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Noise and Vibration Analysis of Diesel Engine fueled using Diesel and Neem Biodiesel with Inclusion of MoO3 Nano Particles

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Abstract: Biodegradable, renewable, and environmentally friendly oxygenated fuels will replace fossil fuels. A single-cylinder, four-stroke, variable compression ratio, compression ignition engine was tested for performance, combustion, emission, and vibration. Biodiesel from inedible neem, which contains 30–45% wt oil, may replace traditional liquid fuels. This work esterified and transesterified methanol and triglycerides at a 7:1 molar ratio to extract biodiesel at 96% volume. This research uses diesel and neem methyl ester (NME) at 50, 75, and 100 ppm. Engine testing at 1500 rpm and 15:1 compression ratio are performed under various loading circumstances. The vibration levels were reduced for 75 ppm inclusion of MoO3 in biodiesel blends when compared with diesel fuels. As the load increased vibrations observed were at maximum.
Keywords: Transesterification, Neem methyl ester, Noise, RMS, Vibrations

I. INTRODUCTION

Because of quick decline of fossil fuel supplies, ecological problems, and strict emission laws, oxygenated fuels such as biodiesels and alcohols have become necessary. Biodiesel generated from waste restaurant grease, vegetable oils, and animal fats [1,2]. In certain nations, the use of biodiesel is required. Since mid-2011, the government of Malaysia has enforced use of blends of diesel fuel in some parts of the nation [3]. India has committed to reducing its emission intensity by 33–35% by 2030. India's energy imports have increased from 20% to 33% over the last decade, and might reach 50% by 2030. There are advantages to using biodiesel over raw vegetable oil, including a higher cetane number, a lower viscosity, and a higher heating value [4]. According to the results of a performance and emission study conducted by Hirkude et al. [5] on a compression ignition (CI) engine fuelled by waste frying oil methyl ester, biodiesel has a somewhat worse brake thermal efficiency (BTE) than diesel at higher loads. For both diesel and biodiesel, Mallikappa et al. [6] found that BTE increases with increasing load, perhaps because of lower heat losses. Waste plastic oil increased hydrocarbon (HC) and smoke emissions by 15 and 40% at full load, respectively, compared to diesel, according to research conducted by Mani et al. [7]. Biomass from agricultural goods, tree trimmings, discarded paper, and grass may be used to make alcohol [8]. Diesel reduces alcohol's weak lubricity and vaporisation. Diesel-alcohol combinations exhibit low lubricity, cetane number, viscosity, and volatility [9, 10] However, biodiesel may emulsify diesel and alcohol [11]. Biofuel may boost alcohol's lower cetane number [12]. Huang et al. [13] found that diesel-oxygenated fuel blend influences NOX emissions more at higher loads. Methanol's energy efficiency and high-pressure catalytic synthesis from waste biomass gasification make it a popular alcohol [14]. Zhu et al. [15] showed that 5% methanol and 95% diesel reduced CO and HC emissions while enhancing BTE. At low engine loads, adding M5 and M10 (methanol 5% and 10%) to BD50 (biodiesel 50% and diesel 50%) delayed combustion for BDM5 and BDM10 [16]. Methanol, ethanol, or butanol added to the B30 (biodiesel 30%, diesel 70%) fuel mix increased BTE and decreased brake specific fuel consumption, according to Yilmaz and Vigil [17]. (BSFC). Methanol and biodiesel are oxygenated fuels because they contain 10-12% and 50% oxygen by weight [16,18]. Diesel engines with high compression ratios create increased noise and vibration [19,20]. Engine vibration has several origins since every physical activity in engine operation emits a vibration signal [21]. The combustion process also causes engine vibration, although mechanical component vibration is less evident. The engine head's non-stationary vibration data is analysed in time and frequency domains [22]. How et al. [3] found that B50 at 0.86 MPa reduced engine vibration by 13.7% compared to diesel. Prasada Rao et al. [23] found that 3% methanol in diesel fuel stabilized combustion. Diesel, Neem Methyl Ester, and diesel-biodiesel blend (B20) with Molybdenum trioxide MoO3 nano particles at varied weight fractions are evaluated in the engine. Diesel-biodiesel-methanol blends contain 80% diesel (at 50 ppm, 75 ppm and 100 ppm of MoO3 nano particles). This study examines how NME, diesel-biodiesel-methanol mixed fuels containing Molybdenum trioxide nano particles, influence engine noise and vibration compared to baseline diesel fuel.

