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To Study the Performance and Emission Characteristics of 5% Hydrogen Blend in Diesel Engine

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Abstract

Compressed natural gas has already been adopted as a regular transportation fuel in many countries including parts of India. On the other hand, hydrogen despite its proven "clean burning characteristic" is not being widely used as an alternative fuel. This research explains how addition of hydrogen to existing. Diesel fuelled engine can ensure an early entry of hydrogen into our energy infrastructure. Hydrogen is considered a promising alternative fuel due to its high energy density, clean combustion, and potential for reducing greenhouse gas emissions. Blending hydrogen with conventional fuels like diesel has gained attention as a strategy to introduce hydrogen into existing transportation infrastructure without requiring extensive modifications. This abstract focuses on the investigation of 5% hydrogen and diesel blends as a potential fuel mixture for internal combustion engines. The study involves the evaluation of various properties and performance characteristics of the 5% hydrogen and diesel blends. These properties include the combustion characteristics, engine performance, emissions, and overall fuel economy. Experimental tests are conducted using a test engine under controlled conditions, allowing for comprehensive data collection and analysis.

Keywords: Hydrogen Blend, Diesel Engine, Potential Fuel, Natural Gas, High Energy Density.

1. Introduction

In recent years, the pursuit of sustainable and efficient energy solutions has gained significant momentum. As a result, researchers and engineers have been actively exploring alternative fuels to reduce greenhouse gas emissions and address the challenges associated with traditional fossil fuels. One such avenue of investigation has been the blending of hydrogen with diesel, presenting a promising solution for improving the performance and environmental impact of conventional diesel engines.

Hydrogen, being the most abundant element in the universe, possesses several favorable characteristics as a fuel. It is a clean-burning fuel that produces only water vapor as a byproduct when combusted. Its high energy content per unit mass, along with its wide flammability range, makes it an attractive option for power generation. However, the widespread adoption of pure hydrogen fuel is limited by the challenges of production, storage, and distribution.

To overcome these challenges and leverage the advantages of both hydrogen and diesel, researchers have explored the blending of these fuels. By mixing hydrogen with diesel in various proportions, it is possible to create a fuel blend that combines the strengths of both components. This blending process allows for the utilization of existing diesel infrastructure and engines, reducing the need for costly modifications or replacements.

The performance analysis of hydrogen and diesel blends encompasses a range of factors, including combustion characteristics, engine efficiency, emissions reduction, and overall system performance. By understanding and optimizing these parameters, researchers aim to unlock the potential of these blends as a viable and sustainable energy solution.

One key aspect of performance analysis is the combustion characteristics of hydrogen and diesel blends. Hydrogen's high flame speed and wider flammability limits can enhance combustion efficiency and reduce ignition delay when blended with diesel. This leads to improved engine responsiveness, smoother combustion, and potentially higher power output. Additionally, the combustion of hydrogen-diesel blends can result in lower pollutant emissions, such as nitrogen oxides [NOx], particulate matter [PM], and carbon dioxide [CO2].

Another important consideration is the impact of hydrogen-diesel blends on engine efficiency. The energy content of hydrogen is higher than diesel on a mass basis, offering the potential for increased thermal efficiency. However, challenges such as hydrogen's lower energy density and combustion characteristics must be carefully balanced to achieve optimal performance. Additionally, engine modifications and control strategies may be required to fully capitalize on the benefits of these blends.

1.1. Literature Review

In this research, effects of hydrogen addition on a diesel engine were investigated in terms of engine performance and emissions for four cylinders, water cooled diesel engine. Optimum results were obtained at the mixture of 0.80 lpm. As a general, hydrogen addition made NOx emissions decrease for all cases except for 0.80 lpm case at high load. For Soot, HC and CO emissions, hydrogen mixture formations generated good results in all cases when compared to that of the single diesel fuel cases. In the current investigation, the enrichment of hydrogen with the honge biodiesel blend and diesel is used in a compression ignition engine. The present work is to estimate the performance of diesel engine fuelled with diesel [D] and honge biodiesel blend [HB20] with and without hydrogen enrichment [1].

