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EFFECT OF FUEL ADDITIVE CONCENTRATION ON PERFORMANCE AND VIBRATION CHARACTERISTICS OF A COMPRESSION IGNITION ENGINE

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Abstract

In the past few years, a lot of research work has been carried out on the performance of Compression Ignition (CI) engines with use of additives blended with diesel fuel in different proportions. The properties of additives added in fuel improve the rate of combustion and increases surface area of fuel droplets. The added substances to the fuel are largely associated with gasoline and oil-based fuels to reduce pollution in the environment, enhance mileage and output power of the engine. The utilization of added substances results in improvement of combustion rate, reduction in harmful emissions and enables the use of fuels even at high temperatures. In the present research work, an effort has been made to increase the performance of CI engine by mixing additives in diesel in different proportions. The additive is mixed with diesel in different proportions and the resulting mixtures were designated as M1, M2 and M3 and the test results of these mixtures are compared with pure diesel. The CI engine is tested for frequency of vibration in both longitudinal and transverse directions with mixture of additives and diesel in different proportions and the performance of the engine is compared with the use of these mixtures. For all blended fuels, brake thermal efficiency has been increased up to 6% and fuel consumption has been decreased up to 10% at all loading conditions of the engine. The increase in brake thermal efficiency with M2 fuel is high compared to other blends but showed adverse effects at part loads. The decrease in fuel consumption is very significant with M2 fuel mixture. The use of mixture M3 resulted in significant decrease of fuel consumption up to 13% and increase of brake thermal efficiency up to 8% for all load conditions of the engine. A significant increase in both transverse and longitudinal vibration has been observed with the use of M3 fuel.

Keywords: CI engine, Fuel additive, Vibration.

1. Introduction

The Diesel engine technology assumes a significant job in the transportation sector and more than 80% of commercial vehicles are powered by CI engines. The CI engines are used to power river barges, marine work vessels, electric generators used as power backup in many places and finds its application in almost all the commercial needs. Fuel additives are one of the most important innovations in the field of liquid engineering. The use of fuel additives helps to improve the fuel burning rate, increases surface area and prevents corrosive effects. Over the years a wide range of fuel additives have been used in the interest of environmental protection by reducing emissions, to increase mileage and power output. A broad research work has been conducted by Fayyazbakhsh and Pirouzfar [1] to study the impact of ethanol-diesel mixes with various kinds of added substances on engine performance and exhaust emissions and the investigation is done through experimental modelling and optimization methods. A turbocharged CRDI engine is used for experimentation and factorial design was adopted to optimise the emission parameters, engine parameters and physico-chemical properties. They considered main parameters such as NE, NM and 2- MXEE, metal additives like MN and CE, speed of the engine and load conditions. They showed that the use of diesel-ethanol-(NE+MN) decreases emissions and increases cetane number. The blend diesel-ethanol with (MXEE+CE) gives better engine performance than other additives.

Kaimal and Vijayabalan [2] investigated experimentally effect of using diethyl ether in a diesel engine, fuelled with waste plastic oil and results shows that with increment in percentage of DEE in blends, the BTE increases and BSFC reduced considerably. and also, drastic reduction in NOx and smoke. In another research carried out by Mahalingam and Ganesan [3], 20% of rubber seed oil (B20) mixed with diesel and aluminium oxide (Al_2O_3) and is utilized in the proportions of 10, 20 and 30 ppm. The outcomes appeared an increase in thermal efficiency and decrease of emissions and specific fuel consumptions. The utilization of aluminium oxide mixed with biodiesel improved the burning qualities in the engine and decreased the carbon deposits by 44.8% in the cylinder wall.

The research has been carried out by Attia et al. [4], to inspect the impact of nano added substances on diesel engine execution in various working states of load and speed. The alumina nano particles were added to combination of jojob methyl ester (bio diesel) and ordinary diesel in the extents of 20% biodiesel and 80% traditional diesel with various dosages of 10 to 50mg/l. The study recommended that the appropriate nano additives dose of about 30mg/l gives better engine performance. The results show that the BSFC is reduced by 6%, thermal effectiveness is expanded by 7% and engine emissions have been decreased for example NOx about 70%, CO around 75 %, smoke darkness about 5%, and UHC around 55 %. A comparative study was carried out by Shekhawat and Padwa [5] to find alternative for diesel fuel and to increase the performance of the engine. A review was done on mixing of oxygenated added substance at various rate with sole diesel and considered the consequences for different execution boundaries. An improvement in BSFC, combustion performance and decrease in engine emission were reported.