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II. MATERIALS AND METHODS

A. Materials

Neem oil is made by extracting and crushing neem seeds. The neem oil was transesterified in two stages using methanol, H_2SO_4, and NaOH. In this work, Molybdenum trioxide (MoO3) nano particles were also employed to improve their properties.

B. Biodiesel Preparation

Neem methyl ester is transesterified from raw neem oil in this study. Raw neem oil's viscosity is reduced by this method. This process converts vegetable oils with big triglyceride molecules into minor straight chain molecules for CI engines. Neem Methyl Ester is manufactured from raw neem oil in two processes. The first phase is acid-catalyzed esterification, which decreases raw neem oil's free fatty acid (FFA) value to 1%. The second step is alkali-catalyzed esterification. 1000 ml of raw neem oil is heated to 55 degrees Celsius, then 120 ml of methanol is added and stirred. After adding 3 cc of H2SO4, the liquid is whirled for 1.5 hours at 55°C. The solution settles in a separating funnel for 12 hours after the reaction. Create two layers. Glycerol is on the bottom and neem methyl ester on top. Alkali-catalyzed esterification of the neem methyl ester is then heated to 55°C. 5 g of NaoH dissolved in 200 ml methanol is added to this solution and agitated for 1.5 hours at 55 degrees Celsius. After the reaction, the solution settles for 24 hours. Neem Methyl Ester increases while glceryol declines. The esterified is purified with distilled water. Blends B20+ MoO3 50, 75, and 100 ppm are created by mixing diesel, Neem Methyl Ester, and methanol. Diesel and Neem Methyl Ester are tested using ASTM standards.

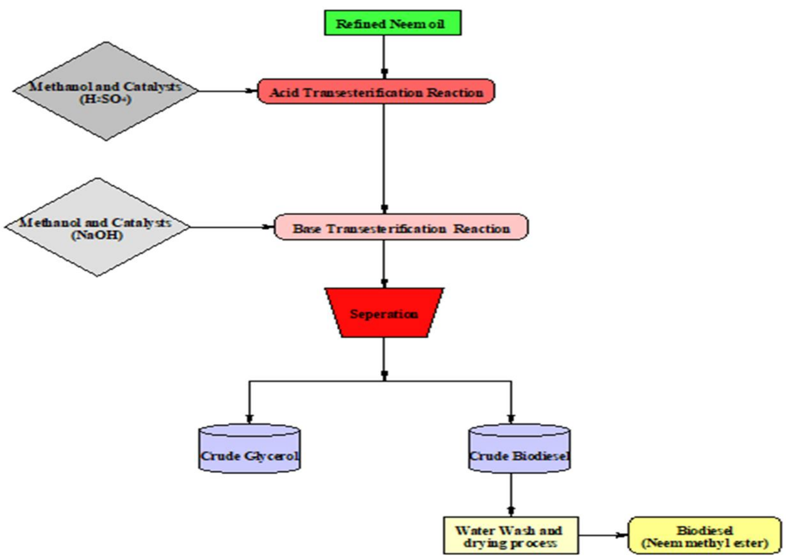

Figure 1: Two-stage Transesterification Process

Table 1: Thermo physical Properties of Neem Methyl Ester

Fuel Property	Diesel	Neem Methyl Ester	ASTM Methods
Density (kg/m^3)	846.3	873	D1298
Kinematic Viscosity at 40^{o}C	3.64	4.12	D445
Acid Value (mg NaOH/gm)	0.35	0.33	D664
FFA (mg of NaOH/gm)	0.175	0.501	D664
Pour point^{o}C	-15	4	D2500
Flash point^{o}C	55	172	D93
Fire point^{o}C	74	190	D93
Calorific value (MJ/Kg)	42.72	38.36	D240
Centane index	48.3	53.7	D613
Carbon (%, w/w)	81.33	N/d	-
Hydrogen (%, w/w)	12.78	N/d	-

