THE EFFECT OF USING HYDROGEN AS ADDITIONAL FUEL IN GASOLINE ENGINES ON ENGINE POWER.

Zingirov Saydolim Jurayevich
Associate Professor of Transport Logistics, Andijan State Technical Institute

Annotatsiya: Vodorod Koinotda eng ko‘p tarqalgan element bo‘lsa-da, Yer yuzasida erkin holda kamdan-kam uchraydi. Biroq, vodorodni suv, biomassa yoki tabiiy gaz, quyosh energiyasi, shamol energiyasi yoki gidrogenlash kabi usullardan foydalangan holda atrof-muhitga zarar yetkazmasdan ishlab chiqarish va olish mumkin. Ushbu tadqiqotning asosiy maqsadi benzin-vodorod aralashmasida ishlaydigan ichki yonuv dvigatelining ish ko‘rsatkichlarini o‘zgartirish bo‘yicha tajriba ishlarini o‘tkazish va matematik modelini ishlab chiqishdan iborat. Tadqiqotda qo‘shimcha yoqilg‘i sifatida vodoroddan foydalanishning dvigatel samaradorligiga, yoqilg‘i sarfiga va ekologik oqibatlariga ta’siri o‘rganildi. Eksperimental tadqiqotlar davomida turli miqdordagi vodorodning dvigatel quvvati va samaradorligiga ta’siri o‘rganildi. Natijalar shuni ko‘rsatdiki, biz tanlagan dvigatel uchun vodorodning optimal miqdori daqiqasiga 450 ml ni tashkil etdi. Benzin-havo aralashmasiga doimiy miqdorda vodorod qo‘shish dvigatelning kuch xususiyatlarini yaxshilaydi va yonilg‘i samaradorligini oshiradi, ammo NOx chiqindilarining ko‘payishiga olib kelishi mumkin. Ushbu maqolada eksperimental natijalar asosida dvigatelning optimal ish sharoitlari aniqlanadi va dvigatelning quvvat ko‘rsatkichlari o‘zgarishining matematik modeli ishlab chiqiladi.

Kalit so‘zlar: vodorod, dvigatel, benzin-havo aralashmasi, quvvat, yoqilg‘i, tejamkorlik, o‘t olish energiyasi.

Аннотация: Хотя водород является самым распространенным элементом во Вселенной, он редко встречается в свободном состоянии на поверхности Земли. Однако водород можно производить и получать без ущерба для окружающей среды, используя такие методы, как вода, биомасса или природный газ, солнечная энергия, энергия ветра или гидрирование. Основной целью данного исследования является проведение экспериментальных работ по изменению показателей работы двигателя внутреннего сгорания, работающего на бензино-водородной смеси, и разработка математической модели. В исследовании изучалось влияние использования водорода в качестве дополнительного топлива на эффективность двигателя, расход топлива и экологические последствия. В ходе экспериментальных исследований изучалось влияние различных количеств водорода на мощность и КПД двигателя. Результаты показали, что оптимальное количество водорода для выбранного нами двигателя составляло 450 мл в минуту. Добавление постоянного количества водорода в

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бензиновоздушную смесь улучшает силовые характеристики двигателя и повышает топливную эффективность, но может привести к увеличению выбросов NOx. На основе экспериментальных результатов в данной статье определяются оптимальные условия работы двигателя и разрабатывается математическая модель изменения показателей мощности двигателя.
Keywords: hydrogen, engine, gasoline-air mixture, power, fuel, fuel efficiency, ignition energy.
Abstract: Although hydrogen is the most abundant element in the universe, it rarely occurs in its free state on the Earth's surface. However, hydrogen can be produced and obtained without harming the environment using methods such as water, biomass or natural gas, solar energy, wind energy, or hydrogenation. The main goal of this research is to conduct experimental work on the changes in performance indicators of an internal combustion engine operating on a gasoline-hydrogen mixture and to develop a mathematical model. The study examined the effects of using hydrogen as an additional fuel on engine efficiency, fuel consumption, and environmental outcomes. During experimental studies, the impact of various amounts of hydrogen on engine power and efficiency was investigated. Results showed that the optimal hydrogen quantity for the engine we selected was 450 ml per minute. Adding a constant amount of hydrogen to the gasoline-air mixture improves the engine's power characteristics and increases fuel efficiency, but may lead to an increase in NOx emissions. Based on the experimental results, this article determines the optimal operating conditions of the engine and develops a mathematical model for the changes in engine power indicators.
Keywords: hydrogen, engine, gasoline-air mixture, power, fuel, fuel efficiency, ignition energy.

