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Experimental investigation on noise and vibrations of biodiesel-butanol blends for diesel engine

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Abstract. Diesel engines have extensively used several developing countries to produce electricity. This is done in various sizes, small and medium, which are driven by millions of diesel engine generators. These engines or generators produce vibrations and noisy and pollute the air. Thus, an alternative to diesel is needed for such applications. Turpentine-diesel fuel mixture is one such alternative. However, there have not many efforts made so far to evaluate noise and vibration characteristics. This study is done to try filling the gap and comprehensively investigate the use of Turpentine-diesel mixed fuels. This experiment uses a single-cylinder-4-stroke diesel engine operated at different rpm speeds and engine loads. Detailed measurements are made for engine noise and vibration. This measurement is used to connect the reciprocity of engine noise and vibration. The relationship of chemical parameters and physical properties to the tested fuel explored. The test results using turpentine-diesel fuel show the vibration and noise characteristics better for the upper-middle load. The correlation between noise and vibration characteristics of the test fuel has a strong relationship. This study has provided a detailed phenomenological explanation of the nature of the fuel. Finally, turpentine blends are a viable alternative to diesel fuel, especially in diesel engines

Keywords: diesel engine, noise, vibration, fuel, generator

1. Introduction

The automotive industry currently uses many compression engines, especially large vehicles and generators. The energy of the fuel has been converted into mechanical and electrical energy in the presence of this machine. In general, generator engines are not like automotive diesel engines; because the nature of the design is simpler, it does not move and runs at a constant speed. In general, this engine is noisy and produces vibrations, which are transmitted to the entire engine structure. In addition, a large amount of greenhouse gases is donated from this machine. So that alternative fuel is needed for this engine and does not require a significant change in engine design.

Identification of alternative fuels for diesel has been carried out globally in recent years. These alternative fuels can be grouped into two groups including alcohol-diesel and biodiesel-diesel-oil. Research on noise and vibration in diesel engines using alcohol has not been done in recent years. However, the use of biodiesel fuel mixture has been expressed in the characteristics of the noise and vibration of diesel engines. The characteristics of noise and vibration carried out on diesel engines using a mixture of biodiesel fuel have been investigated by [1– 3]. Their analysis and predictions reported that the properties of fuel and engine vibration are related. Engine vibration is reduced for a mixture of biodiesel-diesel fuel because the fuel has oxygen. The investigation of noise and vibration using a mixture of castor-diesel oil for diesel engines has also been discussed by [4– 6]. The results of the tests showed that the engine combustion noise decreased with the amount of noise around 1–3 dBA for a mixture of diesel-fuel oil compared to pure diesel. Among all the fuels tested for the horizontal, lateral and vertical directions, pure diesel shows the highest vibration.

A different study was carried out by [7– 9], where a mixture of soybean biodiesel and canola fuel was carried out to investigate vibrations in diesel engines. The experimental results reported that pure diesel has a lower vibration compared to biodiesel fuel. The correlation between vibration and engine maximum heat velocity for diesel engines has been investigated by [10], [11]. The frequency of engine vibration was reported at 0.3–5 and 1.5–2.5 kHz because it is caused by a piston slap and the engine combustion process. In a different study, investigations were conducted by [12– 14] on vibration for diesel engines using biodiesel fuel with a common rail system that has high pressure. The results of trials conducted by engine vibration experienced a reduction of 13.7% for a mixture of diesel-biodiesel fuel. Engine vibration is reduced because of the low cylinder pressure when using diesel-biodiesel. The use of Karanja biodiesel fuel running on diesel engines was investigated by [6], [15], [16]. The 20% biodiesel fuel mixture can produce maximum heat release and combustion noise among all fuel samples tested. The 20% biodiesel mixture was reported to have the highest vibration in the vertical direction.

The effect of biodiesel fuel for diesel engine noise was also investigated by [17– 20]. The results of the experiments they conducted observed that the physical and chemical properties of the materials used played a very important role in engine noise. They reported that when using biodiesel with low cylinder pressure reduced engine noise compared to pure diesel fuel. Meanwhile, the noise characteristics for direct injection diesel engines triggered by biofuels and synthesis were investigated [1], [20], [21], [22]. The results of their investigation showed that combustion noise decreases with an increasing percentage of biodiesel fuel and the content of the oil synthesized in fuel. Based on the two cases, noise can decrease because of differences in the combustion phases and the speed of fuel injection. Noise of diesel engines when using fuel methyl ester pomace olive oil with diesel has been studied by [23– 25]. The results showed that the biodiesel fuel they used can reduce engine noise by increasing the amount of cetane.