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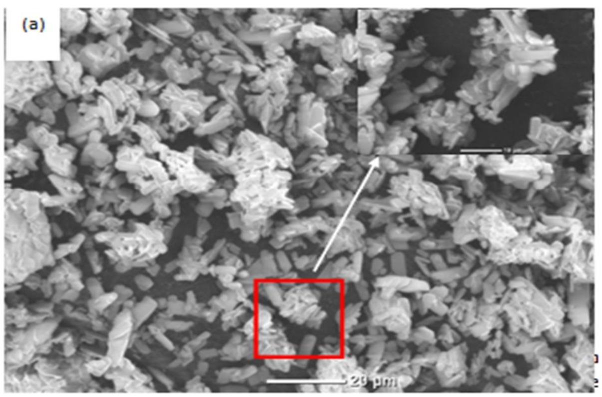
C. Characterization of MoO3 Nanoparticles

The morphology of MoO_3 particles is illustrated in Figure 1. MoO_3 has a pale-yellow colour, has an average size of 1.83 µm, and has a flakes like structure. Its purity is 99%. These substances brought from Nano shell. Under a magnification of 1000x, a JEOL JSM-7001F Field Emission Scanning Electron Microscope (FESEM) was used to detect the micro morphology of MoO_3 particles. The results of this investigation are depicted in Fig. 1.Moreover, MoO_3 particles are difficult to dissolve in diesel because of their mutually attractive nature which causes them to cluster together into larger particles.

Organic polymers and inorganic compounds are often identified using FTIR. Infrared light was used to expose the substance. The nano particle absorbs radiation, producing vibration energy. The signal oscillates between 3300 and 450 cm^{-1}, revealing the chemical structure of nanoparticles. The image below shows the FTIR spectrum of MoO3 nanoparticles. The spectrum revealed peak values in the range of 3600-550 cm^{-1}, with the bulk of peak values lying between the 2000-500 cm^{-1} range.



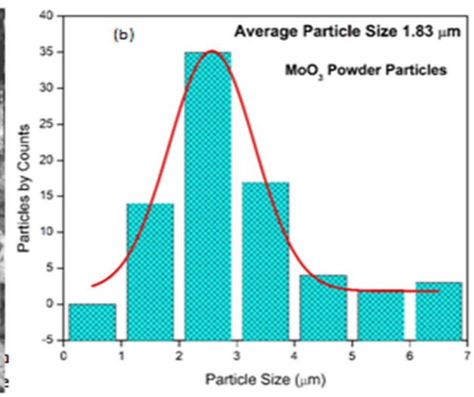


Fig. 1 Morphology of MoO_3 particles (a) SEM images (enlarged view of particles in the inset) of MoO_3 particles and (b) Particle size distribution of MoO_3 particles.

Fig. 2 Morphology of MoO_3 particles (a) SEM images (enlarged view of particles in the inset) of MoO_3 particles and (b) Particle size distribution of MoO_3 particles.

The MoO_3 particles chemical composition was determined using a Philips X Unique II XRF instrument, and the data is represented in Table 2.