In another research done by Tkaczyk et al. [6], FMAX diesel additive and HDOS lubricant oil additive were produced and the effect of catalyst and polar additives on the performance of the engine and exhaust emissions were

investigated. The use of additives to diesel and lubricant oil positively influenced the combustion process in relation to emission of exhaust and fuel consumption. The researchers recommended the use of FMAX with fuel in the proportion of 1:4000 to achieve higher power output. The combustion behaviour and ignition process of Al and Al2O3 nanoparticles are experimentally investigated by AbdAli [7], the nano particles used are stably suspension in mixture of diesel and biodiesel (jatropha). The combustion and ignition performance are enhanced by adding aluminium (40nm) and aluminium oxide (30nm) additive nanoparticles to the fuel mixture. The volume fraction percentage of the nanoparticle's additives is varied from 0.1% to 0.5%. The increase of heat of combustion and reduction in ignition delay were analysed. The authors concluded that the aluminium and aluminium oxide nanoparticles increase the energy density and heat of combustion, reduces evaporation delay. The SEM was used to show the morphology of the state of additives and mixture agglomeration.

A review of bio-diesel/fuel additives on the diesel engine performance and emissions was carried out by Khalife et al. [8], and the additives reviewed were grouped in to five categories such as additives of oxygenated type, metallic based additives and non-metallic additives, water, antioxidants and polymeric-based additives. The researchers discussed the effect of each type of additive on engine performance parameters such as brake specific fuel consumption, brake thermal efficiency and emissions like CO, NOx, HC and particulate matter. The various methods of adding water such as emulsion of water and diesel, direct spray of water and introducing water near to the inlet manifold were illustrated. The benefit and disadvantages of all additives considering in terms of performance and combustion were highlighted. The importance of bio-diesel and its effective utilisation had been analysed by Shahabuddin et al. [9], They conducted experiment to find BP, BSFC, emission characteristics (NOx, HC and CO. etc) and exhaust temperature. The results were compared with normal diesel. The authors concluded that the inclusion of additives to bio diesel (B20+1%) gives better performance and results in reduction of exhaust emission including NO_x .

The CI engine performance analysis and emission characteristics have been reported by Khond and Kriplani [10]. The authors found that the make use of nano particles as additives in fuel and water emulsified fuel is the best method of improving the performance and controlling the emissions. The review paper concluded that the use of nano fluid additives in diesel and bio-diesel increases surface area to volume proportion, catalytic activity in nano size metal oxides and metals. The combustion is improved due to micro explosion phenomenon. Vigneswaran et al. [11], have improved the performance of a single cylinder diesel engine by using 1,4-dioxane a hygroscopic, multipurpose substance as an additive with the ideal mix of DWS. They showed that the brake thermal efficiency of DWSA10 increases up to 7% in comparison with diesel and Hydrocarbon and smoke decreases up to 31.66%, 27.83% respectively in comparison with diesel. They also reported a decrease of 7.5%, 15% in brake specific energy consumption and carbon monoxide respectively of DWSA10 on par with DWS fuel. They concluded that the test fuel DWSA10 with 10% 1,4 dioxane gives a huge improvement in the engine exhibition and decrease in emissions.

The combustion and emission characteristics of diesel-MEA (2-methoxyetheyl acetate) blends were investigated by Yanfeng et al. [12], They utilized MEA as an additive in diesel to decrease the exhaust. The effects of MEA on engine output

emissions and combustion characteristics were studied. A decrease in maximum engine cylinder pressure, shorter combustion duration and delay in ignition were the observations with the use of MEA blends. The use of MEA 15 increased the thermal efficiency by about 2%. They recommended the use of blend containing 15% MEA. Kalam and Masjuki [13] have conducted experiment to assess the impact of anticorrosion added substance in biodiesel on diesel engine performance, smoke and wear qualities. The results of the paper concluded that an increase in power and reduction in emissions when compared to base fuel.

Karthickeyan et al. [14], carried out experiment to study the performance and emission characteristics of blended diesel. The results showed that the blended fuels resulted in lower CO_2 emissions and lower NOx emission. Ayindirli and Celik [15] altered the physical and compound properties of the fuel by adding additives to diesel fuel. The engine torque was improved and BSFC was decreased. It was also observed that the maximum cylinder pressure and heat release rate values had been increased and HC, CO and soot emissions were decreased. Bedar et al. [16], investigated the effect of biodiesel and exhaust gas recirculation on performance and emission characteristics of a CI engine. They used Simarouba glauca biodiesel with blends B20, B40 and 10, 15 and 20% EGR ratios. The results showed that there is a reduction of CO, HC and smoke opacity and increase of NOx with simarouba biodiesel. The investigators concluded that the B20 blend at 15% EGR resulted in better performance characteristics in comparison with other conditions. The impacts of cylinder scraping fault on the performance and vibrations were analysed by Moosavian et al. [17] and found that the engine vibration is extremely capable of recognize piston scuffing fault.

The effect of fault raised due to scratching of piston with cylinder on the vibration behaviour of an engine was analysed by Moosavian et al. [18] and showed that the piston scratching deficiency caused a significant increase in engine vibration [18]. The causes for vibration and to reduce the vibrations at the engine supports have been reviewed by Ramachandran and Padmanaban [19] and he found research gap on the modelling of vibration and engine isolation. Taghizadeh-Alisaraei and Rezaei-Asl [20] investigated on performance, combustion and vibration characteristics of engines by adding ethanol to pure diesel with a different concentration. The results showed that torque and power increases at fuel blend with 6% ethanol as compared to pure diesel and also RMS and kurtosis of vibration on the engine block increases by 4.75 % and 7.75 % as compared to pure diesel. An endeavour was made by Mahdisoozani et al. [21], to assemble all the ongoing works led to decrease and disconnect engine vibration, prior to sending to other vehicle parts, for example, drive shafts and body.

