SCHOLAR PUBLISHING

International Journal of Automotive & Transportation Engineering
ISSN: 3083-9726

Journal Homepage: https://e-journal.scholar-publishing.org/index.php/ijate

# Influence of Oxygenated Fuel and Compression Ratio on Engine Vibration and Noise: A Review

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## Abstract

This review investigates the influence of oxygenated fuel blends and compression ratio (CR) on engine vibration and noise, focusing on experimental studies involving biodiesel and alcohol-based fuels. A consistent trend is observed across various engine configurations, single, four, and six cylinders, where biodiesel blends such as B20 and B40 significantly reduce vibration and noise compared to pure diesel. For instance, experiments show a reduction in average vibration by 1.23%, 2.34%, and 3.54% at engine speeds between 1200–2400 rpm. Moreover, the compression ratio positively correlates with vibration levels; higher CR values (up to 20:1) intensify fluctuations and resonance frequencies, notably around 90 kHz in several test scenarios. Jatropha Methyl Ester (JME) and Karanja biodiesel mixtures exhibit distinct combustion characteristics that influence noise signatures and oscillation behaviour. Advanced diagnostic methods using accelerometers reveal that optimal combustion stages can be precisely monitored with a high correlation coefficient ($R^2 = 0.97$), especially in low-displacement engines. Additives like hydrogen further mitigate vibration by lowering transmitted energy to pistons. The findings underscore the potential of renewable biofuels in achieving better NVH (Noise, Vibration, Harshness) performance while highlighting the necessity for engine-specific fuel optimization strategies. This comprehensive synthesis contributes to the future design of low-emission and quieter internal combustion engines compatible with biodiesel blends.

**Article Info**
Received: 06 April 2025
Revised: 15 May 2025
Accepted: 20 May 2025
Available online: 15 August 2025

**Keywords**
Biodiesel Blends
Engine Vibration
Noise Reduction
Compression Ratio
Oxygenated Fuels

## 1. Introduction

The internal combustion engine (ICE) remains a dominant power source in automotive applications despite the global shift toward electrification. However, engine noise, vibration, and harshness (NVH) concerns have prompted engineers and researchers to explore more sustainable and refined fuel alternatives. Among these, oxygenated fuels, especially biodiesel and alcohol-based blends, have gained increasing attention due to their cleaner combustion characteristics and potential to reduce mechanical stress during engine operation. Engine vibration and noise are directly linked to combustion irregularities, engine speed fluctuations, fuel properties, and mechanical imbalances. Studies by [1–4] demonstrated that single-cylinder diesel engines fueled with biodiesel-diesel blends exhibited lower vibration levels than those running on pure diesel. These reductions are attributed to biodiesel's higher cetane number and oxygen content, which promote more complete and stable combustion.

Further experiments on four-cylinder engines with 20% and 40% biodiesel blends reported average vibration reductions of 1.23%, 2.34%, and 3.54% at engine speeds ranging from 1200 to 2400 rpm [5–8]. The vibration reduction contributes to improved driving comfort and minimizes long-term mechanical fatigue and emissions. Other research highlighted that compression ratio (CR) also plays a critical role in vibration behaviour, where increasing CR leads to higher vibration amplitudes and frequency shifts [3,9–12]. In addition to biodiesel, alternative fuels such as Jatropha Methyl Ester (JME), Karanja oil blends, and alcohol-based fuels like ethanol and methanol have been explored for their vibro-acoustic performance. For instance, significant vibration reductions were observed in six-cylinder diesel engines modified by 12% and fueled with B20 and B40 blends [13–16]. Meanwhile, triaxial accelerometers were used to detect directional vibrations under varying biodiesel concentrations, and consistent noise patterns correlated with combustion dynamics were reported [17–20].

