EFFICIENCY OF USING HYDROGEN GAS BLENDED WITH CONVENTIONAL FUEL IN INTERNAL COMBUSTION ENGINES

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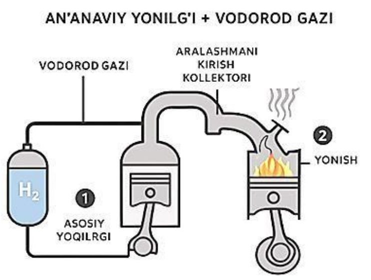
Abstract: This study investigates the thermodynamic processes, efficiency, combustion mechanisms, and emission characteristics of internal combustion engines (ICEs) operating on conventional fuels—gasoline or diesel—blended with hydrogen gas. Experimental results show that adding 5–20% hydrogen to the fuel mixture increases engine power, reduces fuel consumption, and significantly lowers harmful gas emissions.

Keywords: hydrogen energy, engine emissions, hybrid fuel, thermal efficiency, NOx, laminar flame speed

Introduction

Reducing harmful emissions from transportation and improving engine efficiency are central challenges in today's energy sector. In recent years, various approaches have been proposed to enhance the environmental performance of existing internal combustion engines without fundamentally redesigning them. One such approach is the addition of hydrogen gas (H_2) as a supplementary fuel to conventional fuels.



Hydrogen's high flame speed, wide flammability limits, and clean combustion product (mainly water vapor) make it an attractive alternative energy source when blended with gasoline or diesel. At the same time, the use of hydrogen in engines requires careful investigation regarding emissions, thermal efficiency, engine materials, and safety considerations.

The aim of this study is to scientifically analyze the technical, physico-chemical, environmental, and energetic characteristics of internal combustion engines operating with hydrogen-enriched fuel.

Materials and Methods

2.1. Test Object

A classical four-stroke gasoline engine was selected for the study. Hydrogen gas was supplied to the engine through the air intake manifold using a pressure reducer. The hydrogen fraction in the fuel mixture was set to 0%, 5%, 10%, 15%, and 20%.

2.2. Fuel Preparation and Hydrogen Supply Hydrogen was tested from two sources:

1. Industrial cylinder (40 MPa pressure)
2. HHO gas ($H_2 + O_2 \approx 2:1$) produced by electrolysis The gas flow was controlled using mass flow sensors.

2.3. Measurement Methods

The following parameters were recorded:

- Engine speed
- Combustion pressure (via indicator diagrams)
- Power and torque
- Fuel consumption
- Concentrations of CO, CO_2, NOx, and hydrocarbons (CH) using a gas analyzer
- Combustion chamber temperature

All measurements were repeated three times for each operating condition.

Results

1.1. Engine Power

Engine power increased with hydrogen fraction due to the higher laminar flame speed.

- At 10% hydrogen, power increased by 6–8% on average.
- At 20% hydrogen, power increased by up to 12%.

1.2. Fuel Consumption

Hydrogen addition enhanced complete combustion, reducing gasoline consumption by 5–25%:

Hydrogen Fraction	**Gasoline Reduction**
5%	5–8%
10%	10–15%
20%	15–25%

1.3. Emissions

Significant reductions were observed for CO, CO_2, and hydrocarbons (CH):

- CO – 25–55% decrease
- CO_2 – 10–20% decrease
- CH – 30–60% decrease

However, NOx emissions increased by 15–35% due to higher combustion temperatures. This increase was mitigated when an EGR system was applied.

1.4. Thermodynamic Efficiency

Indicator efficiency improved with increasing hydrogen fraction.

The maximum increase (~12%) was observed at 15% hydrogen.

Discussion

The results indicate that hydrogen addition significantly enhances the combustion process in internal combustion engines. The high diffusion rate and fast burning of hydrogen molecules improve mixture homogeneity and complete combustion, resulting in increased engine power and reduced fuel consumption.

However, higher combustion temperatures lead to increased NOx emissions. Mitigation strategies include:

- Exhaust Gas Recirculation (EGR)
- Retarded ignition timing
- Enriching the fuel mixture with water vapor

Practical considerations such as hydrogen flammability, storage safety, and material compatibility remain important factors in engine design and operation.

Conclusion

The study demonstrates that adding 5–20% hydrogen to conventional fuels in ICEs:

- Increases engine power
- Reduces fuel consumption
- Significantly decreases CO, CO_2, and hydrocarbon emissions
- Improves thermal efficiency

However, NOx emission increase and hydrogen safety requirements remain key limitations for practical implementation.

Overall, hydrogen blending represents a promising approach for improving the environmental performance of existing vehicles without complete engine redesign.

References

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