Introduction

In recent years, alongside the development and study of hydrogen-powered internal combustion engines, the use of hydrogen in engines by mixing it with hydrocarbon fuels, especially gasoline, has been advancing. The interesting aspect of this approach is that a slight modification of the serial engine allows for a significant increase in its fuel efficiency, a reduction in the amount of harmful substances in exhaust gases, and a substantial decrease in gasoline consumption. [1].

The relevance of the research lies in its contribution to hydrogen utilization, reduction of fuel consumption, and minimization of exhaust emissions. While numerous studies have focused on the ecological effects of hydrogen addition, its

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impact on the power output of gasoline engines has been less thoroughly investigated.

The aim of the study is to assess the impact of using hydrogen as an additional fuel in gasoline engines on engine power. The research investigates the effects of hydrogen on engine power, fuel efficiency, and exhaust emissions.

The wide concentration range, low ignition energy, and high reactivity of hydrogen allow for targeted influence on the properties of gasoline-air mixtures by adding a certain amount of hydrogen. Adding a small quantity of gaseous hydrogen can significantly expand the combustion concentration limits of a homogeneous gasoline-air mixture [2]. For example, to achieve a lower flammability limit of a = 2, it is sufficient to introduce only 0.03 mass fraction of hydrogen relative to the total amount of fuel into the gasoline-air mixture. However, the practical lean limits for actual engines may be much narrower due to the influence of mixture formation quality, mixture temperature, charge stratification, dilution of the charge with residual gases, and other factors [3]. Research conducted on real engines has confirmed this situation.

The engine's operation in a hydrogen and gasoline-hydrogen mixture remains stable up to values of a = 5-6. In this case, even a slight increase in the observed unevenness of the work process cannot be the main reason for the decrease in the indicator efficiency. Therefore, the residual hydrogen content in the exhaust gases was analyzed to assess losses without full combustion to determine the reasons for the decrease in cycle efficiency when $\alpha > \alpha_{imax}$ when measuring the thermal balance of a hydrogen engine [2]. The analysis results showed that when $\alpha > 3$, the residual hydrogen content increases sharply. This may be due to an increase in the flame attenuation range as a result of the impoverishment of the mixture and an increase in underburning in the layers around the wall as a result of a partial prolongation of the combustion process [4].

Due to the large relative combustion surface in a rotary-piston engine, the first factor is the most characteristic, and the relative heat loss resulting from incomplete combustion in the engine approaches 15% at $\alpha = 4.3$. Thus, the conducted research indicates that the main reason for the decrease in the indicated efficiency of a hydrogen engine is incomplete combustion when $\alpha > 2.5$-3. Therefore, to achieve maximum efficiency in the work process at low loads, it is advisable to limit the air excess ratio within the boundaries of α_{max}. This can be achieved through partial throttling of the engine, i.e., by employing a mixed method of regulating the operating process.

These studies demonstrated that when the engine is supplied with gasoline containing a 5% hydrogen addition relative to the total fuel consumption and with

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an air excess coefficient of α=1.05, the maximum power is maintained at the level of the main engine's power output. This results in an 80% reduction in gasoline consumption, a significant decrease in carbon monoxide and hydrocarbon emissions, and a considerable improvement in fuel efficiency [5].

Research methodology. This experimental study aims to evaluate the operational efficiency and power performance of a gasoline engine when various amounts of hydrogen are added to it.

The research method involved bringing the engine to a specified speed mode and then gradually diluting the gasoline-hydrogen-air mixture until combustion misfires began to occur. Subsequently, the mixture was enriched with hydrogen until the combustion process stabilized. The combustion of the mixture was recorded using a pressure sensor and a loop oscillograph based on the maximum pressure value of the cycle [6]. Recording the pressure in the engine cylinder on a loop oscillograph at low tape speed allowed for the assessment of cycle irregularity in various fuel-air mixture compositions. During the research, the optimal ignition timing was selected for each mixture composition, and the combustion products were analyzed.

