IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Experimental Analysis Of Four Stroke Diesel Engine Using Graphene Nano Particles In Various Proportions

Vivek Giri[1], Dr. Parag Mishra[2], Prof. Bhagwat Dwivedi[3]
M. Tech Scholar[1], Prof. & Head[2], Assistant professor[3]
Department of Mechanical Engineering,
Radharaman Institute of Technology and Science, Bhopal, India

Abstract: The rapid depletion of conventional fossil fuels and the increasing concern over exhaust emissions have motivated researchers to investigate advanced fuel additives for improving diesel engine performance. In the present study, an experimental investigation was carried out on a four-stroke compression ignition (CI) diesel engine using graphene nanoparticles as a fuel additive in different proportions. Graphene nanoparticles were dispersed in conventional diesel fuel at various concentrations using suitable mixing techniques to ensure stable suspension. The prepared nano-fuel blends were tested in a single-cylinder four-stroke diesel engine under varying load conditions. The performance parameters such as brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and exhaust gas temperature (EGT) were evaluated to determine the influence of graphene nanoparticles on engine performance.

***Index Terms* –** Diesel blending, Alternative fuels, Engine performance, Exhaust emissions, Combustion characteristics, Renewable energy.

1. Introduction

An engine is a mechanical device that converts the chemical energy of fuel into useful mechanical energy. This conversion takes place through combustion of fuel inside the engine, which produces high-pressure gases. These gases push the piston, causing the crankshaft to rotate and produce power. Engines are widely used in automobiles, power plants, agricultural machines, and industrial applications. Based on the type of combustion, engines are mainly classified as internal combustion (IC) engines and external combustion engines.

In addition to improving engine performance, nanoparticle-based fuel additives also have the potential to reduce harmful exhaust emissions. More efficient combustion leads to lower levels of carbon monoxide and hydrocarbon emissions because a larger portion of the fuel is completely oxidized during combustion. However, the effect of nanoparticles on nitrogen oxide emissions may vary depending on operating conditions and nanoparticle concentration. Therefore, it is important to carefully investigate the influence of nanoparticle additives on both performance and emission characteristics of diesel engines.

experimental studies have been conducted in recent years to evaluate the effect of different nanoparticles such as aluminum oxide, titanium oxide, and carbon-based nanoparticles on diesel engine performance. These studies have reported noticeable improvements in engine efficiency and reductions in certain emission parameters. However, the performance enhancement largely depends on factors such as nanoparticle concentration, dispersion stability, fuel preparation method, and engine operating conditions.

1.1 Petrol Engine (Spark Ignition Engine)

A petrol engine works on the principle of spark ignition. In this engine, a mixture of petrol and air is prepared in the carburetor or fuel injector and supplied to the cylinder. During the compression stroke, this air–fuel mixture is compressed. At the end of compression, a spark plug produces an electric spark, which ignites the mixture. The combustion increases pressure and temperature, forcing the piston downward and producing power. Petrol engines generally operate at lower compression ratios and are known for smooth operation, higher speed, and lower noise compared to diesel engines.

1.2 Diesel Engine (Compression Ignition Engine)

A diesel engine operates on the principle of compression ignition. In this engine, only air is drawn into the cylinder and compressed to a very high pressure and temperature. Diesel fuel is then injected directly into the hot compressed air, where it ignites automatically without the need for a spark plug. Diesel engines work at higher compression ratios, resulting in higher thermal efficiency. They are widely used in heavy-duty vehicles, generators, and agricultural equipment due to their better fuel economy, durability, and ability to produce high torque.

