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Original Research Article

Determination of Vibration Characteristics on Vertical Axis of a Four Cylinder Gasoline Engine

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Abstract

The vibration characteristics on the vertical axis of a four cylinder 1.4 L Otto engine was investigated under partial throttle opening rates and different engine speeds, in the study. In the first part of the study, vibration measurements were made in terms of acceleration on the top of engine block. The vibration data were determined at five partial throttle opening rates (10%, 20%, 30%, 40%, and 50%) for four different engine speeds (1400 RPM, 2000 RPM, 3000 RPM and 4000 RPM) in terms of RMS (Root Mean Square) and illustrated with graphs. By using polynomial regression method, the characteristics equations for each throttle opening have been formed. In the second part, the measurements were made by changing engine speeds for each throttle opening and the obtained results were compared with the results obtained from the equations.

Key Words: Engine vibration, polynomial regression, throttle rate, root mean square, engine speed

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1. Introduction

In internal combustion engines, vibrations occur due to the motions of rotating, oscillating and linear moving parts. The engine block that mounted on the chassis periodically vibrates because of inertia forces and gas pressure forces [1,2].

The chassis vibration acts on the driver and passengers. So, the engine vibration must be kept under control. In recent years, there have been a lot of studies on the engine vibrations.

Öztürk and Karabulut have investigated the engine block vibrations of a one cylinder - four stroke diesel engine. They made a dynamical model of the piston, connecting rod, crankshaft and the engine block. The model was four degree of freedom system that includes the rotational motion of the crank, the rotational motion of the engine block with respect to the crank axis, horizontal and vertical linear motions of the block. In the analysis, it was determined that the block vibrations with respect to the crank axis are caused by gas forces and the vertical and horizontal vibrations are caused by piston mass and the unbalance of the crank [3].

In a study by Barelli et al., it has been detected that the most powerful vibration signals can be measured on the cylinder head depending on the engine load and combustion frequency in the internal combustion engines [4].

In the other study, Manieniyan and Sivaprakasam used diesel and the bio-diesel derived from mahua as a fuel, respectively. The vibration data as acceleration were measured from the cylinder head, bottom of the engine and crank bearings. The largest amplitude on the cylinder head has been detected when using bio-diesel. In the other points, the largest amplitudes have been obtained when using diesel [5].

Wongchai et al. have investigated the effects of the hydrogen-diesel blend on the engine vibration. Second order polynomial regression analyses were made to find a correlation between the percentage of hydrogen fuel and vibration amplitude. As a result of the study, it has shown that in response to increasing amounts of hydrogen, engine vibration amplitude decreases [6].

2. Measurement of the Vibration

In order to acquire the vibration data, Honda L13A i-DSI engine was used in the experiments as a test engine. This spark ignited gasoline engine has four cylinders, 1.4 L volume and the compression ratio is 10.8.

The test engine runs on a platform that is fixed to the ground with the other parts of the setup (dynamometer, radiator, cooling water tank, fuel tank, battery etc.). The schematic representation of the test engine and all setup are shown in Figure 1.

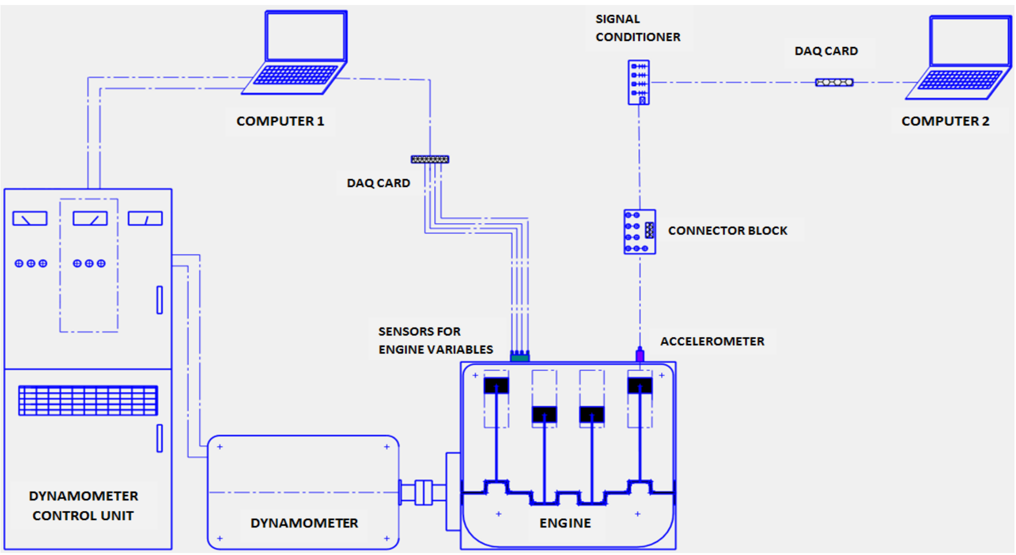

Figure 1. Schema of the engine performance and vibration test setup

A computer with a data acquisition card, signal conditioner, connector block and accelerometer was used for measuring the vibration. Technical specifications of these devices are summarized in table 1.