From the above discussion, it was observed that most of the research work had been carried out with metal additives, oxygenated type additives, non-metallic additives, water, antioxidants and polymeric-based additives to check the effect of these additives on performance parameters such as brake specific fuel consumption, brake thermal efficiency and emissions like CO, NOx, HC and particulate matter. The experimental approach, analytical and numerical methods have been adopted and some optimization techniques have been used to optimise the performance parameters. The findings from the literature reveals that less effort has been made to relate performance parameters with vibrational behaviour of the engine. The present work aims to test a commercial fuel additive which can be mixed with diesel to improve performance of the engine. The experiment is carried out with different

proportions of additive mixed with diesel and the effect of proportions of additive were studied on performance parameters. The vibration characteristics are analysed at different loads with varying proportions of fuel additives mixed with diesel and linked with engine performance parameters. Further the study is extended to understand the vibration behaviour of the engine with respect to various performance parameters.

2. Experimental Setup and Method

The test arrangement comprises of a computerised four stroke single cylinder Diesel engine with Eddy current dynamometer. Figure 1 shows the block diagram of the experimental setup; Figs. 2 and 3 shows the engine used for conduction of experiment with FFT analyser. The engine specifications are listed in Table 1.

The engine instrumentation panel consists of air rate indicator to show air flow rate, torque indicator to measure the torque applied to the engine, speed indicator to measure rpm of the engine, fuel rate indicator to indicate the amount of fuel consumed by the engine, temperature indicators to measure temperature, exhaust gas calorimeter and combustion pressure sensor with water cooling. The severity of vibration is measured in terms of displacement showing the magnitude of engine vibration, velocity - indicating how fast the engine is vibrating and acceleration showing the forces which are causing vibration.

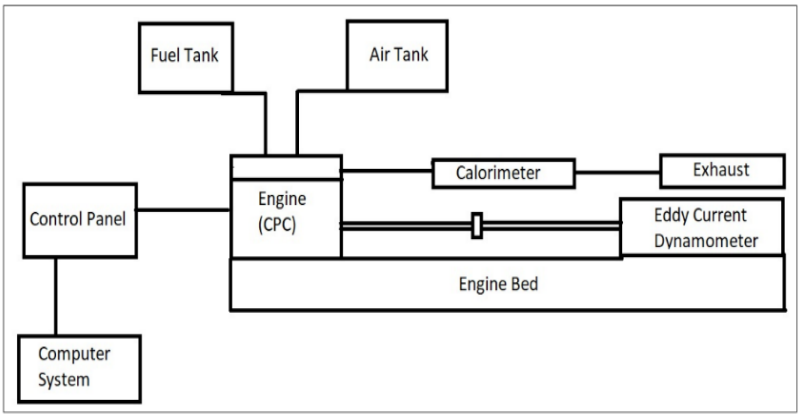


Fig. 1. Arrangement of experimental set-up.

Fig. 2. Computerised four stroke single cylinder diesel engine test rig.

Fig. 3. Computerised four stroke single cylinder diesel engine test rig with FFT analyser to measure vibration.

Table 1. Specifications of test engine.

Parameters	Specification
Engine	4 stroke single cylinder water cooled VCR diesel engine
Manufacturers	Tech-Ed
Rated power	Up to 5HP
Bore	80 mm
Stroke	110 mm
Connecting rod	234 mm
Swept volume	552 cc
CR	12:1 to 20:1
Rated speed	1500
Rated toque	24 N-M
Dynamometer	Eddy current dynamometer water cooled

The engine vibration measurement is one way of understanding the performance of the engine. A tri-axial or 3-axis accelerometer is used to capture axial, radial and tangential vibration (make-MEGGITT, model number- 45A18-1032, 20 mm cube and single threaded ¼-28 4 pin connector). The vibration sensor i.e., Tri-axial accelerometer is mounted in a suitable position on the cylinder head. The output of this tri-axial accelerometer is connected to a 4 channel FFT analyser (make- OROS model number- OR34). The amplitude of vibration in x, y and z directions are recorded by using FFT analyser. The accelerometer (as shown in Fig. 4) output is further recorded for every experimental trial through a computer application software, NV Gate developed by OROS as shown in Fig. 5.

Fig. 4. Tri-axial or 3-axis accelerometer.

Fig. 5. Details of OR34 compact analyser.

The aim of the research work is to check the performance of computerised four stroke diesel engine with different proportions of fuel additives mixed with diesel and compare the results with performance of diesel engine with pure diesel fuel without any additives. Table 2 shows the proportions of the mixture i.e., diesel and fuel additives in different proportions. The experiments are conducted by varying the torque and the load changes are recorded in terms of percentage. For different load percentages the output parameters such as engine speed, fuel flow rate, water flow rate to the engine and calorimeter and engine vibration in x, y and z directions are measured and the corresponding combustion curves are obtained.