Table 2: Chemical Composition of MoO_3 obtained by X-ray Florescence

Compound	SiO_2	CaO	TiO_2	V_2O_5	Fe_2O_3	ZnO	ZrO_2	MoO_3	SnO_2	Re
Concentration Unit	0.181 %	0.228 %	425.5 ppm	32.6 ppm	89.1 ppm	75.1 ppm	155.5 ppm	99.495%	154.0 ppm	34.8 ppm

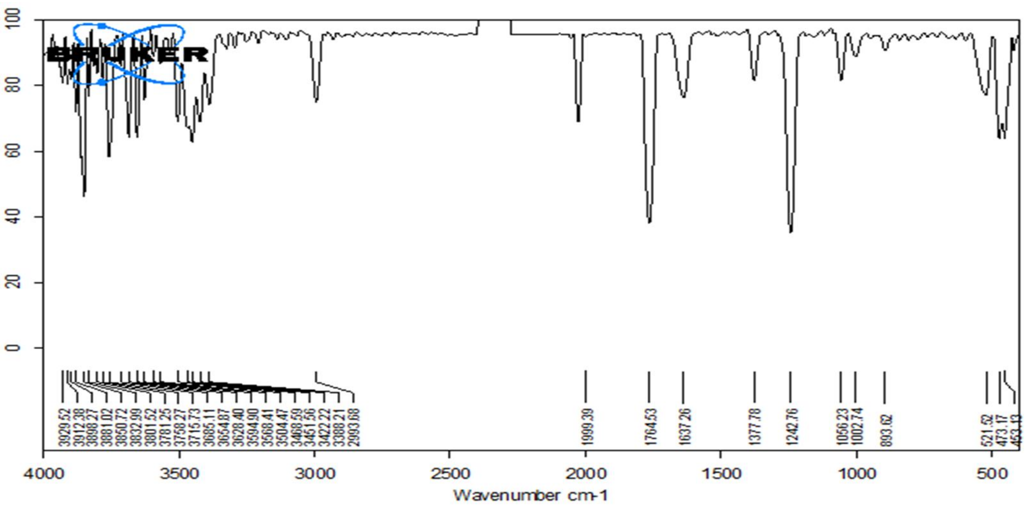


Fig 3 : FTIR spectrometry for MoO3 nano particles included biodiesel

D. Nanofuel Production

A small beaker was initially filled with different quantities of MoO3 nano-particles at 50 ppm and 100 ppm and sonicated with TWEEN 80 as a surfactant for stabilising the nano particle in bio diesel. At 35^{o}C, the whole treatment took 30 minutes. To produce the nano fuel in Biodiesel mix, the surface of MoO3 nano particles was modified. The material was then stirred using a mechanical agitator before being sonicated at 25 Hz. The nano fuel samples were labelled as BD20 + MoO3 50 ppm, BD20 + MoO3 75 ppm and BD20+ MoO3 100 ppm.

III. DIFFERENTIAL SCANNING CALORIMETRY

Differential Scanning Calorimetry (DSC) is an effective method for monitoring the crystallisation of multi component mixtures such as biodiesel. This technique detects latent heat changes in biodiesel when heated or cooled. These exothermic peaks seen at lower temperatures were ascribed to oxidation, whereas those observed at higher temperatures were attributed to combustion and thermal cracking of long-chain fatty acids.