Table 1. Technical specifications of the devices

Device	Model (Type)	Technical Specifications
Accelerometer	PCB 352C18	- Sensitivity: (±10%) 10 mV/g (1.02 mV/(m/s²)) - Measurement Range: ±500 g pk (±4905 m/s² pk) - Broadband Resolution: 0.0005 g rms (0.005 m/s² rms) - Frequency Range: (±5%) 1 to 12000 Hz
A/D Data Control Card	NI PCI-6281	- Two 16-bit analog outputs (2.8 MS/s); 24 digital I/O; two 32-bit, 80 MHz counters - Programmable 40 kHz low pass filters - Correlated DIO (8 clocked lines, 10 MHz);
Amplifer/Signal Conditioner	PCB 482A16	- 4 Channels - Low Frequency Response (- 5%): 0.225 Hz - High Frequency Response (- 5%): 100000 Hz - Broadband Noise (at unity gain): 9.1 µV rms

The top of the first cylinder head was selected for vertical axis vibration measurements and the accelerometer was mounted on it as shown in figure 2.

Figure 2.Positioning of the accelerometer

The vibration amplitudes have been determined as acceleration in terms of m/s^2 in the tests and the each measurement lasted 5 s. The values were measured with varying engine speed, while the throttle rate was kept constant.

In the first part of the experiments, the vibration data were obtained in 10%, 20%, 30%, 40% and 50% throttle opening rates for 1400, 2000, 3000 and 4000 RPM engine speeds, respectively.

Amplitude - time graph for 10% throttle rate is shown in figure 3. The vibration levels can be seen on the graph for four different engine speeds simultaneously. The amplitude changes in response to varying engine speed can easily be realized.

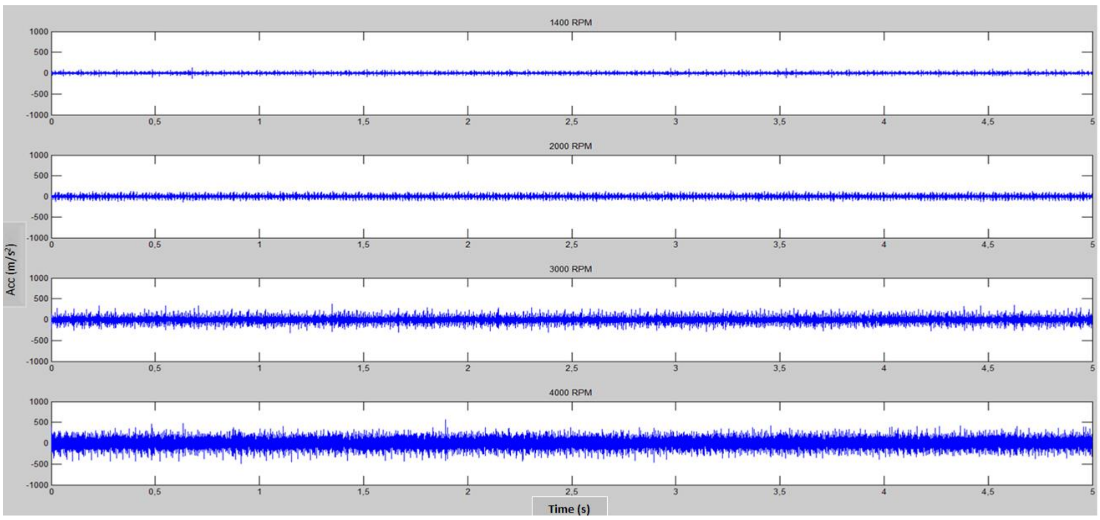

Figure 3. Amplitude (acceleration) - time graph for 10% throttle rate

Determinations of root mean square (RMS) values instead of vibration levels provide great convenience to find characteristic data. RMS values are calculated as;

$$X_{RMS} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2} \qquad (1)$$

RMS values were calculated by using Matlab program and the obtained results have been given in figure 4 for the each throttle opening ratios.

