EXPERIMENTAL INVESTIGATION OF PERFORMANCE AND EMISSIONS OF SI ENGINE USING ETHANOL BLENDING WITH C11-C14 HYDROCARBON FUEL ADDITIVES.

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ABSTRACT

The increasing demand for improved efficiency and reduced emissions in Spark Ignition (SI) engines has led to the exploration of alternative fuel blends. This study investigates the effect of ethanol blending and C11–C14 hydrocarbon additives on the thermal performance and emission characteristics of an SI engine. Ethanol, an oxygenated biofuel derived from agricultural waste, enhances combustion efficiency and reduces harmful emissions such as carbon monoxide (CO) and hydrocarbons (HC). However, ethanol blending also presents challenges such as lower energy density and poor combustion stability. These disadvantages are addressed by incorporating C11–C14 n- alkanes and iso-alkanes, which improve fuel stability, energy content, and overall combustion behaviour. Experimental tests were conducted on a single-cylinder SI engine using various ethanol-gasoline blends with controlled additive concentrations. Key performance parameters, including brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), cylinder pressure, heat release rate, and exhaust gas temperature (EGT), were evaluated. Emission characteristics such as CO, HC, and NOx were also analysed. The results indicate that the combined use of ethanol and hydrocarbon additives not only enhances combustion and reduces emissions but also mitigates the inherent drawbacks of ethanol fuel. Thus, the proposed fuel blends offer a sustainable and efficient alternative for SI engines.

Keyword :- *Spark Ignition (SI) , brake thermal efficiency (BTE), brake specific fuel consumption (BSFC),*

1. INTRODUCTION

The rapid growth of global energy consumption and the increasing environmental concerns associated with the use of conventional fossil fuels have necessitated the development of cleaner, sustainable, and high-performance alternative fuels for internal combustion engines. Among various engine types, the spark ignition (SI) engine remains one of the most commonly used power units for transportation. Conventional gasoline, although widely used, is associated with several critical drawbacks including elevated greenhouse gas emissions, dependency on crude oil imports, limited resource availability, and increased cost volatility. These challenges have encouraged intensive research to partially or fully substitute gasoline with eco-friendly renewable fuels. Ethanol has emerged as one of the most promising alternative fuels due to its renewable nature, high oxygen content, high octane rating, and its ability to improve combustion efficiency. Ethanol–gasoline blends (E5–E30) have been adopted in several countries owing to their potential to reduce carbon monoxide (CO) and unburned hydrocarbons (HC) emissions. However, the use of ethanol in SI engines is accompanied by certain operational limitations such as poor cold-start performance, phase separation, material compatibility issues, and reduced heating value. These challenges demand further investigation to optimize ethanol blending strategies and to improve overall engine performance.

Recent studies have shown that long-chain hydrocarbon additives, particularly those within the C11–C14 range, can significantly enhance the combustion stability, vaporization characteristics, and anti-knock behavior of ethanol–gasoline blends. Such additives possess higher calorific value, improved volatility, and better lubricity compared to ethanol. Incorporating C11–C14 fuel additives into ethanol-blended petrol may reduce the challenges associated with pure ethanol blending and provide a synergistic improvement in engine performance and emissions.

Therefore, this Paper aims to conduct an experimental investigation on SI engine performance using ethanol blending and C11–C14 fuel additives and to perform an analytical evaluation of performance parameters and exhaust emissions. The work attempts to address existing limitations and contribute to the development of more efficient, clean, and stable fuel blends suitable for practical SI engine applications.