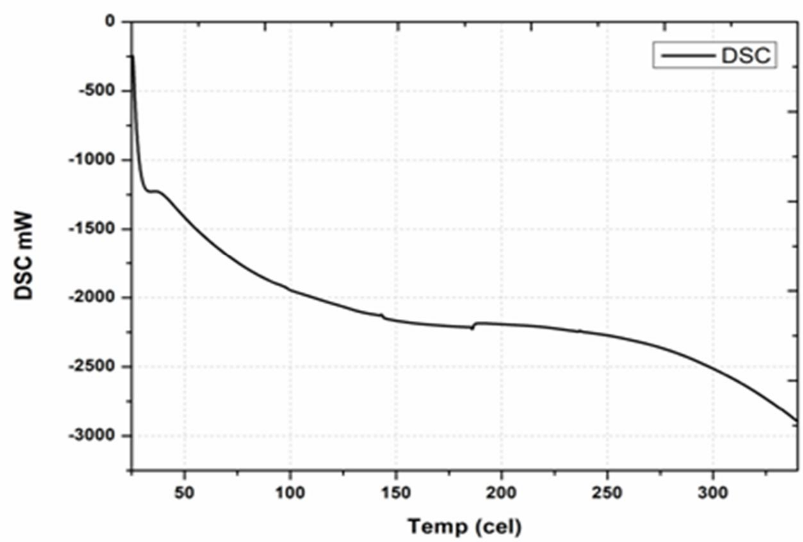


Fig 4 : DSC for MoO3 nano particles included biodiesel

IV. RESULTS AND DISCUSSION

A. Noise and Vibration Characteristics

ICEs' exhaust pollutants, noise, and vibration impact living things [24-25]. As a result, ICE vibration and noise must be kept to a minimum. This section discusses the vibration and noise characteristics of diesel, biodiesel, and nanoparticle-containing test fuels as a function of engine load. Mechanical forces in the cylinder chamber have a significant impact on ICE vibration. Cylinder shaking from CPmax, HRRmax, and pressure rise rate causes noise. Figure 11 depicts the vibration level of test fuels when the engine is running, while Figure 12 depicts the noise level. As seen in Figs. 11 and 12, B10 gasoline caused the maximum vibration and noise at all engine loads. Engine load increased noise and vibration. While increased HRRmax and CPmax might explain this, vibration and noise were reduced at 10 Nm engine load. [26] found equivalent findings.

The sampling rate and analysis lines define the frame length of an FFT. Fewer lines equal a shorter time frame, whereas more lines equal a longer time frame. (Analysis Lines *2) / Sample Rate is the length of each frame required to generate an FFT. The frequency resolution for pure FFT analysis is (Sample Rate/2)/Analysis Lines. If the test engineer knows the FFT resolution, he or she may use 1/FFT resolution to match the time duration of each FFT frame. Increased analysis line count enhances FFT frequency resolution, which is useful for investigating low-frequency information. Raising this number causes the final analysis graphic to have a higher resolution. Higher lines, on the other hand, increase the processing cost, and the additional analysis time could result in a delayed response to change.

