Technical science and innovation

Volume 2020 | Issue 1 Article 3

3-31-2020

INVESTIGATION OF DIESEL ENGINE`S WORKING PROCESS ON LIGHT FUEL

J.O. Khakimov
Tashkent State Technical University, husantwin@mail.ru

M.G. Shatrov
Moscow Automobile and Road Construction State Technical University

J.P. Turdiev
Tashkent State Technical University

Recommended Citation

Khakimov, J.O.; Shatrov, M.G.; and Turdiev, J.P. (2020) "INVESTIGATION OF DIESEL ENGINE`S WORKING PROCESS ON LIGHT FUEL," *Technical science and innovation*: Vol. 2020 : Iss. 1 , Article 3.
DOI: https://doi.org/10.51346/tstu-01.20.1-77-0047
Available at: https://uzjournals.edu.uz/btstu/vol2020/iss1/3

UDC 621.433.052

INVESTIGATION OF DIESEL ENGINE`S WORKING PROCESS ON LIGHT FUEL

J.O. Khakimov, M.G. Shatrov, J.P. Turdiev

Abstract. *The article considers the investigation results of the working process of diesel on light fuel. Consumption of natural resources in the form of hydrocarbon fuels, which is steadily increasing in transport, the number of rolling stock, and combustion products of motor fuels cause environmental pollution. It is shown that the transition to cheaper alternative types of fuel, by its characteristics, not inferior to liquid motor fuels, is one of the options to reduce operating costs and harmful emissions. The scheme of classification of gas systems of fuel transfer is presented: by design of the system of filling and storage of gas; by quantity of the substituted basic fuel in the system of fuel supply; by method of dosing of fuel; by name and place of sending of a control signal; by design of the unit of decrease in pressure of gas; by design and a site of heating devices of a gas stream of a high pressure; by a method of ignition of a gas-air mix; by a method of change of indicators of working process; by an aggregate condition of used According to the results of theoretical and operational research of the gas engine based on a supercharged diesel engine: the necessity of using a gas injector power supply system has been established; the power and torque of the gas engine created on the basis of a supercharged diesel engine practically do not differ from that of the diesel engine, which is explained by a relatively high degree of compression for engines with spark ignition (ε=2); it has been shown that in the long term it is possible to use gas supply systems under pressure directly into the engine cylinder. As a result, the most affordable commercial alternative fuel for road transport in Uzbekistan turned out to be natural gas.*

Key words: *work process, light fueled diesel, natural resources in the form of hydrocarbon fuels, growth in the number of rolling stock, environmental pollution.*

Uzbekistan's Republic maintains a large fleet of vehicles that do not meet the toxicity standards required. The use of gas fuels is one of the ways that this problem can be solved without significant engine design changes.

Among alternative fuels, natural gas is the most promising for the near future, the motor properties of which allow it to be used for engines with almost no modification of basic models. In addition, the unit's capacity can be maintained, its efficiency increased, and the content of exhaust gas toxic components decreased [1, 12].

Natural gas can be powered by gasoline and diesel engines, as well as other types of engines. Designed gas changes based on standard engines make it easy to convert the engine with minimal design changes from one type of fuel to another.

A gas engine's basic operating principles are well understood, but the development of each new model starts almost from scratch, as the current guidelines are based solely on the formation and service experience of specific engines. Thus, there are no sufficiently clear recommendations for a rational way of regulating the gas engine working process. Available experimental processes of mixing and combustion, and their interpretation are quite contradictory. For the purpose of scientific substantiation of gas engine design and forecasting of their operational, economic and environmental characteristics it is necessary to study in depth the peculiarities of the gas working process, which will allow developing mathematical models of such processes with technical measures and obtaining an experimental assessment of their effectiveness.

Main objectives of the investigation:

- Review and analyze the conversion of diesel engines with natural gas injection;

- To develop a method of conducting comparative experimental studies of diesel engines with supercharging and gas engines based on it;
- To make theoretical researches of influence of constructive and regime factors of gas-feeding equipment on characteristics of the engine;
- To carry out the joint analysis of theoretical and experimental data and to develop recommendations of works on transition of diesel engines with supercharging on a food by natural gas.