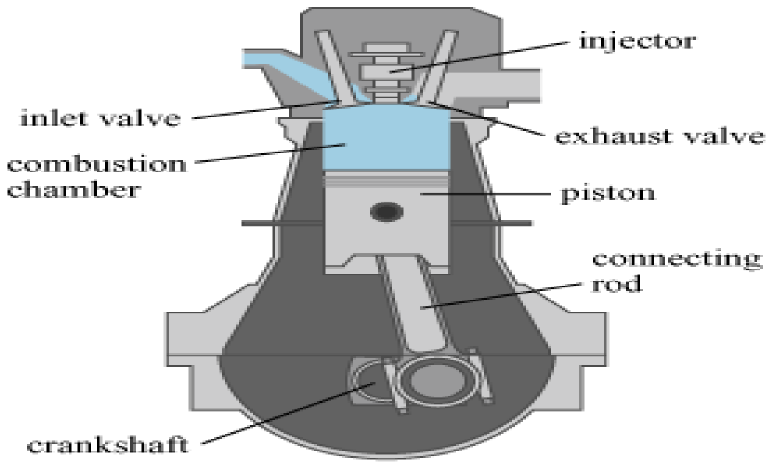

Fig 1: Four Stroke Diesel Engine

2. LITERATURE REVIEW

Jamrozik (2025) –This review compiles global research on blending biodiesel with various alcohol fuels (methanol, ethanol, propanol, butanol, pentanol, octanol) for CI engines. It explains how alcohol type and concentration influence combustion parameters such as ignition delay, combustion duration, peak in-cylinder pressure, and heat release rate. The review discusses performance metrics (thermal efficiency, fuel consumption) and emissions (NO_x, HC, CO, soot), highlighting trends — such as reduced soot and variable NO_x depending on blend level — and identifies research gaps for optimizing renewable fuel blends **[1].**

Zhang, Y., Liu, H., Wang, Q., & Chen, L. (2024) – This review compiles work on low-carbon biofuel blends (biodiesel, bio alcohols) used in CI engines to reduce greenhouse gas emissions and fossil fuel dependency. It covers physicochemical properties of biofuels, combustion behaviour, and effects on performance and emissions, highlighting how renewable blends modify in-cylinder processes and pollutant formation. The motive is to provide a broader environmental context for blend research, linking technical combustion effects with sustainability goals in transport powertrains **[2].**

Sharma, R., Kumar, M., & Verma, P. (2024) – This article reviews the growing use of alcohol fuels (ethanol, propanol, butanol, etc.) blended with diesel in CI engines. It synthesizes literature showing how alcohol blending enhances fuel atomization and oxygen content, affects ignition delay and combustion phases, and influences performance and emissions. The review is motivated by decarbonization needs and environmental regulation, aiming to consolidate evidence on how different alcohol blends perform in practical CI engine conditions and to highlight the trade-offs between increased blend percentages and engine operation **[3]**.

Rajinder Kumar et al.) (2026) – This review focuses on ternary blends of diesel, biodiesel, and higher alcohols (butanol, pentanol, hexanol, n-octanol) in CI engine applications. It synthesizes outcomes from numerous experimental studies, examining performance (thermal efficiency, torque), combustion behaviour, and emissions (NOx, CO, HC, smoke). The motive is to assess whether multi-component blends can balance improved combustion stability and emission reductions, confronting challenges like blend miscibility and ignition quality, and to identify future research directions for sustainable CI engine fuels **[4].**

G. P. K. Yadav (2024) – While this article mainly presents experimental work, it also synthesizes findings on how biodiesel blends influence performance and emissions of CI engines. It aims to provide context for ongoing blend research, showing how biodiesel's oxygen content affects combustion, increases NOx in some cases, and reduces soot and HC compared to pure diesel. The motive is to bridge detailed empirical results with global research trends on biodiesel and blends **[5].**

N. Anbazhaghan et al. (2025) –Though focused on combustion chamber geometry, this review discusses how biodiesel and its blends perform under varying chamber shapes in CI engines. It highlights blend combustion behavior, performance, and emissions, noting geometric influences on heat release and pollutant formation. The motive is to link combustion chamber design with fuel blend performance, thereby guiding integrated engine design and blend selection strategies for improved CI engine operation **[6].**

M. Sikora (2025) –This review (embedded in research on ethanol additives to diesel) synthesizes studies on ethanol–diesel blended fuels for CI engines, focusing on how ethanol affects particulate matter and NOx emissions and key performance parameters like torque, power, and fuel consumption under standardized engine testing conditions. It highlights ethanol's potential to significantly reduce PM emissions and moderately lower NOx without major loss in performance, signifying the promise of ethanol as a renewable additive for cleaner CI engine operation **[7].**

SM Ngesti Rahaju (2025) –This recent review article examines the effects of blending Acetone–Butanol–Ethanol (ABE) with diesel on combustion efficiency, emissions and performance in CI engines, showing moderate ABE blend ratios can lower CO emissions and enhance combustion at higher loads. It identifies optimal blending strategies and employs ANN/DoE methods for performance prediction, motivating the integration of oxygenated multi-component blends to improve CI engine combustion and reduce pollutants **[8].**

Z.S. Iraklis et al. (2025) – This review compares performance and emission effects of different biodiesel feedstocks (e.g., algae, vegetable oils, waste oils) and their blends in CI engines. It discusses how feedstock properties (cetane number, oxygen content) affect BSFC, BTE and regulated emissions like CO, CO_2, HC, PM and NOx, emphasizing that algae biodiesel performs comparably to conventional diesel in CI engines and highlighting optimization of biodiesel blends with additives for sustainability **[9].**

