Development of a program for converting diesel engines to natural gas

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Abstract. For the transfer of diesel engines to work on compressed natural gas, a program of experimental research of diesel engines is presented, including the development and optimization of natural gas supply and control systems, determination of effective indicators and indicators of toxicity and smoke content of exhaust gases, determination of the actual pressure of the working fluid in the diesel cylinder with the processing of indicator diagrams, analysis of the parameters of the combustion process and heat release, selection and description of the necessary equipment for bench experimental studies.

The urgency of the problem of protection of atmospheric air from harmful emissions is growing year by year. At present, in many regions of the country there is an extremely negative environmental situation, due to the fact that the scale of human economic activity forms a significant increase in permissible loads on natural complexes, and the restoration of disturbed geosystems is extremely slow. Therefore, the problem of reducing atmospheric pollution has long crossed the border of individual States and even entire continents, has acquired an international character and has become almost common to all countries of the world. Harmful substances entering the atmosphere are carried by air currents over vast areas, regardless of the borders of States [1-5].

As power plants in the world are in operation millions of internal combustion engines that produce more than 85% of energy and consume more than 1 billion tons of oxygen per year, while emitting hundreds of millions of tons of toxic substances into the atmosphere. The rapid development of the auto-tractor fleet leads to excessive consumption of oil fuel. In Russia, in the next few decades, the need for fuels, including automotive, is increasing significantly. And due to the fact that diesels have high fuel efficiency (25...30% in relation to gasoline engines), this type of engine should be considered as the most promising in almost all sectors of the economy. But the level of pollution from diesel emissions is increasing year by year. In this regard, the creation of environmentally friendly diesel power plants operating on alternative fuels of non-oil origin has become the prevailing trend in the development of energy in the country [6-11].

The most suitable alternative fuel is compressed natural gas-methane. Methane is the most complete type of fuel of all possible substitutes for liquid petroleum motor fuels. Switching to it does not require changing the design of serial engines, the engine becomes more versatile and can run on two fuels at the same time, without harm to the workflow when working on serial liquid fuel. The cost of natural gas will be lower in comparison with the conversion of oil into serial diesel fuel, since the technological process requires only drying and cleaning. Also, the known reserves of natural gas are...
several times higher than the proven reserves of oil fields. The use of natural gas requires an infrastructure that includes a network of gas pipelines and gas stations, which currently already exists in many regions of Russia [12-15].

Diesel engines running on natural gas can reduce the toxicity, smokiness of exhaust gases, are widely used for work in areas with limited air exchange (for example, warehouses, greenhouses). The compressed natural gas power system allows replacing up to 80% of diesel fuel and significantly reduces the soot content in the exhaust gases. Therefore, the development of a program for the conversion of diesel engines to run on natural gas with the selection of the necessary equipment for bench experimental research is an urgent task. [16-19].

The comparative method is used as the basis for bench-based experimental research. The structural scheme of experimental research is shown in figure 1.

Experimental research is carried out in several stages, including the development and optimization of natural gas supply and control systems, the determination of power, economic indicators, characteristics of the combustion process and heat release, environmental components with the determination of the concentration of toxic components (NOx, CO, CO2, CHx and soot) on the adjustment, load and speed characteristics of the test of a diesel engine on diesel fuel and natural gas. At the final stage, an assessment of the integral toxicity and smoke content of exhaust gases of a diesel engine running on natural gas is carried out under actual operating conditions in accordance with current regulations [20-23].

An electric brake stand SAK-N670 with a balancing pendulum mechanism was used as a loading device for experimental studies of diesel engines (figure 2). The installation was equipped with the necessary measuring equipment and devices. The speed of the diesel crankshaft was measured using an electronic digital tachometer TC-1. The main fuel consumption was determined using an electronic flowmeter AIR-50. The time of the experiment was measured using an electronic stopwatch. Natural gas consumption was determined by volumetric method using a gas flowmeter GFC-6 with a modernized reference system based on the meter MES-66. The air consumption consumed by the diesel engine was determined using the gas meter RG-400, installed in front of the intake receiver and pulse counter MES-66. To indicate the combustion process in the diesel cylinder, an electropneumatic indicator MAI-5A was used [24-27].
A two-stage gas reducer for reducing gas pressure was mounted directly next to the meter for measuring the flow of natural gas. There was also a filter with an electromagnetic valve to ensure trouble-free operation and controlled from the control panel. The exhaust gas pressure and discharge in the inlet pipeline before and after the natural gas mixer was measured using U-shaped liquid pressure gauges. Humidity and barometric pressure of the surrounding air were measured by a psychrometer and an aneroid barometer. Ambient air temperature and fuel temperature were measured with mercury thermometers. The temperature of the exhaust gases of the diesel engine was measured using thermocouples. As secondary devices used logometer M-64 and electronic digital voltmeter F-4202 [28-33].

A mobile gas station based on a 2PTS-4 tractor trailer was used for natural gas refueling (figure 3a). Exhaust gas sampling was performed by gas intakes of the automatic gas analysis system ASGA-T (figure 3b), installed on the engine exhaust pipe. The smoke content of the exhaust gases was measured using the "BOSCH-EFAW-68A" smoke meter. Adjustment and check of the fuel pump was carried out on the stand for testing of the fuel equipment KI-22205. Adjustment and testing of injectors was carried out on the stand for testing injectors KI-3333. As a result of the selection of...
equipment, diesel engines of the MMZ family were transferred to work on natural gas. Table 1 and 2 shows the results of studies of the diesel engine for natural gas operation.

### Table 1. Results of researches of power and economic indicators of work of the diesel engine 4F 11.0/12.5 on a nominal mode.

| Fuel        | Indicators                          | Power, kW | Specific effective fuel consumption, g/(kW*h) | Total fuel consumption, kg/h |
|-------------|-------------------------------------|-----------|---------------------------------------------|------------------------------|
| Diesel      |                                     | 55.2      | 243                                         | 13.4                         |
|             | (corresponds to the diesel process) | 55.2      | 207 (decrease by 14.8%)                     | 13.8 (increase by 3.0%)     |
| Natural gas |                                     |           |                                             |                              |

### Table 2. Results of researches of indicators of toxicity and smokiness of exhaust gases of the diesel engine 4F 11.0/12.5 on the nominal mode.

| Fuel        | Indicators                          | NOx, %    | C, Bosch | CO2, % | CO, %  |
|-------------|-------------------------------------|-----------|----------|--------|--------|
| Diesel      |                                     | 1320      | 6,2      | 10,5   | 0,20   |
|             | (increase by 9.9%)                  | 9,9 times | 6,9 times| 46,7%  | 25,0%  |
| Natural gas |                                     | 1450      | 0,9      | 5,6    | 0,15   |
|             | (decrease by 6,9 times)             |           |          |        |        |

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