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Research Article

REDUCING POLLUTION WITH HYDROGEN FUEL IN DIESEL ENGINES

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Obidjon Ergashev
Research Institute of Environment and Nature Conservation Technologies, Uzbekistan

Zikrilla Alimov
Research Institute of Environment and Nature Conservation Technologies, Uzbekistan

ABSTRACT

The integration of hydrogen fuel in a diesel engine has gained significant attention as a promising alternative to conventional fossil fuels. This combination offers potential advantages such as reduced emissions of harmful pollutants and improved fuel efficiency. By introducing hydrogen into the combustion process of a diesel engine, the overall performance can be enhanced while addressing environmental concerns. This abstract explores the feasibility and benefits of using hydrogen fuel in diesel engines, highlighting its potential impact on sustainable transportation and the environment.

KEYWORDS

Diesel engines, hydrogen, alternative fuels, emissions, fuel efficiency, new combustion modes, catalytic converters, exhaust gas recirculation, sustainable energy, transport systems.

INTRODUCTION

To date, we have invested much of our research efforts to suppress in-cylinder pollutant formation in diesel engines. A significant portion of the effort has been directed towards exploring the use of new combustion modes that have reduced pollutant formation in the naturally aspirated and boosted diesel engine. Increasingly stringent emissions regulations will force the engine to be equipped with a 3-way catalyst or NOx trap to further reduce the formation of regulated pollutants. However, the use of such after treatment

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devices will require the engine to run at an air-fuel ratio other than the lean operation which it is most efficient. Running the engine stoichiometrically or with increased EGR to reduce NOx formation both result in increased fuel consumption and higher heat load in-cylinder, negating the positive effects of the new combustion modes on fuel efficiency and soot. An alternative to these strategies would be to run the engine with a different fuel that would allow it to meet stringent emissions regulations while maintaining or improving the fuel efficiency of the engine. Hydrogen has been viewed as one of the most promising alternative fuels. The main problem with using hydrogen in a diesel engine is the low power output. This is due to the low energy density and wide flammability limits of hydrogen which result in high heat release rates and ultimately engine knock. To implement hydrogen combustion in a diesel engine, no engine modification and no injector development is required [1-2].

The utilization of hydrogen fuel in diesel engines presents a compelling avenue towards achieving cleaner and more efficient transportation systems. With growing concerns over environmental pollution and the finite nature of fossil fuels, the integration of hydrogen as an alternative fuel source holds immense promise. This introduction delves into the rationale behind incorporating hydrogen fuel in diesel engines, outlining the potential benefits, challenges, and implications of this innovative approach. By exploring the synergies between hydrogen and diesel technology, this paper seeks to shed light on the transformative potential of this integration in the realm of sustainable energy and transportation [3-4].

METHODS

Methodology of laboratory testing of diesel engines [5]

2.1 . Stand operation procedure

- Balancing machine works in generator mode.
- Turn on the main switch in the distribution cabinet (Fig. 1).
- Set the range switch on the right side of the remote control to position III. In accordance with the intended direction of rotation of the balancing generator, set the switch under the rotation frequency device in the appropriate position.
- Turn on the main control current switch on the right side of the remote control. "Resistance operation" signal light indicates readiness for operation.
- Activate fan switch.
- Activate the trigger switch. Setting the excitation voltage to 220 V using the control device on the remote control.
- Setting the regulators to the push position using the "Increasing number of revolutions" button.
- The balancer generator can now be controlled from the engine under test.

1) Then use the buttons "The number of revolutions is increasing - decreasing" located on the right side of the remote control.

2) Deactivation is carried out in the following sequence:

a) turning off the engine from the balancer generator;

b) turn on the engine fan;

c) turn off the main switch in the distribution cabinet.

- Engine installation for testing.

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● Braking of the internal combustion engine on the electric brake stand is carried out in accordance with GOST 7057-2001, section, without removing the tractor from the tractor chassis through the power take-off shaft. During the test, the tractor is installed indoors.

Figure 1. Distribution cabinet with load resistance

Figure 2. Control panel

● Engine testing frequency is set according to GOST 70/23.2.7-88 [8].

● To brake the engine, the tractor must be driven to a standstill (remove the PTO cover first) and the PTO drive shaft of the tractor is used for the most useful rotation speed of the balancer shaft when braking engines of different power using the cardan shaft. connection with the intended reducer.