The object of research is the ISUZU 4HG1 engine of the ISUZU NQR-71 truck.

Theoretical research is carried out using the mathematical apparatus of the computer-based regression analysis and operational tests are carried out.

The scientific background has been developed for the use of natural gas in supercharged diesel engines.

The practical value of the work involves the design of a methodological approach to the use of compressed natural gas in supercharged diesel engines on the ISUZU 4HG1 diesel engine as an example.

The scope of the work includes identifying and studying matters related to the conversion of an ISUZU NQR-71 truck on compressed natural gas power supply, conducting theoretical and experimental research on the selected topic. In-depth analysis of literary and electronic information sources, and documents containing the results of previous work on this topic [2, 5, 14]. Carrying out theoretical research and operational tests of trucks with diesel and gas fuel supply systems. The generalized analysis of the results of theoretical and experimental research is carried out.

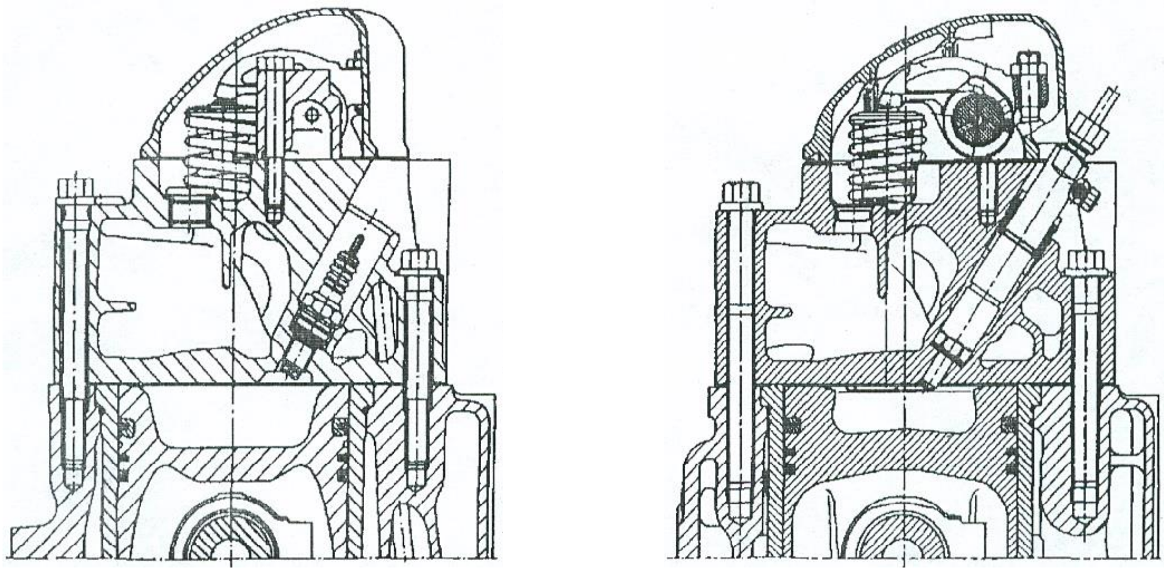
Analysis of the modern condition of gas engine fuel supply systems.

The main difference between a gas engine and a diesel prototype is the complete replacement of one power system with another. If a truck is converted from diesel to gas, the fuel tanks and the entire diesel fuel supply system are removed. Instead, gas cylinders are installed, the system of high and low pressure gas mains, the system of gas fuel dosing, and the ignition system are installed. At the same time, depending on the design features of the engines, and primarily the presence of a turbocharger, there are also different working processes in the engine.

A sufficiently high specific power density is obtained by the spark-ignition gas engine, which works on the principle of "stoichiometric composition of the mixture". However, compared to diesel and gas engines running on "poor blend compositions", the thermal loads on the engine parts increase significantly, which leads to the need to revise the design and materials of a number of base diesel parts. At the same time, the content of NO_x nitrogen oxides in the exhaust gases increases significantly, and in order to reduce them, "stoichiometric" gas engines must be equipped with three-component exhaust gas neutralizers [3, 8, 13].