In the present study, a single cylinder spark ignition [SI] engine is modified to operate with hydrogen gas with ECU [Electronic Controlled Unit] operated timely manifold injection system. From the results of the tests, it is clear that hydrogen gas can be used in the existing SI engines without any major modifications in the existing engine and can be operated smoothly using TMI system [2]. The purpose of this study is to use the hydrogen diesel mixture in turbocharged CI engine equipped with dynamo-meter and examine the performance and emission indicators by comparing it with sole diesel mode. The relatively low hydrogen volume fraction [1.96%] bellow the LFL reduced in-cylinder pressure of the CI engine however improved emissions. Presence of hydrogen within the range of tested HES contributed the decrease of BSFC [3].

By changing position [increased opening] of throttle in SI engine operated under low load improve the energy balance of the engine [lower energy losses] [4]. Partial load operation of SI engines is conventionally achieved by the use of a throttle to control the airflow or air-fuel mixture into the engine. The presence of hydrogen in mixture with biogas or methane allowed the SI engine to operate with higher values of lambda, which could be difficult without its addition, since this gas extended the limits of combustion [5]. A hydrogen fueled internal combustion engine has great advantage on exhaust emission in comparison with a conventional engine from fossil fuel. Due to the higher pressure and temperature associated with hydrogen usage the engine parts are solicited at higher values than Petro-diesel fuels [6].

Diesel engines are inevitable parts of our daily life and will be in the future. Expensive after-treatment technologies to fulfill normative legislations about the harmful tail-pipe emissions and fuel price increase in recent years created expectations from researchers for alternative fuel applications on diesel engines. In this study, the effect of 25% and 50% hydrogen addition on performance, emissions and combustion characteristics at full load and 750, 900, 1100, 1400, 1700, 2100 r/min engine speeds are investigated [7].

The extensive use of petroleum products as a fuel for engines results in global warming due to greenhouse emissions. By comparing the experimental values with the diesel engine, it is observed that Corn oil blend can be used as an alternate fuel for diesel engine. NOX emission can be reduced by using EGR method in diesel engine [8]. The prime intention of this work is to provide a maximum replacement for diesel using hydrogen in a common rail direct injection equipped diesel engine power. However, it is also concluded that there was an increase in NOx emissions, which needs to be reduced shortly [9, 10].

1.2. Experimental Set-up:

All trials were performed on Twin cylinder 3.7 kW Diesel engine at 1500 rpm. Diesel Fuel injection is made at 180 bars whereas hydrogen is injected in inlet manifold at 2 bars. Electrical dynamometer with load bank is used to calculate the brake power of the engine. AVL 5 gas analyzer is used to calculate HC, CO, CO2, O2 and NOx emission during varying load conditions. Smoke meter is used to calculate the smoke in the exhaust. All trials were performed at varying load and constant speed. Hydrogen addition is made at inlet manifold. The flow meter is used to maintain the constant flow rate of 5 lpm hydrogen at all loads. Flame trap and flame arrestor is used to avoid backfire in the engine. Compression ratio of 22:1 and diesel fuel supply at 180 bars is maintained constant at 1500 rpm during the experimentation. The trials were performed at no load, part load, medium load and full load condition with constant speed.

Satisfactory measurement of air flow rate is very difficult, it is easier to measure the flow rate of a compressor, the flow rate of which is pulsating. These pulsations are damped by fitting a diaphragm in a suitable volume air box with an orifice provided, placed away from the engine. The pressure difference across the orifice is measured by manometer. The capacity of air box is 500-600 times the swept volume of the cylinder of the engine. The pressure difference should be limited to about 150 mm. The effect of compressibility of air is considered to be negligible. The quantity of fuel consumed in a given time should be known for assessing the quality of the engine for both petrol and diesel engine. The fuel is made to run through a measuring device. This can take fuel from a reservoir containing fuel of known quantity and time taken for consumption of this fuel is known and noted down.

The arrangement of three-way valve, containing a fuel tank, a burette, and an inlet valve is made to the engine. First the supply valve of the tank is open so that the known quantity of fuel occupies the burette. The time is noted down for the consumption of this volume of the fuel. The engine cylinder is cooled by cooling water circulated by a pump. Its temperature at inlet and outlet are noted down by means of thermometer. In order to calculate the heat carried away by the exhaust gas calorimeter is connected at the engine outlet. Water is continuously circulated in the calorimeter. Its inlet and outlet temperature are noted. The heat carried away by exhaust gas is equal to the heat gained by the water calorimeter. A mechanical type lubrication system is provided to avoid any losses occurring due to friction in moving parts.