1.1 Ethanol as a Renewable Automotive Fuel

Introduction Ethanol, produced primarily through fermentation of biomass such as sugarcane, corn, or agricultural waste, has proven to be a viable automotive fuel. Its use in SI engines offers several advantages including:

- High octane rating (108 RON approx.)
- Lower CO and HC emissions
- Renewable and sustainable production
- Improved combustion due to oxygen enrichment Despite these advantages, ethanol suffers from issues like:
- Lower calorific value
- Poor cold-start characteristics
- Water absorption leading to phase separation
- Requirement of material compatibility modifications

1.2 Role of C11–C14 Long-Chain Hydrocarbon Additives

C11–C14 hydrocarbons consist of long-chain alkanes or isoparaffins that possess: High heating value

- Improved volatility profile
- Good lubricity
- High cetane and octane index
- Better miscibility with gasoline components

When blended with ethanol–gasoline mixtures, these additives can:

- Improve engine power output
- Reduce BSFC
- Enhance vaporization and cold-start behavior
- Reduce corrosion due to reduced ethanol-water interactions
- Improve combustion quality
- Stabilize the fuel blend against phase separation

The use of C11–C14 additives in SI engines remains an under-explored area, and this study aims to fill that research gap.

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2. Need for the Present Study

India has adopted E20 as a target ethanol blending policy by 2025, which increases the need for ethanol-compatible research. Additionally, reducing pollutant emissions such as CO, HC, and NOx from SI engines is crucial for meeting upcoming emission norms.
Present literature lacks sufficient studies combining ethanol blends with C11–C14 fuel additives in commercial SI engines.

Hence, experimental investigation is required to: Improve the performance of ethanol-gasoline fuel

- Overcome ethanol's limitations
- Reduce emissions
- Enhance engine operability in varied condition

2.1 Problem Statement

Ethanol-blended gasoline improves combustion but introduces challenges such as lower calorific value, phase separation, corrosion, and reduced cold-start performance. Meanwhile, C11–C14 additives show potential to enhance fuel properties but remain insufficiently explored. The combined effect of ethanol blending and C11–C14 fuel additives on SI engine performance, combustion, and emissions is not clearly understood.

2.2 Objectives of the Research

The major objectives of the present dissertation are:

1. To prepare ethanol–petrol blends with and without C11–C14 hydrocarbons.
2. To evaluate the performance characteristics of SI engine operating on these blends.
3. To analyze the effect of C11–C14 additives on brake power, brake thermal efficiency, volumetric efficiency, and BSFC.
4. To measure and compare exhaust emissions (CO, HC, CO_2, NOx).
5. To provide analytical and graphical interpretation of results.
6. To identify optimum blend ratio providing maximum performance with minimum emissions.

To propose recommendations for future fuel formulation strategies

3. EXPERIMENTAL METHODOLOGY

Introduction the experimental methodology adopted to evaluate the performance and emission characteristics of a four-stroke Spark Ignition (SI) engine fueled with ethanol–gasoline blends and C11–C14 long-chain hydrocarbon fuel additives. The methodology is structured to ensure scientific accuracy, repeatability, and compliance with standard testing procedures used in automotive fuel research.

3.1 The experimental work consists of:

- Preparing ethanol–gasoline blends with and without C11–C14 additives.
- Conducting controlled trials on a variable-load SI engine.
- Measuring performance parameters such as brake power, brake thermal efficiency, and specific fuel consumption.
- Recording regulated and unregulated emissions.
- Ensuring calibration, instrumentation accuracy ,and experimental repeatability.

Blend Code	% Ethanol	% Gasoline
E0	0%	100%
E10	10%	90%
E20	20%	80%
E30	30%	70%

3.1.1: Preparation of Ethanol–Gasoline Blends

Code	Composition
E20A1	E20 + 1% C11–C14 additive
E20A2	E20 + 2% C11–C14 additive
E30A1	E30 + 1% additive

3.1.2 The blend naming convention

3.2 Test Procedure

Introduction The following procedure is adopted:

1. Fill fuel tank with selected blend.
2. Warm up the engine for 10–15 minutes.
3. Set engine speed to the rated 3000 rpm.
4. Apply load gradually using dynamometer.
5. Measure and record parameters at each load level.
6. Record emissions once readings stabilize.
7. Repeat each test three times for accuracy.
8. Flush fuel lines before changing blends.