Table 2. Mixture compositions of test fuels.

Fuel	Proportion of additive
Diesel	Nil
Mixture 1 - (M1)	5 litters + 0.5 ml of Fuel additive
Mixture 2 - (M2)	5 litters + 1.5 ml of Fuel additive
Mixture 3 - (M3)	5 litters + 2.5 ml of Fuel additive

The flash and fire point of the fuel additives mixed with diesel in different proportions were determined experimentally by using Penskey- Martens apparatus and were tabulated as shown in Table 3. It was observed that the flash and fire point decreases with increase in proportions of fuel additives in diesel (from M1 to M3). The decrease in these properties may be due to improper chemical bonding between diesel and additive molecules.

Table 3. Flash and fire point.

Sl No.	Parameters	Flash Point °C	Fire Point °C
1	Diesel	48.5	58.5
2	M1	43.5	50.5
3	M2	37	46
4	M3	39	46.5

3. Results and Discussion

To understand the effect of fuel additives in different proportions mixed with diesel, the P-Θ angle diagram is drawn at different loads. The engine performance can be evaluated by considering effect of load on brake thermal efficiency, bsfc, bp, the vibration of engine and exhaust emissions. An optimal mixture of fuel additive and diesel can be obtained for best engine performance, to reduce vibration and exhaust emissions.

3.1. Pressure and crank angle (P-θ)

The cylinder pressure as a function of crank angle is recorded for different fuel mixtures and pure diesel as shown in Fig. 6. The fuel mixtures M1, M2 and M3 are tested for pressure-crank angle variation at 60% loading on engine and compared with pure diesel. The proportions of additives in diesel, changes the fuel combustion process in turn affects the recorded pressure data and value of peak pressure. The fuel mixture M3 records a peak pressure of 73bar. The engine records a peak pressure of 68bar when operated with pure diesel. The peak pressure obtained with fuel mixtures M1 and M2 are 70bar and 71bar. The addition of fuel additive to diesel resulted in increase of peak pressure and a maximum peak pressure of 73bar has obtained with M3 i.e., 5 litres if diesel and 2.5ml of fuel additive. The observations from the experiment indicates that a peak pressure of 73bar is obtained with M3 fuel compared to 70 and 71bar of M1 and M2 fuels.

The high peak pressure with M3 fuel is due to low viscosity and proper atomization of mixture particles that results in high heat release rate and improved thermal efficiency. The combustion process accelerates with increase in proportions of fuel additives and is high with M3 mixture and resulted in high peak pressure. Only the effect of proportion of fuel additives in diesel on peak pressure is considered without looking into the adversary/beneficial effect of combustion peak pressure on engine performance. For M3 fuel peak pressure was found 68bar at 40% loading and it increases to 70 bar and 73bar at 50%, 60% loading respectively. Similar trends were observed for different loadings on the engine.

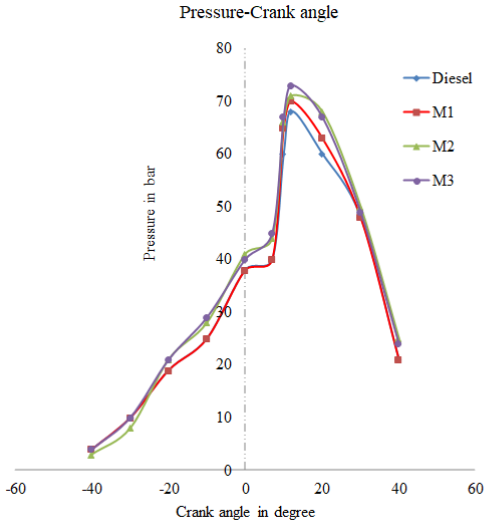


Fig. 6. Variation of pressure with crank angle for different fuel blends at 60% engine loading.

3.2. Performance characteristics of the engine

The engine performance is measured, the parameters related to percentage of conversion of heat energy into power and fuel economy. In this section, the effect of change in load percentage on these two parameters with different fuel mixtures will be analysed.

(a) Effect of load on brake thermal efficiency for different proportions of fuel additives in diesel

The effect of load on brake thermal efficiency for different blends of additives with diesel and pure diesel shown in Fig. 7. At 60% load and when engine run by pure diesel, the engine brake thermal efficiency is 19.17%. The use of M1 fuel increases the brake thermal efficiency by 2 to 6% and increases up to 8% with M3 fuel. A decrease in brake thermal efficiency has been observed with M2 fuel at part loads. At 60% load, the brake thermal efficiency is 19.17% with diesel operation and increases to 19.56% with use of M1 fuel. The brake thermal efficiency decreases to 18.19% and 17.9% for M2 and M3 fuels respectively. It is also seen that the brake thermal efficiency increases with increase in load for all fuels. At part load (20% load), M1 fuel yields higher brake thermal efficiency than other fuels.