From a diagnostic perspective, a methodology using a single accelerometer on a four-cylinder diesel engine was introduced to evaluate combustion behaviour from the start to 95% mass fraction burned (MFB95) [10,21–23]. Their analysis yielded a correlation coefficient ($R^2$) of 0.97, proving that indirect monitoring through vibration signals can effectively capture combustion characteristics. This technique enhances the evaluation of biodiesel compatibility without extensive engine teardown or invasive sensors. Although extensive work has been done on fuel blends and combustion performance, limited attention has been paid to synthesizing the impact of oxygenated fuels and compression ratios on engine vibration and noise in a unified framework. Moreover, a comprehensive comparison across different engine types and fuel properties remains fragmented, lacking a systematic review that integrates mechanical, thermal, and acoustic outcomes.

Therefore, this paper aims to review and analyze recent experimental studies that examine the influence of biodiesel and alcohol-based fuel blends on NVH behaviour under varying compression ratios and engine loads. Emphasis is placed on identifying consistent trends, quantifying vibration and noise responses, and assessing diagnostic techniques applied in previous studies. The novelty of this review lies in its integrated focus on fuel composition and compression ratio effects on engine NVH characteristics. Compiling empirical data and methodologies from various configurations ranging from single-cylinder to six-cylinder engines provides a holistic understanding of how oxygenated fuels contribute to cleaner, quieter, and more efficient engine operations.

## 2. Methodology

This study employs a systematic literature review method to analyze and compare the influence of oxygenated fuel blends and compression ratios on engine vibration and noise. The review encompasses various experimental studies on diesel engines using biodiesel, alcohol-based fuels (such as ethanol and methanol), and blended fuel types under various engine configurations, including single-cylinder, four-cylinder, and six-cylinder engines. The references were selected based on relevance to engine NVH (Noise, Vibration, and Harshness) performance, particularly those reporting quantifiable changes in vibration amplitude, resonance frequency, or combustion noise. A total of 20 key studies were extracted and summarized in tabular format to identify patterns related to the effect of different biodiesel concentrations (ranging from B5 to B100), alternative fuels (e.g., Jatropha Methyl Ester, Karanja oil, Pongamia-Pinnata), and compression ratios varying between 12:1 and 20:1.

Each selected study was examined for engine type, testing conditions (such as engine load and speed), torque behaviour, vibration response, and instrumentation, such as accelerometers with frequency sensitivity up to 90 kHz. Particular attention was paid to studies incorporating diagnostic tools to measure vibration during combustion phases, including advanced signal correlation techniques (e.g., $R^2 = 0.97$ from accelerometer data with mass fraction burned references). Comparative analysis was performed using both quantitative and qualitative synthesis. Quantitative data from multiple studies were extracted to evaluate the percentage change in vibration and noise levels, particularly between conventional diesel and oxygenated fuel blends like B20, B40, and B50. Qualitative assessment focused on trends, diagnostic approaches, and the impact of fuel properties such as density and viscosity on vibration and acoustic performance. Through this methodology, the study provides a consolidated perspective on how fuel composition and compression ratio affect engine dynamics, offering practical insights for future engine design and optimization using renewable fuel alternatives.

