Ткач Михайло Романович

Тимошевський Борис Георгійович

Шалапко Денис Олегович

Проскурін Аркадій Юрійович

Митрофанов Олександр Сергійович

УДК 62.396
У66

METHODS TO IMPROVE THE PERFORMANCE OF DIESEL ENGINES BY ADDING HYDROGEN INTO HIGH PRESSURE LINE

ПОКРАЩЕННЯ РОБОЧИХ ХАРАКТЕРИСТИК ДИЗЕЛЬНИХ ДВИГУНІВ ЗА ДОПОМОГОЮ ДОДАВАННЯ ВОДНЮ В ПАЛИВОПРОВІД ВИСОКОГО ТИСКУ

DOI 10.15589/SMI. 2018.01.12

Mykhaylo R. Tkach М. Р. Ткач, д. т. н., проф.
mykhaylo.tkach@gmail.com
ORC ID: 0000-0003-4944-7113

Borys G. Tymoshevskyy Б. Г. Тимошевський, д. т. н., проф.
borys.tymoshevskyy@gmail.com
ORC ID: 0000-0002-4649-702X

Denys O. Shalapko Д. О. Шалапко, здобувач, викл.
denys.shalapko@nuos.edu.ua
ORC ID: 0000-0002-4311-3908

Arkadii Yu. Proskurin А. Ю. Проскурін, канд. тех. наук
arkadii.proskurin@nuos.edu.ua
ORC ID: 0000-0002-5225-6767

Oleksandr S. Mytrofanov О. С. Митрофанов, канд. тех. наук
oleksandr.mytrofanov@nuos.edu.ua
ORC ID: 0000-0003-3460-5369

Admiral Makarov National University of Shipbuilding, Nikolaev

Национальный университет кораблестроения имени адмирала Макарова, г. Николаев

Abstract. One way to improve the efficiency of diesel engines is the addition of hydrogen (0.2 ... 2.0 % by weight) to the main diesel fuel. An addict of hydrogen to the fuel line between the high pressure fuel pump (HPFP) and nozzle. This achieved by reducing specific fuel consumption at 0,4 ... 2,8 %.

Keywords: internal combustion engine, hydrogen, hydrogen addict

Анотація. Одним з шляхів підвищення ефективності дизельних двигунів є додавання водню (0,2…2,0% по масі) до основного дизельного палива. Запропоновано додавання водню до паливопроводу високого тиску між паливним насосом (ПНВТ) та форсункою. Завдяки цьому досягнуто зменшення питомої витрати палива на рівні 0,4…2,8 %.

Ключові слова: двигуни внутрішнього згоряння; водень; паливо з додаванням водню

Аннотация. Одним из варинатов повышения эффективности дизельных двигателей является добавление водорода в топливную смесь (0,2…2,0 % за массой). Предложено подача водорода в топливопровод высокого давления между топливным насосом (ТНВД) и форсункой. Благодаря этому достигнуто уменьшение удельного расхода топлива на уровне 0,4…2,8 %.

Ключевые слова: двигатели внутреннего сгорания, водород, топливо с примесью водорода

References

Gomes Antunes J.M, Mikalsen R., Roskilly A.P. An experimental study of a direct injection compression ignition hydrogen engine // International Journal of Hydrogen Energy, Volume 34, Issue 15, August 2009, Pages 6516-6522.

Szwaja S, Grab-Rogalinski K. Hydrogen combustion in a compression ignition diesel engine. Int. J. Hydrogen Energy (2009), doi: 10.1016/2009.03.020.

Шкаликова В.П., Патрахальцев Н.Н. Применение нетрадиционных топлив в дизелях: Монография. Изд. 2-е, доп. – М.: Изд-во РУДН, 1993. – 64 с. [In Russian: Shka-

likov VP Patrahaltsev NN The use of unconventional fuels in diesel engines: Monograph. Ed. 2nd, ext. - M .: Publishing House of People's Friendship University, 1993. – 64 p.]

Патрахальцев Н.Н. Повышение экономических и экологических качеств двигателей внутреннего сгорания на основе применения альтернативных топлив: Учеб. пособие. – М.: РУДН, 2008. – 248 с. [In Russian: Patrahaltsev NN Increasing economic and environmental qualities of the internal combustion engine based on the use of alternative fuels: Proc. allowance. — M .: People's Friendship University, 2008. – 248 p.]

