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THE EFFECT OF ADDING HYDROGEN OBTAINED BY THE ELECTROLYSIS METHOD TO DIESEL FUEL

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Annotatsiya: Vodorod-bu energiya tashuvchi bo‘lib, uni ichki yonuv dvigatellarida yondirilganda dvigateldan chiqadigan chiqindi gazlarini deyarli ishlab chiqarmaydigan yonilg‘i hisoblanadi. Vodorod havoda kislorod bilan yonadi va dvigatelning fizik qismlarini to‘g‘ridan-to‘g‘ri harakatga keltiriruvchi kengayadigan issiq gazlarni hosil qiladi.
Kalit so‘zlar. Dizel dvigatellari, Vodorod, Muqobil Yonilg‘i, Emissiya, Qayta tiklanadigan energiya.
Аннотация. Водород является носителем энергии и считается топливом, которое практически не производит выхлопных газов двигателя при его сжигании в двигателях внутреннего сгорания. Водород горит в воздухе вместе с кислородом, образуя расширяющиеся горячие газы, которые непосредственно приводят в движение физические части двигателя.
Ключевые слова. Дизелние двигатели, Водород, Альтернативное топливо, Выбросы, Возобновляемые источники энергии.
Abstract: Hydrogen is an energy carrier, and we can consider it as a fuel that practically does not produce engine exhaust gases when burned in internal combustion engines. Here, hydrogen burns together with oxygen in the air, forming expanding hot gases that directly drive the physical parts of the engine.
Key words. Internal combustion engines, Hydrogen, Alternative fuel, Emission, Renewable energy.

Introduction.

At present, diesel engines are widely used in agriculture, transportation, and industry due to their high efficiency, reliability, manufacturability, and fuel economy. However, the increasing number of diesel-powered vehicles is considered a major drawback because it contributes to environmental pollution and intensive consumption of petroleum as an engine fuel [1].

Several approaches have been proposed to mitigate the problems associated with fuel consumption; nevertheless, most of these solutions require long-term development and additional infrastructure investments.

Literature Review

A notable characteristic of hydrogen is that it forms the basis of most organic compounds, producing various types of hydrocarbon fuels such as propane, natural gas, and gasoline. For high-energy fuel cells, hydrogen can be obtained from other hydrocarbons by applying heat in a process known as reforming, which increases the overall energy output.

In diesel engines, exhaust gas purification and noise reduction are primarily achieved within the engine itself, that is, by controlling the combustion process [2]. The combustion process occurs

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as a result of the interaction between several key elements-fuel, the required amount of oxygen, and the mechanical systems and components of the internal combustion engine.

In most vehicle engines, diesel fuel is produced by blending directly distilled hydrotreated petroleum fractions with catalytically cracked light gas oil. Diesel fuel typically contains the following groups of hydrocarbons (%): normal paraffins - 5...30, isoparaffins - 18...46, naphthenes - 23...60, and aromatics - 14...35 [3].

An analysis of the combustion process shows that the fuel entering the combustion chamber (as illustrated in Figure 1) requires a certain amount of time to completely evaporate and oxidize with oxygen. The longer this duration, the greater the deviation from the theoretical parameters and the lower the combustion efficiency. The ignition delay period is generally within a crankshaft rotation angle of 12–25° or 0.001–0.003 s. Table 1 presents the combustion stages and their main characteristics in the diesel engine cylinder [4].

The finer the fuel atomization during injection and the higher the air pressure and temperature at the end of compression, the shorter the ignition delay period becomes. Consequently, the combustion parameters improve significantly [5].

The ignition delay period includes the time required for fuel droplets to disintegrate, move slightly within the combustion chamber, heat up, partially evaporate, mix with air, and initiate chemical reactions that lead to self-ignition.

To increase the efficiency of the engine and reduce the level of harmful emissions, it is necessary to ensure more precise control of the injection system and the combustion process. In particular, the complete combustion of the fuel inside the cylinder can theoretically be achieved by supplying an amount of air greater than that required for the stoichiometric ratio.

The high flame propagation rate of the hydrogen–air mixture and the resulting higher pressure rise in the engine cylinders contribute to an increase in the indicated efficiency of the engine [6].