The brake thermal efficiency for all blended fuels improved about 2-6% at all the loads. It indicates that the brake thermal efficiency can be enhanced by adding additives to the diesel and M3 fuel yielded the better results compared to other fuels and approaches the values obtained when pure diesel is used.

The use of M3 fuel ascribed to higher surface region to volume proportion because of more additives and results in more measure of fuel to respond with air. This leads to increase in brake thermal efficiency. The boiling point of mixture decreases due to addition of additives in diesel and this in turn improves evaporation properties and results in better combustion and brake thermal efficiency.

The presence of cerium oxide is high in M3 fuel and also additive concentration is as high as 2.5 ml additive, resulted in liberation of more oxygen. This gives higher brake thermal efficiency at all loads on the engine when running with M3 fuel. Table 4 shows effect of type of additive mixing on brake thermal efficiency.

Table 4. Effect of fuel additives on brake thermal efficiency.

Type of additive mixing with diesel	Brake thermal efficiency	Remarks
M1	Increases by 2-6% for different loads	Desirable
M2	Increases by 20% and decreases at part loads	Some adverse effect at part loads
M3	Increases by 1 to 8% for different loads	Significant

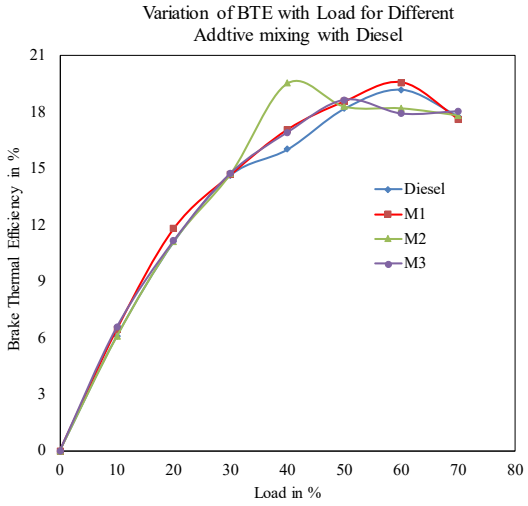


Fig. 7. Variation of brake thermal efficiency with load.

(b) Effect of load on break specific fuel consumption for different proportions of fuel additives in diesel

The variation specific fuel consumption (bsfc) with load for all proportions of the mixtures as shown in Fig. 8. Table 5 shows effect of additive mixing on fuel consumption. It was observed that the mixture M3 gives lower bsfc for all the loads and the least value of 0.438kg/kWh was achieved at 70% loading. For M1 fuel mixture, the bsfc decreases up to 6% for different loadings and for M2 mixture 18% decrease in bsfc has been observed at 40% loading. The mixing of 2.5ml fuel additive per 5 litre diesel (M3 fuel mixture) gives maximum thermal efficiency (with a percentage increase up to 8%) and lowest bsfc (decreases up to 7%). The percentage decrease in bsfc is high at part load and slightly low at higher loads. The experiments also showed that the consumption of fuel is maximum at low loads and minimum at 60 to 70% loading for all types of fuels.

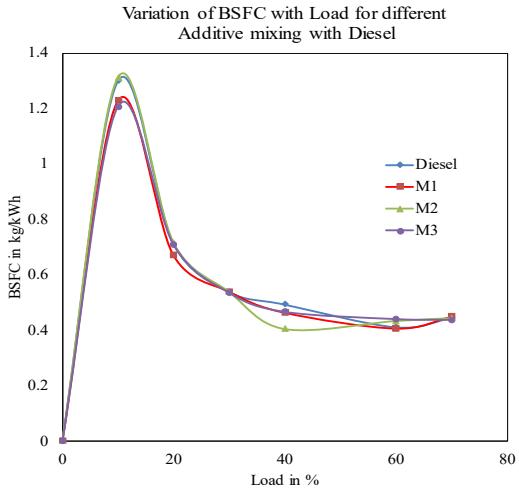


Fig. 8. Variation of BSFC with load.

Table 5. Effect of fuel additives on BSFC.

Type of additive mixing with diesel	BSFC	Remarks	Fuel consumption	Remarks
M1	Decreases by 1-6% for different loadings	Desirable	Decreases by 2to 10% for different loadings	Desirable
M2	Decreases up to 18% for different loadings	Significant	Decreases by 1to 18% for different loadings	Significant
M3	Decreases by 1-7% for different loadings	Desirable	Decreases by 1to 13% for different loadings	Desirable

(c) Effect of load on break power with different proportions of fuel additives in diesel

The Brake Power obtained for different loadings is plotted and is as shown in Fig. 9 and effects are shown in Table 6. When pure Diesel is used, BP increases from 0.392kW at part load to 2.598kW at full load. The use of fuel additives in small proportions (for M1 and M2 fuels) decreases Brake Power output and M3 fuel produces higher Brake Power output for all loading. This shows that the addition of 2.5ml of fuel additive with diesel is more effective than other proportions and results in better performance due to great ignition quality and good fuel viscosity. The M1 fuel has less effect on BP, and it decreases BP by 0.25 to 1.25% for all loadings when compared to pure diesel. The use of M2 fuel significantly decreases BP by 0.6 to 1.8% in examination with pure diesel and the inclusion of 2.5ml of fuel additives with diesel (M3 fuel) slightly increases Brake Power output.