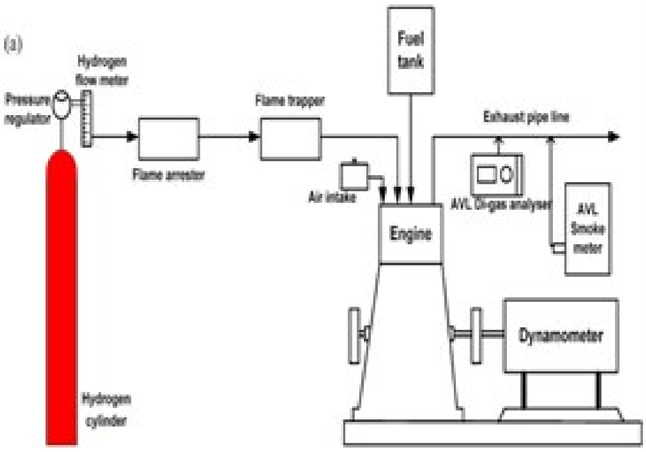

Figure 1: Schematic Diagram of Experimental Setup.

Figure 2: Photo of Experimental Setup

2. Result and Discussion:

Addition of 5% hydrogen has shown improvement in performance and emission characteristics. Hydrogen addition in diesel, enhance the power output of the engine. Due to lower density of hydrogen fuel there is the reduction in volumetric efficiency for 5% hydrogen addition in diesel. It will reduce the air intake as hydrogen injection is in inlet manifold [Fig 3].

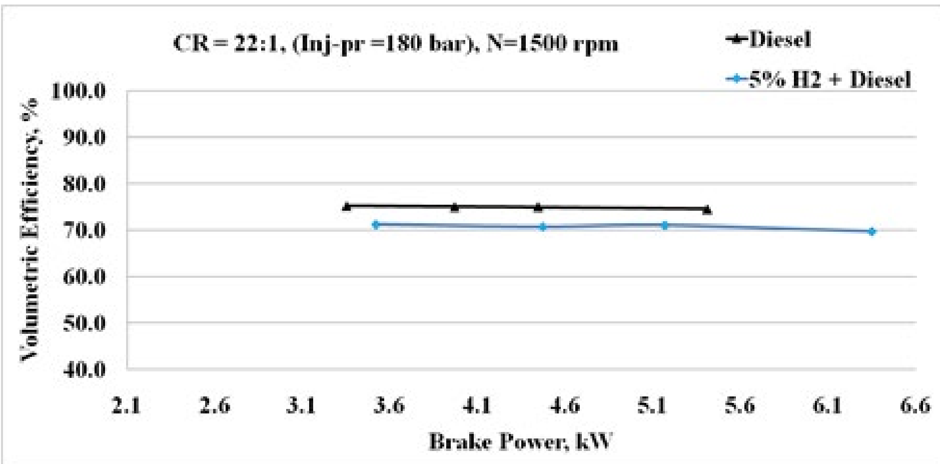

Figure 3: Brake Power Vs Volumetric Efficiency

Hydrogen has a higher calorific value than diesel fuel, meaning it contains more energy per unit volume. This increased energy content can contribute to higher thermal efficiency, resulting in more work output for the same amount of fuel consumed [Fig 4].