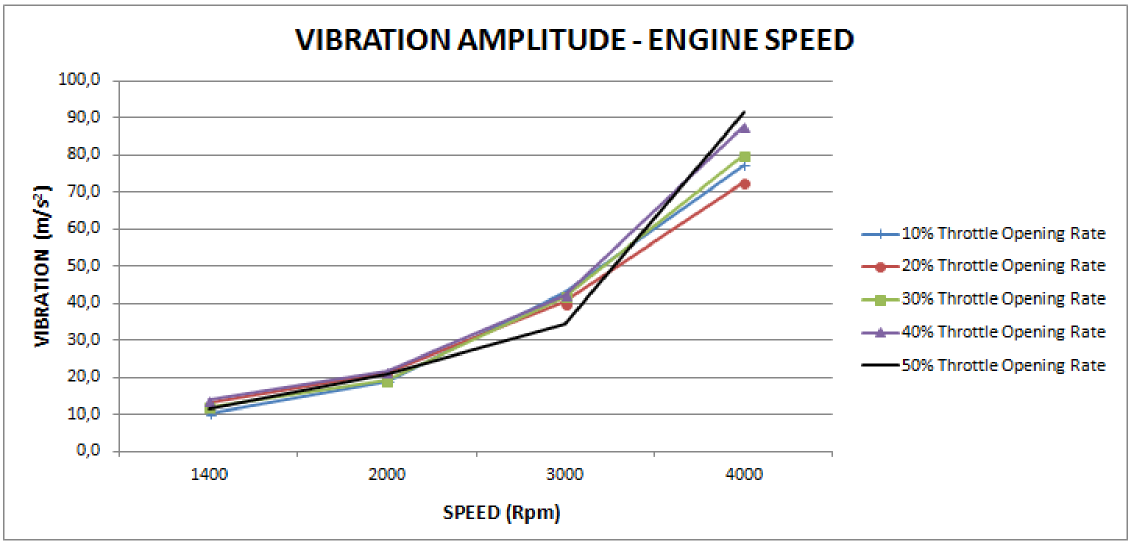

Figure 4.Vibration amplitude (RMS) - Engine Speed (RPM) graph

3. Determination of Characteristic Equations of Each Curve

In figure 4, it can easily be seen that all curves are almost parabolic. If these curves can be defined with quadratic equations, it enables to find not only relationship between engine speed and vibration amplitude but also intermediate values on the graphs.

In the study, polynomial regression method was applied to find the equations of the curves. The equations have been determined by Matlab program practically. The equations are shown in table 2. In the table, x values correspond to engine speed values.

Table 2. Equations of the curves

THROTTLE OPENING RATE	EQUATION	
10%	$5{,}41.10^{-6}.x^2 - 3{,}41.10^{-3}.x + 4{,}27$	$R^2 = 0{,}9999$
20%	$5{,}59.10^{-6}.x^2 - 7{,}43.10^{-3}.x + 12{,}76$	$R^2 = 0{,}9994$
30%	$7{,}36.10^{-6}.x^2 - 1{,}37.10^{-2}.x + 16{,}97$	$R^2 = 0{,}9999$
40%	$9{,}79.10^{-6}.x^2 - 2{,}49.10^{-2}.x + 30{,}56$	$R^2 = 0{,}9978$
50%	$1{,}38.10^{-5}.x^2 - 4{,}56.10^{-2}.x + 50{,}74$	$R^2 = 0{,}9837$

In the second part of the study, the measurements were made by changing engine speeds by amount of 200 from 1400 to 4000 Rpm for each throttle ratio. The obtained results were compared with the results determined from the equations separately.

For all throttle rates, the comparison graphs are shown below in figure 5-9 on which the fitted curve and the experimental curve are presented.