It appears that there is a dearth of work that explores noise and vibration for CI machines. Furthermore, there was little research and knowledge about noise and vibration for CI machines triggered by a mixture of turpentine-diesel blends. Turpentine fuel potential is an alternative to diesel. This study seeks to test and assess the behaviour of CI machines in a comprehensive manner. The work discussed the noise and vibration aspects of the diesel engine for the Turpentine-diesel fuel mixture for different engine speeds.

2. Experimental Setup

This experimental study uses a YANMAR TF120M, 4-stroke, single-cylinder, direct-injection engine. This diesel engine has an output of 7.83 kW and 2400 rpm. The engine specifications for this test are shown in Table 1. The schematic diagram of this experiment can be shown in Figure 1.

Table 1. Detail of engine specifications

Description	Specification
Engine model	YANMAR TF120M
Engine type	Horizontal single-cylinder 4-stroke diesel engine
Fuel injection type	Direct injection
Bore × Stroke (mm)	92 × 96
Displacement (L)	0.638
Injection timing	17° BTDC
Fuel injection pump	Bosch
Injection pressure (kg/cm^2)	200
Compression ratio	17:7
Continuous output (HP)	7.82 kW at 2400 rpm
Rated output (HP)	8.94 kW at 2400 rpm
Cooling system	Water-cooled (radiator type)
Cooling water capacity (L)	2.3

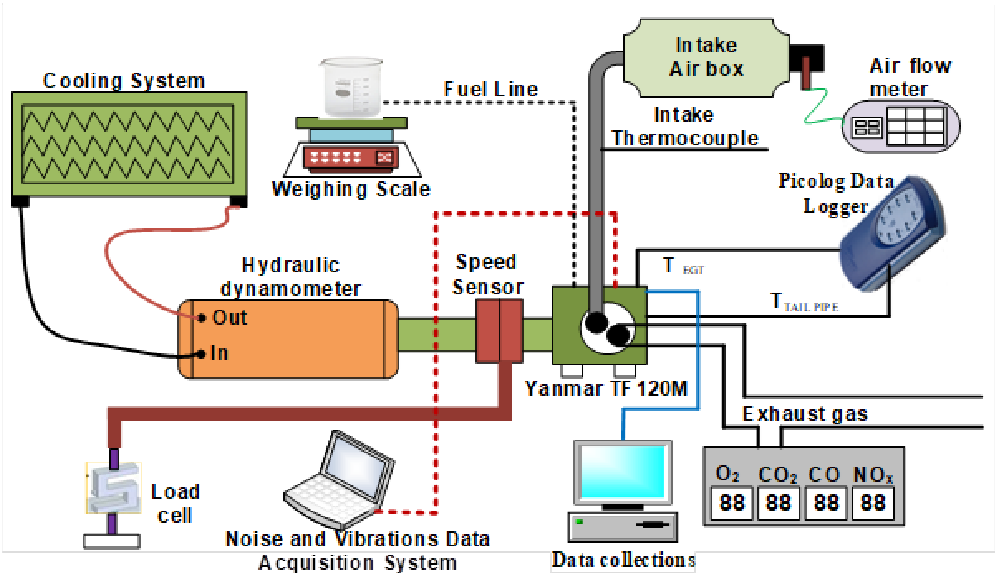

Figure 1. Schematic diagram of the experiment

Noise measurement is taken adjacent to the engine approximately 50 cm to get noise data from each sample of fuel used. Engine vibration is measured in the directions of X, Y, and Z using PCB Piezotronics ICP® Accelerometer (352C22). The specifications of the sensors and the devices used are listed in Table 2.

