**Improvement of Efficiency and Environmental Friendliness of Internal Combustion Engines by Adding Gasoline-Hydrogen Mixture**

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**Abstract.** Hydrogen has long been considered a promising alternative fuel, and this research explores its potential when blended in small quantities with gasoline in conventional car engines. A regular Cobalt engine was taken and tested with a mix of gasoline and just a small portion of hydrogen—around 3 to 8%. Surprisingly, the engine ran better. It used less fuel and gave off fewer harmful gases, like carbon monoxide. There was even a small rise in power, thanks to hydrogen burning faster and cleaner. The setup wasn’t complex. Hydrogen was made by electrolysis and sent into the intake system. No big engine changes were needed. This makes the idea more practical—especially for places where switching to full electric vehicles isn’t an option yet. One thing that came up was a small increase in nitrogen oxide emissions. That might be fixed with exhaust recirculation techniques. Still, these results show there’s real potential in hydrogen-blended fuel, not just for efficiency, but for cleaner air too. The method could work as a temporary bridge toward greener transport without waiting for big infrastructure shifts.

**Keywords:** internal combustion engine, hydrogen enrichment, gasoline-hydrogen blend, fuel efficiency, exhaust emissions, alternative fuels, sustainable transport

**INTRODUCTION**

Transportation, especially road-based movement, is now widely seen as a major contributor to environmental problems. In busy cities, the sheer number of cars and trucks makes air pollution hard to ignore. The exhaust they release contains carbon monoxide, nitrogen oxides, unburned hydrocarbons, and even tiny soot particles. These aren’t just pollutants — they’re threats to human health. Many city dwellers are seeing more cases of asthma, lung diseases, and other respiratory issues, likely because they breathe this air every day.

Right now, around a billion cars are being driven across the globe. It’s hard to imagine, but together they use more than 70% of all the oil produced. And that’s not the only concern. These vehicles are responsible for about half of all harmful emissions, and in large cities, that number can go even higher — as much as 85 or 90 percent. In just the last decade, the number of cars on the road has jumped by more than 20%. This boom in vehicle usage hasn’t just increased energy demand — it has also worsened environmental damage on a massive scale.

In Central Asia, trade and population growth are reshaping transportation needs. Cities are expanding, people are moving more, and goods are being shipped farther and faster. That naturally means more cars, buses, and trucks on the road. This growth is putting pressure on natural resources and adding to the region’s greenhouse gas emissions [1].

Humans have always relied on mobility, but now, the balance between progress and environmental responsibility is being tested. Some studies suggest that motor vehicles alone might account for more than 90% of urban air pollution and nearly half the noise people hear every day [2].

Solving this won’t be easy. Moving to solar or wind power alone isn’t enough. We also need better, cleaner fuels and smarter engine technologies. Hydrogen, biofuels, and electric power aren’t just alternatives anymore — they might be our best shot at making transportation cleaner and more sustainable in the near future [3].

**METHODS**

This research paper analyzes the effect of adding hydrogen to the hydrocarbon-air mixture of a gasoline engine. The main advantage of hydrogen-powered cars is high environmental friendliness, since the product of hydrogen combustion is water vapor.

Hydrogen-air mixtures are characterized by a high rate of combustion in the engine. When mixed with air, hydrogen reliably ignites across a wide range of concentrations, enabling stable engine operation at all speed modes. This leads to an increase in engine efficiency by approximately 25–50% [4, 5]. It is also possible to use hydrogen mixed with natural gas, as hydrogen actively influences the combustion of methane and other hydrocarbon components.

The energetic and ecological benefits of hydrogen addition are significant: hydrogen oxidation releases substantially more energy than any hydrocarbon fuel, and the main combustion products are water vapor and nitrogen oxides. However, the use of *liquid hydrogen* requires powerful and costly cryogenic systems. In practical conditions, the oxidizing agent is atmospheric air, which contains only 21–22% oxygen and about 76% nitrogen. At high temperatures, nitrogen contributes to the formation of harmful nitrogen oxides [6].

