Taib Iskandar, and Heoy Geok How. "Part-load performance and emissions of a spark ignition engine fueled with RON95 and RON97 gasoline: Technical viewpoint on Malaysia's fuel price debate." *Energy Conversion and Management*, 88 (2014): 928-935.