Connecting the shaft of the reducer with the shaft of the balancer using a transmission.

● Install the exhaust pipe to the exhaust pipe of the engine.

● Shut off the fuel supply to the engine from the tractor tank, disconnect the fuel line from the engine coarse fuel filter and connect the fuel line from the fuel gauge assembly instead. If necessary, connect the equipment to measure the thermal regime of the engine.

● Turn on the tumbler on the remote control of the fuel gauge, as a result of which the cover opens and fuel flows from the tank of the device to the engine.

● Remove air from the engine power system.

● If there is any fuel or oil leakage in the engine, eliminate it.

● Check the water in the radiator, the oil in the engine crankcase, fuel pump, regulator and power take-off shaft reducer and top up if necessary.

● Start the engine, turn on the tractor PTO, and gently transfer the engine's average crankshaft rotation from the tractor PTO to the brake shaft. Before doing this, II. and carry out the operations mentioned in Sections III.

● Let the engine run at medium speed for 5 minutes, then increase the crankshaft rotation frequency to the maximum.

● Load the engine (the button "The number of revolutions decreases" on the right side of the remote control) to 0.2-0.3 of the maximum power and run the engine in this mode for 5-7 minutes. Then gradually increase the load to a value of 0.90-0.95 of the maximum power and continue to warm up for 30 minutes to the operating temperature specified in the relevant technical documents for the engine.

● Check and listen to the engine and braking system and the transmission to it during the warm-up process.

2 . 2. Device for measuring fuel consumption.

● Scales and stopwatches of the VNS type are designed to determine the hourly fuel consumption by measuring the duration of consumption of a portion of the fuel given for the experiment during the experience of the engines in stand tests.

2.3 . A device for measuring the frequency of the rotating shaft of a balancer machine.

● A tachometer that measures revolutions of a balancer machine directly on its shaft.

2.4 . Technical safety and industrial sanitation requirements.

● Rotating parts of diesel engines, test stands and measuring instruments must have protective devices.

2.5. Technical service. Each element of the electrobrake stand is subject to mechanical wear, so constant attention to it ensures continuous operation [6].

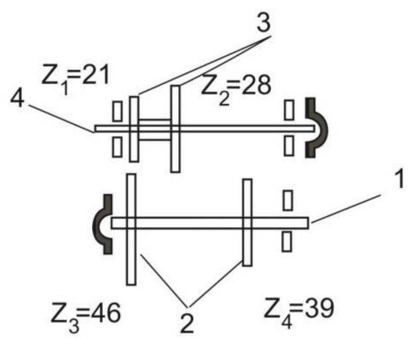

Fig. 3. The reduction scheme of the "Rapido" brake stand

1) From the tractor. 2) Permanently installed 3) Double toothed racks move along the slots 4) Rapido.

(Figure 3). Brake stand reducer scheme

$i_1 = \frac{33}{31} = \frac{46}{21} = 2{,}19$(at 540 rpm for tractors with PTO)

$i_2 = \frac{34}{32} = \frac{39}{28} = 1{,}39$(at 1000 rpm for tractors with PTO)

The optimal operating mode of the two-stage reduction gear balancing machine is possible at a rotor speed in the range of 500-1500 rpm.

When testing tractor engines through the power take-off shaft, it is necessary to increase the speed to the required speed through a reducer (power take-off shaft) installed between the tractor and the balancing machine.

A two-stage reducer (in our case) allows working in two speed modes with a gear ratio i 1 = 2.19 and i 2 = 1.39 on the stand.

Table 1

Determining the indicators of the useful work coefficient of the reducer No. 1 of the Rapido brake stand by the method of thesometry. Rapido = 2.19. Traction cycle through the tractor (QKV) = 540 rpm [7].

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No. P/P	Weight mechanism indicators kg	Test No. 1		Test No. 2		Test No. 3		average value of useful work coefficient
		Repeatability		Repeatability		Repeatability		
		Download increase	Increase in download	Increase in download	Increase in download	Increase in download	Increase in download	
-	-	-	-	-	-	-	-	-

2.5. State Standard Of Uzbekistan Diesel Fuel Technical Conditions Own DSt 989:2010

2.5.1. Technical requirements [8]

2.5.2. Diesel fuel must comply with the requirements of this standard and be prepared according to technological documents approved in the prescribed manner.