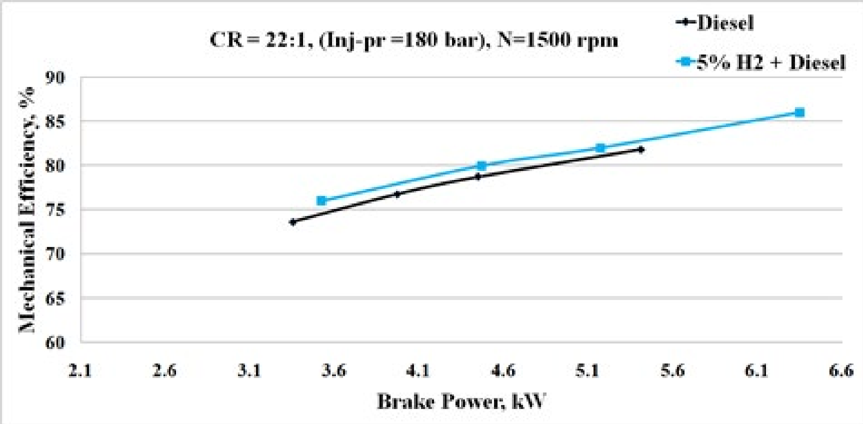

Figure 4: Brake Power Vs Mechanical Efficiency

With 5% hydrogen addition in diesel, the overall energy content of the mixture increased. This higher energy content can potentially contribute to improved thermal efficiency thus improving overall efficiency which results in slight increased in Brake Thermal Efficiency [Fig 5].

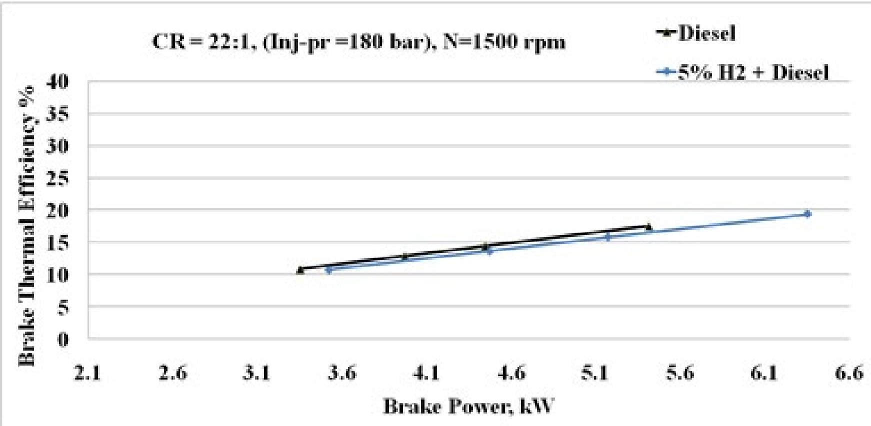

Figure 5: Brake Power Vs Brake Thermal Efficiency

The addition of hydrogen to the diesel blend can improve the combustion process, leading to more efficient burning of hydrocarbon molecules. This can result in reduced HC emissions compared to using 100% diesel fuel [6].

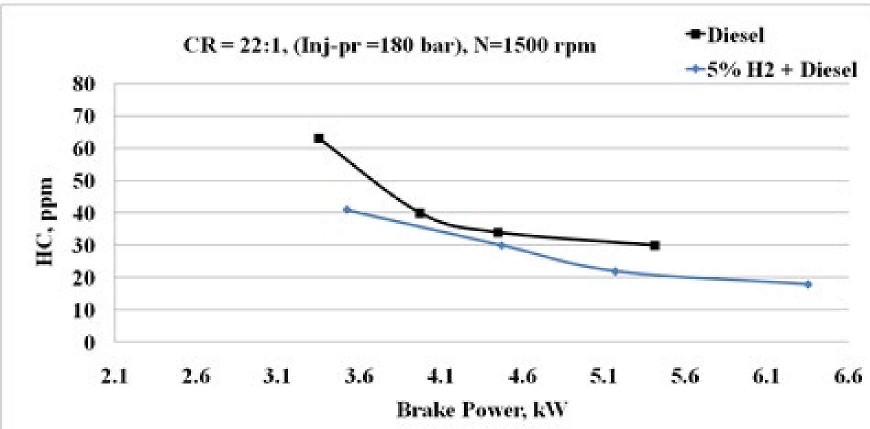

Figure 6: Brake Power Vs Hydrocarbon

When blended with diesel, the addition of hydrogen can decrease the overall carbon content in the fuel mixture. As a result, the combustion of the hydrogen-diesel blend can potentially lead to reduced CO2 emissions compared to using 100% diesel fuel [Fig 7].