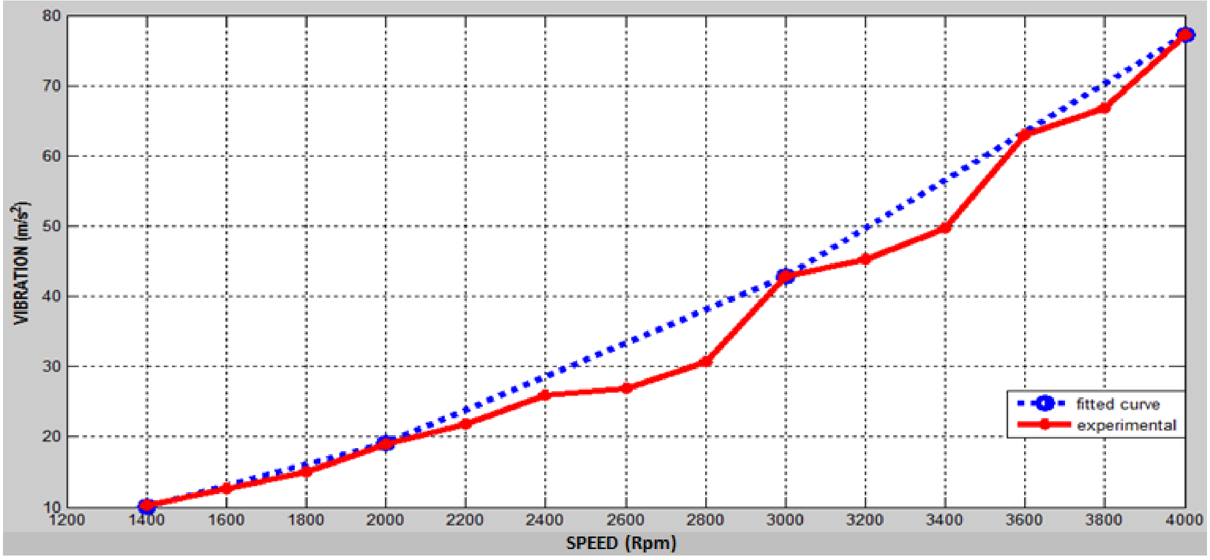

Figure 5. Fitted curve and the curve of experimental results for 10%

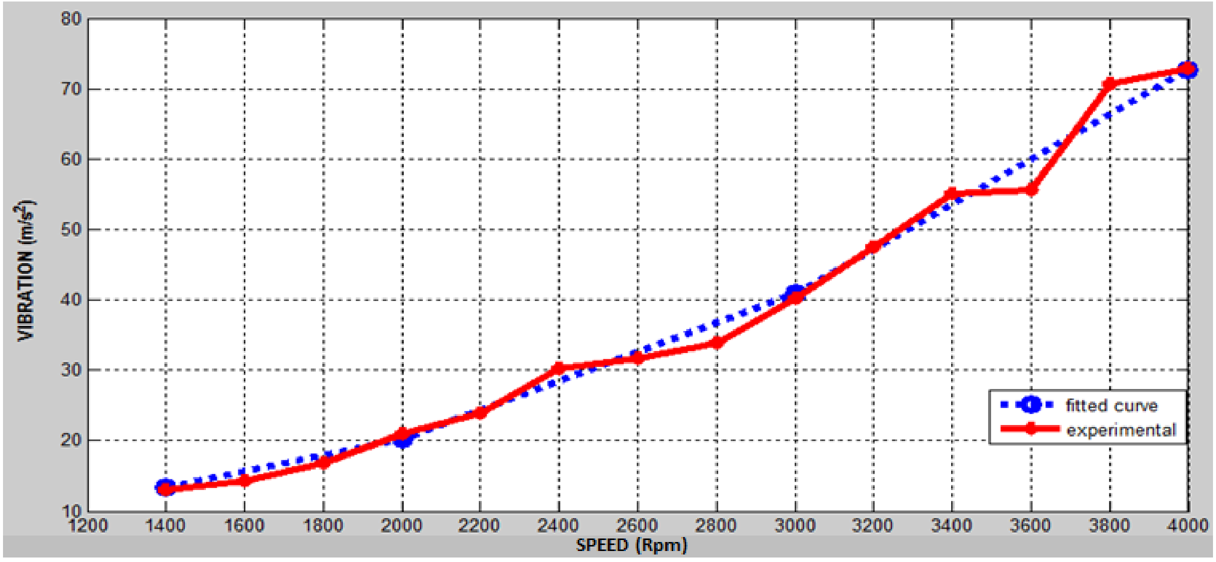

Figure 6. Fitted curve and the curve of experimental results for 20%

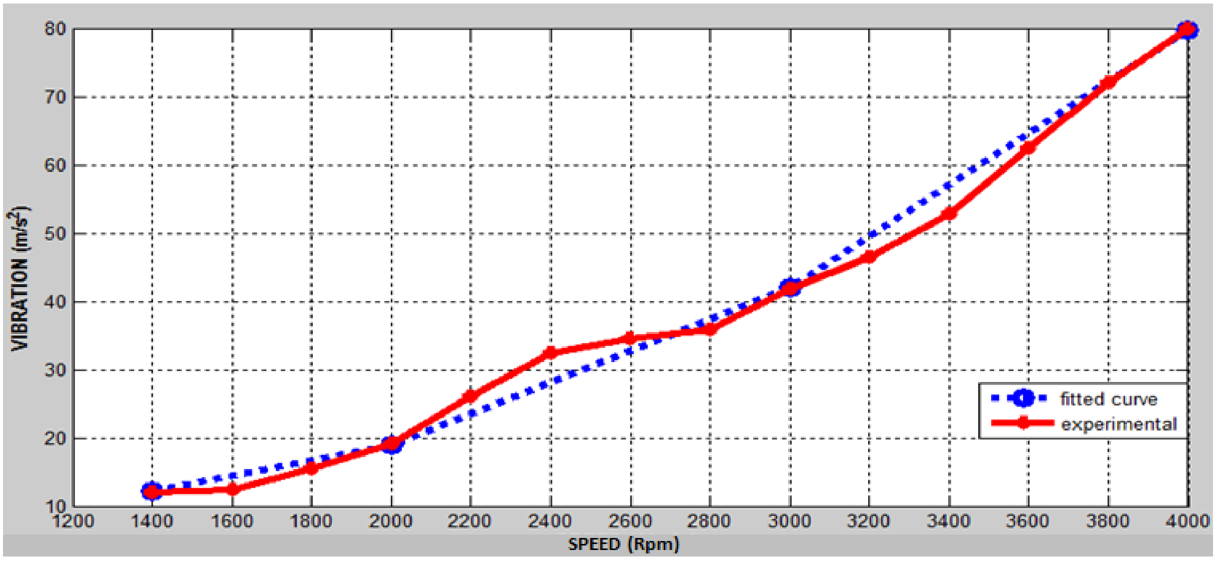

Figure 7. Fitted curve and the curve of experimental results for 30%

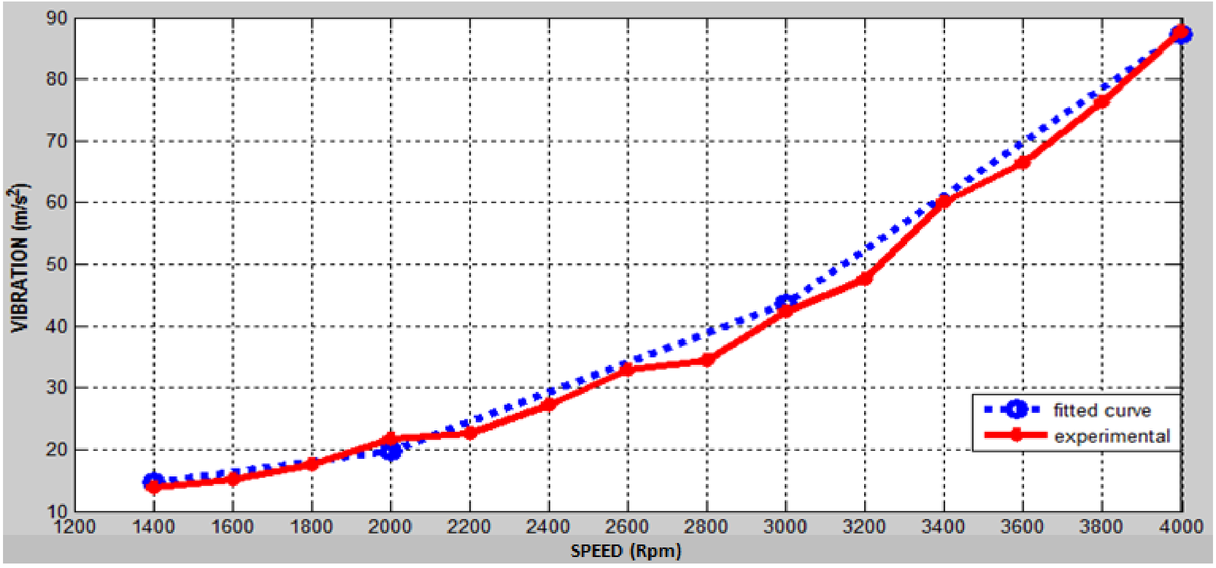

Figure 8. Fitted curve and the curve of experimental results for 40%

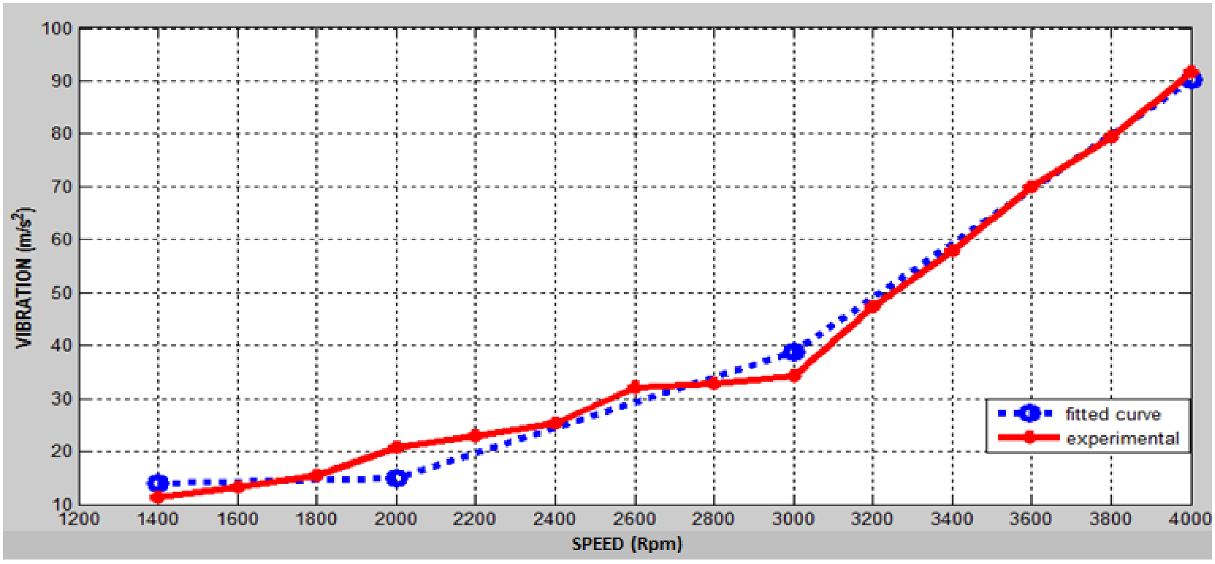

Figure 9. Fitted curve and the curve of experimental results for 50%

4. Conclusion

Main concluding remarks are as follows;

- The experimental study indicates that the vertical axis vibration amplitudes increase in response to increasing engine speed for all throttle rates
- It is shown that the curve fitting techniques especially polynomial regression is applicable for estimating the intermediate vibration values of the engine