The experimental work is carried out in three stages:

1. The gasoline engine is initially operated solely on gasoline, and the key performance indicators (power output, fuel consumption) are determined.
2. Hydrogen addition: Hydrogen is mixed with gasoline in various proportions (5%, 10%, 20%), and the engine power is remeasured. At each stage, the physical and chemical characteristics of the combustion process are recorded.
3. Data collection: For each mixture, power output, fuel efficiency, and exhaust emissions are measured. The heat released and combustion rate are analyzed.

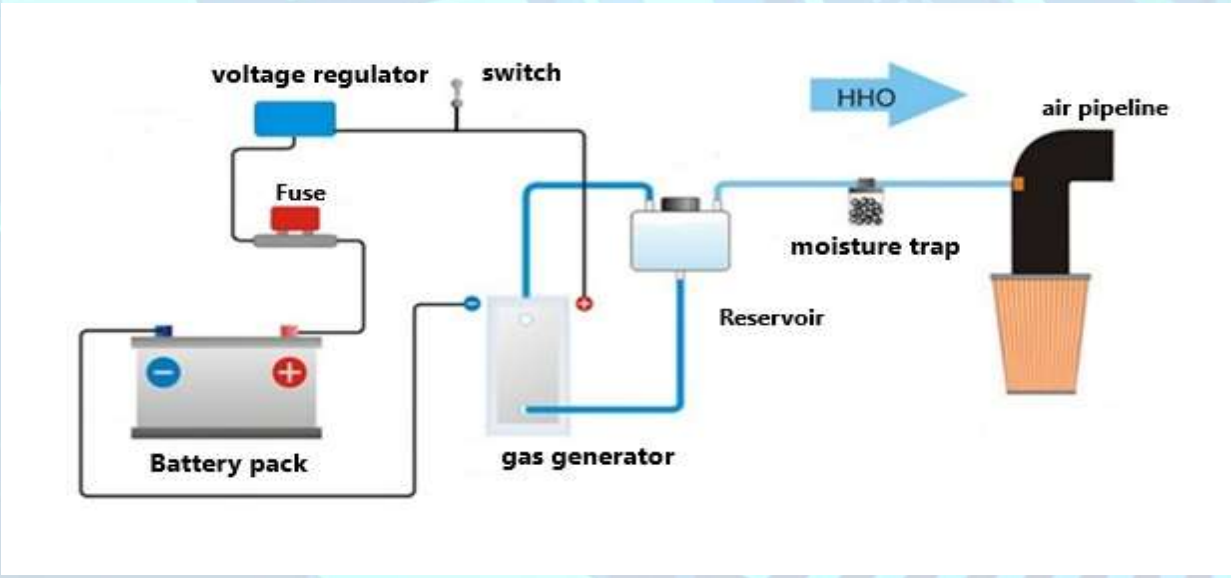
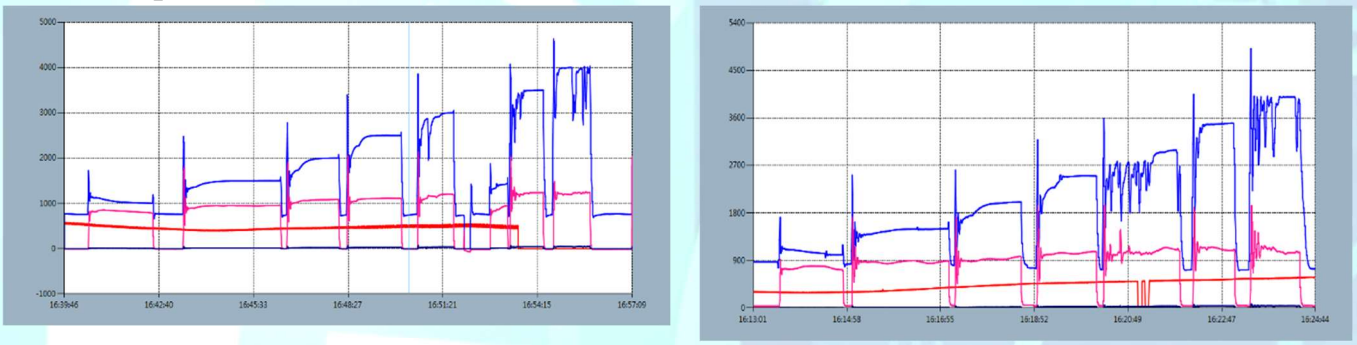


Figure 1. Schematic diagram of hydrogen generator installation in a vehicle.