2.5.3. The fuel must comply with the requirements and values specified in Table 2 in terms of physical and chemical parameters.

Table 2

Naming of the indicator	Value for brand				Control method
	TD-L	TD Z-1	TD Z-2	TDU	
	MUT 02 5131	MUT 02 5132		MUT 02 5131	
1 Cetane number, not less	45	45	45	45	According to GOST 3122 or [1].
2 Density at 20 °C, kg/m ^{3}, not much	860	860	840	860	According to GOST 3900 or GOST ISO 12185 or GOST 31392 or [2] or [3]
3 Fractional composition: 50% drive at temperature, °C, not higher	280	280	280	290	According to GOST 2177 or [4].
driving at 90 % temperature. °C, not higher				360	

96% drive at temperature, °C, not higher	360	350	350		
4 Solidification temperature, °C, not high	Minus 10	Minus 35	Minus 25	0	GOST 20287 and clause 7.3 of this standard or [5].
5 Clouding temperature, °C, not high	Minus 5	Minus 15	Minus 5	5	According to GOST 5066 (second method) or [6].
6 Filtering coefficient, not much	3	3	3	3	According to GOST 19006
7 Amount of water	no	no	no	no	According to GOST 2477 or GOST 31394 or [7].
8 Amount of mechanical impurities	no	no	no	no	According to GOST 6370 or [8].
9 Limit temperature of filtration, °C, not high	Minus 5	Minus 25	Minus 15		According to GOST 22254 or [9] or [26]
10 Specific resin concentration, mg per 100 cm ^{3} of fuel, not much	40	30	40		According to GOST 8489 or [10].
11 Number of iodine, g per 100 cm ^{3} of fuel. not much	6	6	6	6	According to GOST 2070
12 Coking 10% residue, not more than %	0.2	0.3	0.2	0.3	According to GOST 19932 or [11].
13 Usage, %, not much	0.01	0.01	0.01	0.01	According to GOST 1461 or [12].
14 Mass fraction of sulfur in fuel, not more than %: Type I Type II	 0.2 0.5	 0.2 0.5	 0.2 0.5	 0.2 0.5	According to GOST 19121 or GOST 1431 or GOST 1437 or [13] or [14]

15 Mass fraction of mercaptan sulfur, not more than %	0.01	0.01	0.01	0.01	According to GOST 17323

determined the amount of exhaust gases from TD-L diesel under laboratory conditions.

Table 3

Exhaust gas determination table [9].

No	**Model Automobile**	**Automobil e namber**	**Results of measurement of smoke**				
			Before the addition of hydrogen fuel				
			free acceleration mode				
			CO	**CO_2**	**CH**	**NO_x**	**maximum shaft speed mode**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	-	-//-	-	-	-	-	-
No p/p	**Model Automobile**	**Automobil e number**	**After the addition of hydrogen fuel**				
			free acceleration mode				
			CO	**CO_2**	**CH**	**NO_x**	**maximum shaft speed mode**
1	-	-//-	-	-	-	-	-

RESULTS AND DISCUSSION

3.1. Research Methods Of Data Processing And Experimental Tests.

In order to sustainably develop agricultural machinery in the Republic of Uzbekistan and provide producers of agricultural products with modern high-performance machinery and technologies for growing agricultural crops that meet international standards and are suitable for regional natural-climate and soil conditions The center for certification and testing of agricultural techniques and technologies under the Cabinet of Ministers of the Republic of Uzbekistan is a laboratory capable of testing various types of techniques [10].

Figure 4 shows an overview of the Rapido load cell and electric brake stand for PTO testing of tractor engines.

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Figure 4. Working condition of GPF-5-17n electric brake stand "Rapido" weight measuring device when testing tractor pressure.

High-tech environmental, functional and power tests of all types of tractors and vehicles using software to manufacture, create and integrate measuring modules, electronic units, information-measuring systems, microprocessors and various converters into the stand equipment system allows to transfer.

