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Altitude controller influence on environmental and economic performance of ngv fuel-powered engines

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Abstract. The relevance of research is conditioned by the need to ensure efficient operation of the internal combustion engine ICE on NGV fuel at different altitudes above sea level, where there is atmospheric air rarefaction up to 20÷25%. This direction is dictated by the fact that when transferring the ICE operation from gasoline to gas-engine fuel, the engine power decreases from 5 to 15%, moreover, the atmospheric air rarefaction leads to an even greater reduction in engine power and ultimately reduces the performance of the vehicle. Due to violation of the process of combustion of gas-air charge in the cylinder is formed a large amount of carbon monoxide (CO). Research objective is to develop and propose a method of providing such a stoichiometric, fractional composition of the gas-air charge, which will ensure the restoration of the lost power of ICE and provide the optimal value of traction-dynamic characteristics of the car, without increasing toxic emissions. Research object: Variable cross-sectional area of the intake manifold path (ICE), adjustable lumen for atmospheric air intake, atmospheric air pressure sensors adjustable diaphragm with stepper motor. Research methods: analytical modeling of the relationship of the aperture diameter depending on the altitude of the terrain above sea level, on the number of revolutions of the ICE, on the density and temperature of the ambient air. The process of combustion of the gas-air charge in the combustion chamber will be evaluated by the fractional composition of the exhaust, exhaust gases. Research results: Qualitative and quantitative assessment of the application of altitude corrector on the ICE operation mode, stability of the value of excess air ratio at different altitudes above sea level, formation of toxic gas, carbon monoxide, as well as carbon dioxide, hydrocarbon, oxygen, etc. is given.

1 Introduction

From the point of view of environmental damage, motor transport is the leader in all types of negative impact.

Environmental problems of motor transport are a serious reason to reconsider the attitude to the issue of internal combustion engine (ICE) operation, in particular when operating on gas motor fuel in the conditions of mountainous areas of Armenia, where 90%

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of the territory is located at an altitude of 1000 and more meters above sea level, and above 2000m altitude 42% (1).

Pollutants generated during transportation operation mainly consist of gases emitted from ICE vehicles, they are aerosols of complex composition depending on ICE operation mode (2, 3).

Environmental safety of a vehicle (VV) should be ensured in wide intervals of changes in environmental parameters. Operating conditions of the vehicle are very diverse, which significantly affects the mode of operation of the vehicle and, in particular, the ICE.

The efficiency of operation of ICEs operating on NGV fuel is significantly affected by the altitude of the terrain above sea level.

It is known that at different altitudes above sea level the atmospheric pressure varies within wide limits [3,4]

up to 1000 meters atmospheric pressure 86.6 kPa (650 mm st.)

up to 2000 meters atmospheric pressure 73.3 kPa (530 mm st.)

up to 3000 meters atmospheric pressure 64.0 kPa (460 mm st.)

As a consequence, ICE power is reduced due to the thinning of atmospheric air entering the cylinder. At the same time, it is known that the power of a gasoline engine running on NGV fuel is reduced within 5 to 15% due to lower calorific value compared to gasoline. As a result, the traction and dynamic properties of the vehicle are reduced, environmental and economic performance deteriorates, fuel consumption increases, etc.

2 Methods and materials

Let us consider the working process in the ICE cylinder when operating under conditions of atmospheric air rarefaction (2, 3, 4). It is known that ICE operates steadily on NGV fuel at the excess air ratio of 0.75 ÷1.45 in the case when ICE operates steadily on gasoline at the excess air ratio of 0.95 ÷1.03. However, at steady operation on gasoline fuel ICE does not provide the necessary injectivity due to a significant reduction of power, crankshaft revolutions set is hampered and multiplicative activity is reduced (4). The fuel-air charge entering the engine cylinder does not burn completely due to the lack of oxygen, which leads to a sharp increase in the amount of carbon monoxide "CO" (carbon monoxide), the most toxic gas emitted by the car into the atmosphere. By the decision of the Government of the Republic of Armenia of 2007, the normative base of emissions for gas-fueled vehicles was defined. According to this normative base, CO emissions for gas-fueled vehicles are 3.0% at idle engine speed and 2.0% at medium speed. However, the existing "EURO" norms of different classes of CO emissions are standardized in the dimension of gr/km, which does not correspond with the norms approved by the Government of the Republic of Armenia.

In conditional operation of the Republic of Armenia, where the beginning and the end of the route of cargo and passenger transportation differ in altitude up to 1500 meters above sea level, the operation of the engine on gas-motor fuel becomes extremely unstable, both in terms of traction and dynamic, and environmental indicators.

In order to improve the combustion process of the gas-air charge in the cylinder, it is necessary to ensure the appropriate stoichiometric ratio of the fractional composition (3, 6, 5).

