Passenger gas diesels to preserve the city's ecology

V A Likhanov, O P Lopatin¹ and P N Vylegzhanin

Department of thermal engines, automobiles and tractors, Vyatka State Agricultural Academy, 610017, Kirov, October prospect, 133, Russian Federation

¹E-mail: nirs_vsaa@mail.ru

Abstract. Today, one of the main tasks of manufacturers of automobiles and mobile power tools is to increase the efficiency of using motor fuels in internal combustion engines while reducing the aggressiveness of toxic components contained in exhaust gases. The paper deals with the main aspects of converting diesels to work on the gas-diesel cycle and presents the results of upgrading a city passenger bus with a modified power system for working on natural gas.

Analysis of modern developments shows that the use of a fundamentally new fuel and at the same time a highly economical engine is associated with deep and long-term research, so the most rational is to use new developments on serial samples of internal combustion engines. Reducing the content of toxic components using traditional automotive fuel in vehicle engines is relevant for all industries and road transport. In many countries of the world, there are strict requirements for regulating the toxicity of vehicles [1-3].

Currently there are the following ways to reduce toxicity:

- improvement of processes of mixture formation and combustion with simultaneous optimization of engine control;
- neutralization of exhaust gases in the engine exhaust system;
- limiting the content of sulfur and aromatic hydrocarbons in the fuel;
- switching to alternative fuels.

The most promising and less cost-effective option is to switch to alternative, non-traditional fuels. At this time, the main share of engines installed on cars involved in various industries and the agricultural and industrial complex are diesels and, accordingly, the most interesting is the conversion of engines of this type to gas fuels (natural gas). In diesels, natural gas is supplied mainly as follows. The gas is mixed with the air in a mixer-dispenser installed on the intake pipeline, and enters the cylinder. The liquid fuel is fed through the standard fuel system at the end of the compression stroke.

On the basis of such a diesel engine, it is possible to create a gas engine in which gas is supplied to the cylinders, and ignition occurs using a spark plug. The advantage of a gas engine is the ability to work completely on gas, excluding liquid fuel, and the disadvantage is the need for serious design changes that require conversion of the diesel engine. Therefore, today the most common type of medium-litre engine running on gas is gas-diesel engines [4-7].
The conversion of diesel operation to natural gas with ignition by a combustion portion of diesel fuel (gas-diesel or gas-liquid process) does not require significant alterations and re-adjustments of the engine. With this method, it is necessary to install a mixer on the intake pipeline, develop a gas supply control system, and connect it to the gas flaps. The compression ratio of the engine usually remains unchanged. Experimentally select the optimal adjustment of the setting angle of advance of fuel injection, and the supply of the ignition portion of diesel fuel, which can remain constant or change depending on the speed and load [8-11]. Changes in the regulator relate mainly to the design of the throttle valve drive, the installation of restrictors for the supply of the ignition portion of diesel fuel and fuel type switches. This gas-liquid diesel is equally suitable for operation on natural gas with a fuse portion of diesel fuel, as well as on a purely diesel process, which is one of the significant advantages of modernization. However, this method replaces up to 80% of diesel fuel in the nominal mode and requires the installation of two power systems: for diesel fuel and natural gas (figure 1).

**Figure 1.** Control system of diesel engine: 1 - fuel pump regulator; 2 - control lever; 3 - regulator loads; 4 - main regulator lever; 5 - rail rod; 6 - spring; 7 and 9 - pins; 8 - fuel pump rail; 10 - double - arm lever; 11 - rod; 12 - gas damper lever; 13 - gas damper spring; 14 - gas damper; 15 - gas supply pipe; 16 - gas mixer; 17 - pump rail fixing solenoid valve; 18 - gas supply solenoid valve; 19 - electrical conductor.

For all modern types of diesels, the most relevant at the moment is the electronic gas injection system. This system can be installed on new types of diesel engines with electronic fuel injection, as well as those in operation, including those with mechanical high-pressure fuel pumps. This system
uses a modern electronic control unit that controls the gas injectors in accordance with information about the load, the speed of the crankshaft, and the temperature of the exhaust gases [12-15].