5. Laboratory research implementation processes

The main problem of using hydrogen is the availability of a way to get it in the right amount and store it on board the tractor. Therefore, although there are experienced hydrogen filling stations in a number of countries (more than 10 in the world), clean hydrogen cars are not widely used at the moment. The method of using hydrogen fusion somewhat simplifies the issues of storing the small amount of hydrogen needed, for example in cylinders, but still requires a refueling infrastructure. Therefore, it is better to use an autonomous source of hydrogen, which allows you to obtain it in its pure form or in a mixture with other gases. At the same time, modern science has a number of methods, including methods of obtaining hydrogen by electrolysis of water and catalytic conversion of hydrocarbons. The prospects of the catalytic conversion method have been separately considered above, but these methods have not been applied in practice and require time and financial costs associated with the organization of scientific research [11].

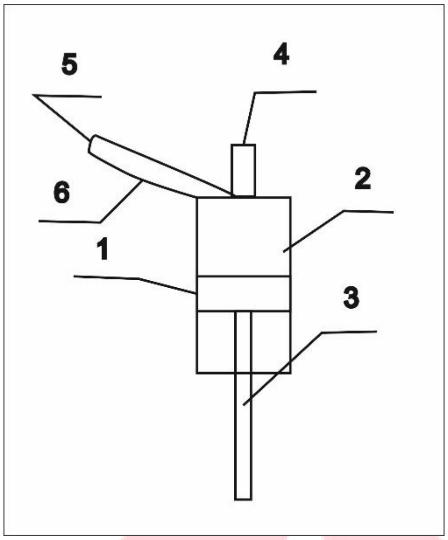

Figure 7. A scheme for supplying hydrogen gas as an additional fuel to a diesel engine.
1- piston, 2- cylinder, 3- connecting rod, 4- diesel fuel, 5- air, 6- hydrogen gas.

Hydrogen gas was additionally supplied to the diesel engine under laboratory conditions (Fig. 7).

3.2. Diesel engine test results.

Table 4.
D-243 CHARACTERISTICS

Block material	cast iron
Fuel type	diesel
Number of cylinders	4
The number of valves in the cylinder	2
Piston path, mm	125
Cylinder diameter, mm	110
Compression ratio	16
Engine volume, cubic cm	4750

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Engine power, ok/rev.min	60/2200
Torque, Nm/rev.min	298/1600
Engine weight, kg	430 (D243)
Fuel consumption, ls	8.8
Engine-mounted vehicles	MTZ-80, 82, 892, 952 MTZ MT-353, MP-403, MGL-363, MMP-393, MPL-373 TTZ-811 TTZ-812 Belarus-90, 820, 821, 900 EK-12, EK- 14 EO-3323 VP-05-04

3.3 . Power and fuel economy and economic performance of the tractor [12]

Experimental tests used the stands, laboratory devices and equipment of the Center for Certification and Testing of Agricultural Techniques and Technologies, Laboratory of Testing Tractor Vehicles and Loaders.

The tests were carried out on the TTZ-812 tractor rear , "Rapido" weight head (manufactured in the former GDR), 160 kW electric brake stand. Experiments were carried out using an experimental laboratory device of an (electrolyzer) type hydrogen generator connected to an electric brake stand, developed by scientific staff of the Research Institute of Environment and Nature Conservation Technologies. Methods of obtaining hydrogen by electrolysis of water are well studied, there are industrial examples of electrolyzers with various production efficiencies, including those that meet the requirements of internal combustion engine. Their disadvantages are a high level of energy consumption (about 3 kW of energy is needed to obtain 1 m 3 , that is, about 0.1 kg of hydrogen) and relatively large dimensions.

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Figure 8. General view of an electrolyzer with a productivity of 0,3 m^{3}/hour

Experimental tests were carried out in order to determine the main power and fuel-saving and economic indicators of the TTZ-812 tractor and to use hydrogen fuel instead of diesel fuel.

3.4. Methodology

Laboratory experiments were conducted in compliance with GOST 30747-2001 (ISO 789-1-90).

When braking through the operation of a diesel engine tractor, it was determined that the useful work coefficient of the intermediate reducer was taken into account and the efficiency of the 2 cardan shaft with four joints was taken into account. The rotation speed of the brake machine was recorded by the universal measuring system Testo-400. Engine fuel consumption was measured on a VNC-type scale. During the tests, the temperature of fuel and ambient air, as well as atmospheric pressure and humidity of atmospheric air were determined. During the tests, the cabin's air conditioning system was turned off. The tractor does not have a pneumatic brake system.