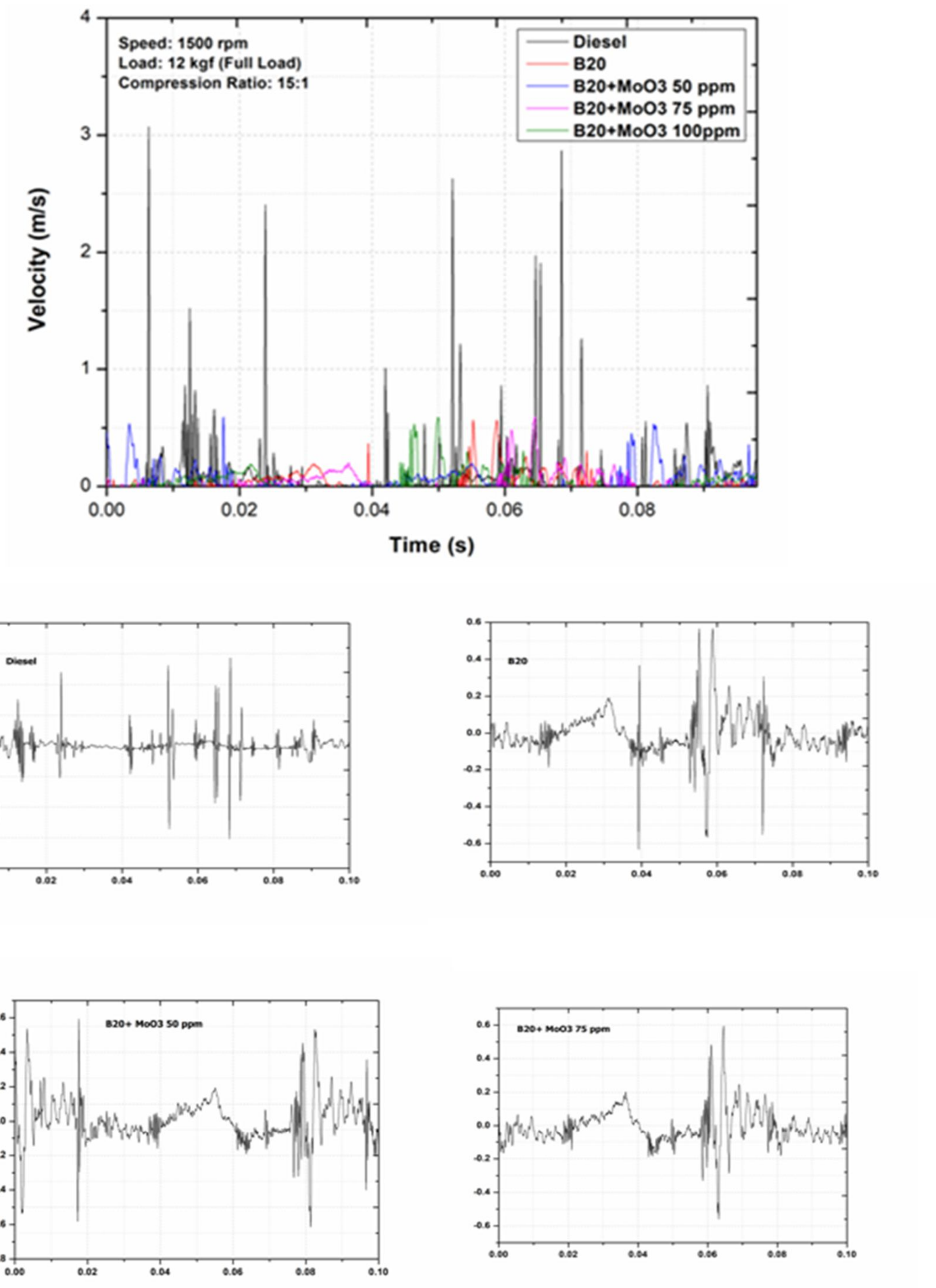


Fig 5: Variation in velocity of Neem methyl ester blends with MoO3 nano particles Inclusion

The highest vibration amplitude is found in the B20 fuel, which has an engine load at 12 kgf that is 22% lower than with pure diesel, according to experimental results shown in the following figures. These results demonstrate the effects of vibration and noise when using a mixture of biodiesel fuel and diesel with MoO3 nanoparticles. In contrast, discrepancies that were found during the research of the temporal domain might be used to identify the combustion variables. The reason for this was due to the difference in gas pressure that occurred within the combustion chamber, as well as the fact that biodiesel is an upper oxygenate fuel, meaning that it contains more oxygen than regular diesel does [27].

B. RMS Velocity and Combustion Noise

The degree of noise produced by engines that use internal combustion is directly connected to the variable mechanical forces that occur inside the cylinder. An increase in the pressure within the cylinder has a direct impact on the wall of the combustion chamber, which results in vibrations in the engine block. The subsequent vibration contributes to the noise in the surrounding area. When it comes to diesel engines, the combustion process is generally regarded to be the most significant contributor to the noise. When the injection pressure is turned up to its maximum, it might cause the gas in the combustion chamber to move about quickly.

Consequently, the noise and vibration may be managed by reducing the amount of time that the ID is active. The graphs of changing total vibration levels and engine noise dependent on loads are shown in Figures 6 and 7, respectively. These graphs apply to all gasoline mixes that include nano particle inclusions.

