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EVALUATION OF FUEL EFFICIENCY IN GASOLINE-POWERED VEHICLES THROUGH THE USE OF HYDROGEN BLENDS

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Abstract:
Today, more than 14,000 hydrogen-powered vehicles are operating on the streets of European countries. Major global automotive companies such as Mercedes-Benz, Toyota, and Hyundai are investing heavily in the development of hydrogen technologies. So, what makes hydrogen superior to other traditional fuels? What are the prospects for hydrogen-powered transport?
The hydrogen-powered engine was invented in 1806 by François Isaac de Rivaz. The scientist produced hydrogen through the electrolysis of water. The piston engine he created is known as the De Rivaz engine. As we all know, hydrogen is a gas. It is a flammable gas and is also used in the production of electricity. Hydrogen can be found in nature both in free form and as a component of other gases. It is worth noting that hydrogen can be used as a fuel, particularly in heating systems. Since hydrogen is odorless and tasteless, it does not harm the environment.
Hydrogen can be obtained in several ways. Electrolysis is the most commonly used method. In this process, oxygen and hydrogen are produced from water using electric current. The resulting hydrogen is then further processed. To be more specific, 1 kilogram of hydrogen can be obtained from 10 kilograms of water and 50 kilowatts of electrical energy. If we want to generate electricity from this 1 kilogram of hydrogen, it will produce 33.3 kilowatts of electricity. This raises the question: why should we spend 50 kilowatts of electricity to produce 1 kilogram of hydrogen that only gives us 33.3 kilowatts in return? The point is that

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hydrogen is considered a renewable energy source, and in addition, it can be stored and used for other purposes. Energy losses during the production process are natural.
One kilogram of hydrogen can supply electricity for 24 days. If the same amount is used in a car, it can cover a distance of 100 kilometers.
Reducing the toxicity of gases emitted from spark-ignition gasoline engines is a critical requirement for the development of the automotive industry. The continuous tightening of toxicity standards is driven by the need to reduce environmental stress in large cities due to active use of motor vehicles. Many researchers have shown that hydrogen has several properties that make it possible to reorganize the operating process of spark-ignition engines when used as an additive to hydrocarbon fuels. This means it can significantly increase their efficiency and reduce the toxicity of exhaust gases. It is well known that the efficiency of the combustion process in an internal combustion engine primarily depends on the laws of thermal energy supply.
Hydrogen has proven to be a highly explosive substance when used as fuel in internal combustion engines, and safety considerations must be taken into account. Due to its low ignition energy, pre-ignition is a major issue. Its short quenching distance allows the flame to propagate easily.

Objective of the Study:
To determine the characteristics of using hydrogen to improve the combustion efficiency in a gasoline engine.
According to the first method, conducted studies [1] showed that adding hydrogen accounting for 6% of the fuel mass contributed up to 11% of the total energy input. During the tests, the engine was started using gasoline, and hydrogen was supplied only after ignition. This ensured safe operation and eliminated the risk of hydrogen leaking into the room during engine start-up.
The main conclusions of many studies are appealing for broader implementation in mass-produced vehicles. First, for example, a dual-fuel system (gasoline + hydrogen) could be used during cruise control operation with lean mixtures at stable speeds. Then, during acceleration, the system can be activated to ease the engine's performance under increased load. Another example could be its

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application in a hybrid vehicle system. In such a case, the engine charges the battery and can operate in a fuel-saving mode with both fuels. This significantly reduces fuel consumption by 15–20% and also ensures a reduction in the emission of toxic exhaust gas components.

Yeleman and Desouki [2] studied the combustion properties of the hydrogen-air mixture and found that it has a higher autoignition temperature than the gasoline-air mixture, which increases its resistance to premature ignition. Gorenje and others also reported similar findings.

Lucas and Richards [3] conducted experimental studies by adding small amounts of hydrogen to a spark-ignition engine running on gasoline. The engine was operated at full throttle with a constant amount of hydrogen and throughout the entire load range, using only hydrogen during idling. As the load increased, the gasoline content was increased. A wide-open throttle reduces pump losses. Under these economic operation conditions, CO and NOx emissions were reduced, although HC typically increased.

Sfinteanu and Apostolescu [4] reported on the performance of a passenger car engine operating solely on gasoline, which was limited to approximately $\lambda = 0.83$ (lambda). Meanwhile, the hydrogen-gasoline engine continued to operate with extremely lean mixtures. The combination of hydrogen and gasoline provided a 25% reduction in CO emissions and maintained approximately the same concentration of NOx.