The following results were obtained during the experiments [9-13]:

3.5 . Power and fuel economy indicators of the tractor

Test results of TTZ - 812 tractor (power take-off shaft).

The maximum rotation frequency of the diesel crankshaft at idle speed, min^{-1} 2293 .

Rotational torque in power take-off shaft at the rotation frequency of the tail part corresponding to the nominal rotation frequency of the diesel crankshaft, N·m 864.62

Torque in power take-off shaft when the diesel engine is operating in the maximum torque mode, N·m 1025.75

The rotation frequency of the power take-off shaft tail part when the diesel engine is operating in the maximum torque mode, min^{-1} 410.5

Atmospheric conditions (average values during the test):

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- ambient air temperature °C + 9.5
- atmospheric pressure kPa 99.1
- relative humidity of ambient air % 59.9

Maximum coolant temperature °C 80.

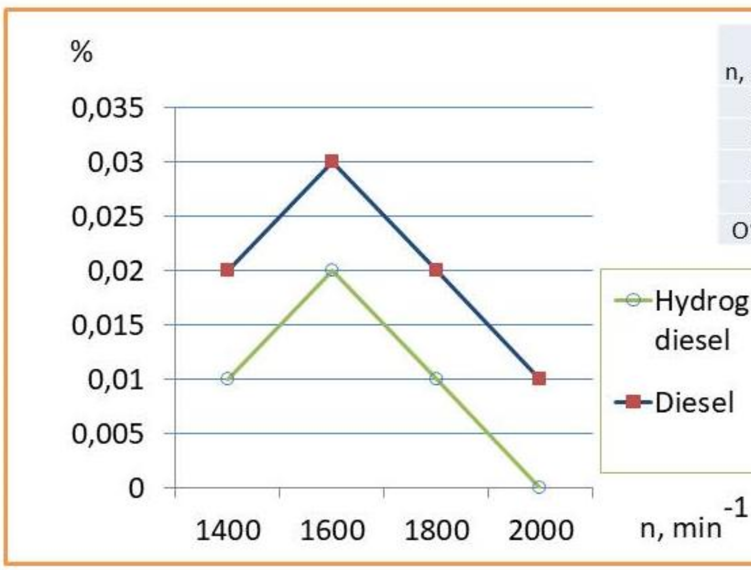
Engine oil temperature, °C 80.

Table 5.

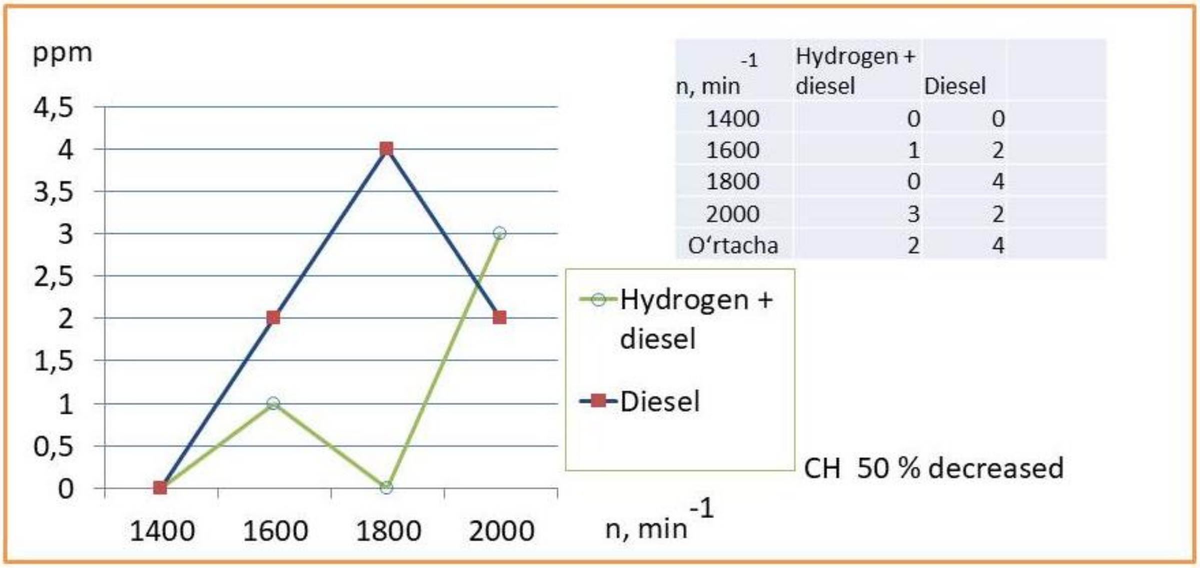
The amount of diesel engine exhaust gases and the amount of exhaust gases when hydrogen is added