It is known that in the gas engine running on "poor mixture compositions" the level of thermal loads on the main parts of the engine does not exceed the level of thermal loads of the base diesel engine, and in some modes (when operating on α=1,5 ... 1,7, i.e. modes of full load), even appear to be slightly lower [4, 20].

The gas engine was structurally constructed using a diesel model. The main design feature is replacement of diesel injectors with spark plugs and further development of pistons and heads to reduce the degree of compression to 12...13 units (Fig.1).



a) b)

Fig. 1. Example of a gas engine (a) and diesel prototype (b)

In terms of complexity, the gas engine power supply network can be divided into four generations. Similar to gasoline cars, the main sign of division can be the way of dosing and supply of gas fuel to the engine cylinders.

Gas-diesel systems continue to develop along with the advancement of gas-vehicle engine control systems. The experience of operation of gas-diesel vehicles in the middle of the 90s of the last century has shown the inefficiency of work and unsatisfactory environmental characteristics, low reliability and maintainability [6, 15]. However, today there are developments of fuel systems with direct gas supply to cylinders of engines operating in gas-diesel mode (Fig. 2).

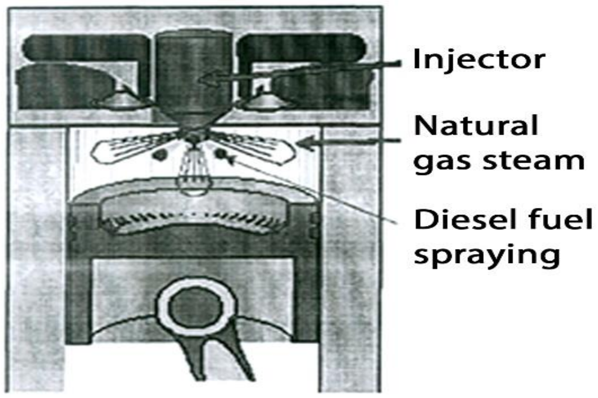


Fig. 2. MAN and Westport gas-diesel engine project with HPDI technology

MAN and Westport's HPDI technology is a direct injection of high-pressure gas and diesel fuel. This approach allows to achieve high replacement of diesel fuel with gas, up to 95% (while mechanical systems reached only 40...70% replacement), the same traction and power characteristics with a diesel prototype, the best environmental characteristics, high efficiency, working process on the type of diesel [7, 21].

There is a need to develop a completely new gas supply system, a microprocessor-based control system and engine management algorithms when converting a diesel engine's working cycle to light oil.

Fuel supply systems for gas engines based on diesel engines.

The transformation of a diesel engine into a gas option is economically feasible as the cost of production of diesel and gas-diesel is lower than the cost of a gas engine and, on the other hand, the low cost of natural gas helps you to recover the costs in a short time.

In the above case, there may be two approaches for diesel engines:

- gas-diesel supply with replacement of up to 70...80% of diesel fuel with gaseous fuels (reduced petroleum gas or compressed natural gas);
- conversion to gaseous fuel only

Each of the two solutions described above has its advantages and disadvantages. However, the main advantage of the second solution is the creation of an engine running on environmentally friendly fuel with sufficient natural resources [9, 18].

Gas supply systems are multistage direct control gearboxes whose workability is determined by the discharge that occurs in the motor mixer.

The classification of gas fuel supply systems is presented below (Fig. 3).

