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# Vibration Analysis on Palm Oil Methyl Ester Biodiesel as a Fuel with The Additional of Butanol

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**Abstract**. Along with the development of alternative fuel to replace the usage of petroleum-derivatives, the vibration in the diesel engine has become one of the main focus by researchers recently. The biodiesel has been investigated numerously since the application does not need any modification of the engine and with the different fuel properties, the biodiesel can enhance or deteriorates the engine. Hence, this study will be carried out to investigate the effect adding butanol in two different biodiesel blends by using vibration analysis. The vibration level will be determined in velocity term in RMS by using uniaxial accelerometer. The results indicated that the B10Bu10 blend shows a better reduction in vibration level with the decrement more than 30% for both speed in 25% load while in the 50% load, the decrement was observed to be 13.46% for 1800 RPM and 22.9% for the 2100 RPM. Finally, it can be conclude that the usage of biodiesel with the additional of butanol can improve the vibration level in the diesel engine, however, with an additional volume of biodiesel in the blend tends to increase the vibration level in certain condition.

## 1. Introduction

With the development of the technologies nowadays has made the engine used widely in many sectors such as automotive, construction, agriculture, etc [1-3]. The application of the engine was chosen based on their characteristics such power produced, fuel consumption and the efficiency. As an option that covered all the criteria, the diesel engine has been used due to its high power produced, good fuel consumption and high efficiency [1-6].

Despite of all the advantages of the diesel engine, there are several major drawbacks from the usage of the engine and of them is the depletion sources of fossil fuel. Since the diesel were produced from a non-renewable source, it is a must to consider the availability to preserve it for the future use. It has been stated that based on current fossil fuel reserves, the source will be completely exhausted by 2055 [7-9]. This phenomenon has led to the many invention of alternative fuel in order to replace the hundred percent use of diesel as a fuel. By reducing the dependency on the fossil fuel, the alternative fuel can prolong the estimated period for the fossil fuel to be exhausted. As a promising solution, one of the inventions that seems to have a possibility to be a substitution for the diesel is the biodiesel [10-13].

Biodiesel is a biodegradable fuel that were produced from a renewable sources such as vegetable oils, animal fats and waste products that has gone under some specific processes to produce almost likely

diesel fuel with some improvements in terms of emission and eco-friendly [14-15, 43-44]. There are several ways to produce the biodiesel but the most common is the transesterification which is through the chemical process and reaction [16-21]. Can be utilized up to 20% percent of blending ratio with the diesel without any major modification on the engine has lead the biodiesel to be a way better than other alternative fuels [17,22-27].

However, with the utilization of biodiesel as an alternative fuel also had a few detonations and one of the most significant is the vibration level in the engine[28-31]. This matter has become a serious issue among the researcher since the high blend ratio of biodiesel will produces a higher vibration level which are the consequences effect from the high combustion pressure[32-35]. Kadam et al.[36] has performed an optimization of compression ignition (CI) engine operated with Simarouba Biodiesel with four controlled factors namely as fuel fraction, compression ratio, injection pressure and injection timing with four different level. It was observed that among those input parameters, the compression ratio is the most significant parameter for the vibration response and followed by fuel fraction, injection pressure and injection timing. They also use a multiple regression analysis by least square method to identify the correlation between the parameters and the output which is vibration level. It was revealed that the 20% of fuel fraction has given the lowest vibration level and it can be concluded that by increasing the fuel fraction, the vibration levels were found to be decrease. For the other parameters, the vibration level at the lowest value when the compression ratio was reduced, also when the injection pressure at the highest value with 270 bar and the injection timing at 25° before Top Dead Center (bTDC) which means that 1° more than diesel engine manufacturer's recommendation.

While in different work, Ahmet Çalık has investigates the vibration characteristics of CI engine operated with diesel and Waste Cooking Oil (WCO) biodiesel enriched with hydrogen gas. The investigation has been done by using different types of fuel and engine speed. The results indicated that the highest vibration levels were measured in z-axis which is vertical due to the upward and downward motion of the piston. It has been stated that in all engine speeds, the vibration levels were found to be highest with the use of conventional diesel fuel and the decrement was observed about 3.6% when using WCO. Further decrement was recorded when the hydrogen was introduced, by diminishing about 1.5% and 4% of vibration level respectively when using conventional diesel and WCO biodiesel [31].