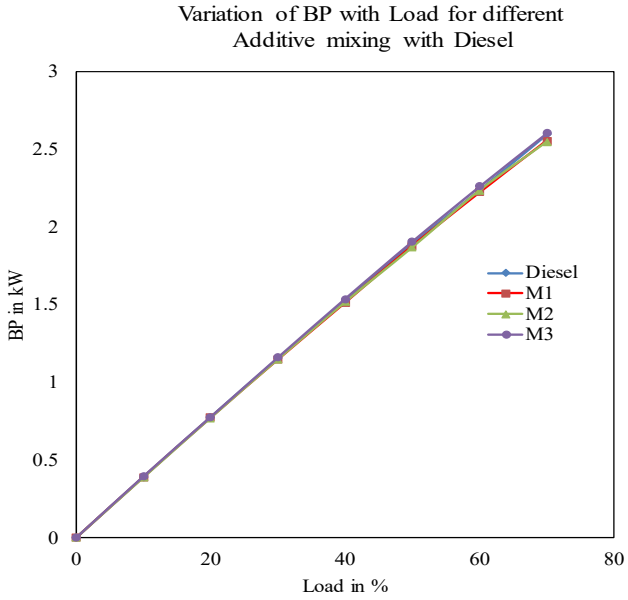


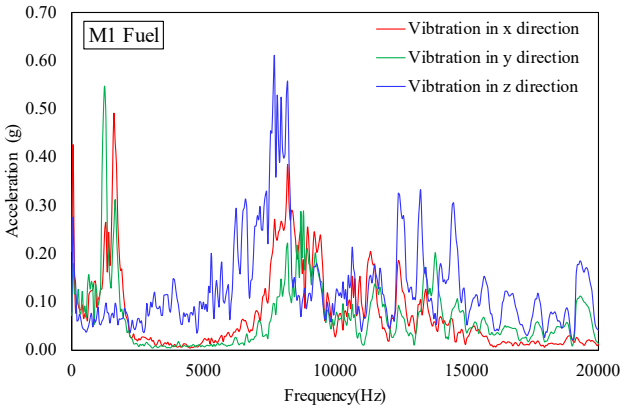
Fig. 9. Variation of BP with load.

Table 6. Effect of fuel additives on brake power.

Type of additive mixing with diesel	BP	Remarks
M1	Decreases by 0.25-1.5% for different loadings	Less effect
M2	Decreases by 0.6 to 1.8% for different loadings	Significant
M3	Increases by 0.2 to 0.8% for different loadings	Less effect

3.3. Effect of engine load on vibration for different proportions of fuel additives in diesel

The effect of engine vibration on performance is investigated with help of a tri-axial accelerometer placed on engine head and tested for different mixture at various load conditions. Figures 10(a) and (b) shows the plot of accelerations obtained by tri axel accelerometer in *x*, *y* and *z* direction for different types of fuel additive mixture. It is seen from Fig. 11 and Table 7 that the magnitude of vibration in transverse direction (x and z plane) is high with the use of M3 fuel. The M3 fuel produces high vibration even in longitudinal direction (y-plane) at low and high loads and less in the range of 20 to 60% of engine loading. The high peak pressure of 73bar with the use of M3 fuel is the main cause for high engine vibration in both transverse and longitudinal directions. The higher brake power output with use of M3 fuel may be another reason for more engine vibration. The increase in additive concentration in the diesel resulted in increase of ignition delay and engine performs abnormally which leads to increase in combustion pressure and tendency of knocking. The abnormal behaviour of the engine may also be due to piston scuffing and scratching fault. It is also observed that the engine vibration level can be decreased by increasing engine speed and load and is less at 40 to 60% of loading for all fuels.



