

Experimental Investigation of Performance and Emission Characteristics of a DI Diesel Engine Using Hexenal Diesel blends

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Abstract—The growing concern over fossil fuel depletion and stringent emission regulations has accelerated the search for sustainable alternative fuels. In this study, an experimental investigation is carried out to evaluate the performance and emission characteristics of a direct injection diesel engine using hexanol–diesel blends. The experiments are conducted on a single-cylinder, four-stroke, water-cooled diesel engine operating at constant speed under varying load conditions. Test fuels are prepared by blending hexanol with diesel in different volume proportions (5%, 10%, and 15%), denoted as H5, H10, and H15, respectively. Performance parameters such as brake thermal efficiency and brake specific fuel consumption are analysed, along with emission parameters including carbon monoxide, hydrocarbons, and nitrogen oxides. The results indicate that hexanol addition improves combustion efficiency and significantly reduces harmful emissions. Among the tested blends, H10 exhibits the best balance between performance enhancement and emission reduction, making it a promising alternative fuel for diesel engines.

Keywords — Hexanol, Diesel Engine, Oxygenated Fuel, Emissions, Brake Thermal Efficiency, Alternative Fuels

1. INTRODUCTION

DIESEL ENGINES ARE WIDELY USED IN TRANSPORTATION, AGRICULTURE, CONSTRUCTION, AND POWER GENERATION DUE TO THEIR HIGH THERMAL EFFICIENCY, DURABILITY, AND RELIABILITY. COMPARED TO SPARK IGNITION ENGINES, DIESEL ENGINES OFFER BETTER FUEL ECONOMY AND HIGHER TORQUE OUTPUT, MAKING THEM

SUITABLE FOR HEAVY-DUTY APPLICATIONS. HOWEVER, THE EXTENSIVE USE OF DIESEL ENGINES HAS RESULTED IN SIGNIFICANT ENVIRONMENTAL CONCERNS DUE TO HARMFUL EXHAUST EMISSIONS SUCH AS CARBON MONOXIDE (CO), HYDROCARBONS (HC), NITROGEN OXIDES (NOX), AND PARTICULATE MATTER.

IN RECENT YEARS, INCREASING ENVIRONMENTAL REGULATIONS AND THE DEPLETION OF FOSSIL FUEL RESOURCES HAVE DRIVEN RESEARCH TOWARD ALTERNATIVE FUELS AND FUEL ADDITIVES. ONE OF THE MOST EFFECTIVE APPROACHES TO IMPROVE COMBUSTION EFFICIENCY AND REDUCE EMISSIONS IS THE USE OF OXYGENATED FUELS. THESE FUELS CONTAIN OXYGEN WITHIN THEIR MOLECULAR STRUCTURE, WHICH ENHANCES THE COMBUSTION PROCESS AND REDUCES INCOMPLETE COMBUSTION PRODUCTS.

ALCOHOL-BASED FUELS HAVE GAINED CONSIDERABLE ATTENTION DUE TO THEIR RENEWABLE NATURE AND CLEANER COMBUSTION CHARACTERISTICS. LOWER ALCOHOLS SUCH AS METHANOL AND ETHANOL HAVE BEEN WIDELY STUDIED; HOWEVER, THEIR PRACTICAL APPLICATION IS LIMITED DUE TO LOW CETANE NUMBER, POOR MISCIBILITY WITH DIESEL, AND LOWER CALORIFIC VALUE.

HIGHER ALCOHOLS SUCH AS HEXANOL HAVE EMERGED AS PROMISING ALTERNATIVES BECAUSE OF THEIR SUPERIOR FUEL PROPERTIES. HEXANOL EXHIBITS BETTER MISCIBILITY WITH DIESEL, HIGHER ENERGY CONTENT, AND IMPROVED COMBUSTION CHARACTERISTICS. THE PRESENCE OF OXYGEN IN HEXANOL PROMOTES COMPLETE COMBUSTION, LEADING

TO REDUCED EMISSIONS AND IMPROVED ENGINE EFFICIENCY.