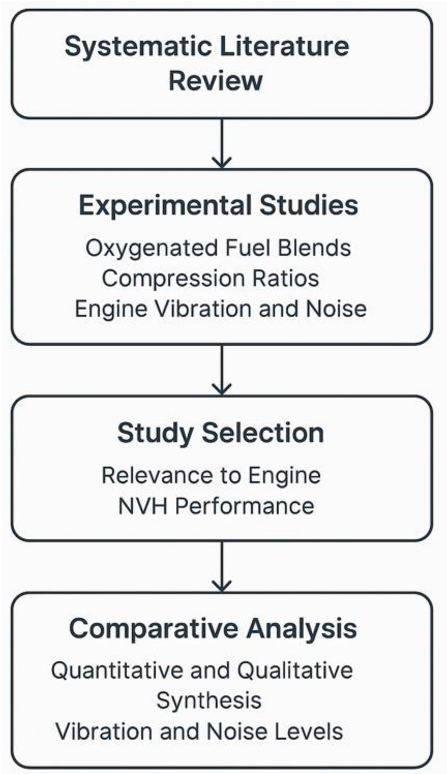


**Figure 1**: Methodology Flowchart: Oxygenated Fuel and Engine NVH Review

**Figure 1** illustrates the structured methodology adopted in this review to evaluate the influence of oxygenated fuel blends and compression ratio on engine vibration and noise. The process is divided into four sequential stages, representing a systematic and logical approach to synthesizing experimental findings from previous studies. The first stage, Literature Selection, involves identifying and selecting relevant peer-reviewed research articles examining biodiesel, alcohol-based, and other oxygenated fuels in diesel engines. These studies were chosen based on their focus on NVH (Noise, Vibration, Harshness) performance and the variation of compression ratios in their test conditions.

In the second stage, Data Extraction, critical technical information is gathered from each selected study. This includes details on engine types (single, four, or six-cylinder), fuel blend compositions (such as B20, B40, B50), testing conditions (engine load and speed), compression ratios (ranging from 12:1 to 20:1), as well as the measured outcomes in terms of vibration levels and noise intensity. The third stage, Parameter Comparison, involves a cross-analysis of performance data, particularly quantifying reductions in vibration (e.g., 1.23% to 3.54%), changes in resonance frequencies (up to 90 kHz), and how increasing compression ratio affects engine dynamics. The review also highlights diagnostic

approaches, such as using accelerometers and combustion tracking methods with high correlation ($R^2$ = 0.97) between vibration signals and combustion stages.
Finally, the Integrated Analysis and Synthesis stage consolidates all findings into comprehensive tables and narrative insights, identifying key trends and patterns across engine configurations and fuel types. This step emphasizes the synergistic effect of fuel blend composition and compression ratio on improving NVH characteristics, offering practical implications for cleaner and quieter diesel engine operation. The flowchart thus serves as a visual guide for the methodological rigour and innovation presented in this review.

## 3. Result & Discussion

**Effect of fuel blends on the vibration of the engine**
Nowadays, automotive companies have made various changes to the engine, especially for the vehicle engine, to avoid vibration and noise disturbing the driver. The changes made by the automotive industry in reducing vibration and noise in machines include making the latest technology, replacing newer engine materials, and changing the exhaust system. The most vibrations and suspension noise can be classified according to the problem when the vehicle is running; for example, the sensitive engine speed will cause vibrations in that area unit directly associated with engine speed instead of others (not vehicle speed and driving conditions). Symptoms seem to be amended in direct proportion to the engine rate. The speed of a sensitive vehicle might cause vibration and disturbance at a specific engine speed or a modification in direct proportion to the time of auto speed. The acceleration or sensitive decelerations also can cause vibration or noise to be noticeable once the vehicle speed changes (such as once ranging from stopping, passing, retarding or sliding). The randomness found on the engine provides vibration or noise that arises, and which can disappear while not having a transparent affiliation with the engine revolutions per minute, vehicle speed, or driving conditions. Generally, the source of vibration and noise on the machine is shown in **Figure 2**.