With the same type of biodiesel which is WCO, Chiatti et al.[37] has carried out a work to identify the vibration characteristics in the city car engine without the additional gas introduced to the cylinder. They have concluded that the RMS of acceleration is significantly affected by the engine speed. The RMS values was observed to be increased with the increment of the engine speed due to the working principle of mechanical components in the engine and this was confirmed by [32]. Out of three types of blending ratio, B20 was found to have the lowest vibration level compared to B10 and B40.

By considering the presence of bio-alcohol in the biodiesel, a work has been done by Madhava et al. to investigate the effects of blending the Neem Methyl Ester (NME) with the bio-alcohol namely as methanol in term of vibration. It was found that at full load, the vibration levels were reduced by 36.4%, 50.7% and 40.4% for NME compared to diesel at first, second and third highest peak amplitude. They also found that with further increment of methanol in the blending ratio will increase the vibration level in the engine. Hence, it can be said that the presence of methanol will help to improve the vibration level and the blending ratio must be suitable in order to reduce the it [38].

After doing a thorough literature survey, it was found that there is still a research gap using a Palm Oil Methyl Ester (POME) blends with the butanol. Hence, this work is proposed to investigate the vibration level in the diesel engine fuelled with the POME + Butanol by carry out the investigation with the different engine speed and load.

## 2. Experimental Setup
### 2.1 Compression Ignition Engine
The diesel engine (YANMAR TF 120M) that will be used in this experiment is a single cylinder, direct injection and coupled with a hydraulic dynamometer to give load to the engine. The load will be given by 25% and 50% that will be clarified as low and medium load to give a real-application of the engine. The engine was shown in figure 1 and the specifications as listed in table 1.
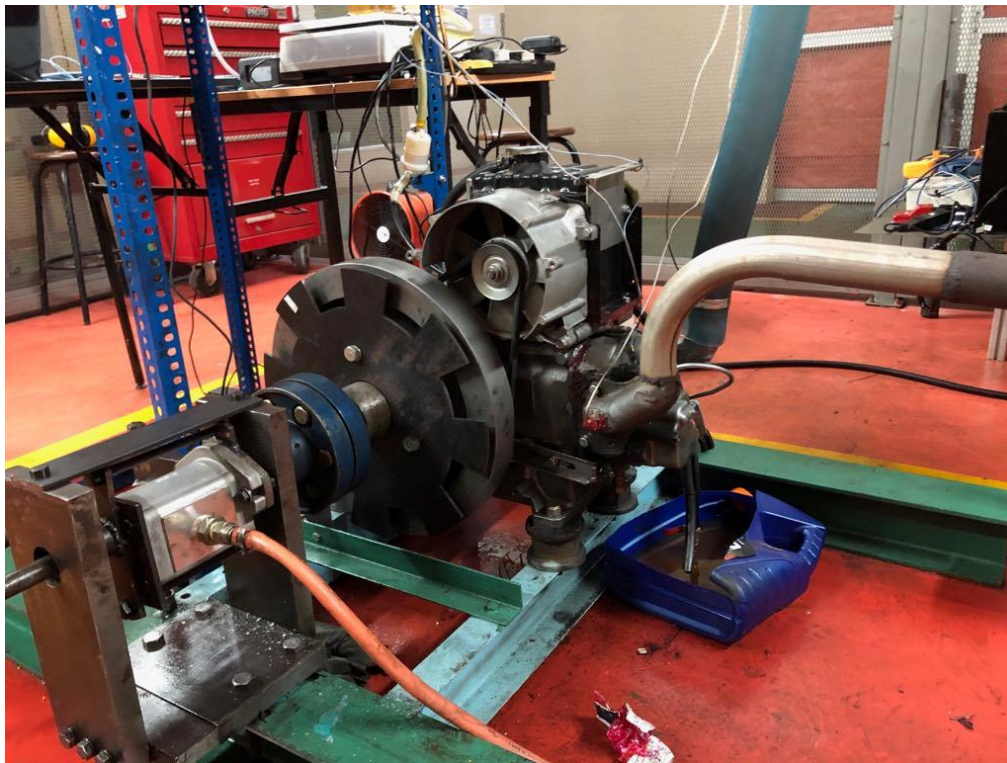
**Figure. 1** YANMAR TF 120M CI Engine