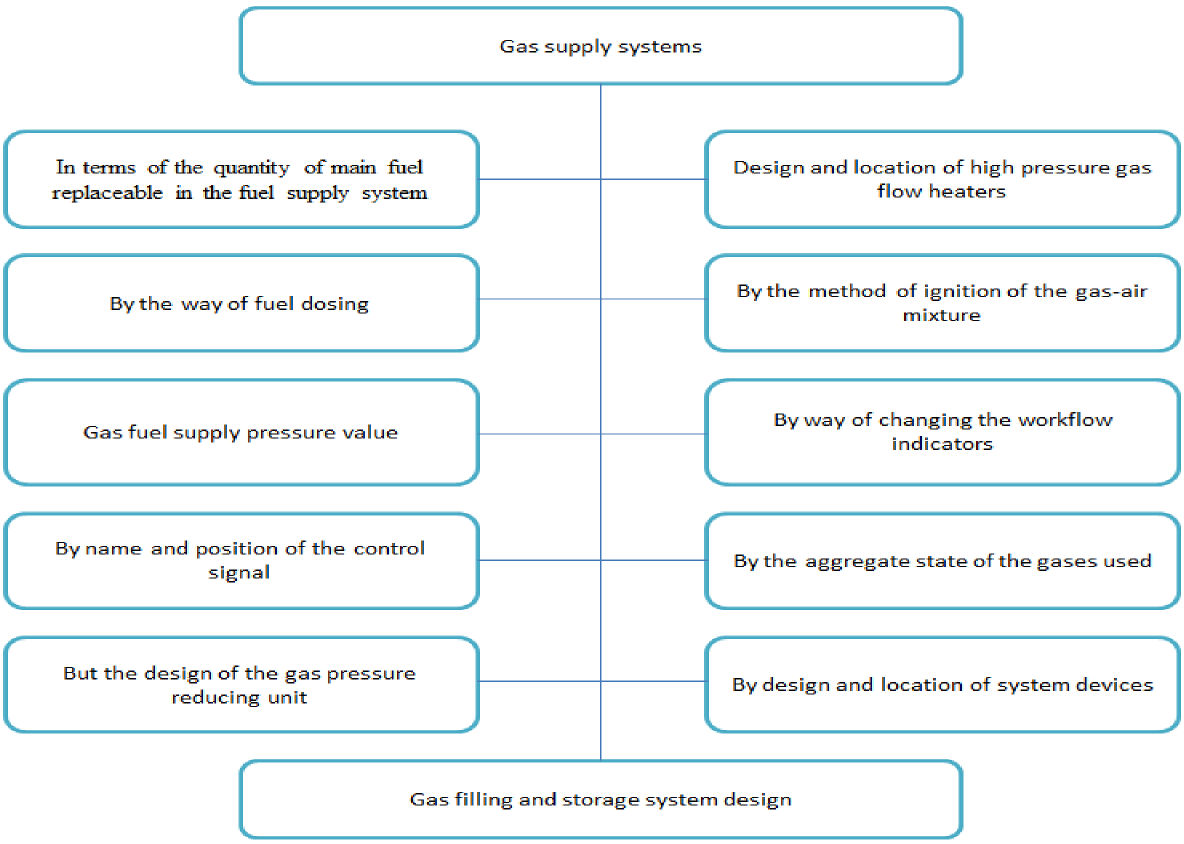


Fig. 3. Classification scheme for gas fuel supply systems

Theoretical studies on the choice of parameters of the fuel supply system in the gas engine with supercharger.

The following work has been done:

- development of design documentation (selection of the type of power supply systems (ejector and injector); selection of the ignition system type; selection of the type of interrupter-distributor; introduction of changes in the cylinder head; introduction of changes in the piston; introduction of changes in the drive of the interrupter-distributor; introduction of changes in the intake system for the installation of gas injectors or development of gas mixing device for the ejector power supply system; selection of types of electronic control unit (ECU) taking into account the coordination of work with the selected basic system of ignition;

- Thermal operation of a light fuel diesel engine was analyzed;
- Combustion heat of the fuel is not equivalent to the calorific value of the fuel mixture. The laws of additivity (addition) are not applicable in the calculations.