Table 2. Accuracy of various devices and sensors

Description	Specification
Sensitivity (±15 %)	1.0 mV/(m/s²)
Measurement Range	±4900 m/s² pk
Frequency Range (±5 %)	1.0 to 10000 Hz
Frequency Range (±10 %)	0.7 to 13000 Hz
Frequency Range (±3 dB)	0.3 to 20000 Hz

Resonant Frequency	≥50 kHz
Broadband Resolution (1 to 10000 Hz)	0.04 m/s² rms
Non-Linearity	≤1 %
Transverse Sensitivity	≤5 %

3. Results & Discussion

This experimental study was carried out at five engine speeds at a load of 25% and 50% using turpentine-diesel additive fuel that is, pure diesel with added 0.2% turpentine oil to diesel engines. The vibration measurements result from the use of turpentine additives compared to pure diesel fuel. Experiments were carried out at engine loads of 25% and 50% with engine speeds of 1200 to 2000 rpm at intervals of 200 rpm. Vibration signal data is taken from each load and different engine speeds to see engine vibration levels when using different fuels.

The results of the tests carried out using turpentine oil additives with pure diesel are shown in Fig. 2 and 3 where the use of turpentine oil additives results in lower engine vibrations for all speeds tested at 25% load. The engine vibration also depends on the speed of the engine; the higher the speed of the engine vibration, the more the engine decreases. The use of pure diesel produces the highest vibration at 1200 rpm around 1.1 magnitudes compared to turpentine additive oil which only reaches 0.6 magnitudes. In general, the overall engine speed tested for a 25% additive turpentine load results in less vibration than pure diesel. The reason is that turpentine oil has alcohol in it, so it can produce softness when burning the engine.

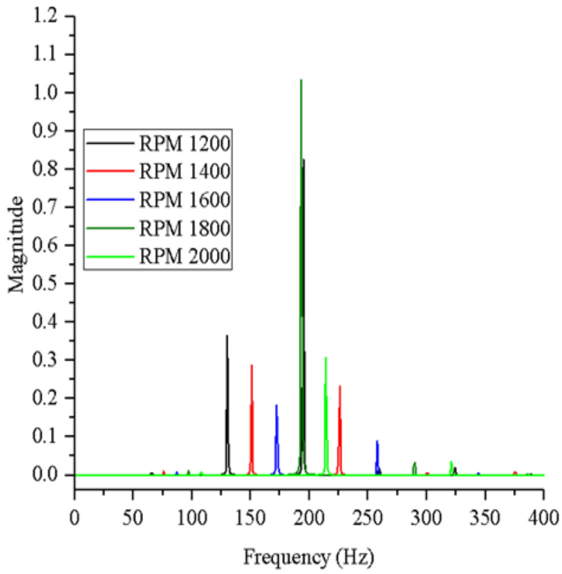

Figure 2. Vibration at load 25% and different speed using diesel fuel

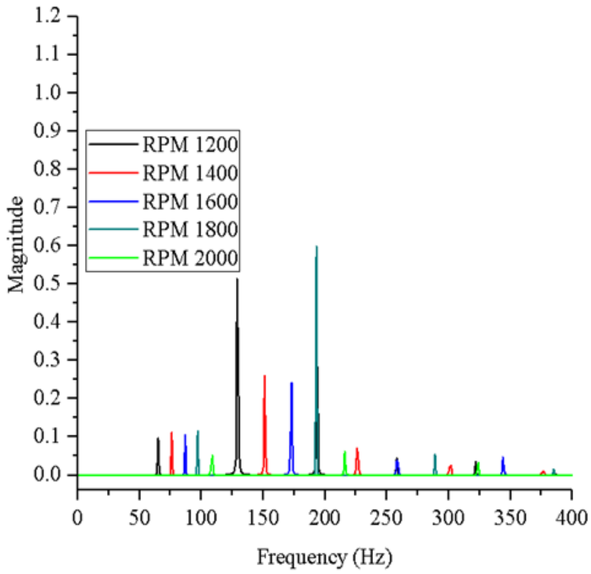

Figure 3. Vibration at load 25% and different speed with additive of turpentine

The next experiment was carried out at 50% engine load with the same speed between 1200 to 2000 rpm using diesel fuel and then compared to turpentine additive oil. From Fig. 5. it can be explained that the use of turpentine additive oil produces less vibration than pure diesel fuel shown in Fig.4. Diesel fuel produces the highest vibrations up to 1.1 more magnitudes for 1200 rpm engine speed whereas when using additive oil for 1200 rpm, it only reaches a magnitude of 0.7. However, there is a slight difference in the engine speed of 1600 rpm diesel fuel as they produced less vibration than the turpentine additive oil. Whereas at 1400 rpm almost has an equation.