**Table 1.** Engine Specifications

| Specifications | YANMAR TF 120M |
|---|---|
| No of Cylinder | 1 |
| Cylinder Bore x Stroke, mm | 92 x 96 |
| Displacement, cc | 0.638 |
| Cooling System | Hopper/Radiator |
| Dimensions: Length x Width x Height, mm | 695 x 348.5 x 530 |
| Compression Ratio | 17.7 |

*2.2 Preparation of the Fuel*
In order to run the experiments, the fuel must be prepared just right before the experiment to ensure that the mixture was completely dissolve together. There are three types of fuel that will be used where the diesel as a baseline fuel, the second one is the POME10+Bu10 and the last one is the POME15+Bu10. The mixtures were prepared using the mechanical stirrer (IKA RW 20 digital) with the rpm range of 700-800rpm for 15 minutes. The preparation of the fuel can be seen in the figure 2 below.

**Figure.2** Blending process of the fuel

*2.3 Vibration Measurement*

For collecting the vibration data, NI-DAQ max instrument and uni-axial accelerometer were used in this work. The accelerometer sensor was placed right on the top of cylinder head to measure the vibration level from the piston movement since among the three axis which consists of vertical, longitudinal and lateral, the vertical and the longitudinal axis always shows a higher peak compared to the lateral. This condition will depend on the type of the engine used due to different types of working principle. For every experiment, the engine will be warmed up and let be stabled before recording the vibration measurement. The connection of the instruments and the location of the sensor were depicted in figure 3 and 4 below.
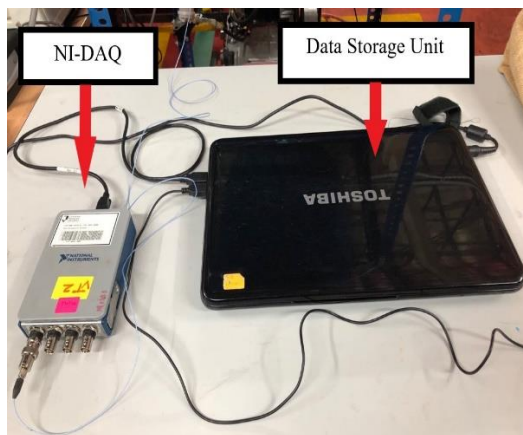
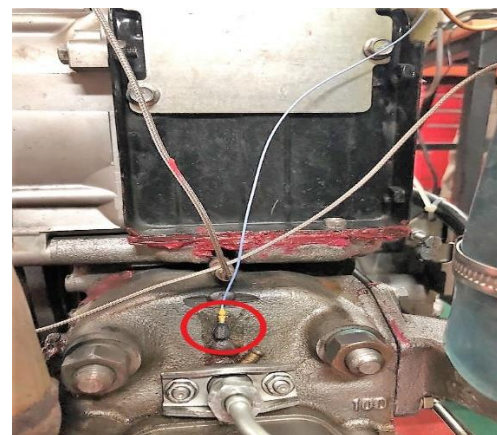

**Figure 3**. Connection of Instrument



**Figure 4**. Sensor Location

**3. Results and Discussion**

All the data that has been taken from the measurements has been plotted and analysed using MATLAB according to the engine speed and load. Figure 6 and figure 7 below will indicates the results on 25% load applied to the engine in 1800 RPM and 2100 RPM while figure 8 and figure 9 will show the results for the 1800 RPM and 2100 RPM with 50% of load. From all the graph shown below, it can be said that for every parameter the peak will happened at double frequency from the first peak frequency. This findings were consistent with findings of past studies by Patel et al. [39] which found that the peak of

in-cylinder pressure occur in multiples of 12.5Hz. Since the vibration level were significant affected from the fluctuations of the in-cylinder pressure, then this theory will be related.