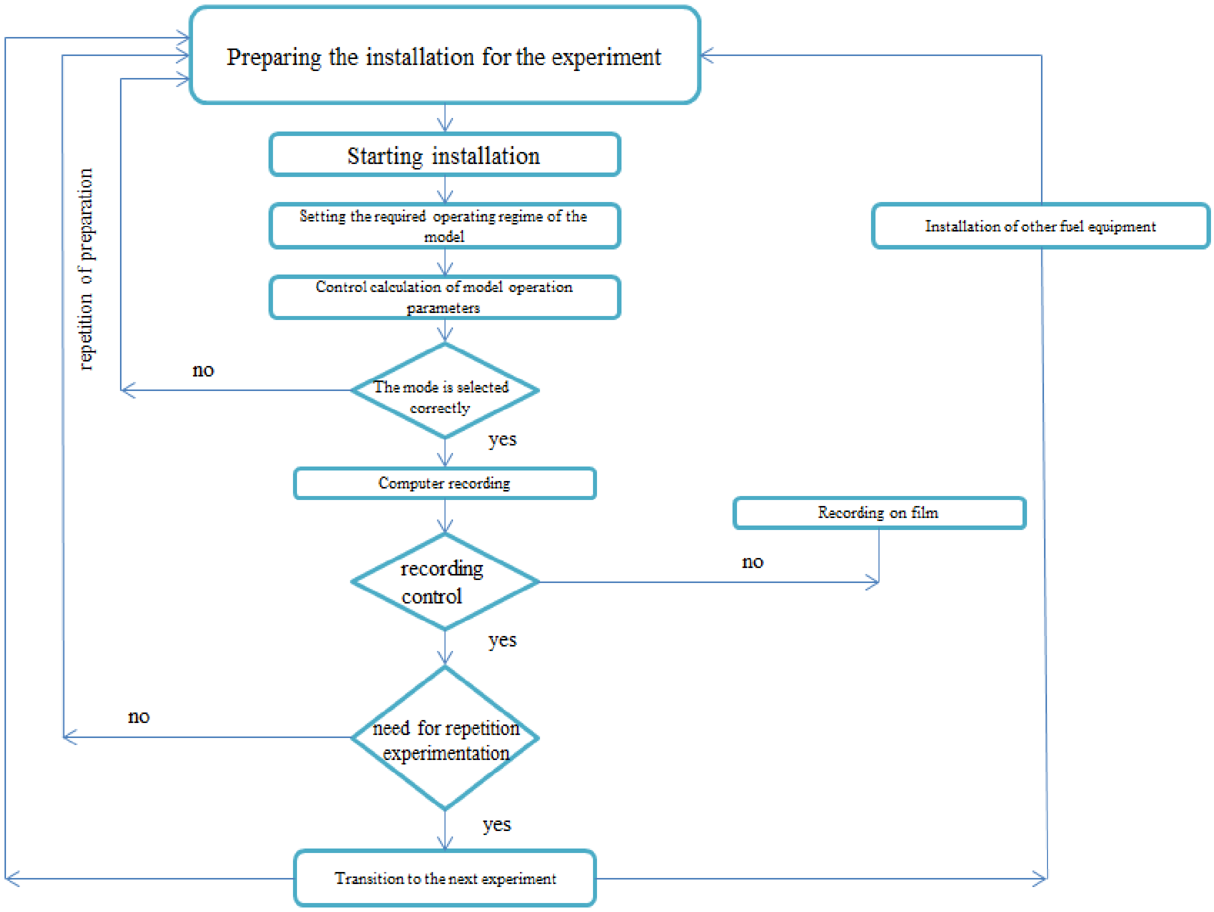


Fig. 4. Algorithm of the experiment

Testing of the gas engine with supercharger.

Throughout research practice, experimental methods are commonly used along with computational-theoretical methods to determine the parameters of gas engine fuel apparatus [10, 11, 17]. This is explained by the fact that all theoretical research methods are based on certain hypotheses and, therefore, are approximate and require testing (Fig. 4). In addition, the values of some values can be obtained only by experiment. Thus, experimental research is a necessary part of the process of creation and improvement of engine gas supply equipment.

The object of testing in this work is ISUZU NQR-71, designed for the transport of various goods with GVW of 4 tons [16, 19].

Table 1 shows the technical data of the ISUZU NQR-71 turbocharged diesel engine and gas engine based on it.

Table. 1.