THIS STUDY AIMS TO EXPERIMENTALLY INVESTIGATE THE PERFORMANCE AND EMISSION CHARACTERISTICS OF A DIRECT INJECTION DIESEL ENGINE USING HEXANOL–DIESEL BLENDS. DIFFERENT BLEND RATIOS ARE TESTED UNDER VARYING LOAD CONDITIONS TO EVALUATE PARAMETERS SUCH AS BRAKE THERMAL EFFICIENCY, BRAKE SPECIFIC FUEL CONSUMPTION, AND EXHAUST EMISSIONS. THE OBJECTIVE IS TO DETERMINE THE OPTIMAL BLEND THAT PROVIDES IMPROVED ENGINE PERFORMANCE WITH REDUCED ENVIRONMENTAL IMPACT.

2. LITERATURE REVIEW

The increasing demand for sustainable and cleaner fuels has led to extensive research on alcohol-based additives in diesel engines. Long-chain alcohols such as pentanol, octanol, and hexanol have gained significant attention due to their favourable physicochemical properties and potential to enhance combustion efficiency.

Rajesh Kumar et al. [1] investigated the use of n-octanol as a diesel fuel additive and reported a reduction in brake specific fuel consumption along with an improvement in brake thermal efficiency. Additionally, a significant reduction in nitrogen oxides (NO_x) emissions and smoke opacity was observed, highlighting the advantages of higher alcohols in diesel combustion.

Yeung and Thomson [2] studied the combustion characteristics of hexanol in diffusion flames and demonstrated its effectiveness as an alternative fuel due to improved ignition stability and reduced emission formation. Their findings confirmed that hexanol possesses suitable combustion properties for compression ignition engines.

Heifer et al. [3] analysed the ignition behaviour of alcohol fuels and concluded that long-chain alcohols exhibit stable combustion characteristics at higher temperatures. Campos-Fernandez et al. [4] reported that pentanol–diesel blends showed improved combustion efficiency and reduced emissions due to enhanced oxygen availability during combustion.

Further studies by Wei et al. [5] indicated that pentanol blends resulted in longer ignition delay but significantly

reduced hydrocarbon and carbon monoxide emissions. Similarly, Li et al. [6] demonstrated that alcohol–diesel blends improved atomization and reduced soot formation while maintaining engine efficiency.

Duncan Aluko et al. [7] specifically investigated hexanol–diesel blends and observed a considerable reduction in particulate emissions due to improved fuel properties. Zhang and Balasubramanian [8] reported that the addition of alcohol fuels enhanced brake thermal efficiency and improved overall combustion performance.

From the literature, it is evident that long-chain alcohols, particularly hexanol, have strong potential as diesel fuel additives. However, limited studies are available on the performance of hexanol under varying load conditions in direct injection diesel engines. Therefore, this study aims to bridge this research gap by experimentally analysing the performance and emission characteristics of hexanol–diesel blends.

3. EXPERIMENTAL SETUP

The experimental investigation was conducted on a single-cylinder, four-stroke, water-cooled direct injection (DI) diesel engine. The engine was operated at a constant speed of 1500 rpm and coupled with an eddy current dynamometer for load application. The experimental setup was designed to evaluate the performance and emission characteristics of hexanol–diesel blends under varying load conditions.

Fuel consumption was measured using the burette method, which ensured accurate determination of fuel flow rate. The engine was initially operated with pure diesel to achieve steady-state conditions, followed by testing with different hexanol–diesel blends, namely H5, H10, and H15. Each test was conducted under identical operating conditions to ensure consistency and reliability of the results.

The emission parameters such as carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_x) were measured using an exhaust gas analyser. Smoke opacity was determined using a standard smoke meter based on the principle of light absorption. The measuring instruments were calibrated prior to experimentation to minimize errors.

The key performance parameters analysed during the experiment include brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and exhaust gas temperature (EGT). These parameters were evaluated at different engine load conditions to study the effect of hexanol blending on engine performance.



Fig 1 Engine Setup

A. Engine Specifications

The engine used for the experimental study was manufactured by Kirloskar Oil Engines Ltd., India. The specifications of the test engine are presented in Table I.

Table I Engine Specifications

Parameter	Specification
Manufacturer	Kirloskar Oil Engine Ltd., India
Type of Engine	Direct Injection Diesel Engine
Number of Cylinders	Single Cylinder
Number of Strokes	Four Stroke
Cooling Type	Water Cooling
Engine Speed	1500 rpm
Brake Power	3.5 kW @ 1500 rpm
Bore Diameter	80 mm
Stroke Length	110 mm
Compression Ratio	17.5: 1
Type of Loading	Electrical Loading (Eddy Current Dynamometer)
Method of Starting	Electric Starting

Orifice Diameter	0.02 m
Dynamometer	0.185 m
Arm Length	

B. Measuring Instruments

An eddy current dynamometer was used to apply load on the engine. Fuel consumption was measured using a burette setup. Exhaust gas emissions were measured using an I3SYS gas analyser, which detects CO, HC, and NOx emissions. Smoke opacity was measured using a smoke meter.