The analysis of hydrogen delivery methods to the engine cylinder showed that the main methods can be grouped as follows:

1. Supplying hydrogen together with intake air to the engine cylinder.
2. Individual dosing of hydrogen in the intake valve area of each engine cylinder.
3. Supplying hydrogen to the engine cylinder at a pressure of 0.2–4 MPa.
4. Injecting liquid hydrogen into the intake manifold or directly into the engine cylinder. According to the first method, conducted studies [1] showed that with hydrogen added at 6% of the fuel mass, the energy introduced by hydrogen could account for up to 11% of the total energy input from the fuel. During the tests, the engine was started using gasoline, and only after that was hydrogen supplied. This ensured safe operation and eliminated the risk of hydrogen leakage into the room during engine start-up.

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Furthermore, hydrogen not only affects engine performance and toxic emissions, but also has a significant impact on the lean burn limit of the mixture for stable operation. It has been found that increasing the amount of added hydrogen increases engine torque and efficiency across all mixtures, up to the effective lean limit of the mixture at α = 0.91 and above. At the same time, the effect of hydrogen becomes more pronounced as the mixture becomes leaner.

When the engine operates with 6% hydrogen, it can achieve an effective lean limit at a mixture ratio of 1.3, at which point torque and power increase, and specific fuel consumption improves by approximately 35%. In addition, there is a significant impact on the engine's performance.

The use of hydrogen raises the lean burn limit of the mixture to α = 1.47, whereas for gasoline alone this limit is α = 1.24. Even as the mixture is leaned out, the engine continues to operate smoothly and controllably.

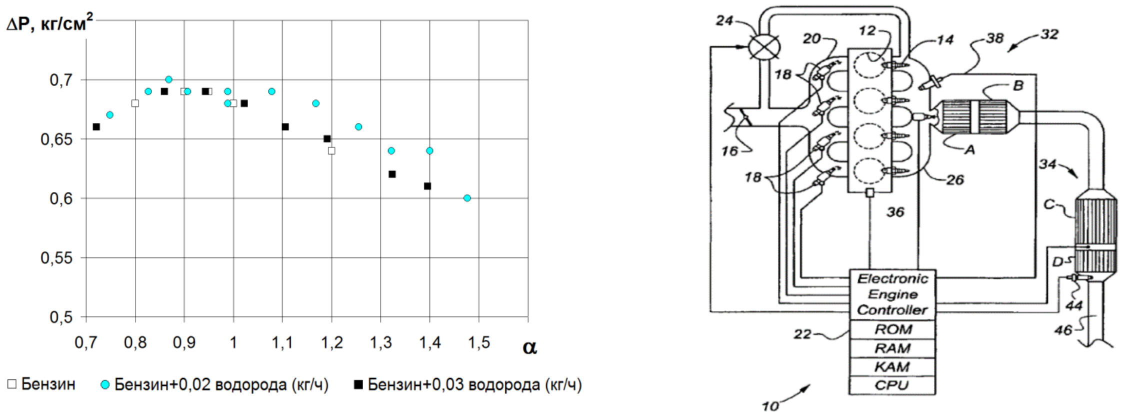

Figure 1. Hydrogen-powered engine

This allows us to determine, using the state equation for the remaining mixture, the amount of the working mixture in the engine cylinder composed of residual gases and fresh mixture. Their quantities are determined by air and fuel flow sensors. Thus, studying thermodynamic changes in deeply interrelated fuel-efficient modes is highly relevant for identifying opportunities to improve the combustion process efficiency in engines and related devices.

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Conclusions

The device we are proposing is designed in such a way that its construction has been simplified, and we recommend it for production.

1. Adding up to 6% hydrogen by fuel mass not only significantly affects engine performance and toxic emissions, but also extends stable operating limits when the mixture becomes lean. It was found that increasing the amount of added hydrogen improves engine torque, power, and efficiency across all mixtures (for air-fuel equivalence ratios α = 0.91 and above, up to the effective lean limit of the mixture). Moreover, the effect of hydrogen increases as the mixture becomes leaner.
2. When the engine operates with 6% hydrogen, an effective lean limit of the mixture is achieved at α = 1.3, where torque and power increase, and specific fuel consumption is reduced by approximately 35%. Additionally, the engine operates smoothly and in a controlled manner.
3. The use of hydrogen extends the lean limit of the mixture to α = 1.47, while for pure gasoline it is limited to α = 1.24.

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