DEVELOPMENT OF MICROPROCESSOR SYSTEMS
CONTROL OF GAS ICE FOR OPERATION WITH LIQUEFIED
PETROLEUM GAS

Abstract. The expediency of converting the transport diesel engines in operation into gas internal combustion engines with spark ignition for operation on liquefied petroleum gas has been substantiated. It is shown that the use of liquefied petroleum gas instead of diesel fuel can reduce the operating costs of vehicles. Multifunctional electronic microprocessor control systems based on Avenir Gaz 37 level “A” and Avenir Gaz 37 level “B” electronic control units have been developed. It is shown that an electronic microprocessor control system with an Avenir Gaz 37 electronic control unit of level "A" allows converting diesel engines into gas internal combustion engines with LPG supply through a gas-air mixer into the intake manifold. The test results showed the high energy and efficient performance of the gas internal combustion engine. The second electronic microprocessor control system with an electronic control unit Avenir Gaz 37 of level "B" allows converting diesel engines into gas internal combustion engines with LPG injection through an accumulative power supply subsystem and multipoint injection of liquefied petroleum gas (Common Rail type) in combination with the use of a contactless electronic subsystem ignition with a movable voltage distributor and a cylinder filling control subsystem with a charge of the working mixture. At the same time, Avenir Gaz 37 "B" ECU with a loaded B1 level software module provides group injection of LPG into the intake manifold and sequential injection with a B2 level software module. The principle of operation of each of the three subsystems, which the D-240-LPG."B" gas engine is equipped with, is described. The tests carried out on the D-240-LPG."B" gas engine with the Avenir Gaz 37 "B" control unit confirmed its operability.

Keywords: internal combustion engine, electronic control system for a gas internal combustion engine, micro-processor electronic control unit Avenir Gaz 37 of level «A» and level «B», liquefied petroleum gas.
It is well known that liquefied petroleum gas (hereinafter - LPG) occupies third place in the world (after traditional diesel fuel and gasoline) in terms of consumption of transport motor fuels [1]. In addition, it is known that the consumption of LPG as a motor fuel for vehicles over the past three years in Ukraine has come close to the consumption of gasoline. This is because LPG is the cheapest motor fuel in Ukraine [2].

Therefore, in recent years, the institute has been working on the development of electronic control systems for gas internal combustion engines intended for re-equipment of transport diesel engines in operation into gas internal combustion engines. The basis of electronic control systems are the developed and manufactured electronic microprocessor control units (hereinafter - ECU) Avenir Gaz 37 "A" and Avenir Gaz 37 "B" [3].

Tests of electronic control systems were carried out on a gas internal combustion engine converted on the basis of the D-240 diesel engine. The diesel power supply and injection system were removed from the diesel engine, and the diesel cylinder head was modified for installing spark plugs. To reduce the compression ratio, new modified pistons were installed with a modified shape (volume) of the combustion chamber, which provided a decrease in the geometric compression ratio, from $\varepsilon = 16,0$ to $\varepsilon = 9,5$. In addition, the D-240-LPG-"A" gas internal combustion engine was retrofitted with a system for feeding and supplying LPG to the intake manifold through a gas-air mixer, a cylinder filling control system with a charge of the working mixture, as well as a contactless electronic ignition system with a movable voltage distributor and ECU Avenir Gaz 37 "A".

In Fig. 1 shows a gas D-240-LPG-"A" with an ECU Avenir Gaz 37 "A" installed on a Zöllner electric load stand. The main technical characteristics of the gas D-240-LPG-"A" were determined based on the results of its tests on the Zöllner electric load stand.

The test results showed that the maximum power of the gas internal combustion engine is $N_{c, \text{max}} = 57.5$ kW at $n_0 = 2200$ min$^{-1}$, and the maximum effective torque is $M_{e, \text{max}} = 304$ N·m, at $n_0 = 1300$ min$^{-1}$. The torque reserve is 22 %. Thus, the rated power of the D-240-LPG gas was 97% of the rated power of the D-240 diesel. The
tests of the D-240-LPG-"A" gas internal combustion engine with an electronic control system have been completed, and the obtained positive energy and economic indicators are described in detail [4].

