# Optimization Possibilities and Enhancing Combustion of SI Engines through Fuel Supplementation

Niket Ashok Shinde
*Assistant Professor, Sinhgad Institute of Technology*

***Abstract*—this paper presents the introduction of supplementary fuel into the gasoline–air mixture of spark ignition (SI) engines significantly improves engine efficiency and reduces the concentration of harmful exhaust gases compared with conventional gasoline-only operation. However, under lean mixture conditions, an increase in nitrogen oxide emissions has been observed. This study investigates engine performance at varying gasoline-to-supplementary-fuel ratios and explores methods of regulating engine power quality.**

***Index Terms*—Spark Ignition Engine, Supplementary Fuel Alternative Fuels, Lean Combustion, Engine Efficiency**

## I. INTRODUCTION

With today's growing energy concerns, research has increasingly focused on reducing fuel consumption through the use of alternative fuels, while simultaneously lowering toxic exhaust emissions. Among the main candidate's methanol, ethanol, and hydrogen hydrogen stands out as a promising future fuel due to its abundance in nature.

Two methods of applying supplementary fuels in SI engines can be explored: (a) complete substitution of the conventional fuel, and (b) partial supplementation alongside gasoline. This paper emphasizes the second approach, as it offers notable reductions in fuel consumption and toxic emissions without requiring complete reliance on alternative fuel storage. Furthermore, only small amounts of supplementary fuel are required, thereby mitigating storage-related challenges.

During operation, supplementary fuel can be used alone for starting and idling, while partial-load conditions benefit from its addition to the gasoline–air mixture. Under full-load operation, the engine reverts to gasoline-only combustion. Since urban driving predominantly involves partial loads, the supplementation method provides substantial potential for reducing air pollution from vehicle exhausts.

## II. LITERATURE REVIEW

The growing need for energy conservation and reduction of harmful emissions has stimulated extensive research into alternative fuels for spark ignition (SI) engines. Supplementary fuels, particularly hydrogen, methanol, and ethanol, have received considerable attention due to their potential to improve combustion efficiency and mitigate the environmental impact of conventional gasoline engines.

Early studies by Peschka (1981, 1980) demonstrated the technical feasibility of liquid hydrogen utilization in automotive applications, highlighting both performance benefits and challenges related to storage and refueling infrastructure. Carpetis (1982) compared storage costs of onboard fuel systems for hydrogen-powered vehicles, establishing the economic considerations that continue to shape supplementary fuel adoption. Buchner (1978) further proposed hydrogen hydrides as a viable storage method, providing a foundation for subsequent technological developments.

Karim (2003) provided an extensive overview of hydrogen as a supplementary fuel in SI engines, emphasizing its wide flammability limits, high flame speed, and low ignition energy, which enable stable lean-burn operation. Lean combustion has been identified as a critical factor for improving thermal efficiency and reducing carbon-based emissions (CO, $CO_2$, and HC). However, the accompanying increase in combustion temperature often results in elevated nitrogen oxide (NOx) emissions. To address this, Shudo and Nabetani (2001) investigated the impact of hydrogen combustion on heat losses and constant-volume characteristics, noting that supplementary fuel addition significantly alters the thermodynamic cycle of SI engines.

Das (2002) reported on experimental programs at the Indian Institute of Technology (IIT Delhi), where hydrogen supplementation improved fuel economy and extended lean operating limits. Similarly, Verhelst and Wallner (2009) provided a comprehensive review of hydrogen-fueled internal combustion engines, concluding that supplementation offers practical advantages in reducing petroleum dependence while lowering carbon emissions. Their work also underlined challenges related to backfiring, pre-ignition, and volumetric efficiency losses due to the low density of hydrogen

## III. EXPERIMENTAL SETUP

The experiments were conducted on a four-cylinder, four-stroke spark ignition (SI) engine, VAZ-2103. An electric induction brake was employed to apply and measure engine load. Exhaust gases were analyzed using non-dispersive infrared (NDIR) analyzers for carbon monoxide (CO) and unburnt hydrocarbons (HC), and chemiluminescent analyzers for nitrogen oxides (NOx).