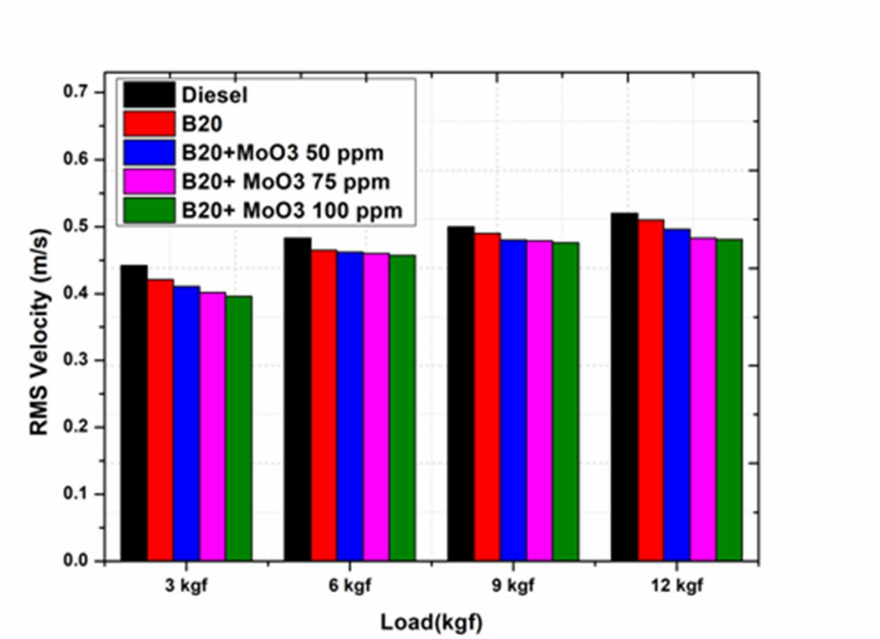


Fig 6: RMS velocity Vs load.

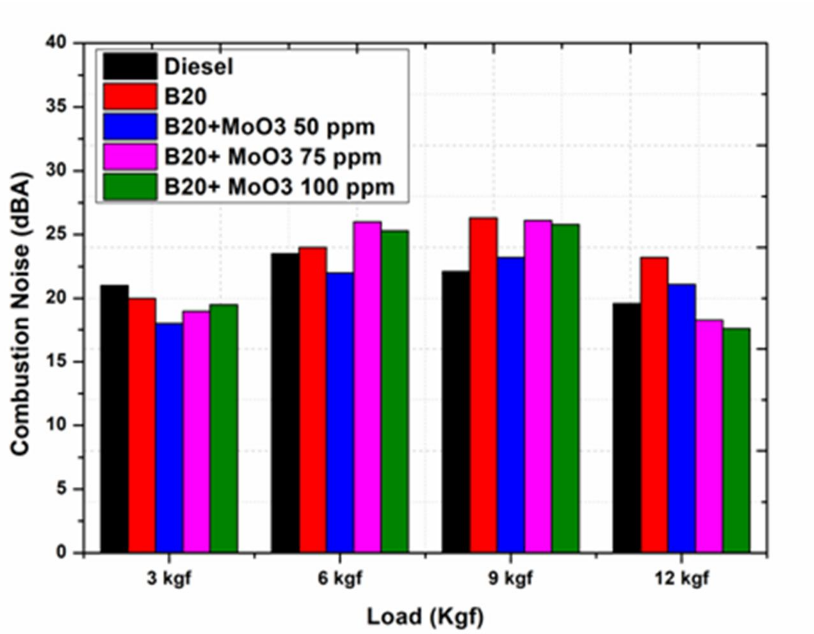


Fig 7: Combustion Noise Vs load.

V. CONCLUSION

The investigation of the effects of vibration and noise on the engine brought about by the use of various fuel mixes is going to be the primary subject of this critical evaluation. Throughout the course of our research, we came across a number of studies that explored the impacts of vibration and noise on combustion engines. The use of diesel and biodiesel fuel has been the method of choice for the majority of the research carried out on the impacts of vibration and noise on equipment. Since biodiesel with nano particle inclusion has greater heat levels than diesel, the impacts of vibration and noise were marginally reduced when using biodiesel fuel as opposed to pure diesel. This is due to the fact that biodiesel is more energy efficient.