- The fitted curves for all throttle opening rates are very close to the experimental curves
- The coefficient of determination (R^2) values are more than 0,98
- Generally, the difference between the values (obtained from fitted curve and experimental results) is less than 10% and maximum error is 6 m/s^2

Engine vibration-performance relationship can be investigated in future studies. The vibrations in three axes and the torsional vibration can be determined in comparison with the torque and power values produced by the motor. Passenger comfort and engine performance can be considered together to determine the optimum operating range of the engine.

5. References

[1] Pulkrabek, W., “Engineering Fundamentals of the Internal Combustion Engine”, John Wiley & Sons, 2001.

[2] Çetinkaya, S., “Motor Dinamiği”, Nobel Publishing, 1999.

[3] Karabulut, H., Öztürk E. and Çınar, C., “Dynamic Modeling and Investigation of Vibrations of a Single Cylinder Four-Stroke Diesel Engine”, J. Fac. Eng., Arch. Gazi University, vol. 26(1), pp. 173-183, 2011.

[4] Barelli, L., Bidini, G., Buratti, C. and R. Mariani, ‘‘Diagnosis of Internal Combustion Engine through Vibration and Acoustic Pressure Non-intrusive Measurements’’, Applied Thermal Engineering, vol.29(8), pp. 1707-1713, 2009.

[5] Manieniyan, V. and Sivaprakasam, S., ‘‘Vibration Analysis in DI Diesel Engine Using Diesel and Biodiesel’’, International Journal of Engineering Trends and Technology (IJETT), vol.4 , Aug. 2013.

[6] Wongchai, B., Visuwan, P. and Chuepeng, S., ‘‘The Vibration Analysis of Diesel Engine with Hydrogen-Diesel Dual Fuel’’, American Journal of Applied Sciences, vol. 10(1), pp. 8-14, 2013.