In order to determine the dynamic properties of the engine, a bump test was carried out. This test was intentionally to obtain the natural frequency to avoid the effect of resonant frequency in the combustion frequency. By giving force through impact hammer as the input and the reading from accelerometer as the output, the frequency response function of the engine will be determined. From the figure 5 below, it can be seen that two natural frequencies happened in the engine at 13Hz with the amplitude of 0.00927 g/N and 24Hz with 0.00254 g/N. Hence, these two frequencies will be avoided during the experiment in order to know the exact frequency that happened by combustion excitation forces.
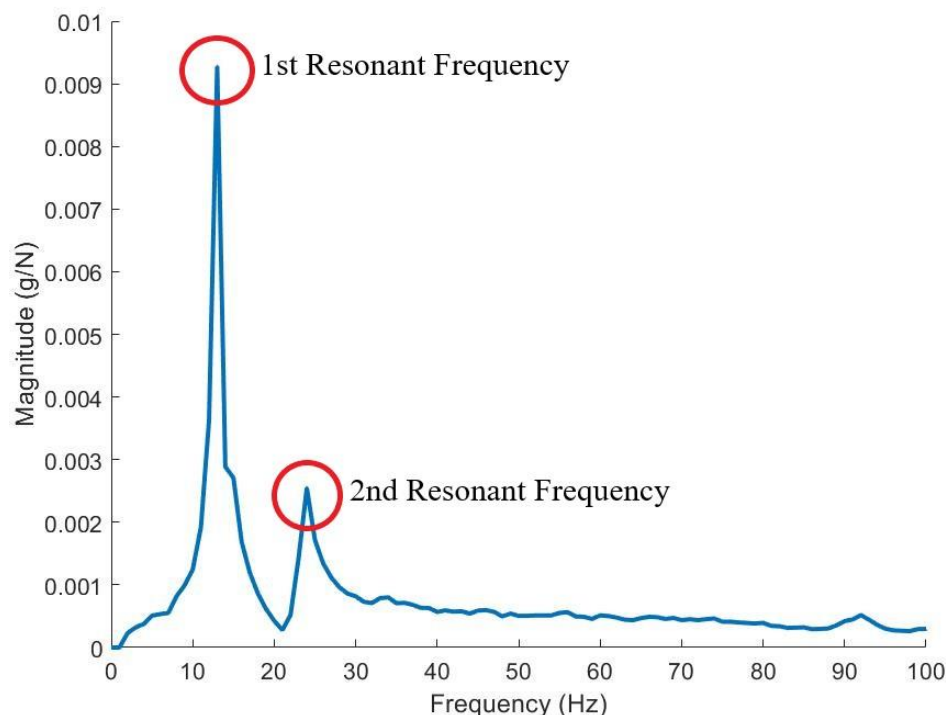