Technical characteristics of ISUZU NQR-71

1.	Wheel configuration / driving wheels	4x2 / rear	4x2 / rear
2.	Load capacity, kg	4000	4000
3.	Length	6214	6610
4.	Width	2150	2150
5.	Height	2454	2454
6.	Wheelbase	3815	3815
7.	The front wheel track	1665	1665
8.	Rear wheel track	+1650	1650
9.	Chassis weight, kg	2500	2500
10.	Permissible gross weight, kg	8000	8000
11.	Engine brand	ISUZU NQR-71, four-stroke turbocharged diesel engine	ISUZU NQR-71, four-stroke gas turbocharged
12.	Number and arrangement of cylinders	4 in a row	4 in a row
13.	Degree of Compression	19: 1	12: 1
14.	Working volume, cm3	4554	4554
15.	Maximum power, kWhp. (rpm-1)	89/121 (3200)	89/121 (3200)
16.	Maximum torque, N · m (min-1)	304 (1800)	304 (1800)
17.	Engine toxicity level	Compliant	Compliant
18.	Engine lubrication system	Crankcase. Combined: under pressure from a gear pump and spray	Crankcase. Combined: under pressure from a gear pump and spray
19.	Motor location	Front longitudinal	Front longitudinal
20.	Steering wheel control	Power steering screw - ball nut - rail sector	Power steering screw - ball nut - rail sector
21.	High pressure fuel pump	"ZEXEL", in-line	HBO ISUZU
22.	Fuel tank capacity, liter	one hundred	one hundred
23.	Stabilizers	Front and rear axle stabilizers	Front and rear axle stabilizers
24.	Maximum speed, km / h	one hundred	one hundred
25.	Control fuel consumption	At a speed of 60 km / h: 18 l. per 100 km	At a speed of 60 km / h: 18 m^3 per 100 km
26.	Fuel consumption monitoring range	At a speed of 60 km / h, at least 500 km	At a speed of 60 km / h, at least 300 km

Thus, as a result of theoretical and operational research of the gas engine based on a supercharged diesel engine:

1. The necessity of using the gas injector power supply system is established.

2. The power and torque of the gas engine created on the basis of the supercharged diesel engine practically do not differ from the diesel parameters, which is explained by a relatively high degree of compression for engines with spark ignition (ε=2).

3. It is established that in the long term it is possible to use the systems of gas supply under pressure directly into the engine cylinder.