A Redwood viscometer was used to determine the viscosity of the fuel blends. Flash point and fire point were measured using a standard open cup apparatus. Density measurements were carried out using a hydrometer.

All measurements were repeated to ensure accuracy and consistency of experimental data.

4. FUEL PREPARATION AND PROPERTIES

The preparation of fuel blends plays a crucial role in determining the performance and emission characteristics of diesel engines. In this study, hexanol was used as an oxygenated additive and blended with conventional diesel fuel in different volume proportions.

The blending process was carried out using the splash blending method, which involves mixing the required proportions of diesel and hexanol in separate containers and shaking thoroughly to ensure homogeneity. This method is simple, cost-effective, and widely used for laboratory-scale fuel preparation.

The test fuels were prepared in three different blend ratios, namely H5, H10, and H15, representing 5%, 10%, and 15% hexanol by volume, respectively. Pure diesel was used as the baseline fuel for comparison.

A. Blend Composition

The composition of the prepared fuel blends is presented in Table II.

Table II Full Blend Composition

S.no	Blend name	% of hexanol	% of diesel
1	B5	5	95
2	B10	10	90
3	B15	15	85
4	B20	20	80

B. Fuel Properties

The physical and chemical properties of diesel and hexanol significantly influence combustion behaviour. Important properties such as density, viscosity, calorific value, and cetane number were considered in this study.

Hexanol, being an oxygenated fuel, contains inherent oxygen in its molecular structure, which enhances the combustion process and reduces incomplete combustion products. Compared to diesel, hexanol has slightly lower calorific value but higher oxygen content, which improves combustion efficiency.

The properties of diesel and hexanol used in this study are summarized in Table III.

Table III properties Of Diesel And Hexanol

Fuel Properties	Diesel	Hexanol
Molecular Formula	C ₆ H ₁₆	CH ₃ (CH ₂) ₄ CH ₂ OH
Molecular weight	190 – 220	102.18
Density at 20°C (.10 ³ Kg/m ³)	0.829	0.8218
Latent Heat of Evaporation, kJ/kg	250	486
Boiling Point (°o.)	180 – 360	175 – 203
Flash Point (°C)	65 – 88	68

Kinematic Viscosity (Centi Stoke)	3.35	5.32
Heat Value (kJ/Kg)	43350	39100
Cetane number	45-50	42

The addition of hexanol to diesel influences these properties, leading to variations in combustion characteristics and emission behaviour. The presence of oxygen in hexanol promotes complete combustion, resulting in reduced emissions of carbon monoxide and hydrocarbons.

5. RESULTS AND DISCUSSION

The performance and emission characteristics of the diesel engine were evaluated using hexanol–diesel blends under varying load conditions. The results obtained for different parameters such as brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and exhaust emissions are discussed in detail.

A. Brake Thermal Efficiency (BTE)

Brake thermal efficiency is an important parameter that indicates how effectively the chemical energy of fuel is converted into useful mechanical work. It was observed that BTE increased with an increase in engine load for all fuel blends.

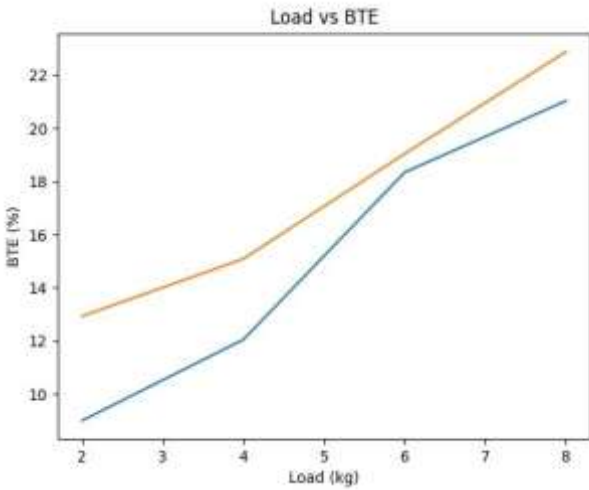
Among the tested fuels, the H10 blend exhibited higher brake thermal efficiency compared to pure diesel and other blends. This improvement is attributed to the presence of oxygen in hexanol, which enhances combustion efficiency and promotes better fuel oxidation. However, at higher blend ratios such as H15, a slight reduction in efficiency was observed due to lower calorific value and increased viscosity.