Керимов З.Х. Математическое моделирование неустановившихся процессов в двухфазном потоке в системе впрыска топлива дизельного двигателя // Азербайджанское нефтяное хозяйство. – Баку. – 2003. – №7. – с. 42–47. [In Russian: Kerimov ZH Mathematical modeling of transient two-phase flow in the fuel injection system of the diesel engine // Azerbaijani oil industry. – Baku. – 2003. – № 7. – p. 42–47.]

Керимов З.Х. Математическое моделирование гидродинамических процессов с учетом двухфазной среды в граничных полостях дизельной системы впрыска топлива// Авиационно-космическая техника и технология. – 2004. – № 8(16). – с. 63-69. [In Russian: Kerimov ZH Mathematical modeling of hydrodynamic processes taking into account the two-phase medium in the boundary cavities of diesel fuel injection system // Aerospace technics and technology. - 2004. - № 8 (16). – p. 63-69.]

Патрахальцев Н.Н., Савастенко А.А., Виноградский В.Л. Регулирование начального давления топлива – методы и средства повышения экономичности и эффективности работы дизелей // Автомобильная промышленность. – 2002. – № 3. – с. 8–19. [In Russian: Patrahalsev N.N. i dr. Regulirovanie nathalnogo davlenija topliva — methody i sredstva economical effectivity // Automobile promyshlennost. — 2002. – N 3. – S. 8–19.]

Тимошевський Б.Г., Ткач М.Р., Шалапко Д.О. «Поліпшення робочих характеристик дизельних двигунів за допомогою додавання водню» // Водний транспорт, 2016 – №2 (25) – 24-28 с. [In Ukrainian: Tymoshevsky BG, MR Tkach, DO Shalapko "Improving the performance of diesel engines by adding hydrogen" // Water Transport, 2016 – №2 (25) – 24–28 p.]

Problem. Despite progress in the creation of highly efficient internal combustion engines for vehicles and stationary power plants, reducing fuel consumption and reducing emissions of harmful exhaust gases is currently the actual problem.

Modern design. One solution to this problem is to supply hydrogen to the cylinder engine and burning it on your pace. This design based on the supply of hydrogen into the combustion chamber when filling the cylinder. Hydrogen is fed into the air receiver and together with air entering the cylinders of engine. [1].

Further, the essence of the process is the principle of the gas diesels, ignition of hydrogen in the combustion chamber is inflammation from diesel fuel ignition. This hydrogen can be used as main and as additional fuel, depending on the aspect ratio (the amount by weight) of hydrogen to diesel fuel.

The main disadvantage of this process is to reduce the ratio of excess air, which leads to loss of engine power, and significant increase of the maximum combustion temperature and increasing concentration of NO_x in the exhaust gases.

Using hydrogen as a primary fuel ICE currently is not feasible because of the cost and difficulties of hydrogen storage in large quantities. Obviously, for ICE is suitable partial replacement of hydrocarbon fuels by hydrogen that supply the engine cylinders. Small fuel additions of hydrogen can increase operational efficiency internal combustion engines and their environmental safety. Using hydrogen as small additives to engines creates problems associated with its production and storage. The use of environmentally friendly hydrogen additives particularly useful when entering vessels in coastal waters and ports where the main burden falls on toxic diesel generators. The use of small additions of hydrogen to diesel fuel improves the quality of mixture formation and combustion of fuel in the cylinders of the engine. Hydrogen additives lead to a reduction self-ignition speed processes and reduce time delay ignition.

The main part. One way to solve this problem is to use a small (0.2 ... 1.0% by weight) impurities hydrogen into liquid fuel of main engine. It should be noted that in this case, hydrogen is not used as an energy source that depose hydrocarbon fuel, and as a catalyst for the specified burn fuel in the cylinders of internal combustion engines.

The claim that hydrogen is acting as a catalyst for the combustion process is based on the fact that the small amount of it, despite the high calorific value ($Q_n = 120$ mJ / (KGC)) the quantity (up to 1.0% by weight) does not affect for combustion as an additional fuel. However, the presence of hydrogen in the cylinder stimulate the process of burning and it will act as a catalyst.