Operational adjustment of gas-cylinder vehicles depends on the location (altitude), simply put, on the value of atmospheric pressure. For example, when adjusting the stoichiometric composition of the gas-air charge at an altitude of 800 meters above sea level, the engine works steadily, but at an altitude of 1800 meters above sea level, the stable operation of the engine is violated due to changes in the fractional stoichiometric composition of the gas-air charge and the excess air ratio violates the combustion process,

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which immediately leads to a decrease in engine power, increased fuel consumption (5, 6, 7).

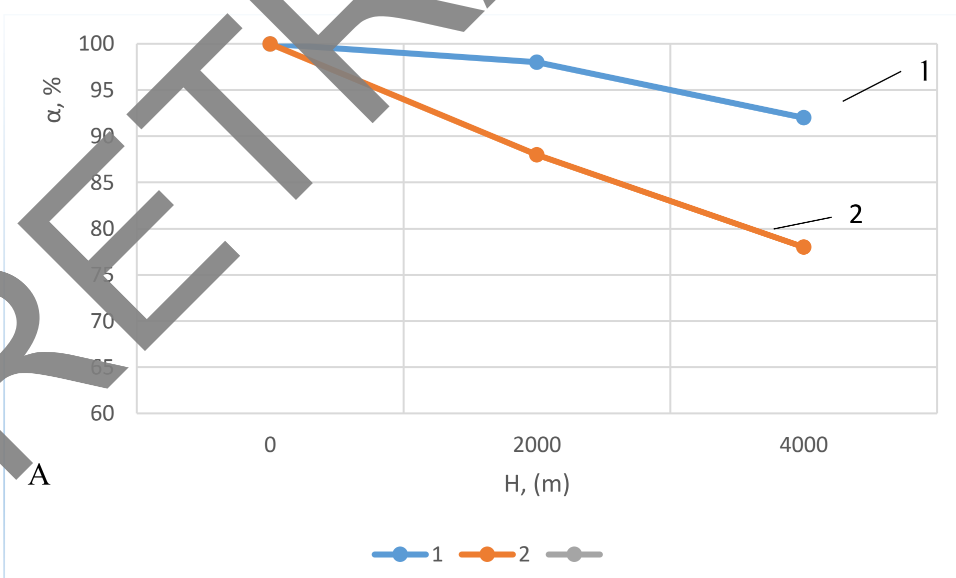
Modern cars are equipped with the fourth-generation gas-cylinder equipment, in which the fuel equipment reacts by regulating the amount of gas-engine fuel, thus balancing the composition of the gas-air charge and the excess air ratio.

Due to the large ICE power of modern passenger cars, the reduction of power is not noticeable on the traction and dynamic properties. However, for trucks the power reduction is quite noticeable.

It is well known that for complete combustion of gas-air charge entering the cylinder stoichiometric composition must meet the condition 1k.9.4, that is, one kilogram of gas requires 9.4 kilograms of atmospheric air. At such fractional composition of the charge excess air ratio corresponds to an average of 1.2-1.3, which is optimal for the main operating modes of the engine.

Taking into account the fact that the main number of gasoline vehicles is transferred to gas motor fuel, there is a need to change the cross-section (lumen) of air intake into the intake manifold to ensure the appropriate composition of the gas-air mixture. ICE operating in mountainous terrain, at atmospheric air rarefaction even when operating on gasoline there is a mismatch of stoichiometric composition of gasoline and atmospheric air, to regulate this process special altitude controllers are used (1). There are known designs of altitude controllers, which regulate gasoline flow rate depending on geographical location (atmospheric pressure). Altitude controllers have not been widely used, although the development of "Solex", "Weber", the design developed by scientists of the Georgian Polytechnic Institute in the 70s of the last century had a positive effect, etc. (1) Application of altitude controllers allowed to provide the change of excess air ratio and to save fuel considerably. This is a proven fact according to the results of tests by V.V. Dvali, R.R. Makhaldiani. [1]

The diagrams obtained during the tests of gasoline-powered cars with a working volume of 2.4 liters are shown in Fig. 1.