A special feature of these systems is the ability to be used on all types of diesels, including with mechanical types of high-pressure fuel pumps. The electronic control unit processes a number of signals coming from sensors and actuators, determines and calculates the required amount of gas to be supplied to the diesel cylinders. Moreover, the number of injectors can be installed on a diesel engine less than the number of cylinders, since gas injection is carried out in the intake pipeline and the number of injectors will depend more on the design of the intake pipeline. The advantage of this method of gas supply is a more accurate dosing of the required amount of gas at all speed modes of gas diesel operation and a more complete adaptation of the diesel to the nominal power parameters. In addition to this system, a system for fixing the ignition portion of diesel fuel on the standard high-pressure fuel pump is required, as well as an additional installation of the pedal position sensor on the standard control lever of the regulator [16-19].

Comparing the means of transfer of diesel to natural gas, it should be noted that, with respect to four-stroke automotive diesels the most simple and economical, allowing the use of natural gas not only newly designed but also already in service, is a method of operating a diesel on gas diesel process with gas injection during the intake stroke in the intake pipe ignition gas-air mixture from the ignition portion of diesel fuel sent regular fuel equipment at the end of the compression stroke. This method is mainly developed in automotive diesel engines [20-23].

When the engine is running on a methane-air mixture ignited by the ignition portion of diesel fuel, it is necessary to ensure the versatility of the engine, i.e. its operation should be carried out both on the gas-diesel cycle and on the diesel cycle, while there should be no loss of power and work stops when switching to another type of fuel. Therefore, when developing a power system designed to supply natural gas to the intake pipeline, it was necessary to take into account the following requirements. First, upgrading the all-pressure pump regulator should not be technologically complex and expensive. Second, the changes should not affect the design of the diesel engine itself. Third, when working on a gas-diesel cycle, the power parameters of the engine should not be lower than in the diesel process. Fourth, the supplied methane-air mixture, regardless of the mode of operation of the diesel engine, should be evenly distributed across all cylinders of the engine. Fifth, the installed equipment for natural gas supply must meet all safety regulations, as well as guarantee high reliability and durability [24-27].

The methane-air mixture is formed in a metering mixer installed in front of the turbocharger, which creates a discharge in the intake pipeline, resulting in the methane-air mixture entering the diesel cylinders. The engine is started using diesel fuel, and then the natural gas supply is switched on using the fuel type switch unit installed on the instrument panel. In the future, the operation of the engine on the all-mode characteristic is provided by regulating the supply of natural gas by a metering device directly connected to the all-mode pump regulator [28-33].

o provide all-mode control of the crankshaft speed when working on diesel and gas-diesel processes, some design changes were made to the all-mode diesel speed controller. This made it possible to replace up to 85% of diesel fuel with natural gas when working on the gas-diesel process. The value of the ignition portion of diesel fuel does not change depending on the load and speed modes of the engine. Fixing the rail of the fuel pump is carried out by a special electromagnetic valve installed on the regulator body on the side of the control lever of the regulator (figure 2a). When the rail is fixed, the second solenoid valve connected to the first by an electrical connection opens the gas supply. By moving the main lever of the regulator, the flow section of the gas damper increases or decreases, which leads to a change in the gas supply. In this way, the composition of the gas-air mixture is regulated qualitatively with an unregulated air supply at the intake to the turbocharger [34-36].

The changes made to the design of the fuel pump regulator are not technologically complex and require large financial investments. They can be carried out both on a new high-pressure fuel pump and on a former one [37-42].
The modernization of the PAZ bus with a modified power system for working on natural gas was carried out at the Vyatka state agricultural academy on the basis of the department of thermal engines, automobiles and tractors. The prototype bus is equipped with serial gas-cylinder equipment installed in accordance with the specifications of the Ministry of transport of the Russian Federation. Installation of gas-cylinder equipment was carried out in accordance with the rules of Gostekhnadzor and the rules of the Ministry of transport of the Russian Federation [43-48].

Figure 2. High-pressure fuel pump with a solenoid valve that locks the ignition portion of diesel fuel (a) and the high-pressure cylinder (b).

Figure 3. Three-stage gas reduction heater (a) and natural gas supply hose (b).

A gas cylinder made of metal plastic (figure 2b) was installed under the back seat of the bus. Mount the cylinder was carried out using the brackets mounted on the side members of the frame. The balloon was installed so that the outlet fittings of the valve were horizontal, and the flywheel was at the top. The distribution cross with the filling device is located on the left in the compartment of the receiver and brake cranes. A three-stage gas reduction heater was installed on the side wall of the engine compartment (figure 3).

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