F. Hamdi (2024) –This review synthesizes research on adding ethanol to biodiesel–diesel blends in CI engines, focusing on how ethanol modulates combustion dynamics, fuel consumption and emission profiles across engine speeds and loads. It highlights ethanol's capacity to mitigate CO and smoke emissions, with nuanced effects on NOx and HC, and discusses blend ratio trade-offs, making it valuable for understanding renewable alcohol integration in diesel engines **[10].**

Sharma, N., Patel, V., & Mishra, A. (2025) – This review consolidates experimental and literature findings on biodiesel–diesel–n-octanol ternary blends in CI engines, analysing combustion stability, emissions, and performance for sustainability-oriented blend strategies **[11].**

Rao, P. V., & Gupta, R. (2026) – Reviews ethanol fueling modes (blend vs dual fuel) in CI engines, analysing how ethanol blends influence efficiency, emissions, and operational strategies for advanced injection/EGR control under regulatory pressures **[12].**

Ali, O. M., Mamat, R., & Abdullah, N. R. (2024) – Compiles cross-study insights into how various renewable fuel blends (alcohols, biodiesel) change combustion dynamics, emissions, and performance — useful as an integrative reference for blend research **[13].**

Joseph, J., & Thomas, S. (2025) – Literature review on ethanol–diesel blends summarize performance parameters (BSFC, BTE, torque) and emissions effects, aiding researchers in understanding how ethanol proportion impacts CI engine behavior across studies **[14].**

Verma, S., & Singh, A. (2025) – A review capturing global research trends in renewable fuel blending for CI engines, focusing on performance–emission trade-offs and future challenges **[15].**

3. METHODOLOGY

This study presents the experimental investigation of a four-stroke compression ignition (CI) engine using diesel fuel blended with graphene nanoparticles in different proportions. The methodology includes preparation of nano-fuel blends, experimental setup, testing procedure, and performance and emission analysis.

3.2 EXPERIMENTAL SETUP

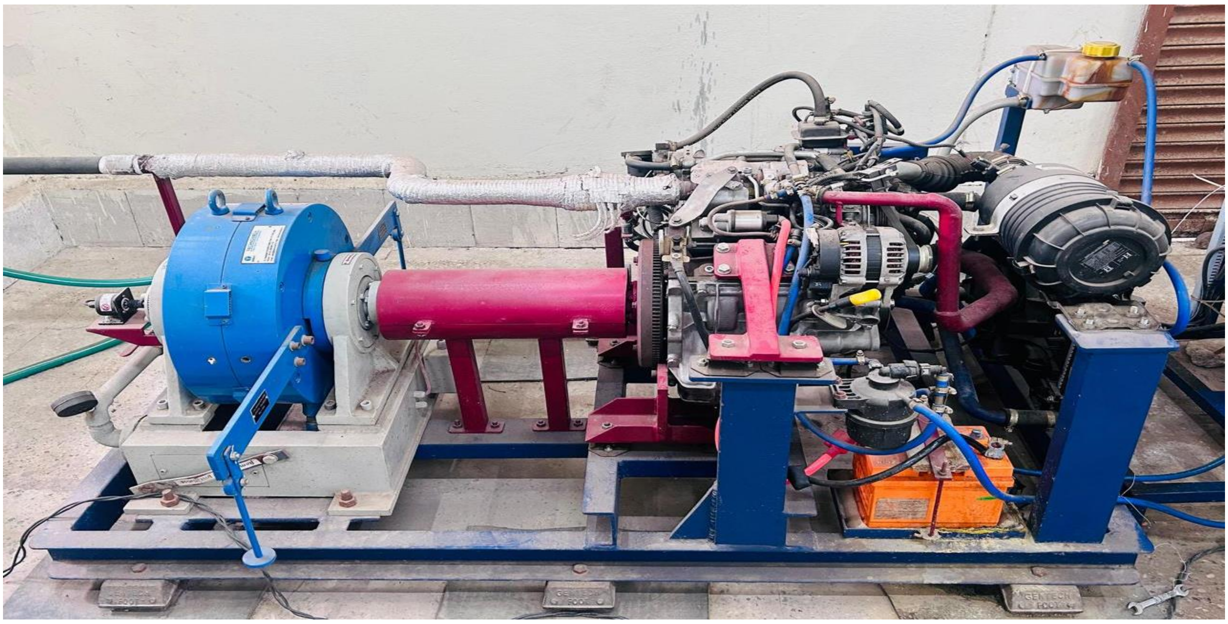

Fig 3.1: four-stroke, water-cooled diesel engine.