Table 1.
Combustion stages and characteristics in a diesel engine cylinder

Combustion stage	**Crankshaft rotation angle, φ°**	**Duration, µs**	**Droplet diameter, µm**	**Piston movement direction**	**Pressure, MPa**	**Temperature, °C**
Ignition delay (point 1)	12-25	0,001-0,003	30,40	Upward	2,5-5	750-1000
Rapid combustion (point 2)	10-20	0,008-0,0015	10,20	Upward	6-9	1600-1800
Controlled combustion (point 3)	15-25	0,0012	Vapor phase	Downward	5,5-8	1800-2200
Afterburning (point 4)	50-60	0,0035-0,005	Burned fuel	Downward	3-4	630-930

Table 2.
Properties of hydrogen at 25°C and 1 atm

Property	**Unit**	**Hydrogen (H_2)**

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Auto-ignition temperature	K	858
Minimum ignition energy	MJ	0.02
Flammability limits	(vol% in air)	4–75
Stoichiometric mixture	(vol% in air)	29.53
Molecular weight	g/mol	2.016
Density	kg/m³	0.0838
Air–fuel mass ratio	kg air/kg fuel	34.4
Flame speed	cm/s	270
Specific gravity	–	0.091
Adiabatic flame temperature	K	2318
Heating value	kJ/kg	120,000
Octane number	–	130
Cetane number	–	—
Boiling point	K	20.27

Hydrogen, which possesses a significantly higher flame propagation speed compared to hydrocarbons, acts as a specific pre-ignition catalyst that initiates the combustion of the working mixture. This ensures rapid and complete burning within a short period of time, leading to higher pressure and greater heat release, thereby contributing to an increase in engine torque [7]. As a result of complete fuel combustion, the concentration of harmful substances in the exhaust gases is considerably reduced.

Problem Statement and Aim of the Study

The lower flammability limit of hydrogen is several times higher than that of petroleum-based fuels, which enables internal combustion engines operating on hydrogen–diesel mixtures to achieve greater efficiency compared to those running solely on conventional hydrocarbon fuels.

The specific fuel consumption can be determined as follows:

$$g_t = \frac{G_b + G_{H_2} \cdot G_H H_2 / G_{H_b}}{N_e}$$

Where G_b , G_{H_2} – represent the consumption rates of diesel fuel and hydrogen, respectively (g/h); $G_H H_2$, G_{H_b} – denote the lower heating values of diesel fuel and hydrogen, respectively (kJ/kg); N_e- effective (brake) power of the engine [8].

Table 3.

Main characteristics of diesel fuel and hydrogen

Property	**Diesel**	**Hydrogen**
Fuel density, kg/m³	860	0.0899
Minimum ignition energy, MJ	0.23	0.02

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Net calorific value, MJ/kg	43.76	120
Stoichiometric air requirement, kg air/kg fuel	14.3	34.3
Maximum laminar flame speed, m/s	0.20	2.75
Diffusion coefficient, cm²/s	0.078	0.63
Flame propagation concentration limit, α	α_{max} –0,9; α_{min} –5,0	α_{max} –0,22; α_{min} –4,0

When hydrogen is used as a partial substitute in diesel engines, it acts as a component of a mixed fuel, expanding the engine's operating limits, improving knock resistance, and modifying the overall performance characteristics. At the same time, hydrogen serves as an additive to diesel fuel, enhancing both the energy–economic and environmental properties of the combustion process, similar to the complete oxidation of hydrocarbon fuel.

However, in diesel engines operating with an external hydrogen–air mixture, a slight decrease in power output may occur due to oxygen deficiency, which prevents complete combustion of the fuel. To compensate for the lack of oxygen and to achieve a stoichiometric mixture, it is necessary-based on experimental observations-to increase the intake manifold air pressure by approximately 0.05 bar by adjusting the supercharging configuration. This ensures that, under constant hydrogen and diesel supply conditions, the engine power returns to values comparable to those of a conventional diesel engine without hydrogen supplementation [9].

Results

In practical applications, converting the chemical energy of organic fuels into electrical energy through the use of fuel cells is of significant importance. Low-temperature (around 150°C) liquid-electrolyte fuel cells, which commonly employ concentrated solutions of sulfuric or phosphoric acid and alkaline electrolytes such as KOH, are widely used.

The generation of electrical energy in an electrolysis element is based on an electron exchange process between the reducing and oxidizing agents, accompanied by the formation of new compound reaction products (Figure 1).