Studies of small impurities of hydrogen to the main liquid diesel fuel, which were conducted in the laboratory of promising energy technologies make it possible to assert that the impurities hydrogen lead to intensification of the burn process diesel fuel (especially heavy fuel) so that the workflow of ICE shifted to the left, which brings it to process at constant volume. It was also found that while there is a redistribution of heat balance ICE: reduces the proportion of heat that is emitted into the environment cooling system and exhaust gases. This leads to increased engine efficiency by 0.5 ... 5.0% depending on the amount of impurities hydrogen and the load, as confirmed by other researchers [1 – 3].

Previous studies have shown small impurities of hydrogen positively affect work on partial and transient conditions and using heavy grades of basic diesel fuel. In these cases, the relative positive effect is greatest.

However, the results are qualitative and not allowed to develop working methods of calculation processes using hydrogen impurities, ultimately determine the number of rational hydrogen addition in cylinder diesel ICE, to provide practical recommendations on the modernization of ICE at the use of such additives.

One very important factor that influences the efficiency of hydrogen impurities is a way to input into the engine. Adding hydrogen to the engine intake in the early stages of implementation was found as a simple tool use. But this means complication of internal combustion engine regulation, but also not completely safe by allowing formation of explosive mixtures in the intake tract and its inflammation followed by an explosion. Such phenomena have been observed, in internal combustion engines operating on the cycle Otto and diesel engines.

One possibility is the supply of small impurities of hydrogen using the solution proposed by a research team led by prof. N. N. Patrahaltseva [5]. The main idea is that hydrogen is added into diesel fuel on a wave of low pressure in high pressure pipe using a special device Thus on the pressure wave, diesel fuel saturated with hydrogen and fed nozzle and then injected into the cylinder of the engine. After injection and reducing the pressure in the cylinder, hydrogen is released from the diesel fuel and promotes for further grinding drops and diffuses rapidly in the cylinder space. Number hydrogen, which is added to the diesel fuel supply, is regulated by hydrogen pressure at the inlet to the unit. We should note that the amount of hydrogen that fed into the fuel pressure is inversely proportional to the engine load [8] and engine speed (fig. 1, 2).

However, the scientific literature not found sufficient information on the results of the pilot study about addition hydrogen into liquid fuel of main engine. Therefore, the objective of study was experimental confirmation of this theory and get high quality results.

Schematic diagram of solution is shown in fig. 3, and fig. 4 shows the waveform parameters in said system fuel cell [3].

Objective of hydrogen - to increase the heat generated during the chemical reactions, so that together with the heat introduced into the charge mixture to increase the total amount of heat and thus make the process more stable ignition. Hydrogen is in this case acts as energy saturated additives accelerating combustion. And thanks to the presence of hydrogen near the electrodes achieved the greatest effect on its additives.

The oscillograms in fig. 3 shows that the opening of the valve fig. 4 occurs when the expansion wave formed at the cut-off of supply and discharge valve landing on the saddle, approaches the valve. It is opened (opening of volume occurs inside the high pressure line) and the additive is introduced into the high pressure line, and, preferably near the nozzle to eliminate the potential ingress additives cutoff line in the high-pressure fuel pump and so on. In the next cycle hydrogen caught into the pipe is mixed with diesel fuel, dissolved therein. Then the next cycle thus obtained by mixed fuel in the usual way is injected into the cylinder. When hydrogen is in fine droplets of fuel is released in the volume of the combustion chamber, thereby creating the conditions for a volumetric fuel combustion and increasing combustion efficiency.

Application of this solution allows not to make significant changes in the design of the engine or fuel system, provide a high enough level of quality regulation and safety in the use of hydrogen.