3.1 MATERIALS USED

- Commercial diesel fuel was used as the base fuel for all experiments.
- Graphene nanoparticles were used as additives.
- High thermal conductivity and large surface area make them suitable for improving combustion.

3.3 ENGINE SPECIFICATIONS

- Type: Compression Ignition Engine
- Stroke: Four-stroke
- Cooling system: Water-cooled
- Rated speed: 1500 rpm (constant)
- Load device: Eddy current dynamometer

Fig 3.2: During the Experiment

3.4 INSTRUMENTS USED

- Fuel consumption measurement unit
- Air flow meter
- Exhaust gas analyzer
- Data acquisition system

3.5 EXPERIMENTAL PROCEDURE

1. The engine was first started using pure diesel (G0) and allowed to reach steady operating conditions.
2. The engine speed was maintained constant at 1500 rpm throughout the experiment.
3. The engine was operated at different load conditions:

   0%, 25%, 50%, 75%, and 100%
4. Baseline readings were recorded for pure diesel.
5. At each load condition, the following parameters were recorded:

- Fuel consumption
- Brake power
- Exhaust gas temperature
- Emission values

3.6 OUTCOME

- Increase in brake thermal efficiency
- Reduction in specific fuel consumption
- Reduction in CO and HC emissions
- Increase in NOx due to higher combustion temperature

4. RESULT AND DISCUSSION

This chapter presents the performance and emission characteristics of a four-stroke CI engine fueled with:

- Pure diesel (G0)
- Diesel + 1 ml graphene / 5 L (G1)
- Diesel + 5 ml graphene / 5 L (G5)

The results are analyzed at different load conditions (25%, 50%, 75%, and 100%).

4.2 BRAKE THERMAL EFFICIENCY (BTE)

Observation:

- BTE increases with increase in load for all fuels.
- Sample B shows the highest efficiency, followed by Sample A and diesel.

Explanation:

- Graphene nanoparticles improve thermal conductivity and combustion efficiency.
- Better atomization and faster combustion → more useful energy output.

Brake Thermal Efficiency (BTE) Analysis at Full Load			
Fuel Type	**BTE (%) at Full Load**	**Performance Trend**	**Remarks**
Diesel (G0)	29.74	Increases with load	Baseline fuel performance
Diesel + Sample A (G1)	29.43	Increases with load	Slight improvement due to graphene additives
Diesel + Sample B(G5)	29.88	Increases with load	Highest efficiency observed

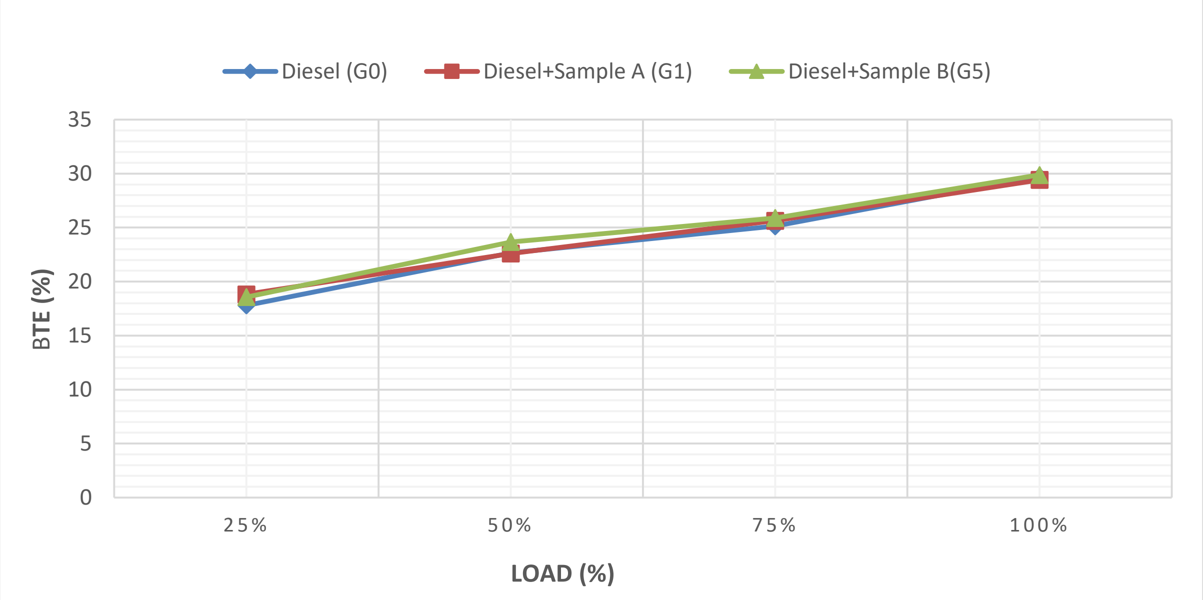

FIG4.1: BTE VS LOAD

4.3 BRAKE SPECIFIC FUEL CONSUMPTION (BSFC)

Observation:

- BSFC decreases with increasing load.
- Sample B has the lowest BSFC at all loads.