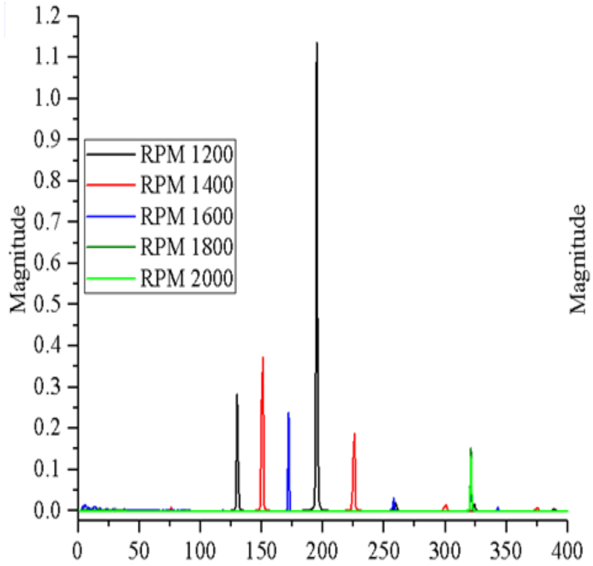

Figure 4. Vibration at load 50% and different speed using diesel fuel

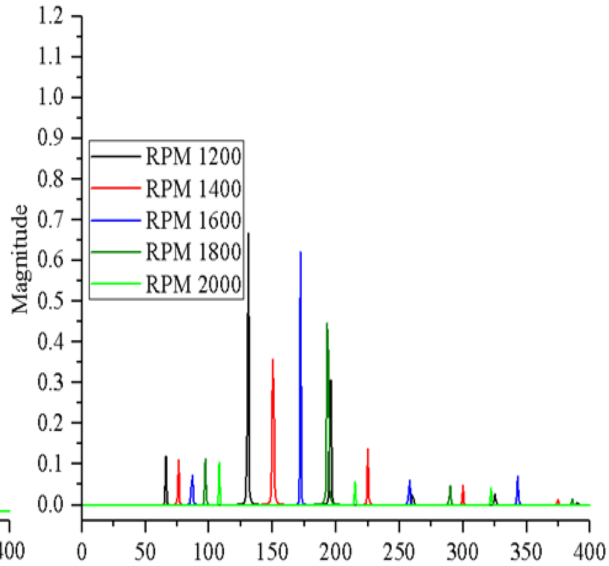

Figure 5. Vibration at load 50% and different speed with additive of turpentine

The results of the experiments that have been done to measure the vibration of the engine using pure diesel fuel with additives show little difference for engine load; where the engine load begins to increase, engine vibration also increases. However, for all speeds tested, turpentine additive oil can generally produce less vibration than when using pure diesel fuel. So it can be concluded that turpentine additive oil is good for use in diesel mixtures. However, turpentine oil is more expensive, therefore, it has not been applied extensively on combustion engines.