Previous studies that have been conducted in the laboratory of promising energy technologies using an improved device of this type has shown that use of the device is very efficient in terms of rational adding hydrogen to diesel fuel and can increase engine efficiency and thus reduce fuel oil consumption by improving the characteristics input of heat in ICE, and promotes redistribution components of the heat balance in the direction of reducing heat loss in the system with cooling and exhaust gases. According to preliminary estimates of experimental data, reducing the consumption of diesel motor 8V12/12

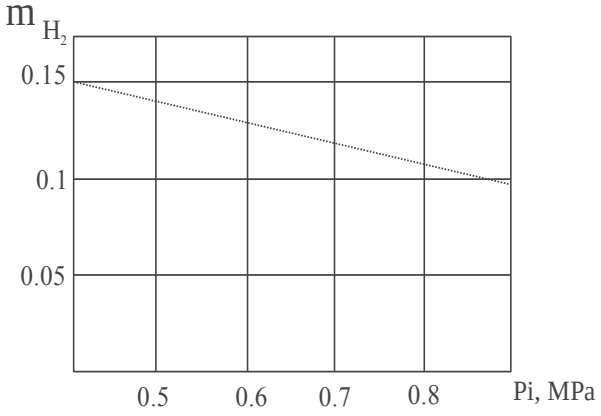

Fig. 1. The calculated dependence of the amount of dissolved H_2 load diesel 6CHN12/14, S*=10 sm^2 n = 1,700 rpm

* The surface area of the hydrogen dilution chamber

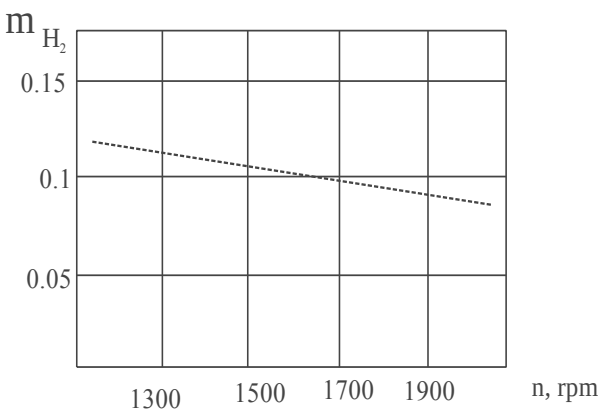

Fig. 2. The calculated dependence of dissolved H_2 from speed of diesel 6CHN12/14 at S = 10 sm^2, P_i = 0.896 MPa

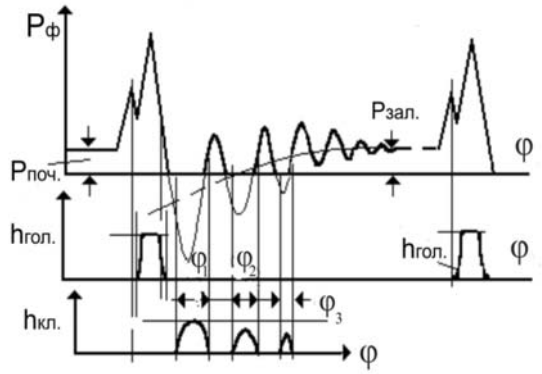

Fig. 3. Oscillograms changes in fuel pressure at the injectors ($P_{ф.}$), movement of the injector needle (hгол) and movement of the hydrogen valve ($h_{кл.}$)

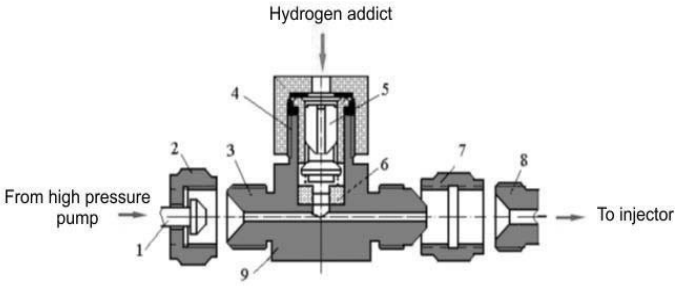

Fig. 4. Schematic diagram of the feeder and small impurities of hydrogen to diesel combustion engines [3]

(KAMAZ 740.11-240) is 0.4 ... 2.8% depending on the amount of hydrogen (0.1 ... 0.6% by weight) and load ICE (0,25...0,75 *Ne*). Inc addition, data were obtained for improving the environmental performance of the engine, the emissions of hydrocarbons (SmNn) decreased by 40 ... 50%, carbon monoxide (CO_2) — 15 ... 25%. Along with this was found that emissions of nitrogen oxides (N_xO_y) increased by 3 ... 7%, due to a certain increase in the maximum temperature cycle.