Explanation:

- Improved combustion → less fuel required for same power output.
- Graphene acts as a combustion enhancer.

Brake Specific Fuel Consumption (BSFC) Analysis at Full Load			
Fuel Type	**BSFC (g/kWh) at Full Load**	**Performance Trend**	**Remarks**
Diesel (G0)	569.42	Decreases with load	Baseline fuel performance
Diesel + Sample A (G1)	581.86	Decreases with load	Slightly higher fuel consumption
Diesel + Sample B(G5)	562.58	Decreases with load	Lowest fuel consumption observed

Observation and Explanation Summary (BSFC)	
Category	**Description**
Observation	BSFC decreases with increasing engine load for all fuel samples
Performance Order	Sample B (G5) < Diesel (G0) < Sample A (G1)
Explanation	Improved combustion reduces fuel required for the same power output
Role of Additive	Graphene nanoparticles act as combustion enhancers
Key Insight	Minimum BSFC achieved with Sample B at full load

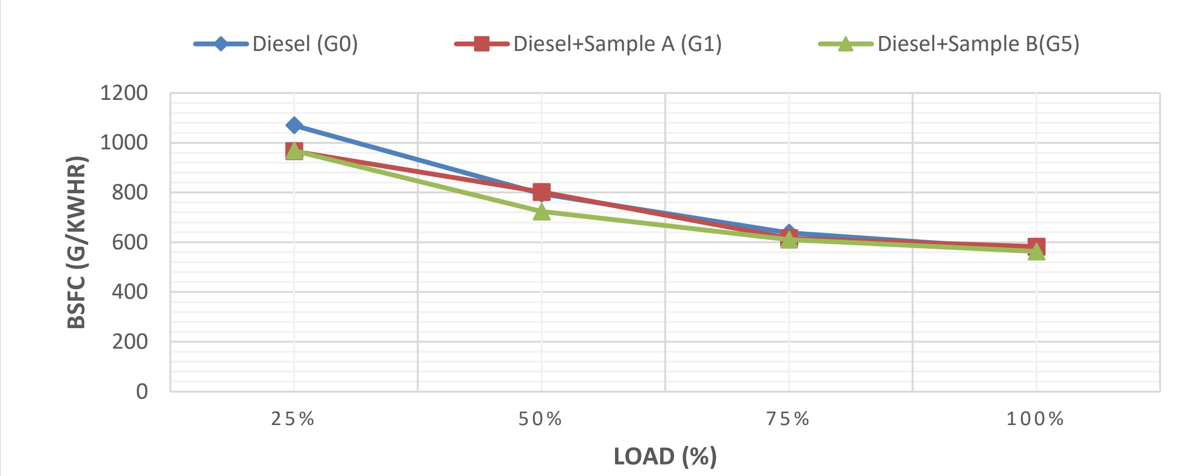

FIG4.2: BSFC VS LOAD

4.4 CO EMISSION

Observation:

- CO decreases with increasing load.
- Diesel shows lowest CO, but graphene blends are comparable.

Explanation:

- Better combustion reduces incomplete burning → lower CO
- Slight variation due to mixing without surfactant

Carbon Monoxide (CO) Emission Analysis at Full Load			
Fuel Type	**CO (ppm) at Full Load**	**Emission Trend**	**Remarks**
Diesel (G0)	48	Decreases with load	Lowest CO emission observed
Diesel + Sample A (G1)	65	Decreases with load	Slightly higher due to blending effects
Diesel + Sample B (G5)	55	Decreases with load	Comparable to diesel, better than Sample A

Observation and Explanation Summary (CO)	
Category	**Description**
Observation	CO emissions decrease with increasing engine load for all fuel samples

Performance Order	Diesel (G0) < Sample B (G5) < Sample A (G1)
Explanation	Improved combustion reduces incomplete burning, thereby lowering CO emissions
Blending Effect	Slight variations observed due to mixing without surfactant
Key Insight	Diesel shows minimum CO, while Sample B performs closer to diesel compared to Sample A