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The test stand is equipped with a DW160H vortex flow dynamometer for load control. The FDJ-001 engine test stand has the capability to measure various engine parameters, including crankshaft rotation speed, crankshaft torque, power output, fuel consumption, exhaust gas emissions, and other engine characteristics. The FDJ-001 engine test stand can handle a maximum torque of 500 N*m, a maximum crankshaft rotation speed of 12,000 rpm, and a maximum power output of 160 kW.

Tests are conducted according to GOST 14846-2020 at a temperature range of 283 K < T < 313 K (10 °C < T < 40 °C) and an atmospheric pressure range of 80 kPa < B < 110 kPa (600 mm Hg < B < 825 mm Hg). If the temperature and pressure are outside the specified limits, they are recorded in the test protocol and test report.



a b

Figure 2. Electronic graphs obtained from the FDJ 001 inductive braking test stand (a: gasoline-air-hydrogen; b: gasoline-air).

To develop the correlation coefficient and regression equation for the relationship between engine power and crankshaft angular acceleration, we will use the following formulas [8]

$$:\bar{x} = \frac{f_1 x_1 + f_1 x_2 + \cdots f_n x_n}{f_1 + f_2 + \cdots + f_n} = \frac{\sum fx}{n} \qquad (3.2)$$

Here:

$\bar{x}$ – average value;;

$x_1, x_2 \ldots x_n$ – values of the first variable;

$f_1, f_2 \ldots fn$ – values of the second variable;

$$r = \frac{(x_1-\bar{x})(y_2-\bar{y})+(x_2-\bar{x})(y_2-\bar{y})+\cdots+(x_n-\bar{x})(y_n-\bar{y})}{\sqrt{(x_1-\bar{x})^2+(x_2-\bar{x})^2+\cdots+(x_n-\bar{x})^2}\sqrt{(y_1-\bar{y})^2+(y-\bar{y})^2+\cdots+(y_n-\bar{y})^2}} \qquad (3.3)$$

r- correlation coefficient

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$$Rx_{/y} = \frac{(x_1-\bar{x})(y_2-\bar{y})+(x_2-\bar{x})(y_2-\bar{y})+\cdots+(x_k-\bar{x})(y_k-\bar{y})}{(y_1-\bar{y})^2+(y_2-\bar{y})^2+\cdots+(y_n-\bar{y})^2} \quad (3.4)$$

$$Ry_{/x} = \frac{(x_1-\bar{x})(y_2-\bar{y})+(x_2-\bar{x})(y_2-\bar{y})+\cdots+(x_k-\bar{x})(y_k-\bar{y})}{(x_1-\bar{x})^2+(x_2-\bar{x})^2+\cdots+(x_n-\bar{x})^2} \quad (3.5)$$

$Rx_{/y}$ is the regression coefficient of x calculated with respect to y, while $Ry_{/x}$ is the regression coefficient of y calculated with respect to x.

Accordingly, a regression equation has been developed for x with respect to y or for y with respect to x.

y =1,94x+7,7 (3.8)

Testing the adequacy of a mathematical model using the Student-Fisher criterion:

To calculate the variances, it is necessary to examine the differences between the expected results of the model and the experimental data [2].

Total variance (S_u^2): This is calculated from the difference between model and experimental values [9]:

$$S_u^2 = \frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n-1}$$

Here:

y_i— experimental value;

y_i — Average value of experimental data;

n — number of observations.

Model variance **(S_m^2):** The variance of the difference between the values calculated from this model and the experimental values

$$S_m^2 = \frac{\sum_{i=1}^{n}(y_i - y_{model})^2}{n-m}$$

Calculating Fisher's statistical criterion: The Fisher coefficient (F) is calculated as the ratio of variances :

$$F = \frac{S_m^2}{S_u^2}$$

By performing the above steps using the values calculated in the mathematical model and experimental data, the reliability of the model and the adequacy of the mathematical model are determined using the Fisher criterion.

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