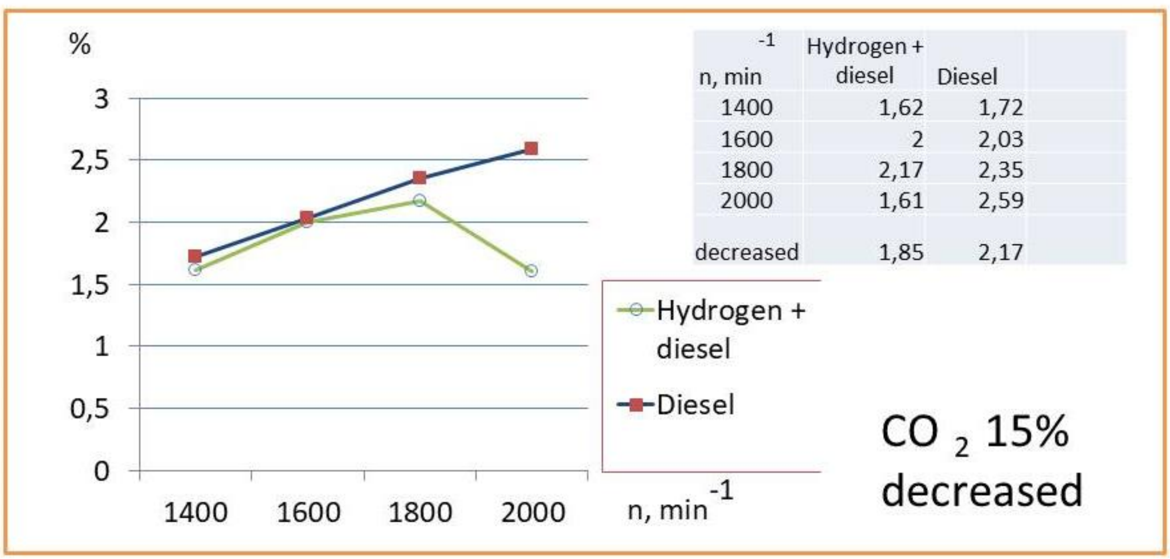
Model	Diesel				RPM	When hydrogen is added				RPM
	CO	CO2	CH	NO_x		CO	CO2	CH	NO_x	
TTZ 812	0.02	1.72	0.00	18.41	1000	0.01	1.62	0.00	18.32	1000
	0.03	2.03	0.02	17.80	1400	0.01	2.00	0	17.79	1400
	0.02	2.35	0.04	17.68	1600	0.01	0.17	0	17.56	1600
	0.01	2.59	0	16.97	2000	0	1.61	0.03	10.71	2000
Average	0.02	2.17	0.015	17.71	1500	0.0075	1.35	0.0075	16,095	1500

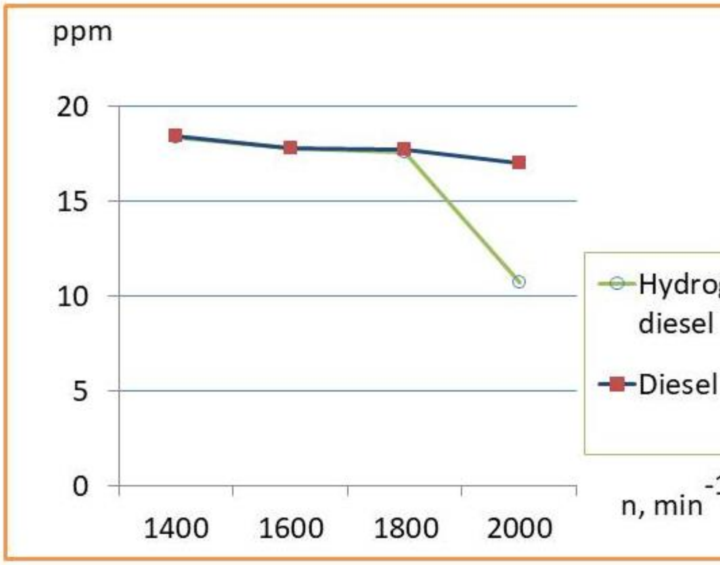
The results of exhaust gases in Table 4 were obtained on the 5-component gas analyzer "Infrakar 5M-2.01". The results at the bottom of the table show that 100 grams of hydrogen was added per hour to the DTL. The environmental results are shown in Figure 9, with CO reduced by 50%. It can be seen that CH decreased by 50%, CO2 decreased by 15%, and Nox decreased by 10% [14].