**Figure 5**. Bump Test of The Engine

By focussing at the operational frequency for each parameter, it was found out that there is a significance changes between each fuel. From figure 6, it is notable that the diesel was the highest vibration level compared to B10Bu10 and B15Bu10 with the value of 0.002123, 0.001343 and 0.001605 m/s. The decrement observed when using B10Bu10 was 36.74% while the B15Bu10 reduced about 24.4%. For the speed of 2100 RPM that were depicted in figure 7, the results still show the same trend where the highest vibration level was diesel. However, the overall vibration level for this speed was decreased compared to previous speed. When increasing the speed, with the value of 0.000891, 0.000455 and 0.000765 m/s for diesel, B10Bu10 and B15Bu10, the B10Bu10 tends to show a better reduction with 34.34% while the B15Bu10 still reduce the vibration but only with small percentage which is 14.14%. This condition may happen due to the high engine speed that lead to short premixing combustion phase hence will lead to incomplete combustion.
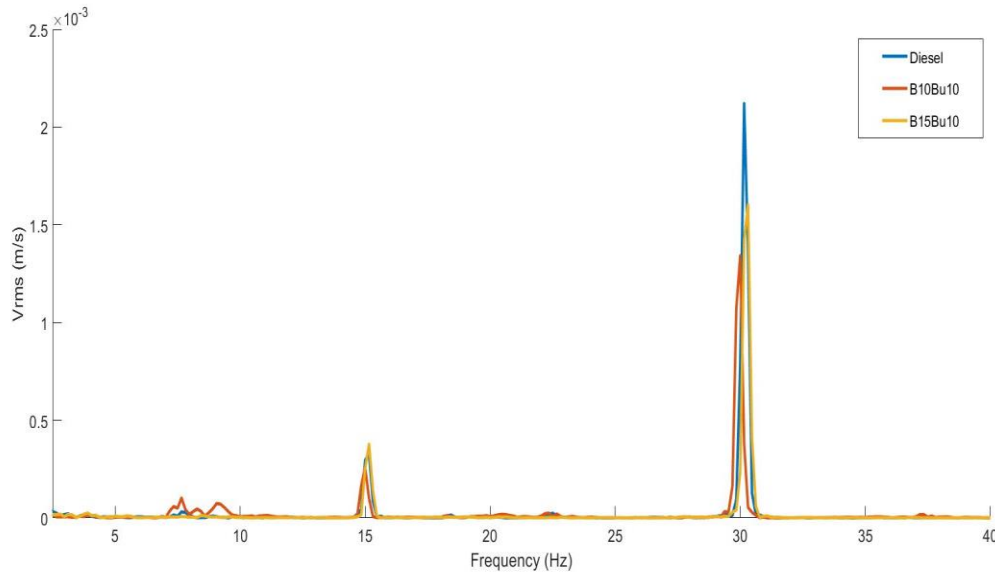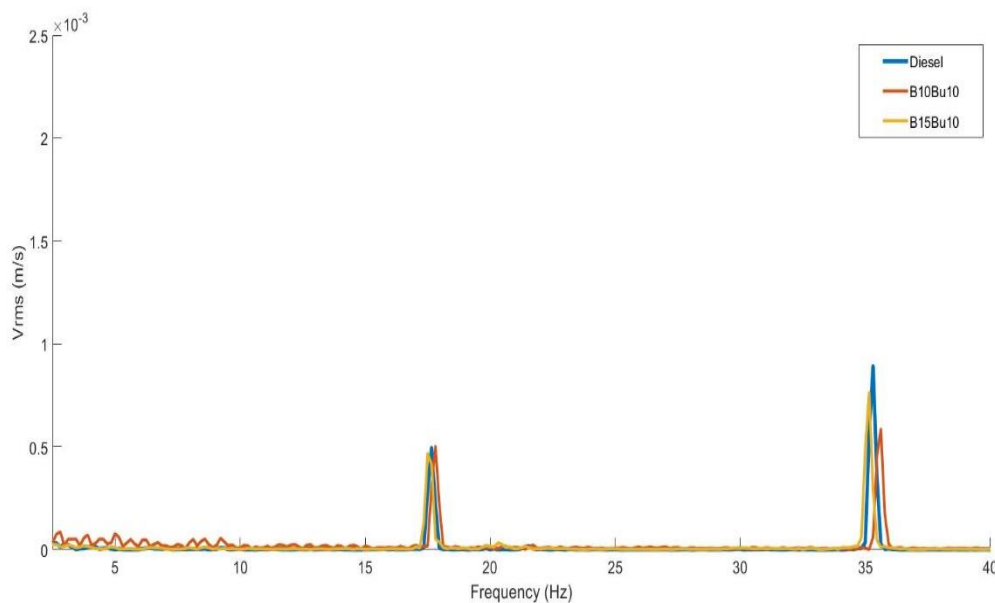
**Figure 6.** 1800 RPM with 25% of Load



**Figure 7.** 2100 RPM with 25% of Load

Despites the peak frequencies in 25% load were dominated by diesel fuel, in 50% load, the B15Bu10 tends to shows a significance differences where it contributes a highest peak frequency. As can be observed from figure 8 below, the B15Bu10 contributes to higher vibration level as the load increases. It can be said that by increasing the biodiesel amount in the blends will increase the viscosity of the fuel that will affect the spray penetration and atomization of the fuel [37]. This theory can be confirmed when the B10Bu10 shows a lower peak when compared to diesel and B15Bu10. Being added that at higher loads, the air-fuel mixture will be uneven hence will leads to poor combustion [40-42]. However, it was noticed that when the speed was increased, the overall vibration level will decrease. The same phenomenon also happened in 25% load. With the value of 0.001931, 0.001671 and 0.002198 m/s for diesel, B10Bu10 and B15Bu10, the decrement when using B10Bu10 was 13.46% and when