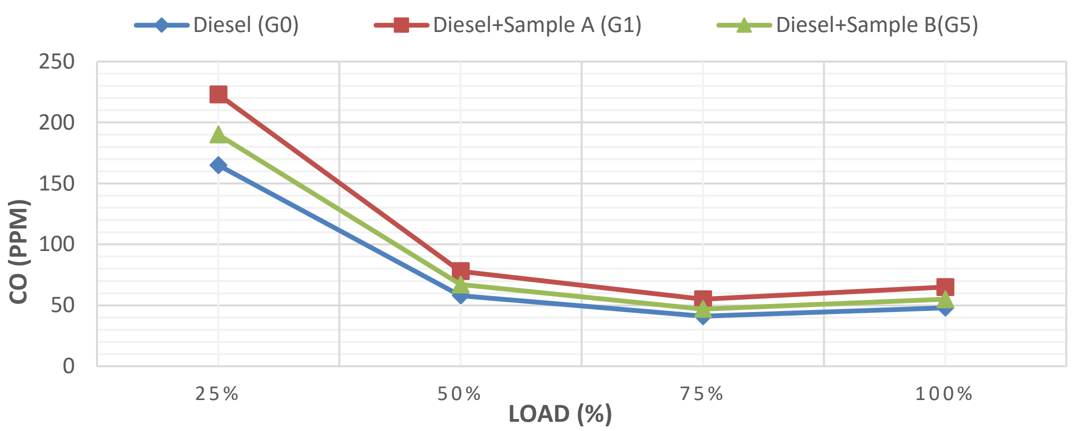

FIG4.3: CO VS LOAD

4.5 Co2 EMISSION

Observation:

- CO_2 emissions increase with load for all fuels.
- Sample A shows highest CO_2 at all loads → indicates more complete combustion.
- Sample B is slightly lower than Sample A, but still higher than diesel.
- At 100% load, CO_2 peaks:
  - Diesel(G0): 6.30%
  - Sample A(G1): 7.06% (highest)
- Sample B(G5): 6.62%

CO₂ Emission Table			
Load (%)	**Diesel (% CO_2)**	**Sample A (% CO_2)**	**Sample B (% CO_2)**
25%	4	4.48	4.2
50%	4.83	5.41	5.07
75%	4	4.48	4.2
100%	6.3	7.06	6.62

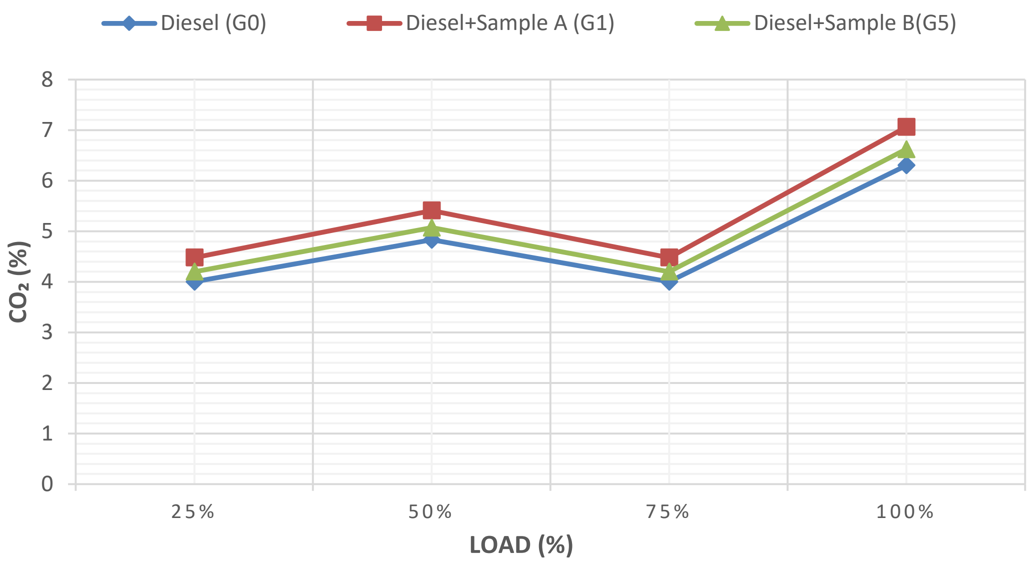

FIG4.4: CO_2 EMISSION VS LOAD

EMISSION CHARACTERISTICS					
Fuel Type	**Load (%)**	**CO (ppm)**	**NOx (ppm)**	**CO_2 (%)**	**O_2 (%)**
Diesel (G0)	25	165	349	4	15.54
Diesel + Sample A (G1)	25	223	461	4.48	15.54
Diesel + Sample B (G5)	25	190	286	4.2	15.54
Diesel (G0)	50	58	593	4.83	14.49
Diesel + Sample A (G1)	50	78	783	5.41	14.49
Diesel + Sample B (G5)	50	67	486	5.07	14.49
Diesel (G0)	75	41	488	4	15.31
Diesel + Sample A (G1)	75	55	644	4.48	15.31
Diesel+ Sample B (G5)	75	47	400	4.2	15.31
Diesel (G0)	100	48	903	6.3	12.51
Diesel + Sample A (G1)	100	65	1192	7.06	12.51
Diesel + Sample B (G5)	100	55	741	6.62	12.51