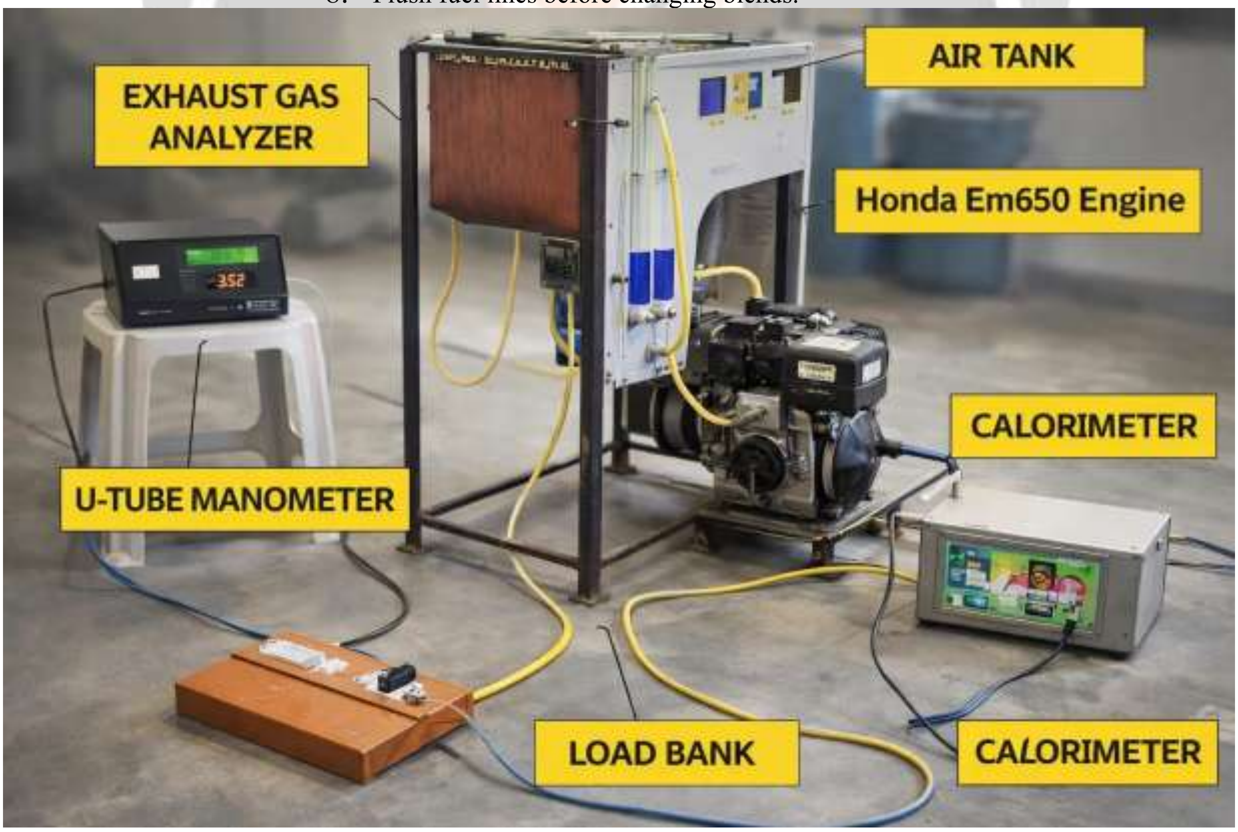
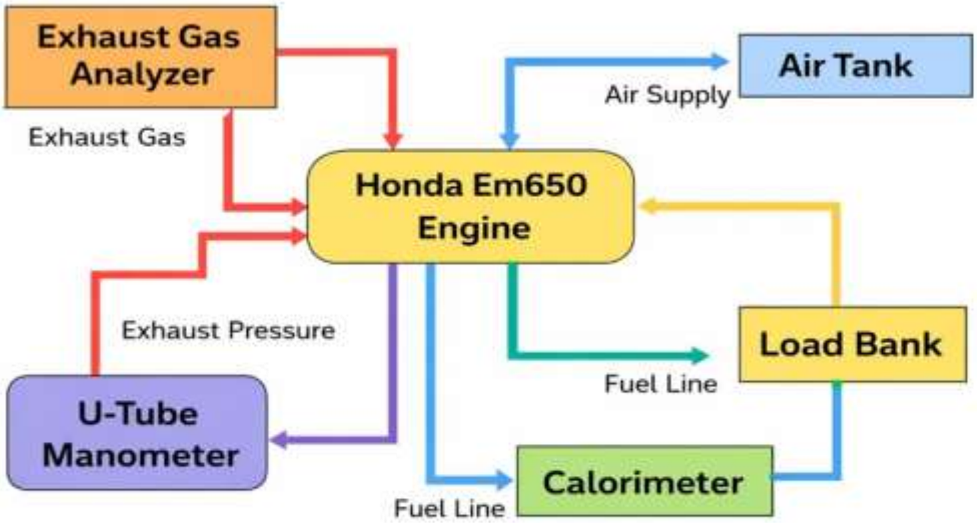