using B15Bu10, a sudden increment with 12.15% was observed. It is notable that when using biodiesel+butanol as a fuel owing to slightly early combustion frequency. This condition may happen due to the high cetane number of the biodiesel+butanol blends which lead to shorter ignition delay. From figure 9, it can be noticed that the diesel still contributes higher vibration level with the value of 0.000987 m/s while the B10Bu10 and B15Bu10 with 0.000761 and 0.000913 m/s. The decrement was observed to be 22.9% for the B10Bu10 and 7.5% for the B15Bu10. It can be concluded that the B10Bu10 does show a positive result by reducing the vibration level in both load condition compared to those two fuels. These conditions had proven that the B10Bu10 has a better fuel property with its blend ratios between diesel, biodiesel and butanol.
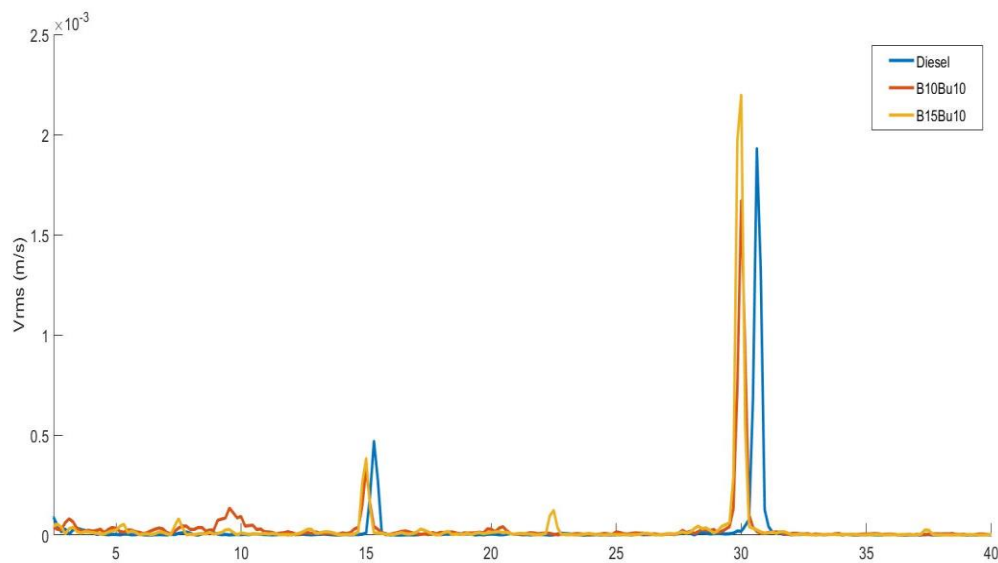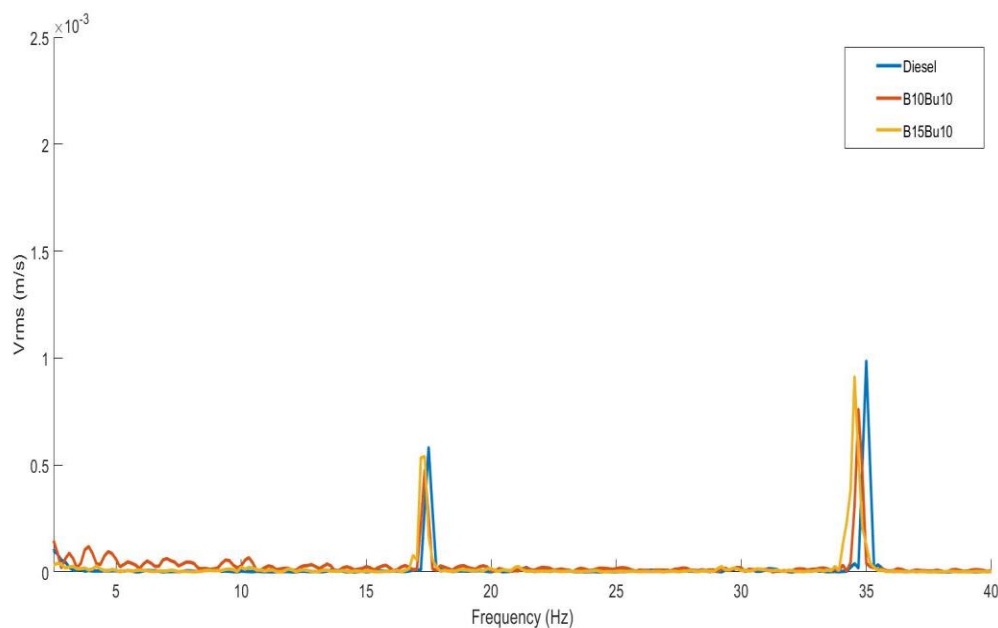


**Figure 8.** 1800 RPM with 50% of Load



**Figure 9.** 2100 RPM with 50% of Load

## 4. Conclusion
After all the experiments and the analyzation of data were done, it was found that out of the three fuel that has being used, the B10Bu10 shows the best results by reducing the vibration level in both load conditions as high as 49%. With a further increment in biodiesel volume in the blends will increase the vibration level at high load which is related with the kinematic viscosity of the fuel that can affect the fuel atomization hence will lead to incomplete combustion. However, the best fuel still needed to be investigated by other analysis in order to ensure that it can replace the fully usage of diesel in current engine.

## Acknowledgement

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