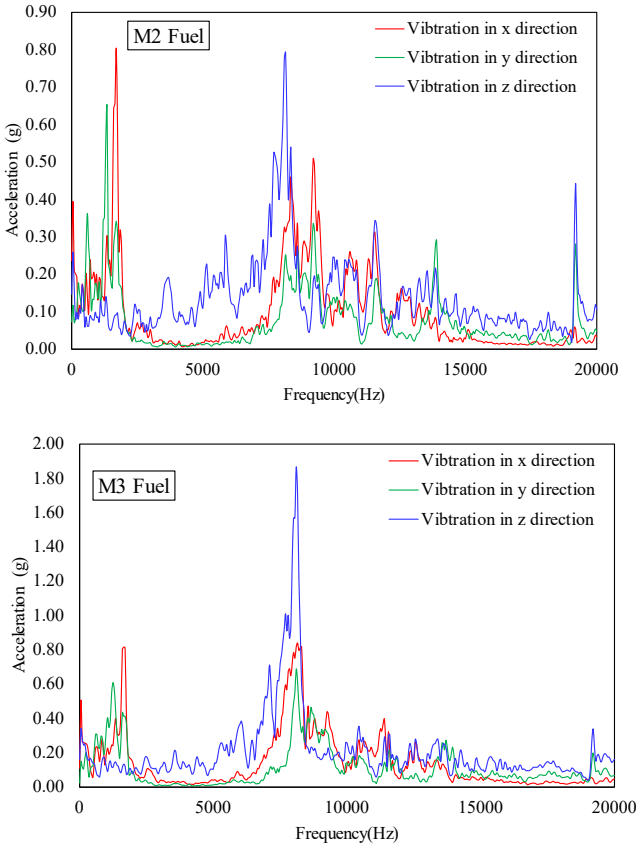
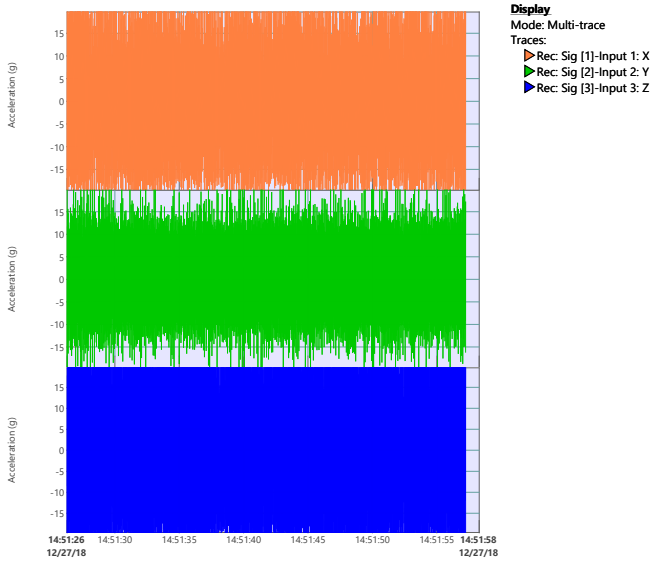
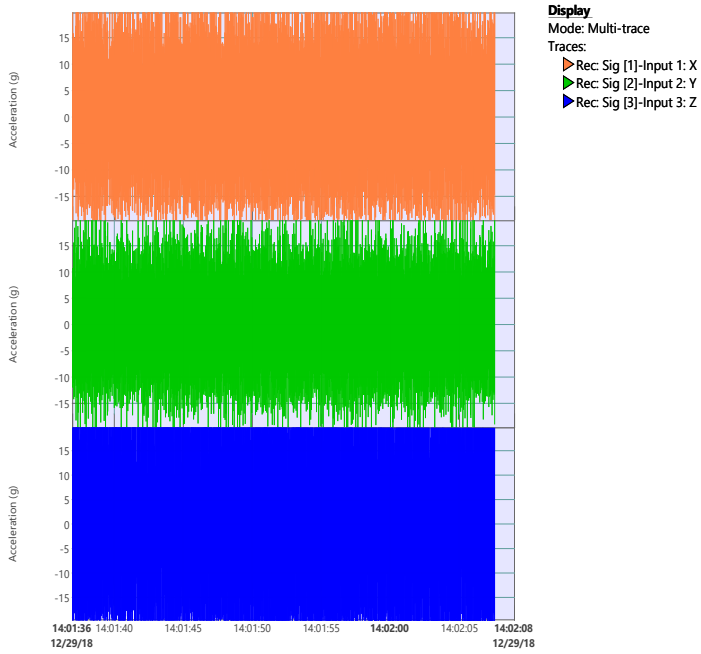


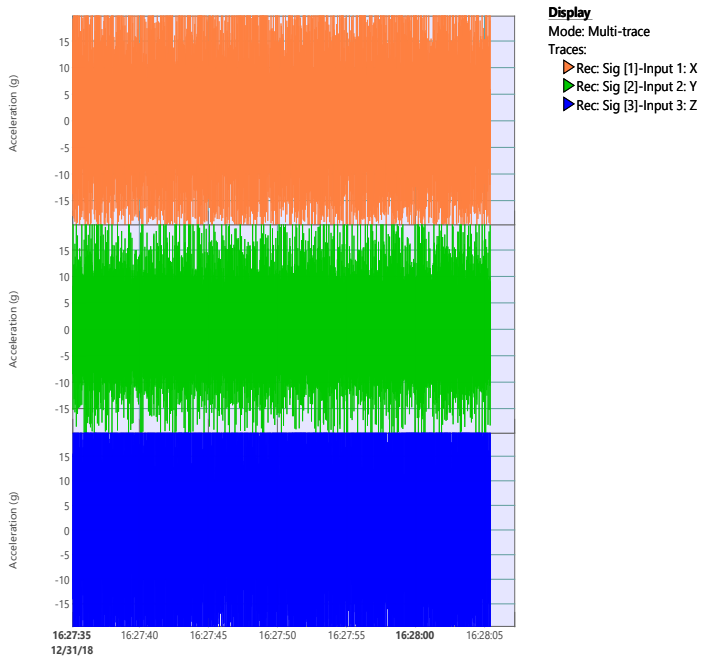
Fig. 10(a). Vibration pattern at 60% load for different fuel mixtures.