Therefore, the problem of replacing conventional fuels with liquid hydrogen goes beyond the scope of automobile engine design. Nonetheless, it has been demonstrated that alternative fuels, including hydrogen, can be introduced into internal combustion engines with minimal modification. Hydrogen is typically used in gaseous form due to the difficulties of liquid storage at its low boiling point (−252.88 °C).

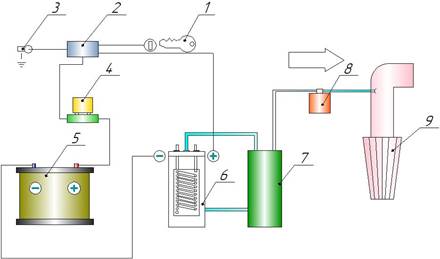
Indicator diagrams of typical engine cycles show that the theoretical efficiency of internal combustion engines cannot exceed 50%—a principle proven by Sadi Carnot as early as 1824. Modern gasoline engines achieve about 38% efficiency, while diesel engines reach just under 42%. Consequently, even a 4–5% improvement is considered significant, given the scale of engine usage [7].

The approximate thermal energy distribution in a piston engine is as follows: ~35% is lost via exhaust gases, ~17% is carried away by the coolant—losses that can be minimized through the use of ceramic or isotherm-resistant materials with low thermal conductivity, ~13% accounts for mechanical losses, such as piston-cylinder friction and crank mechanism movement [8, 9].

Without major structural changes, conventional piston engines can be supplied with gasoline or diesel fuel enriched with 3–8% hydrogen. The main industrial method of hydrogen production used in this study is steam reforming of methane (natural gas), represented by the reaction: CH4 + 2H20 = CO2 + 4H2 - 165 kJ.

Analysis of typical reactions of hydrocarbon fuel oxidation shows that even this small step will dramatically improve performance, efficiency and exhaust gas composition [10]. But for the possibility of using hydrogen additive, it is necessary to cool the piston and other elements of the internal combustion engine, interacting with combustion products, due to the increase in temperature in the combustion chamber.

Adjusting the hydrogen-gasoline ratio allows for more precise engine control. Hydrogen obtained from water burns in the engine and, depending on mixture settings, may even enrich the atmosphere with oxygen. The exhaust mainly consists of oxygen and water vapor, where the oxygen originates from the electrolysis process used to produce the hydrogen.



**FIGURE 1.** Schematic diagram of hydrogen generator  
1-key; 2-relay; 3-mass; 4-fuse; 5-battery; 6-hydrogen generator; 7-tank; 8-moisture separator; 9-air filter

This electrolysis-based method is among the most versatile and well-researched approaches to hydrogen generation. It also offers:

− high purity of produced hydrogen, up to 99,99 % and higher;

− simplicity of technological process, its continuity, possibility of the most complete automation;

− possibility of obtaining valuable by-products - heavy water and oxygen;

− generally available and inexhaustible raw material - water;

− physical separation of hydrogen and oxygen in the very process of electrolysis.

Furthermore, this configuration facilitates liquid cooling of the working components, allowing for higher compression ratios and the safe use of 3–8% hydrogen as a fuel additive. This results in increased combustion temperature, improved thermal efficiency, and significantly lower emissions. These principles were tested in an experimental two-stroke rotary engine, where liquid-cooled pistons allowed stable hydrogen use without thermal degradation of the moving parts [10].

**MATERIALS**

In recent years, there has been a tightening of requirements regarding the environmental characteristics of fuels. Deviations from fuel quality standards result in serious disturbances in engine operation, including increased risk of vapor lock, intermittent fuel supply, premature wear of fuel system components, excessive tar content, and accumulation of solid particles in combustion products [11].

During Uzbekistan’s transition to a market economy, the number of registered vehicles has increased almost threefold, exceeding 3 million units. This expansion of mobile and stationary equipment has led to a sharp increase in oil and fuel consumption. In cities like Tashkent, Samarkand, Bukhara, and Fergana, over 80% of air pollution is attributed to road transport [12, 13].