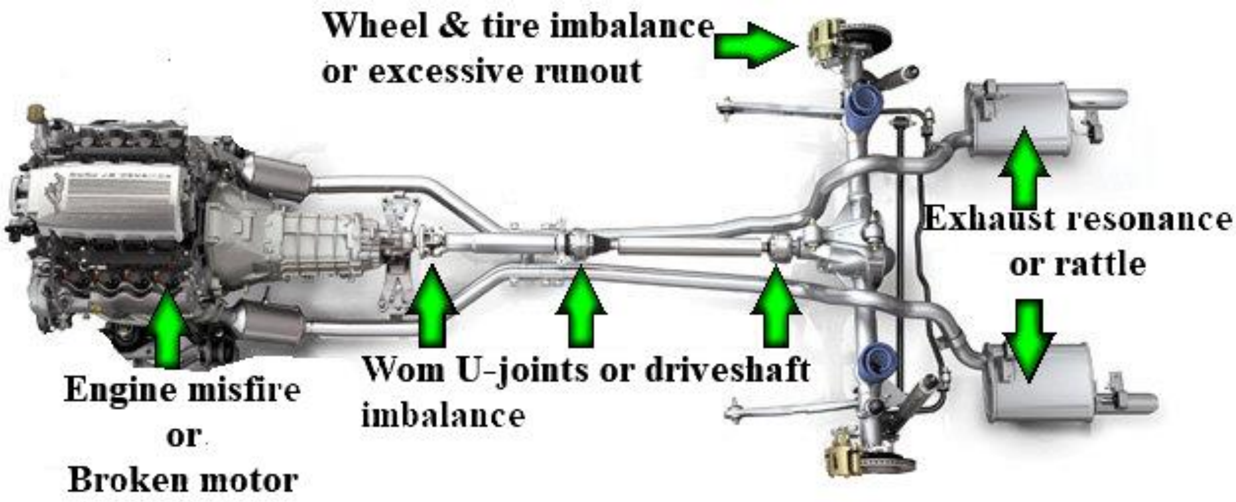


**Figure 2**: The primary vibration source on the machine

Some research has done some analysis in reducing vibration and noise on the engine because it was completed by [1–4,24]. Their research trials were conducted on a single cylinder diesel engine purged of mixed fuel between diesel-biodiesel. The results of their research reported that vibrations decreased when diesel fuel was mixed with biodiesel instead of pure diesel. Meanwhile, a different study by [5,6,25–27] conducted experiments on four-cylinder engines fueled by diesel-fuel biodiesel by making 20% and 40% mixtures at engine speeds between 1200 and 2400 rpm. Their research showed that the experiments performed slightly decreased the vibration on the average machine decrease by 1.23%, 2.34%, and 3.54%. A study was conducted by [9,28,29] to reduce engine vibration and noise by making different fuel and speed volumes. Experiments in their research were performed on four-cylinder engines and also single cylinders, while the fuel used was like (Sunflower and Canola Biodiesels, Bio Gas and Bio Diesel, Jatropha Methyl Ester (JME) and Diesel).

**Table 1.** The effect of fuel blend and different cylinders on the vibration and noise.

| Blend fuel | Cylinder | HRR | CHR | ROPR | BSFC | Density | Viscosity | Vibration | Noise | Ref |
|---|---|---|---|---|---|---|---|---|---|---|
| Diesel-Biodiesel | Single cylinder | X | X | X | X | X | X | ↑ | **X** | [1] |
| Diesel-Biodiesel | Single cylinder | ↑ | X | X | X | X | X | ↑ | ↑ | [2] |
| Diesel-Biodiesel | Single cylinder | X | X | X | X | X | X | ↑ | **X** | [3] |
| Diesel-Biodiesel | Four-cylinder | X | X | X | X | X | X | ↑ | **X** | [5] |
| Diesel-Biodiesel | Four-cylinder | X | X | X | X | X | X | ↑ | **X** | [6] |
| Diesel-Biodiesel | Single cylinder | X | X | X | X | X | X | ↑ | **X** | [4] |
| Diesel-Biodiesel | Six-cylinder | X | X | X | X | X | X | ↓ | ↓ | [30] |
| Diesel and Jatropha Biodiesel | Single cylinder | X | X | X | X | X | X | ↓ | ↓ | [31] |
| Diesel and Jatropha biodiesel | Single cylinder | ↑ | X | X | X | X | ↑ | ↑ | ↑ | [32] |
| Biodiesel, Petroleum | Single cylinder | X | X | X | X | X | X | ↑ | ↑ | [33] |
| Biodiesel, Petroleum | Six-cylinder | X | X | X | X | X | X | ↑ | | [13] |
| Karanja biodiesel and blends | Single cylinder | ↑ | ↑ | X | X | X | X | ↑ | ↑ | [17] |
| Biodiesel, Pongamia-Pinnata and Tung oils | Single cylinder | X | X | X | ↑ | ↑ | ↑ | ↑ | | [34] |
| Biodiesel and Methanol | Four-cylinder | X | X | X | X | X | X | ↑ | ↑ | [35] |
| Ethanol-Diesel | Single cylinder | X | X | ↑ | X | X | X | ↑ | ↑ | [36] |
| Ethanol–Gasoline | Single cylinder | X | X | X | X | X | X | ↑ | ↑ | [37] |
| Methanol and Ethanol Gasoline | Single cylinder | X | X | X | X | X | X | ↑ | | [38] |
| Sunflower and Canola Biodiesels | Four-cylinder | X | X | X | X | X | X | ↓ | | [9] |
| Bio-Gas and Bio-Diesel | Single cylinder | X | X | X | X | X | X | ↓ | ↓ | [28] |
| Jatropha Methyl Ester (JME) and Diesel | Single cylinder | X | X | X | ↑ | X | ↑ | ↓ | | [29] |