Required amount of hydrogen on board the vehicle of the event, such as KAMAZ 4308 (capacity fuel tank - 250 l (210 kg) while adding 0.5% hydrogen to diesel fuel is 2.1 kg, in any medium storages is quite acceptable. For example, when using metal hydride battery with the use of intermetallic TiFe, mass unit rated at 130...140 kg with the volume of 20...22 l, and the use of composite cylinders based on polymer materials — 13 ... 17 kg in a volume 28...30 liters.

However, these data are largely qualitative in nature and cannot be used for the final conclusions and recommendations for implementation.

Preliminary economic analysis of the effectiveness of small impurities of hydrogen into diesel fuel allows to assert that the cost of additional hardware and hydrogen has sufficiently small quantities compared to the cost of the engine is 0.09 ... 1.14%. Additional costs of hydrogen are about 0.11 ... 0.53% of the diesel fuel consumed (using hydrogen technical grade B or lower grade). In this case, reducing the cost of diesel fuel is about 4...9%, which makes the overall positive economic and environmental effects.

Towards the implementation of these measures need to solve complex tasks, primarily related to the experimental researches of working process of a diesel internal combustion engine using small impurities of hydrogen, definition of rational parameters of the process and the appropriate amount of hydrogen, which is added to diesel fuel to achieve maximum effect.

Findings

1. The use of small impurities of hydrogen as a catalyst combustion of diesel fuel, in the case of heavy grades, reduces fuel consumption and reduce the burden on the environment by reducing harmful emissions.

2. The need for an adequate mathematical models of workflow in ICE using small impurities that are made in the manner and mathematical models of the processes that take place in the device for supplying fuel by hydrogen.

3. Implementation of this measure is cost-effective and can be implemented at the current level of technology.

4. The proposed technical solution can be used in the composition of marine diesel power plants that run on heavy grades of fuel. The production of hydrogen can be carried on board by electrolysis. Using small impurities of hydrogen is particularly appropriate when working at partial and transitional modes activities vessels in ports, narrows, shed and other areas with high demands on environmental performance power plants.

Список литературы

[1] **Gomes Antunes J.M, Mikalsen R., Roskilly A.P.** An experimental study of a direct injection compression ignition hydrogen engine // International Journal of Hydrogen Energy, Volume 34, Issue 15, August 2009, Pages 6516–6522.

[2] **Szwaja S, Grab-Rogalinski K.** Hydrogen combustion in a compression ignition diesel engine. Int. J. Hydrogen Energy (2009), doi: 10.1016/2009.03.020.

[3] **Шкаликова В.П., Патрахальцев Н.Н.** Применение нетрадиционных топлив в дизелях: Монография. Изд. 2-е, доп. – М.: Изд-во РУДН, 1993. – 64 с.

[4] **Патрахальцев Н.Н.** Повышение экономических и экологических качеств двигателей внутреннего сгорания на основе применения альтернативных топлив: Учеб. пособие. – М.: РУДН, 2008. – 248 с.

[5] **Керимов З.Х.** Математическое моделирование неустановившихся процессов в двухфазном потоке в системе впрыска топлива дизельного двигателя // Азербайджанское нефтяное хозяйство. – Баку. – 2003. – №7. – с. 42–47.

[6] **Керимов З.Х.** Математическое моделирование гидродинамических процессов с учетом двухфазной среды в граничных полостях дизельной системы впрыска топлива// Авиационно-космическая техника и технология. – 2004. – № 8(16). – с. 63–69.

[7] **Патрахальцев Н.Н., Савастенко А.А., Виноградский В.Л.** Регулирование начального давления топлива – методы и средства повышения экономичности и эффективности работы дизелей // Автомобильная промышленность. – 2002. – № 3. – с. 8–19.

[8] **Тимошевський Б.Г., Ткач М.Р., Шалапко Д.О.** «Поліпшення робочих характеристик дизельних двигунів за допомогою додавання водню» // Водний транспорт, 2016 – №2 (25) – С. 24–28.

Статтю рекомендує до друку
д-р техн. наук, проф. *С. І. Сербін*