Fig. 1. Photo of a D-240-LPG-A gas engine installed on a Zöllner electric load stand of the B-350AC type

Also, at the present time, the institute continues to research electronic control systems for gas engines (the second level of complexity - level "B"). These studies are carried out on the D-240-LPG-"B" gas engine. The transition from the difficulty level "A" of the D-240-LPG-"A" gas internal combustion engine to the D-240-LPG-"B" level was carried out by replacing the power supply system and the LPG supply (through the gas-air mixer) into the intake pipeline with the LPG multipoint injection subsystem Common Rail type (see Fig. 2).

All elements of special equipment included in the LPG multipoint injection subsystem comply with the requirements of Regulation No. 67 [5].

In addition, the engine is retrofitted with a subsystem for filling the cylinders with a charge of the working mixture with a bypass mechanism for regulating the air flow of the Avenir Gaz 37 ECU of level "B" (see Fig. 2, c). To determine the
current engine speed, a type 60-2 master disk is mounted on its crankshaft, opposite which a rotation speed sensor is installed.

![Image of engine components](image)

- **a** - gas internal combustion engine model D-240-LPG-"B";
- **b** - ECU Avenir Gaz 37 "B";
- **c** - a subsystem for filling the cylinders with a charge of the working mixture

**Fig. 2. External view of the gas internal combustion engine model D-240-LPG-"B", installed on the Zöllner electric load stand**

Algorithms and software have been developed that allows you to control the operation of the D-240-LPG-"B" gas internal combustion engine, in particular, its subsystem for multipoint injection of LPG by gas electromagnetic nozzles into the intake manifold, as well as the subsystem for filling the cylinders with a charge of the working mixture.

It should be noted that the basic electronic circuit and the printed circuit board made on its basis, as well as the case of the Avenir Gaz 37 "B" ECU are used without changes to control the operation of gas internal combustion engines of all three sublevels of complexity. Only the software modules are changed, and for the "B2" sublevel also the design of the master disk (obturator) of the interrupter-distributor [6-8]. It should be added that the software module of the "B1" level provides group injection of LPG, and the software module of the "B2" level is sequential.

In addition, during idling in the process of warming up the "cold" gas internal combustion engine, the Avenir Gaz 37 "B" ECU controls the idle speed controller and the amount of cyclic LPG supply so that when the gas internal combustion engine warms up, its speed decreases.
In the case of starting a "cold" gas internal combustion engine, the ECU Avenir Gaz 37 "B" provides an increase in the duration of the LPG starting supply (injection) impulses, and when a "hot" engine is started - a decrease.

It should also be noted that the developed electronic control systems for gas internal combustion engines with ECU Avenir Gaz 37 "B" with software modules of levels "B1", "B2" and "B3" are designed so that they allow the control unit to calculate the value of the current crankshaft speed engine both on the basis of the signals of the speed sensor, and on the basis of the signals of the Hall sensor of the movable voltage distributor by a contactless electronic ignition system.

This ensures the regular (trouble-free) operation of the control system (in particular, the ECU) in the event of a failure of the crankshaft speed sensor of the gas internal combustion engine.

Thus, the tests carried out showed that the developed electronic control systems with ECU Avenir Gaz 37 "B" with software modules of levels "B1" and "B2" perform all the functions assigned to them and ensure the operation of gas engines D-240-LPG-"B1"and D-240-LPG-"B2". At the same time, the content of carbon monoxide and hydrocarbons in the exhaust gases of engines D-240-LPG- "B1" and D-240-LPG- "B2" meet the requirements of National Standard of Ukraine No. 4277 [9].

A further direction of work is associated with the development and research of electronic control systems for a gas engine with a subsystem for neutralizing exhaust gases. The transition to this level of complexity was carried out by installing a mass air flow meter and an integrated temperature sensor on the gas engine D-240-LPG- "B", as well as a three-way catalytic converter and one lambda probe.

The algorithm of operation of the gas control system gas engine D-240-LPG- "B" with sequential injection and a subsystem of exhaust gases neutralization, the operation of which is provided by the software module of the "B3" level, has been developed.

As a result, the expediency of converting the diesel engines of vehicles in operation into gas-powered internal combustion engines with spark ignition for operation on LPG was substantiated on the basis of the use of the developed
electronic control systems with ECUs Avenir Gaz 37 "B" with software modules of different complexity levels.

References:
5. Regulation No. 67 LPG vehicles.