References

1. Grafov P.O. Stimulirovanii primeneniya prirodnogo gaza v kachestve motornogo topliva v nekotorix stranax mira (dannie 1999-2002 gg.) / P.Grafov // AvtoGazoZapravochniy Kompleks + Alternativnoe toplivo, 2015. №1. S. 66-69.
2. Lotko V., Lukanin V.N., Xachiyan A.S. Primenenie alternativnix topliv v dvigatelyax vnutrennego sgoraniya. – M.: MADI (TU), 2000. – 311 s.
3. Matmurodov F., Sobirov B., Tulanov I., Mirzaabdullayev J., Khakimov J., Daminov O. Mathematical Modeling of the transfer of energy forces from the engine through hydro transmission and hydro differential to executive bodies. // World Journal of Mechanics (Web of Science). – USA, Scientific Research Publishing, 2019; P. 105-112.
4. Xakimov J.O., Mirzaabdullaev J.B., Muxammadjonov M.N. Analiz vozmojnosti ispolzovaniya prirodnogo gaza s tselyu snijeniya teplovix nagruzok v porshnevix dvigatelyax i uluchsheniya ix ekologicheskix pokazateley. // Mejdunarodnaya nauchno-prakticheskaya konferentsiya “Avtomobile- i traktorostroenie”. – Minsk, 21-24 may 2019 g. S. 146-149.
5. Matmurodov F.M., Daminov O.O., Mirzaabdullayev J.B., Hakimov Zh.O. Mathematical modeling of transfer of the moment from the engine to the executive mechanism. – Austria, Vienna. “East West” Association for Advanced Studies and Higher Education GmbH. // European science review (Scientific journal). 2017 (March–April); № 3–4. P. 75-77.
6. Tulaev B. Matematicheskoe modelirovanie protsessov teploobmena v DVS. Monografiya. – T.: Adabiyot uchquni, 2018 yil, – 176 b.
7. Bazarov B.I. Nauchnie osnovi energo-ekologicheskoy effektivnosti ispolzovaniya alternativnix motornix topliv. Dis. … dokt. texn. nauk. – Tashkent: TADI, 2006. – 302 s.
8. Tulaev B., Xakimov J.O., Daminov O.O. Matematicheskaya model gazoballonnogo avtomobilya s dvuxtoplivnoy sistemoy pitaniya. // J: Texnicheskie nauki i innovatsiya, 2019. №1(01), S. 44-49.
9. Daminov O.O., Mirzaabdullaev J.B., Xakimov J.O. Texniko-ekonomicheskoe obosnovanie perspektivi primeneniya vodoroda v kachestve topliva DVS. // J: Sotsialno-gumanitarnie nauki v sisteme obrazovaniya, 2019. №2, S. 94-100.
10. Dvigateli vnutrennego sgoraniya. V 3 kn. Kn. 1. Teoriya rabochix protsessov: Uchebnik dlya VUZov / Lukanin V.N., Morozov K.A., Xachiyan A.S. i dr./ Pod red. Lukanina V.N. i Shatrova M.G. – 3-e izd., pererab. i ispr. – M.: Visshaya shkola, 2007. – 479 s.: il.
11. Bechtold R.L., Wilcox G. An Assessment of the Infrastructure Required to Refuel a Large Population of Natural Gas Vehicles. //SAE Technical Pap. Ser. № 892068, 1989. 23 p.
12. Development of oxygen sensor for compressed natural gas engine. / Kubota Hiroshi, Fujita Hiroyuki, Okawa Teppei, Muzitani Akio // JSAE Rev. 2000: 21: №2. P. 241-263.
13. Dual fuel engine, which utilizes valve lubricant as a pilot fuel. Patent №5870978 SSHA, MPK6F02B7 / 06 / Willi Martin L., Wu Min, Fischer Seffrey T.; Caterpillar Inc. - №79350; Zayavl. 15.05.98; Opubl. 16.02.99; NPK 123/27.
14. Erdgas-mobil Multiplea Fiat Bupower // AMZ: Auto, Mot., Zubehor, 2000; 88: №9. P. 40-41.
15. Eroxov V.I. Sistemi vpriska topliva legkovogo avtomobilya. – M.: Transport, 2002. – 174 s.
16. Tulaev B.R., Xakimov J.O., Mirzaabdullaev J.B. Matematicheskaya model peremesheniya reyki toplivnogo nasosa dvigatelya vnutrennego sgoraniya. // East European Scientific Journal. (Warsaw, Poland). №2 (30), 2018. part 2. P. 66-68.
17. Pat. 2211360 RF, MPK 7 F 02 M 21/04, F 02 V 69/04. Dvuxtoplivnaya sistema pitaniya dlya gazovogo DVS / N.G. Pevnev, A.V. Trofimov, I.V. Xamov (RF) // Otkritiya. Izobreteniya, 2018. №24.

18. Pevnev N.G. Dvuxtoplivnaya sistema pitaniya karbyuratornogo dvigatelya / N.G.Pevnev, A.P.Elgin // Avtomob. dorogi Sibiri: Sb. dokl. mejdunar. nauch.-texn. konf./ SibADI. – Omsk, 2016. S. 495-497.
19. Pevnev N.G. Signalizator minimalnogo rezerva gaza v ballone avtomobilya / N.G. Pevnev, A.K. Gavrilov, L.N. Buxarov // Avtomob. Transport, 2010. №10. S. 38-39.
20. Perspektivi primeneniya mikroelektronnix sistem toplivopodachi i upravleniya DVS pri zamene jidkogo topliva na gazovoe. / Krupskiy M.G., Kuzin V.E., Kuyanov Yu.F. // Vestnik mashinostroeniya, 2000. №7. S. 31-33.