n, min -1	Hydrogen + diesel	Diesel
1400	0,01	0,02
1600	0,02	0,03
1800	0,01	0,02
2000	0	0,01
O'rtacha	0,01	0,02


ppm
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
1400
1600
1800
2000
n, min -1
n, min -1 | Hydrogen + diesel | Diesel
1400 | 0 | 0
1600 | 1 | 2
1800 | 0 | 4
2000 | 3 | 2
O'rtacha | 2 | 4
Hydrogen + diesel
Diesel
CH 50 % decreased


%
3
2,5
2
1,5
1
0,5
0
1400
1600
1800
2000
n, min -1
n, min -1 | Hydrogen + diesel | Diesel
1400 | 1,62 | 1,72
1600 | 2 | 2,03
1800 | 2,17 | 2,35
2000 | 1,61 | 2,59
decreased | 1,85 | 2,17
Hydrogen + diesel
Diesel
CO 2 15% decreased



n, min-1	Hydrogen + diesel	Diesel
1400	18,32	18,41
1600	17,79	17,8
1800	17,56	17,68
2000	10,71	16,97
O'rtacha	16,01	17,72

Figure 9. In diesel and hydrogen gas in addition when working of the engine ecological indicators.

3. 5. Analysis of power and fuel efficiency and economic indicators of the tractor QKV according to the results of brake tests

In order to determine the main power and fuel efficiency and economic indicators and evaluate their compliance with the data of the tractor manufacturing plant, brake tests of the TTZ-811 tractor with a diesel engine of the D-243 model were conducted by power take-off shaft.

The tests of braking the tractor through the rear PTO were carried out on the electric brake stand with a power of 160 kW, with a "RAPIDO" stand (manufactured by the GDR) and a step-up reducer with a gear ratio of i p =2.19.

The parameters of the tractor with a diesel engine were determined in braking by means of 2 cardan shafts (power take-off shaft) with an intermediate reducer and four articulated joints in accordance with GOST 30747-2001 (ISO 789-1-90), the rotation frequency of the brake machine was determined by electropulse assembly of revolutions 'recorded by the work counter.

Engine fuel consumption was measured on type scales. During the tests, the temperature of the fuel and the ambient air, as well as the atmospheric pressure and humidity of the ambient air were determined and taken into account during the pilot test.

The power take-off shaft indicators of the tractor obtained during the tests were brought to standard conditions, and the values of the correction coefficients are used from GOST 18509-88.

The useful work coefficient in transferring the torque from the engine to the output shaft of the power take-off was assumed to be equal to 0.92.

According to the results of brake tests of the tractor during 39 hours of operation, the maximum power at

2200 min -1 engine crankshaft rotation frequency (power take-off shaft) is 54.4 kW, with the addition of hydrogen 57.25 kW (according to factory data - 54 was not more than kW).

The specific fuel consumption at the maximum power of the engine

was 253.76 g/kW·h hours on diesel with 269.8 g/kW·h hydrogen addition (according to test data, from 269.8 g/kW·h does not exceed).

The coefficient of nominal screw torque reserve was 18.63%, which is within the permissible requirements (15%) [15-16].

CONCLUSION

The maximum power of the TTZ-811 tractor with the D-243 engine in the power take-off shaft is 5-13% more than the factory requirements, which can be explained by the sufficient performance of the tractor.

The specific fuel consumption is reduced by 6% from the test requirements.

The torque reserve reserve is 20.15% and meets the requirements of the tractor manufacturer -15%.

Experimentally, the addition of hydrogen in a suitable volume to a diesel fuel air mixture engine resulted in a reduction of hydrocarbon emissions of up to 40%, while the values of NOx and CO emissions were also reduced.

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