The experimental results in their research indicated that vibrations and noise can be reduced by using a fuel mixture instead of pure diesel. The results of various studies that have been done before to reduce the vibrations and noise of machines are shown in **Table 1**. Most researchers [106,107,108,109,110], as described in **Table 2**, reported that fluctuation in the engine could increase with increasing compression ratio (CR). Biodiesel fuel was stated to be more environmentally friendly than petroleum fuels because it is a renewable energy source that decreases exhaust emissions, such as HC, CO, and non-combustible particles [33,39–41]. However, the specialised literature highlights the need for further investigation of performance, emission characteristics, and NVH in engines equipped with the latest technology on biodiesel blends. Behaviour investigations on vibro-acoustic small engine displacement, especially on micro-cars fueled by a mixture of biodiesel distilled from scrap oil and ultra-sulfur diesel fuel with 40% lace volume. This demand is made to reduce chemical pollution and noise, congestion, and parking difficulty in urban areas so that microcars become one of the future solutions, especially for using biodiesel fuel.

Furthermore, the noise index was evaluated on the emission components of the combustion energy. With an increased noise index for all mixtures by increasing engine speed, B10 was higher in most testicles than B40 and exhibited different behaviour. Furthermore, it was explained that indirect methods for diagnosing engines were potentially more significant [10,42–44]. The previous methodology was developed by putting an accelerometer on a four-cylinder diesel engine to determine the increase in combustion. High data pressure on the accelerometer with in-cylinder was used to evaluate the vibration signal at startup, 50% fuel consumption when the engine spins (MFB50) until the combustion process was completed (MFB95) on a two-cylinder engine. From the reported results, the correlation value of the squared coefficient increased by 0.97; thus, a single accelerometer can determine the optimal combustion process on a single-cylinder engine with the help of control algorithms. Then, reduced engine vibration was reported after a 12% modification on the engine [13]. Also, using a mixture of vibration fuel on the engine varied greatly. From the analysis results, the decline in vibration on the typewriter was by using fuel with volumes B40 and B20. The results showed decreases in diesel engines (D100) versus biodiesel (B100). However, the highest vibration was obtained on B30 and B50. With different engine speeds, the torque curve can create a stable oscillation.

Furthermore, the engine's vibrations in the lateral and longitudinal piston directions were analysed using three different accelerometers [17]. In biodiesel mixtures, at 20%, there was a height of burning noise with shorter correlated combustion duration, increased combustion, and high overheating. The invention of vibration on the engine when K20 fuel was used. The use of microphones on the engine's external highs on KB100 on all loads from the other fuels. However, the source of the noise was caused by the difference in the separate process during combustion. The conclusions from this study, with various fuels tested, showed that the maximum spray penetration at KB20 was consistent with combustion noise, ignition, and thermal velocity.