The carburetor was partially modified to allow precise manual control of gasoline supply, and regular ethylated gasoline was used as the primary fuel. Air consumption was measured using a calibrated nozzle. Supplementary fuel was stored in a high-pressure container and fed to the carburetor diffuser at 20–100 mm $H_2O$ above atmospheric pressure, with consumption measured via a rotameter

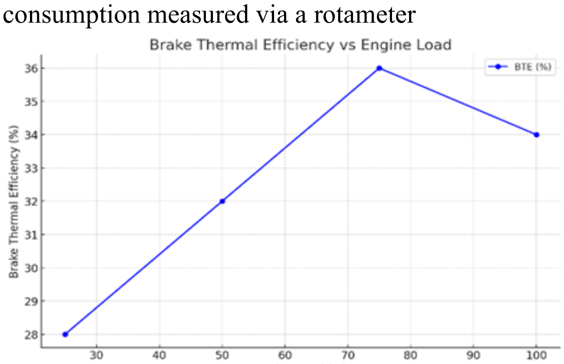


Fig 1: Brake Thermal Efficiency vs. Engine Load

## IV. ENGINE PERFORMANCE WITH HYDROGEN SUPPLEMENTATION

A few series of experiments were carried out. For one of the series two of the values of hydrogen flow to the gasoline-air mixture were kept constant (0.18 kg h and 0.29 kg h-l). The engine load was realized accord- Ing to the standard method for this engine, i.e. quantity regulation and the cross-section of the main fuel jet was smaller than the standard one. The aim of this series of experiments was not to weaken the gasoline-hydrogen- air mixture too much but simply to replace one ingredient of the fuel (gasoline) with hydrogen and to estimate the influence of this supplementation on the engine performance. Figure I shows the alteration of the carbon monoxide, unburnt hydrocarbons, nitrogen oxide and the gasoline consumption when the engine load was changed for two values of the hydrogen flow. It is clear that the excess air ratio is not considerably increased (about 20%) when hydrogen is added but the change in the toxic components CO and HC is considerable. The decrease of CO is 25 to 96% and that of HC in the limits of 15 to 64%. The gasoline consumption decreases on the average by 23 to 25% and the percentage content of hydrogen (the percentage content of hydrogen is defined as the hydrogen mass relation to the whole hydrogen and gasoline mass used in that experiment) changes in the limits of 2 to 6% and 4 to 10% at 0.18 and 0.29 kg h hydrogen consumption, respectively.

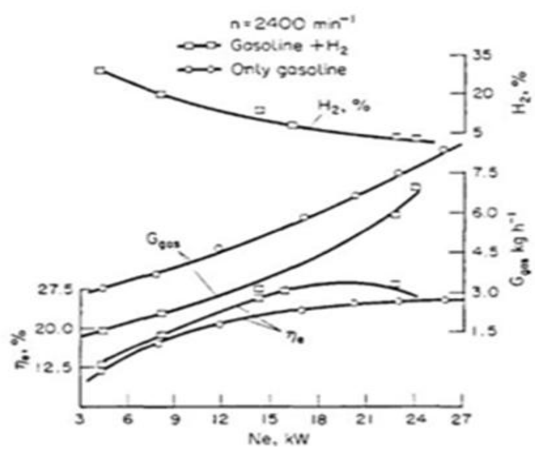


Fig 2: Change of toxic components concentration in the exhaust gas at load performance and different hydrogen flows.

## V. CONCLUSION

Small quantities of supplementary fuel extend the lean operating limit of SI engines beyond what is achievable with gasoline alone. Lean-burn operation enabled by supplementation improves fuel economy and overall efficiency. Supplementation reduces CO and HC emissions significantly, especially under quality load regulation. Water addition to the mixture effectively reduces NOx emissions without severely affecting engine output. Supplementary fuel can be incorporated into conventional SI engines with minimal modifications, offering significant reductions in petroleum consumption.

Further studies are needed to address increased HC emissions at very lean conditions and to optimize water injection strategies

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