The utilization of hydrogen in internal combustion engines does not require a highly complex system. The main difference lies in maintaining the fundamental principles of the conversion process while modifying the method of mixture delivery and ignition. Compared to conventional diesel operation, hydrogen fuel ensures a much faster reaction rate even under low-pressure conditions within the fuel system.

The formation of the air–fuel mixture does not necessarily require the presence of atmospheric air, as the residual vapor in the combustion chamber passes through the radiator and condensation stages, subsequently reverting to H_2O [10].

Naturally, this version of the fuel cell design includes a dedicated electrolyzer that ensures sufficient hydrogen generation for participation in the regenerative hydrolysis process with oxygen.

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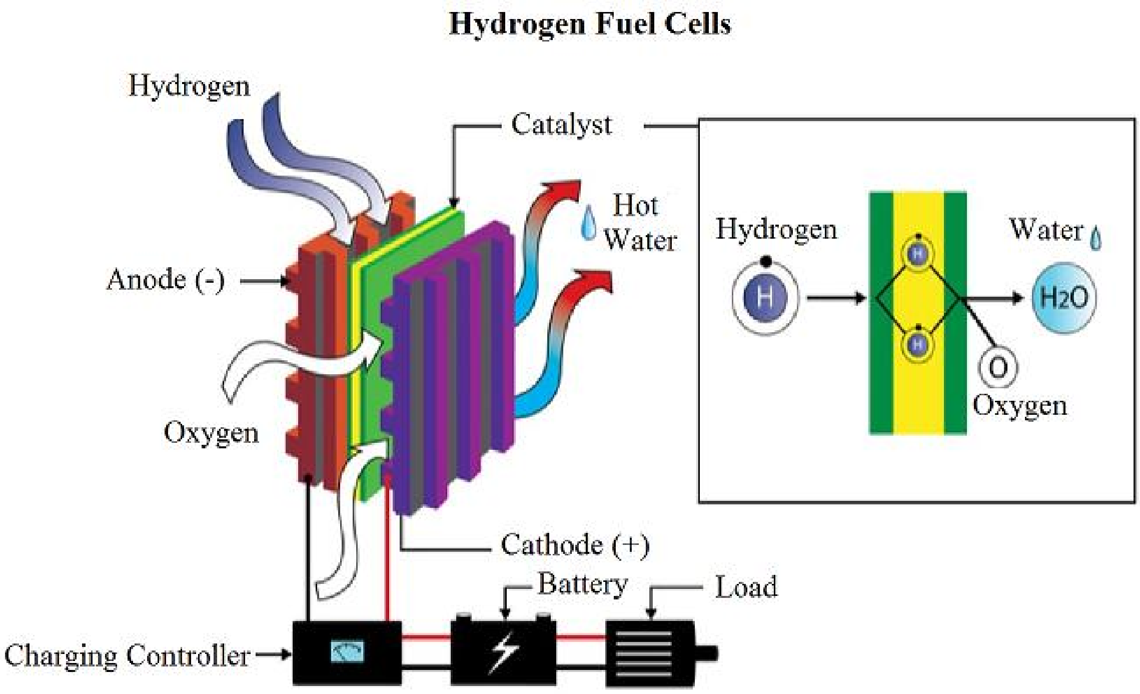

Figure 1. Schematic diagram of the hydrogen–oxygen element

When hydrogen is added to diesel fuel, a change is observed in the cycle mass of the fuel, ranging from about 10% to 45% [11]. The reduction in convective and radiative heat fluxes results in a corresponding variation in the overall heat utilization coefficient during heat exchange. This phenomenon is one of the factors contributing to the increase in the indicated efficiency of the D-120-44 diesel engine when operating with a specified proportion of hydrogen additive.

Conclusion.

Hydrogen fuel cells provide access to an innovative technology that can significantly reduce the amount of harmful greenhouse gases emitted into the atmosphere. However, the transition toward a hydrogen-based economy is not without risks. To prevent potential environmental challenges, such as ozone depletion, it is essential to minimize the release of hydrogen gas into the surrounding environment.

The development of new and cost-effective technologies for hydrogen production is therefore of great importance. If such processes can be successfully implemented, a substantial reduction in exhaust emissions from transportation systems can be achieved in the near future.

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