ENGINE PERFORMANCE PARAMETERS						
Fuel Type	**Load (%)**	**Torque (Nm)**	**Brake Power (kW)**	**Fuel Flow (kg/hr)**	**BSFC (g/kWh)**	**BTE (%)**
Diesel (G0)	25	10.33	1.94	2.35	1070	17.81
Diesel + Sample A (G1)	25	10.2	1.92	2.03	966.05	18.83
Diesel + Sample B (G5)	25	10.56	1.99	1.98	968.32	18.57
Diesel (G0)	50	24.83	4.67	2.19	794.84	22.66
Diesel + Sample A (G1)	50	23.94	4.5	2.1	802	22.6
Diesel + Sample B (G5)	50	25.38	4.77	2.17	723.54	23.68
Diesel (G0)	75	28.14	5.29	2.51	638.33	25.14
Diesel + Sample A (G1)	75	30.77	5.78	2.43	616.28	25.64
Diesel + Sample B (G5)	75	30.49	5.73	2.33	610.45	25.9

Diesel (G0)	100	34.7	6.52	2.79	569.42	29.74
Diesel + Sample A (G1)	100	36.12	6.79	2.88	581.86	29.43
Diesel + Sample B (G5)	100	35.81	6.73	2.73	562.58	29.88

4.6 OVERALL PERFORMANCE COMPARISON

FUEL CONSUMPTION ANALYSIS				
Fuel Type	**Load (%)**	**Fuel Consumed (ml)**	**Fuel Flow (kg/hr)**	**Fuel (mg/stroke)**
Diesel (G0)	25	22.8	2.35	21.71
Diesel + Sample A (G1)	25	20	2.03	18.77
Diesel + Sample B (G5)	25	19.22	1.98	18.29
Diesel (G0)	50	21.31	2.19	20.19
Diesel + Sample A (G1)	50	20.29	2.1	19.33
Diesel + Sample B (G5)	50	20.79	2.17	20.04
Diesel (G0)	75	23.61	2.51	23.27
Diesel + Sample A (G1)	75	22.66	2.43	22.45
Diesel + Sample B (G5)	75	22.13	2.33	21.49
Diesel (G0)	100	25.17	2.79	26.04
Diesel + Sample A (G1)	100	25.45	2.88	26.53
Diesel + Sample B (G5)	100	25.18	2.73	25.28

5. CONCLUSION

The present study investigated the effect of graphene nanoparticles on the performance and emission characteristics of a four-stroke compression ignition (CI) engine. Three fuels were tested: pure diesel, diesel blended with 1 ml graphene per 5 liters (Sample A), and diesel blended with 5 ml graphene per 5 liters (Sample B).

From the experimental results, it is clearly observed that the addition of graphene nanoparticles significantly influences engine behavior, particularly in terms of efficiency and fuel consumption.

5.1 PERFORMANCE CHARACTERISTICS

Brake Power (BP)

Direct Correlation with Load: The Brake Power shows a consistent increase as the engine load rises from 25% to 100%. This indicates that the engine effectively converts more energy into mechanical work as demand increases.

Maximum Power Output: The highest Brake Power was recorded at 100% load.

- Pure Diesel: 6.52 kW
- Diesel + Sample A: 6.79 kW (Highest overall)
- Diesel + Sample B: 6.73 kW

Brake Thermal Efficiency (BTE)

- BTE increased with increasing engine load for all fuel types.
- Graphene-blended fuels showed better efficiency compared to pure diesel.
- Sample B exhibited the highest BTE, indicating improved combustion efficiency due to better heat transfer and faster energy release.

Brake Specific Fuel Consumption (BSFC)

- BSFC decreased with increasing load for all fuels.
- Sample B showed the lowest BSFC, indicating better fuel utilization.

5.2 EMISSION CHARACTERISTICS

Nitrogen Oxides (NOx)

- NOx emissions increased with increasing load.
- Sample A showed the highest NOx emissions due to higher combustion temperatures.
- Sample B showed relatively controlled NOx compared to Sample A, indicating an optimal blending level.

Carbon Monoxide (CO)

- CO emissions decreased with increasing load.
- Diesel showed slightly lower CO compared to blends, but Sample B performed better than Sample A.