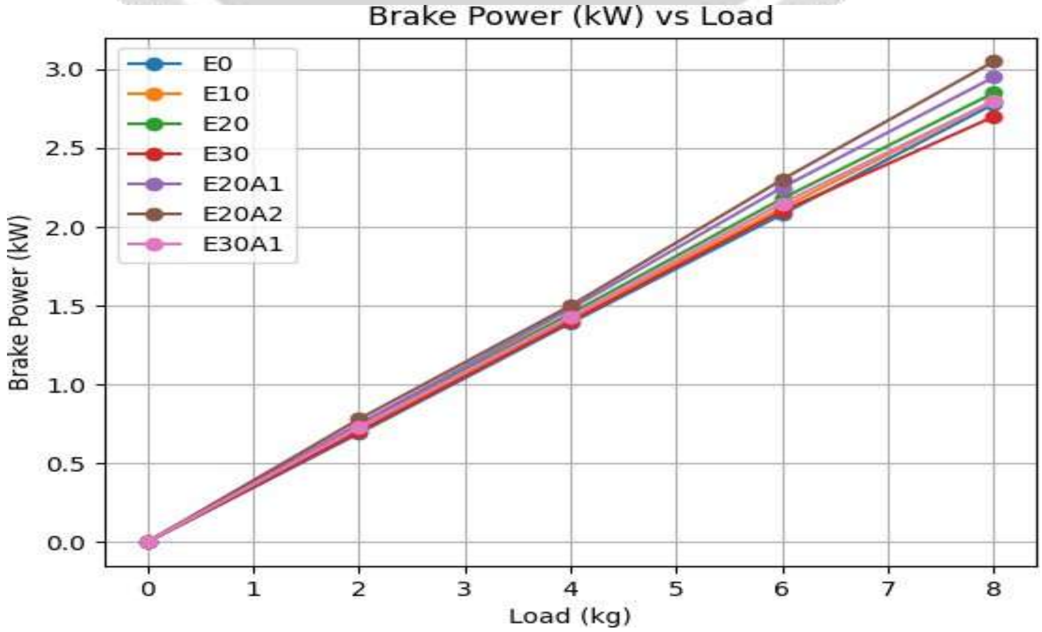
Fig -1: Experimental Setup

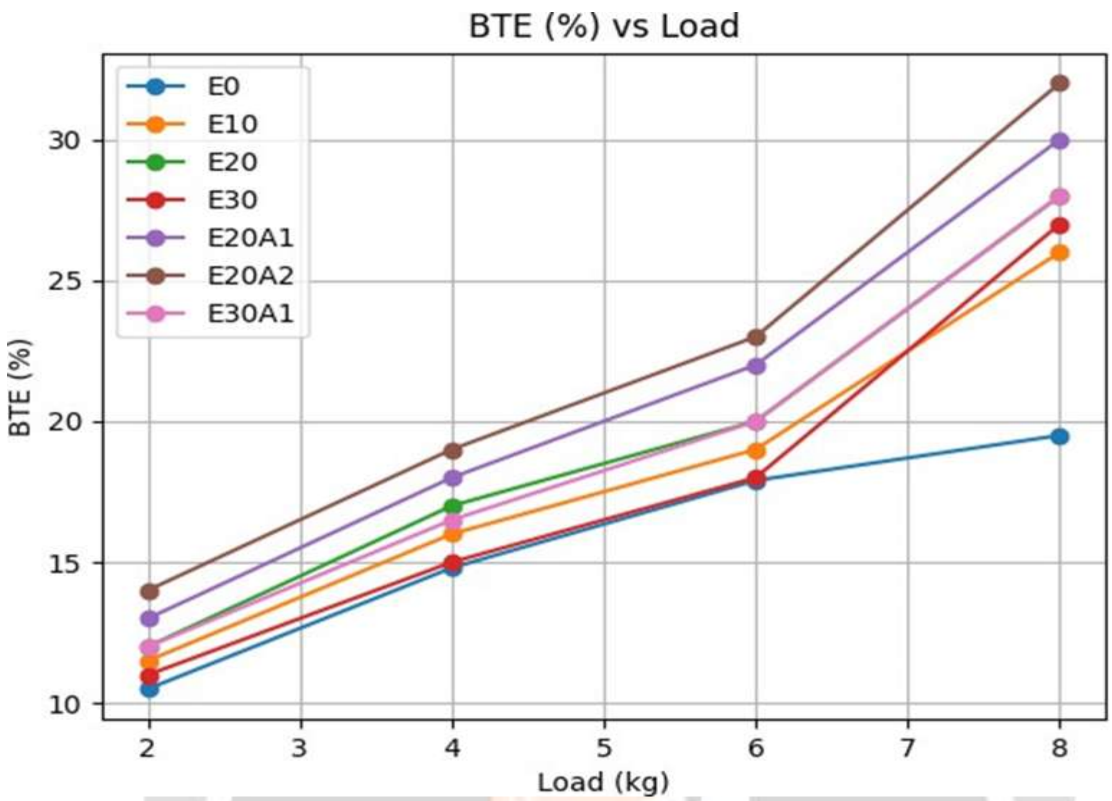


Block Diagram of the Experimental Setup

Fuel Blend	BP (kW)	BSFC (kg/kWh)	BTE (%)	EGT (°C)
E0	2.78	0.43	24.0	360
E10	2.80	0.46	26.0	340
E20	2.85	0.48	28.5	330
E30	2.70	0.52	27.5	320
E20A1	2.95	0.44	30.5	335
E20A2	**3.05**	**0.40**	**31.5**	340
E30A1	2.80	0.46	28.5	325

Comparative Performance Results (Full Load)





BTE was observed to increase with load for all fuel types. Ethanol blends demonstrated higher efficiency than pure petrol due to the inherent oxygen content in ethanol, which facilitates more complete combustion. The addition of C11–C14 additives further enhanced BTE by improving the calorific value and combustion stability. The E20A2 blend achieved the peak BTE of approximately 31.5%.

Fuel Blend	CO (% vol)	HC (ppm)	NOx (ppm)
E0 (Petrol)	3.52	240	110
E10	2.85	215	118
E20	2.20	190	125
E30	1.85	175	122
E20A1	2.05	170	132
E20A2	**1.70**	**155**	**140**
E30A1	1.75	162	128

4. CONCLUSIONS

Based on the comprehensive experimental investigation, the following key conclusions are derived:

Based on the experimental investigation of a single-cylinder SI engine using ethanol-gasoline blends and C11–C14 additives, the following conclusions are drawn:

1. Optimal Blend: The E20A2 (Ethanol 20% + 2% Additive) blend is the most efficient, providing the highest Brake Power (3.05 kW) and Brake Thermal Efficiency (31.5%).
2. Fuel Economy: The C11–C14 additives successfully reduced the high BSFC typically associated with ethanol fuels.
3. Environmental Impact: Ethanol blends significantly reduce CO and HC emissions, making them a viable alternative for reducing the carbon footprint of SI engines.

Key Outcomes of the Study

Ethanol blending up to 20–30% is a viable replacement for petrol in SI engines without major modifications.
C11–C14 hydrocarbons enhance fuel energy density and improve engine performance when used with ethanol blends.
Combined ethanol–additive blends offer a significant reduction in harmful emissions.
The experimental results support the practical implementation of ethanol-based fuel systems in the automotive sector.
The research contributes to development of sustainable, low-emission transportation fuels.

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