Globally, over 1.2 billion vehicles are on the road. Gases emitted into the atmosphere from a single car contain more than 200 toxic substances. On average, one car annually consumes more than 4 tons of oxygen and emits about 800 kg of carbon monoxide and 40 kg of nitrogen oxides.

Overall, more than 250 types of toxic gases are released from vehicles. A single light-duty vehicle driven approximately 15,000 km per year consumes 4.5 tons of oxygen and emits about 530 kg of carbon monoxide, 97 kg of nitrogen oxides, and more than 10 kg of rubber particles [14]. Thus, automobiles not only absorb atmospheric oxygen—essential for living organisms—but also release harmful pollutants into the environment.

The combustion of 1 kg of automotive fuel produces about 2.7 kg of CO₂, which accumulates in the upper atmosphere and contributes to the greenhouse effect. In urban areas, CO₂ concentrations can reach 250–500 mg/m³ and persist for up to four months [15].

In addition to carbon dioxide, vehicle emissions contain unburned hydrocarbons, aldehydes, carcinogens, and other harmful substances. Their composition is presented in Table 1.

**TABLE 1.** Quantity and composition of exhaust gases

|  |  |  |
| --- | --- | --- |
| Components | Petrol Engine (%) | Diesel Engine (%) |
| Nitrogen | 74.0–77.0 | 76.0–78.0 |
| Oxygen | 0.3–8.0 | 0.5–6.0 |
| Water vapor | 3.0–5.5 | 3.0–6.5 |
| Carbon dioxide | 5.0–12.0 | 1.0–10.0 |
| Carbon monoxide | 0.1–10.0 | 0.1–5.0 |
| Carcinogens | 0.2–3.0 | 0.009–0.5 |
| Aldehydes | 0–0.2 | 0.001–0.009 |
| Sulfur oxides | 0–0.002 | 0–0.003 |
| Carbon black | 0–0.04 | 0.01–1.1 |
| Benzopyrene | 0.01–0.02 | up to 0.01 |

These harmful substances affect plants both directly—by destroying chlorophyll and cellular structures—and indirectly—by penetrating the root system through the soil. The degree of impact varies by gas composition and plant species.

To mitigate these environmental effects, one solution is the use of alternative fuels in combination with conventional ones. At present, almost all industrialized nations conduct extensive research to develop environmentally friendly, efficient, cost-effective, and readily available alternative fuels. Some options—such as liquefied petroleum gas, compressed natural gas, ethanol, methanol, and plant-based fuels—are already widely used [16, 17].

Hydrogen also stands out as a prospective motor fuel. Its main advantages include high energy content, clean combustion, and an essentially unlimited resource base. It has the highest energy-per-mass ratio among all chemical fuels [18]. Furthermore, hydrogen can be derived from diverse sources: nuclear energy, biomass, renewable sources, and conventional hydrocarbons.

Although no alternative fuel has yet fully displaced petroleum-based fuels due to economic and technical limitations, hydrogen remains among the most promising candidates for improving the ecological sustainability of internal combustion engines.

**RESULTS**

The fundamental and theoretical calculations evaluating the effect of hydrogen addition to gasoline in a Cobalt vehicle engine are presented in Table 2. Key thermodynamic and performance parameters were recorded and compared for pure gasoline and gasoline enriched with 3–8% hydrogen [19].