S .no	load	diesel	Brake thermal efficiency		
			H1	H2	H3
Uni	kg	%	%	%	%
1	2	9	10.08	12.93	9.5
2	4	12.05	15.27	15.09	15

3	6	18.35	19.63	19.05	20.08
4	8	21.04	22.82	22.89	22.42

Table IV Brake Thermal Efficiency of the Blended

6	0.5423	0.44	0.48	0.43
8	0.4346	0.38	0.38	0.39



fuels

Fig II Load Vs Brake Thermal Efficiency

B. Brake Specific Fuel Consumption (BSFC)

Brake specific fuel consumption represents the amount of fuel consumed per unit power output. The results show that BSFC decreases with an increase in engine load for all tested fuels.

The H10 blend demonstrated lower BSFC compared to diesel, indicating improved fuel utilization. This is due to enhanced combustion resulting from the oxygenated nature of hexanol. However, higher blends showed marginal increases in BSFC due to reduced energy content.

Table V Load Vs BSFC

Load (kg)	Diesel	H5	H10	H15
2	0.908	0.86	0.67	0.90
4	0.6308	0.57	0.57	0.58

C. Carbon Monoxide (CO) Emissions

Carbon monoxide emissions are primarily caused by incomplete combustion of fuel. The results indicate that CO emissions decreased significantly with the addition of hexanol.

The oxygen content in hexanol promotes complete combustion, thereby reducing the formation of CO. Among all blends, H10 showed the lowest CO emissions across all load conditions.

Table VI Load Vs CO Emissions

Load	Diesel	H5	H10	H15
2	0.072	0.046	0.018	0.016
4	0.074	0.040	0.013	0.016
6	0.083	0.041	0.012	0.016
8	0.077	0.039	0.010	0.016

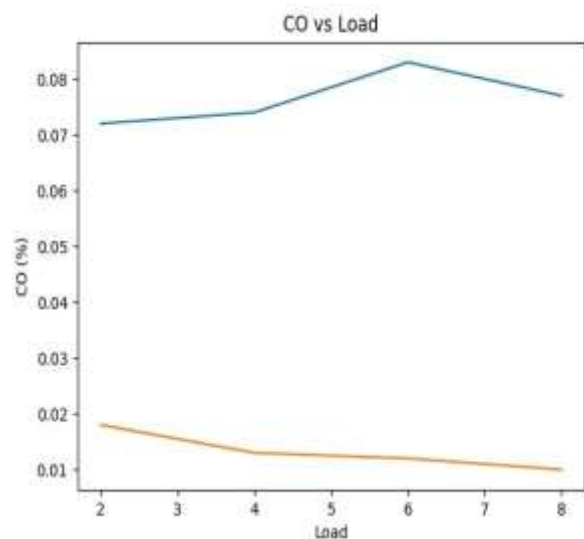


Fig VI Load Vs CO Emissions

D. Hydrocarbon (HC) Emissions

Hydrocarbon emissions result from unburned fuel during combustion. The addition of hexanol reduced HC emissions due to improved oxidation of fuel molecules.

A slight increase in HC emissions was observed at higher blend ratios due to non-uniform mixing and lower combustion temperature.

However, overall emissions were lower than that of pure diesel.