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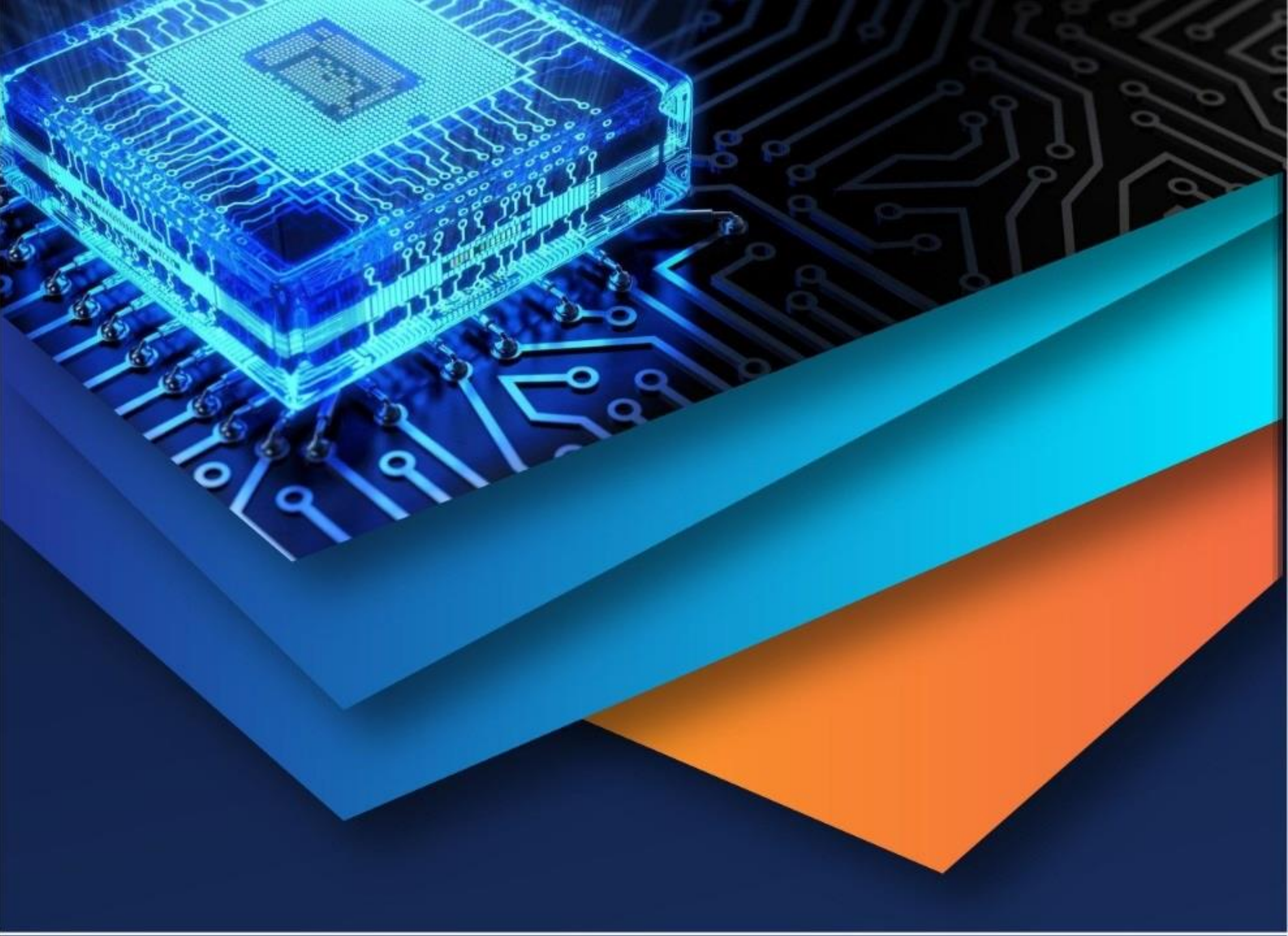

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