**TABLE 2.** Basic and theoretical calculations for hydrogen addition to gasoline in the Cobalt car engine

|  |  |  |  |
| --- | --- | --- | --- |
| Internal combustion engine indicators | Unit | Gasoline | Gasoline + Hydrogen |
| Molar amount of CO₂, M₍CO₂₎ | kmol/kg | 0.064 | 0.061 |
| Theoretical air requirement, L₀ | kmol/kg | 14.95 | 19.91 |
| Molecular change coefficient, μ₀ | – | 1.067 | 1.087 |
| Molar amount of charge, M₁ | kmol/kg | 0.49 | 0.51 |
| Molar amount of combustion products, M₂ | kmol/kg | 0.528 | 0.531 |
| Degree of pressure rise, λ | – | 3.438 | 3.79 |
| Filling factor, η | – | 0.983 | 0.973 |
| End of combustion pressure, Pz | MPa | 8.59 | 9.46 |
| End of expansion pressure, Pb | MPa | 0.478 | 0.528 |
| Specific fuel consumption, gₑ | g/kWh | 310.8 | 271.6 |
| Hourly fuel consumption, Gₕ | kg/h | 24.24 | 21.18 |
| Indicator specific fuel consumption, gᵢ | g/kWh | 238.0 | 215.7 |

The data indicate a reduction in CO₂ emissions (from 0.064 to 0.061 kmol/kg) and an increase in the theoretical air requirement due to leaner and more complete combustion with hydrogen. The degree of pressure rise increased from 3.438 to 3.79, reflecting improved combustion energy output.

Specific fuel consumption decreased from 310.8 to 271.6 g/kWh, and hourly fuel consumption dropped by approximately 12.6% (from 24.24 kg/h to 21.18 kg/h). Indicator-specific fuel consumption also improved significantly.

The increase in end-of-combustion pressure (from 8.59 MPa to 9.46 MPa) and end-of-expansion pressure (from 0.478 MPa to 0.528 MPa) further confirms enhanced thermodynamic performance under hydrogen enrichment.

Additionally, the exothermic reaction of hydrogen and oxygen: H2+0.5∙O2→H2O+285.8 kJ/mol demonstrates hydrogen’s high energy yield, which contributes to these improved performance indicators [20].

**DISCUSSION**

The experimental results clearly demonstrate that enriching gasoline with 3–8% hydrogen improves both the thermodynamic and operational performance of internal combustion engines.

First, the improved combustion efficiency is evident through increased end-of-cycle pressures and reduced fuel consumption. This is due to hydrogen's high flame speed and wide ignition limits, which promote more complete combustion [21]. The increase in theoretical air requirement and molar product ratios suggests cleaner oxidation reactions and reduced formation of carbon-based emissions.

Second, a 20% reduction in specific fuel consumption represents not only economic benefits but also reduced environmental impact. The drop in CO₂ emissions and the increase in pressure values directly reflect the energy efficiency gains, aligning with findings in previous hydrogen-addition studies [22].

However, the slight decrease in the filling factor (from 0.983 to 0.973) may be attributed to hydrogen’s lower energy density per volume compared to gasoline, which requires more intake volume for the same energy output. This effect was negligible in overall efficiency.

While these improvements are promising, some limitations should be addressed. The combustion temperature increase can lead to higher NOₓ formation unless appropriate countermeasures such as EGR (Exhaust Gas Recirculation) or lean-burn strategies are used [23]. Additionally, the infrastructure for hydrogen production, storage, and delivery still poses barriers for large‑scale deployment.

Nonetheless, the ability to implement hydrogen as a minor additive (3–8%) without engine redesign makes it an attractive transitional technology, particularly in countries with large gasoline fleets and limited access to full hydrogen fuel systems.

**CONCLUSION**

Operational tests have shown that the fuel consumption for a Cobalt passenger vehicle using conventional gasoline is 7.2 liters per 100 km, while with the addition of hydrogen to gasoline, the consumption decreases to 5.7 liters per 100 km. This represents a fuel economy of up to 20%z

The conducted scientific and practical research confirms the possibility of using hydrogen as a 3–8% additive to gasoline and diesel fuels in internal combustion engines. Hydrogen addition improves the combustion process, increases engine efficiency, and significantly reduces harmful substances in exhaust emissions.

If automobile manufacturing plants switch to the use of hydrogen addition to fuel in the future, the country will gain substantial economic and environmental benefits. Hydrogen, as a clean and efficient energy carrier, helps reduce both fuel consumption and toxic emissions, providing a promising pathway toward sustainable transport development.

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