M1 fuel



M2 fuel



M3 fuel

Fig. 10(b). Vibration pattern at 60% load for different fuel mixtures.

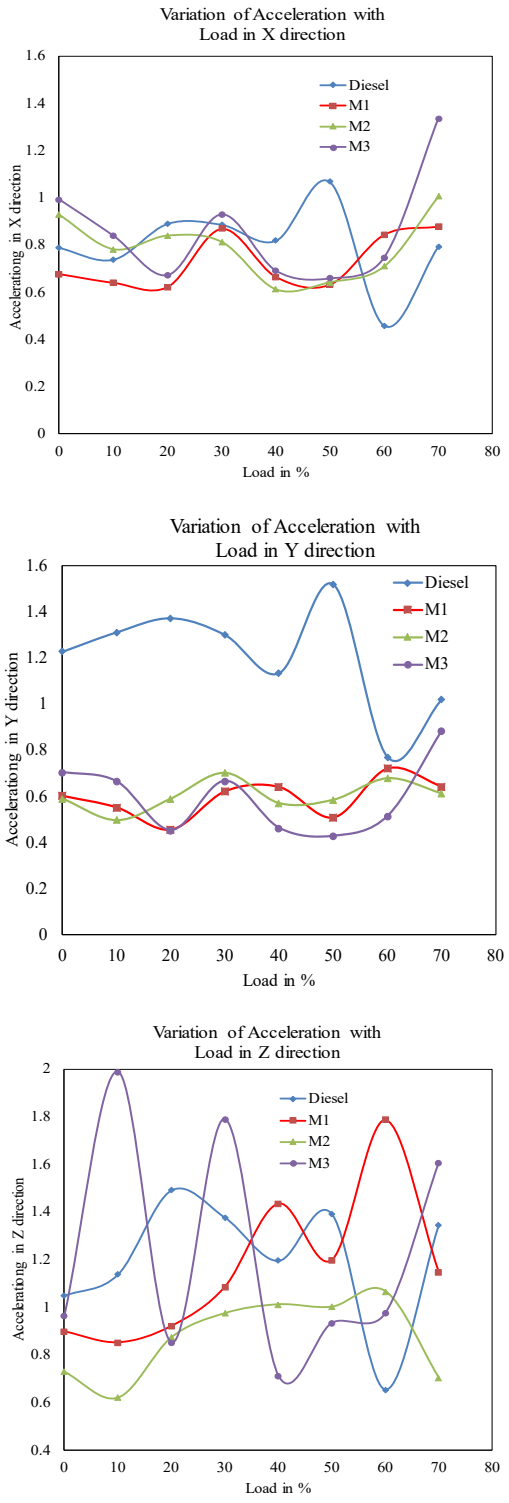


Fig. 11. Load vs vibration in *x*, *y* and *z* directions.

Table 7. Effect of fuel additives on engine vibration.

Type of additive mixing with diesel	Vibration	Remarks
M1	Horizontal plane- 0.6 to 0.9 Vertical plane-0.9-1.1	Transverse and longitudinal direction- more vibration
M2	Horizontal plane- 0.9 to 1.0 Vertical plane-up to 0.7	Transverse direction - magnitude is same longitudinal direction-less vibration
M3	Horizontal plane- 0.9 to 1.3 Vertical plane-0.9 to 1.6	Transverse and longitudinal direction - very high vibration

4. Conclusion

The computerised four stroke diesel engine test rig is used for investigating the performance and vibration characteristics. It can be concluded that the

- The flash and fire point for different blends of additives with fuel are measured. The mixture M3 gives lower flash and fire temperature as compared to other mixture.
- The maximum pressure rise for diesel and mixtures are calculated and for M3 has got the highest peak pressure of 73 bar at 1500rpm at 60% load.
- The brake thermal efficiency increases significantly with M2 fuel but produces some adverse effects at part loads. The use of M3 fuel increases brake thermal efficiency up to 8%.
- The use of M2 fuel decreases fuel consumption significantly up to 18%.
- The brake power output is increased by 0.2% to 0.8% at different loadings by using M3 fuel
- The use of M3 fuel produces high transverse and longitudinal engine vibrations
- The use of M3 fuel is recommended as it produces highest combustion pressure, increases brake power output and brake thermal efficiency compared to other fuels. The bsfc also decreases up to 7%
- The use of M2 fuel decreases bsfc significantly, but produces some adverse effects at part loads and hence not recommended.

Nomenclature

Greek Symbols

θ	Crank angle, deg.

Abbreviations

CI	Compression Ignition
CR	Compression Ratio
M1	Mixture 1
M2	Mixture 2
M3	Mixture 3

References

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