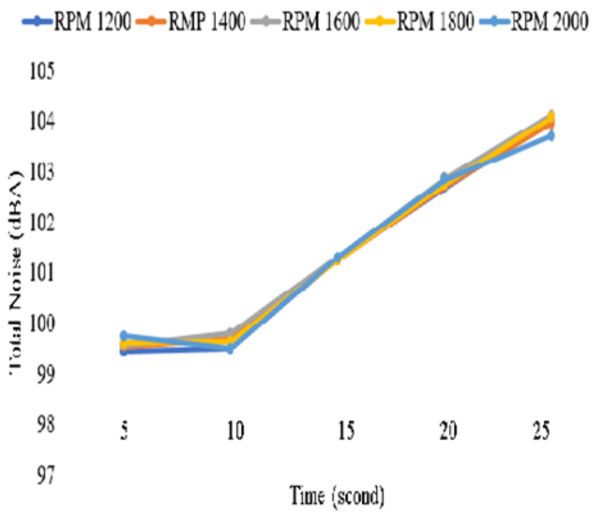

Figure 6. Total noise for different speed at load 25% using diesel fuel

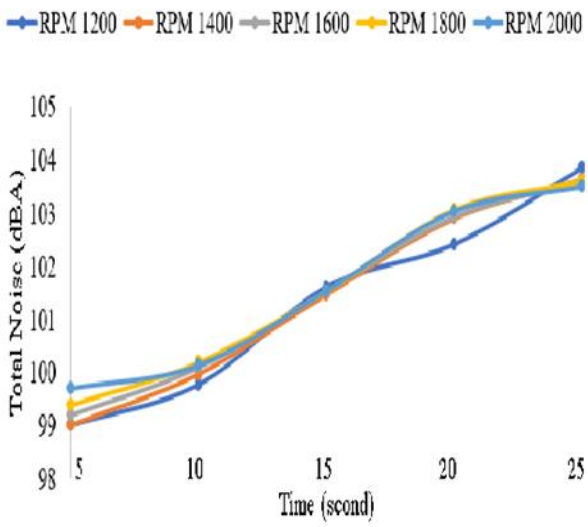

Figure 7. Total noise for different speed at load 25% with additive of turpentine

Figure 6 and 7 show the noise from engine combustion using pure diesel fuel with turpentine additive oil for 25% engine load with different rpm speeds. Noise from combustion using a slightly finer turpentine oil additive are as shown in Fig. 7. The use of diesel fuel for all speeds are higher than that of additive oil shown in Fig. 6. Moreover, the additive oil is slightly more variable compared to the 2000 rpm engine speed, where at 20 seconds it drops slightly while diesel does not have the same trend as additive oil.

Furthermore, combustion engine noise measurements using pure diesel fuel by comparing turpentine additive oil were carried out at 50% engine load with different engine speeds. It is reported that diesel fuel tested as a reference produced higher engine noise than additive oil. The highest noise from diesel fuel is 107 dBA, which is slightly higher than additive oil that reaches 105 dBA. Meanwhile, turpentine additive oil produces the lowest noise at 99 dBA compared to diesel which reaches 100 dBA as shown in Fig. 8 and 9. However, diesel fuel produces more noise trends than oil additives because the use of diesel fuel gets hotter with higher speed and engine load can produce better combustion.

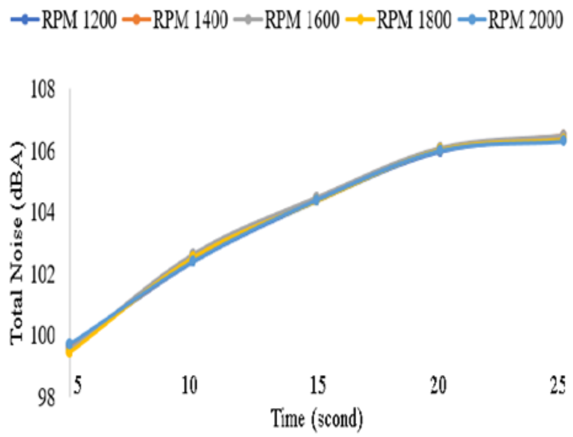

Figure 8. Total noise for different speed at load 50% using diesel fuel

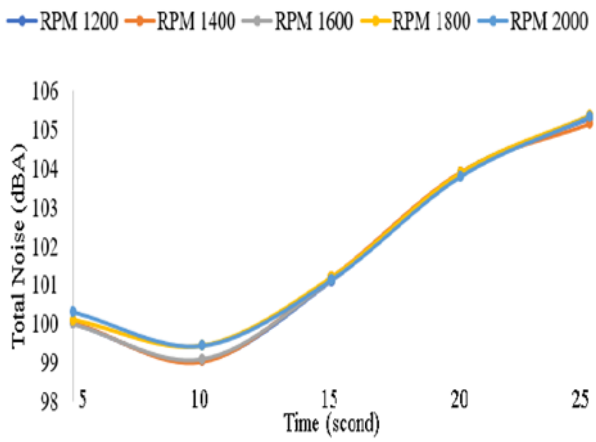

Figure 9. Total noise for different speed at load 50% with additive of turpentine

4. Conclusion

In this work, noise and vibrations of turpentine blends were compared to those for diesel fuel in the engine diesel. Turpentine fuel can produce less noise and vibration, especially when the engine load is higher than when using pure diesel. Moreover, the Turpentine-diesel fuel mixture can reduce considerable exhaust emissions in the engine. For this reason, due to density, the calorific value and viscosity in turpentine fuel are lower than pure diesel. Thus, for the whole sample, turpentine fuel is very suitable as an alternative to diesel fuel, especially for diesel engines. However, this change must be applied with a mixture of fuel and lubricants because additives are very necessary to compensate for the lubrication of the fuel lost due to the presence of turpentine fuel.

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