Table VII Load Vs HC Emissions

Load	Diesel	H5	H10	H15
2	17	5	14	10
4	30	4	16	10
6	17	4	16	10
8	17	5	16	10

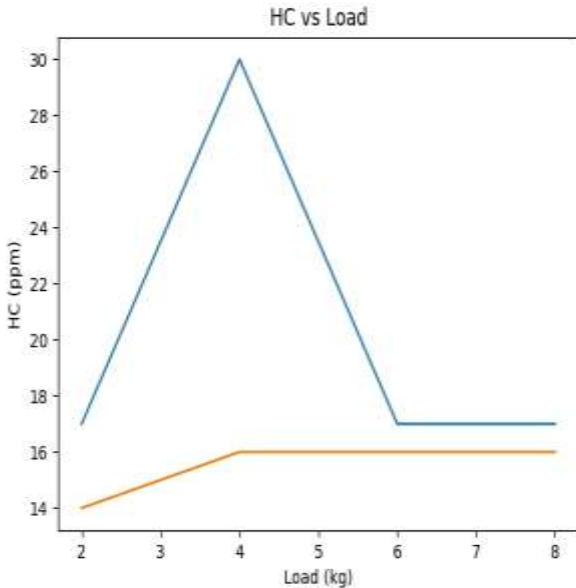


Fig V Load Vs Hydrocarbon Emissions

E. Nitrogen Oxides (NOx) Emissions

NOx emissions are influenced by combustion temperature and oxygen availability. The results show that NOx emissions exhibited slight variation with the addition of hexanol.

At moderate blend ratios, NOx emissions were comparable to diesel, while at higher blends, a slight

reduction was observed due to lower combustion temperatures caused by the cooling effect of hexanol.

Overall, the experimental results indicate that hexanol–diesel blends improve combustion characteristics and reduce harmful emissions. Among all blends, H10 provides the best compromise between performance enhancement and emission reduction.

Table VIII Load Vs NOx Emissions

Load	Diesel	H5	H10	H15
2	204	100	114	184
4	250	317	109	124
6	250	240	160	200
8	340	426	120	130

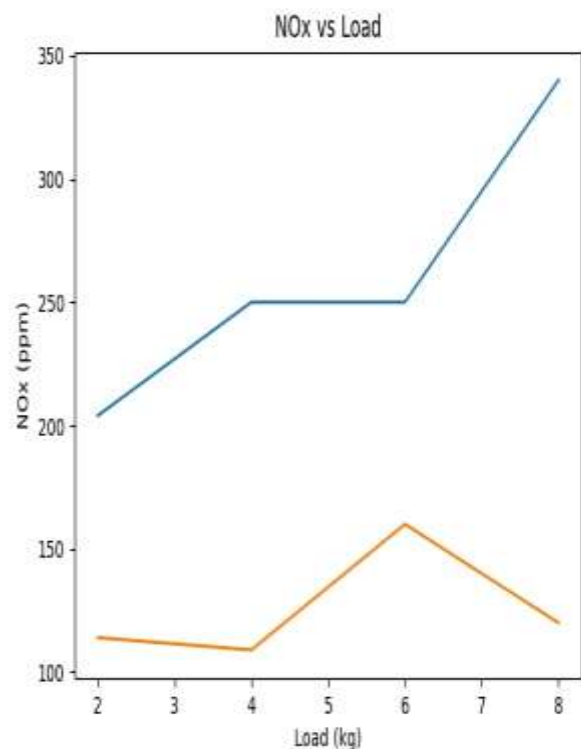


Fig VI Load Vs NOx Emissions

6. CONCLUSION

An experimental investigation was carried out to evaluate the performance and emission characteristics of a direct injection diesel engine using hexanol–diesel blends. The study analysed key performance parameters such as brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC), along with emission characteristics including carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_x).

The results indicate that the addition of hexanol improves combustion efficiency due to its inherent oxygen content. Brake thermal efficiency was found to increase with engine load, and the H10 blend exhibited the highest efficiency among all tested fuels. Brake specific fuel consumption decreased with increasing load, indicating better fuel utilization for hexanol blends compared to pure diesel.

Emission analysis revealed a significant reduction in CO and HC emissions due to improved oxidation during combustion. NO_x emissions showed slight variation depending on blend ratio and combustion temperature, with moderate blends maintaining comparable levels to diesel.

Among the tested blends, H10 was identified as the optimal blend, providing the best balance between enhanced engine performance and reduced emissions. The results demonstrate that hexanol can be considered a promising alternative fuel additive for improving diesel engine efficiency while minimizing environmental impact.

Overall, the use of hexanol–diesel blends contribute to cleaner combustion and offers a sustainable solution for reducing harmful emissions in compression ignition engines.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the Department of Mechanical Engineering, Gnanamani College of Technology, Namakkal, Tamil Nadu, India, for providing the necessary facilities and support to carry out this experimental investigation.

The authors also extend their heartfelt thanks to the faculty members and laboratory staff for their valuable guidance and assistance throughout the research work.

Special appreciation is given to all those who directly or indirectly contributed to the successful completion of this project.

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