**Table 2.** Effect of fuel blend on the vibration of the engine

| Type engine test | Fuel | Test conditional | Torque | TE | CR | Vibration | Resonance frequency | Accelero meter | Ref |
|---|---|---|---|---|---|---|---|---|---|
| 2-cylinder, Four stroke, direct injection, naturally aspirated, water cooler | Biodiesel, Petroleum-derived fuels | 1. Different engine load 60%-biodiesel 40%-90%-biodiesel 10%-80%-biodiesel 20%<br>2. Different fuel B40-B10-B20 | Decreased ↓ | Increased ↑ | 20:1 | Increased ↑ | 90 kHz | Endevco-7240C | [33] |

| Type engine test | Fuel | Test conditional | Torque | TE | CR | Vibration | Resonance frequency | Accelero meter | Ref |
|---|---|---|---|---|---|---|---|---|---|
| three-cylinder, six valves, 1028 $cm^3$, CI engine | Diesel | 1. Different engine load 2. Two test fuel MFB50 and MFB95 | Increased ↑ | X | 17.5:1 | Increased ↑ | 90 kHz | Endevco-7240C | [10] |
| Tractor weight and dimensions, 6-cylinder | Biodiesel, diesel | 1. Different blends of biodiesel in a six-cylinder diesel engine 2. B5-B10-B15-B20-B30-B40-B50 | Increased ↑ | X | 16:1 | Increased ↑ | 6.3 kHz | CTC AC102-1A | [13] |
| DM-10, Vertical, four-stroke, single-cylinder, constant-speed, direct-injection, CI engine | Karanja biodiesel, Baseline mineral diesel | 1. Different blends of biodiesel 0%-20%-40%-60%-80%-100% 2. KB20-KB100 | X | X | 17.5:1 | Increased ↑ | 12.5Hz | MP 4374 and 4517 | [17] |
| Four strokes, Water-cooled | Biodiesel, Pongamia-Pinnata and Tung oils | 1. Different fuel D100-T50-T75-T100-PP50-PP75-PP100 | X | Increased ↑ | 12:1-18:1 | Decreased ↓ | 2Hz-20 kHz | PCB no: 356A33 | [34] |

Finally, an increase in brake performance was observed when using biodiesel fuel, although the addition of hydrogen was found to further increase fuel consumption through the intake manifold [34,45–47]. The addition of hydrogen and biodiesel can reduce vibration. The spectrum frequency decreases with the decrease of energy transmitted to the engine through the piston so that the chemical fuel energy can be changed.

## 4. Conclusion

The use of oxygenated fuels, particularly biodiesel blends, has effectively reduced engine vibration and noise in diesel engines. Several studies reviewed indicate that blends such as B20 and B40 result in average vibration reductions of 1.23%, 2.34%, and up to 3.54% compared to pure diesel, especially within engine speed ranges of 1200–2400 rpm. These effects are more pronounced in single-cylinder engines but are also evident in four- and six-cylinder configurations. Furthermore, an increase in compression ratio (CR) up to 20:1 correlates with intensified vibration fluctuations and resonance frequencies, reaching up to 90 kHz in certain test conditions. Advanced accelerometer diagnostics revealed a high correlation coefficient ($R^2 = 0.97$) between vibration signals and combustion stages, allowing accurate monitoring of the combustion process in single-cylinder engines. Additionally, specific blends such as Jatropha Methyl Ester (JME) and Karanja biodiesel demonstrated unique acoustic and thermal characteristics, with B30 and B50 producing higher vibration amplitudes than other blends. Adding hydrogen to biodiesel reduced spectral vibration frequencies due to lower energy transmission to the piston. Overall, the findings emphasize the potential of biodiesel and oxygenated fuels to improve NVH (Noise, Vibration, Harshness) characteristics and support cleaner, quieter, and more sustainable engine operation.

## Acknowledgement

The authors would like to express their sincere gratitude for the collaborative efforts and contributions made during the preparation of this article. The authors' personal resources fully supported this work and did not receive any specific grant from public, commercial, or not-for-profit funding agencies.

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