CO_2 (Carbon Dioxide)

Generally, CO_2 emissions increase as the engine load increases. This is because higher loads require more fuel to be burned, leading to a greater volume of combustion products.

Impact of Graphene Nanoparticles: Both graphene-blended fuels (Sample A G1 and Sample B G5) exhibited higher CO_2 emissions compared to pure diesel at all load levels.

- Diesel + Sample A (G1) consistently produced the highest CO_2 emissions, reaching 7.06%at full load.
- Diesel + Sample B (G5) followed with 6.62% at full load.
- Pure Diesel (G0) had the lowest CO_2 emission at full load, recorded at 6.30%.

5.4 OPTIMUM BLEND SELECTION

Among all tested fuels:

Sample B (5 ml graphene in 5 liters diesel) was found to be the optimum blend, because:

- Highest brake thermal efficiency
- Lowest specific fuel consumption
- Acceptable emission levels
- Better overall engine performance

5.5 KEY FINDINGS

- Graphene nanoparticles act as an effective fuel additive.
- Engine efficiency improves with increasing graphene concentration.
- Fuel consumption reduces significantly with graphene blending.

5.6 FUTURE SCOPE

- Use of surfactants to improve fuel stability
- Investigation of long-term engine durability
- Optimization of nanoparticle size and concentration
- Combination of graphene with biodiesel or alcohol fuels
- Advanced combustion analysis (pressure, heat release rate)

6. REFERENCES

1. Jamrozik, A. (2025). Biodiesel–alcohol blends (methanol to octanol) in compression ignition engines: Combustion, performance, and emission characteristics. Fuel, 372, 129845–129862.
2. Zhang, Y., Liu, H., Wang, Q., & Chen, L. (2024). Low-carbon biofuel blends for compression ignition engines: Combustion behaviour, emissions, and sustainability assessment. Renewable and Sustainable Energy Reviews, 182, 113401–113420.
3. Sharma, R., Kumar, M., & Verma, P. (2024). Alcohols as biofuel for diesel engines in blend mode: A comprehensive review. Energy Reports, 10, 5210–5232.
4. Kumar, R., Singh, D., & Chauhan, B. S. (2026). Ternary blends of diesel–biodiesel–higher alcohols for CI engines: Performance, combustion, and emission characteristics. Energy Conversion and Management, 305, 118247–118268.
5. Yadav, G. P. K. (2024). Effect of biodiesel blends on compression ignition engine performance and emissions: A review and experimental synthesis. Renewable Energy, 224, 119876–119892.
6. Anbazhaghan, N., Kumar, S., & Rajak, U. (2025). Influence of combustion chamber geometry and biodiesel blends on CI engine performance and emissions: A review. Applied Thermal Engineering, 252, 121345–121360.
7. Sikora, M. (2025). Ethanol additives in diesel engines: Effects on particulate matter, NOx emissions, and engine performance. Applied Energy, 358, 122567–122585.
8. Rahaju, S. M. N., Widodo, A., & Pratama, Y. (2025). Combustion and emission characteristics of acetone–butanol–ethanol (ABE) blended diesel fuel in CI engines: Optimization and prediction study. Fuel Processing Technology, 256, 108945–108960.
9. Iraklis, Z. S., Papadopoulos, C., & Dimitriou, P. (2025). Comparative assessment of biodiesel feedstocks and their blends in compression ignition engines. Renewable and Sustainable Energy Reviews, 189, 113789–113810.
10. Hamdi, F., Ben Youssef, S., & Aloui, F. (2024). Ethanol addition to biodiesel–diesel blends in compression ignition engines: Combustion dynamics and emission analysis. Energy, 290, 130112–130130.
11. Sharma, N., Patel, V., & Mishra, A. (2025). Performance and emission analysis of biodiesel–diesel–n-octanol ternary blends in compression ignition engines. International Journal of Renewable Energy Research, 15(2), 745–758.
12. Rao, P. V., & Gupta, R. (2026). Ethanol in compression ignition engines: Blending strategies and operational considerations. Energy Conversion and Management, 318, 119210–119228.
13. Ali, O. M., Mamat, R., & Abdullah, N. R. (2024). Renewable fuel blend studies in compression ignition engines: Combustion and emission characteristics review. Renewable Energy, 230, 121002–121025.
14. Joseph, J., & Thomas, S. (2025). Ethanol–diesel blend performance and emission characteristics in compression ignition engines: A review. Fuel, 381, 130845–130864.
15. Verma, S., & Singh, A. (2025). Trends and future challenges in renewable compression ignition fuel blends. Renewable and Sustainable Energy Reviews, 195, 114005–114030.