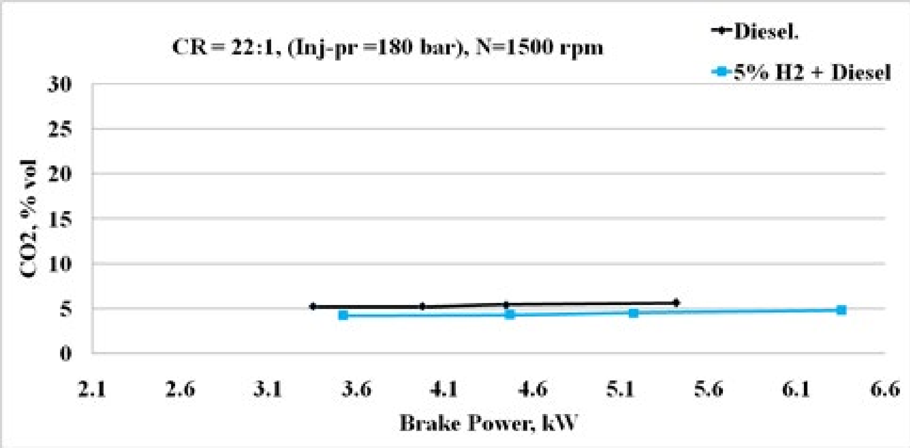

Figure 7: Brake Power Vs Carbon Dioxide

The addition of hydrogen to a diesel blend can potentially have a positive impact on reducing nitrogen oxide [NOx] emissions, which are a significant contributor to air pollution. Due to higher calorific value and higher heating value of hydrogen the heat generated in combustion chamber is higher which gives rise to formation of NOx at higher temperature. Here's how the 5% hydrogen and diesel blend can affect NOx emissions [Fig 8].

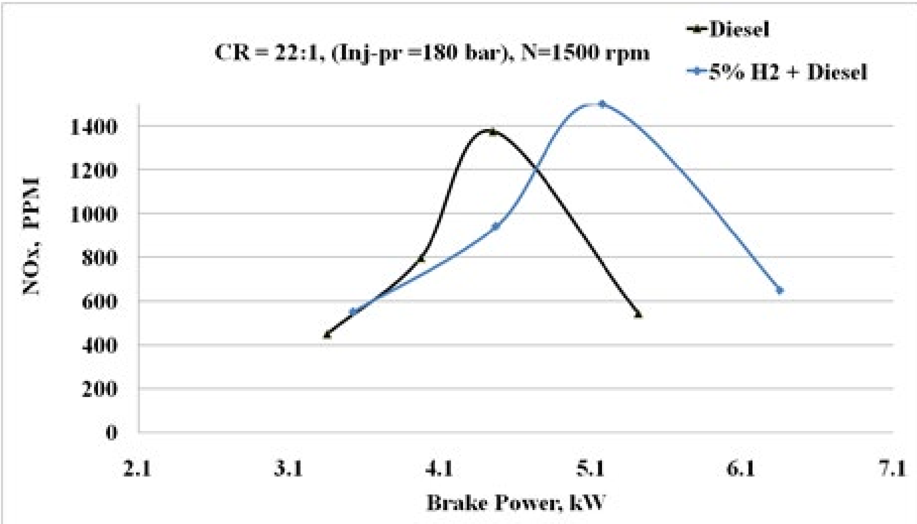

Figure 8: Brake Power Vs Oxides of Nitrogen

Overall, studying the performance of hydrogen and diesel blends is crucial for understanding their potential as a cleaner alternative to conventional diesel fuel. This research can help guide the development of efficient and environmentally friendly combustion technologies, contributing to the global efforts for sustainable energy and reduced emissions.

3. Conclusion

When diesel fuel is blended with hydrogen at a 5 % ratio, it can result in lower emissions of pollutants such as carbon dioxide [CO2], nitrogen oxides [NOx], and particulate matter. Hydrogen has high combustion efficiency and does not produce carbon emissions when burned, making it a cleaner alternative to conventional diesel fuel. By blending hydrogen with diesel, the overall emissions from the fuel can be reduced, contributing to improved air quality and reduced greenhouse gas emissions. Additionally, blending hydrogen with diesel can enhance the energy efficiency of the fuel. Hydrogen has higher energy content per unit mass than diesel, which means that adding a small percentage of hydrogen can increase the overall energy density of the fuel blend. This can potentially result in improved fuel economy and reduced fuel consumption. Overall, while diesel and hydrogen 5 % blends show promise in reducing emissions and improving energy efficiency, their widespread adoption depends on addressing infrastructure challenges, ensuring cost-effectiveness, and promoting the development of hydrogen production technologies.

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