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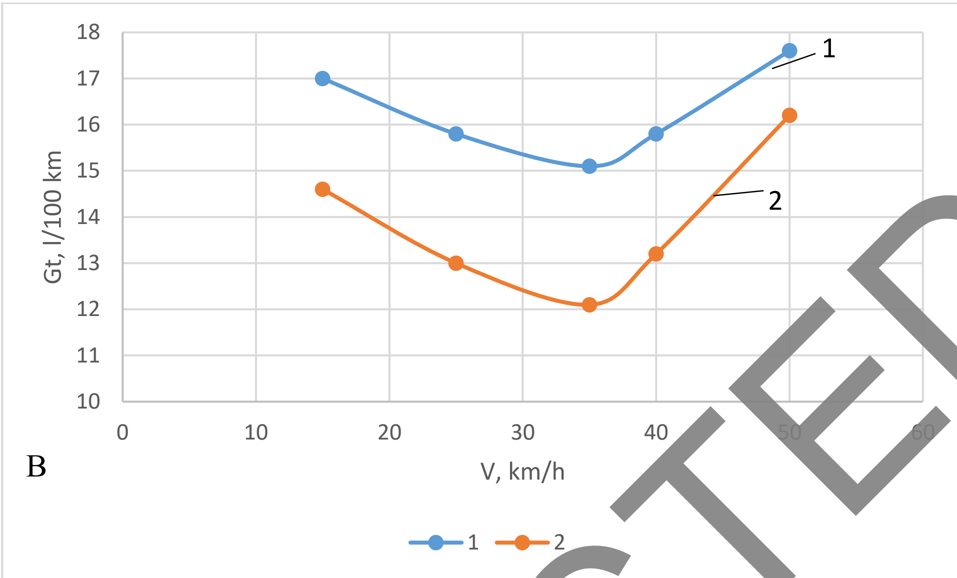

Fig. 1. (A) Change of excess air ratio optimal value (1) actual value (2) B. Economic characteristics of a car operating at an altitude of 2670 m. 1 controller closed, 2 controller open (data according to V. Dvali and V. Makhaldiani).).

3 Results

A similar process occurs when the ICE operates on NGV fuel, with the difference that in this case it is not the amount of fuel that is regulated, but the volume of air entering the cylinder, thus regulating the composition of the gas-air charge. Analysis of the gasoline ICE intake system shows that the lumen area of the intake manifold we calculate for gasoline has a significantly larger area than is necessary for operation on NGV fuel. There is a need to correct the volume of air entering the ICE cylinders (8). Within the framework of research and development work, a design of an altitude controller of the volume of air intake into the cylinder, working from the atmospheric air pressure sensor, was developed. In accordance with the value of atmospheric air the sensor transmits an electric signal to the executive mechanism, then the stepper motor changes the lumen area of the diaphragm through which the atmospheric air passes. The general scheme of the altitude controller is shown in Fig. 2.

This altitude controller developed by the author A. Simonyan [9] (copyright certificate RA N3042 for 2013) has all the necessary structural elements to provide the necessary functional processes of regulation Fig. 3.

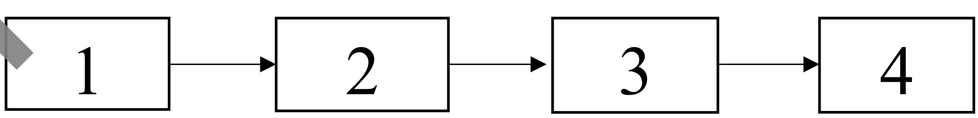

Fig. 2. 1. Atmospheric pressure sensor, 2. transducer, 3. operating mechanism, 4. air inlet diaphragm.

General view of the air intake altitude controller diaphragm is shown in Fig. 3.

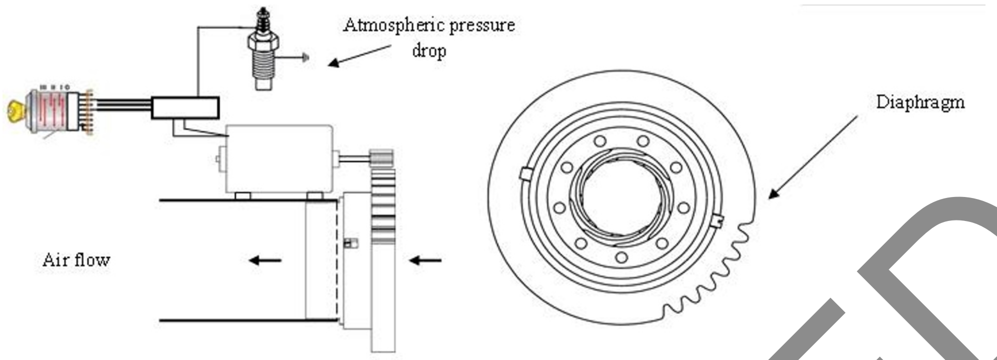

Fig. 3. General view of the altitude controller diaphragm and its components

4 Results analysis

Mounting condition of the altitude controller of the Gazelle car is shown in Fig. 4.

Fig. 4. Installation view of the altitude controller on ICE.

Let us consider the influence of the volume of air intake on the combustion process and on the composition of exhaust gases. From the point of view of the general principles of heat engineering [2-10], the combustion of the gas-air charge in the ICE cylinder depends on the air excess ratio (α). The conducted research shows that the fractional composition of exhaust gases depends entirely on the excess air ratio and has the form shown in Fig. 5.

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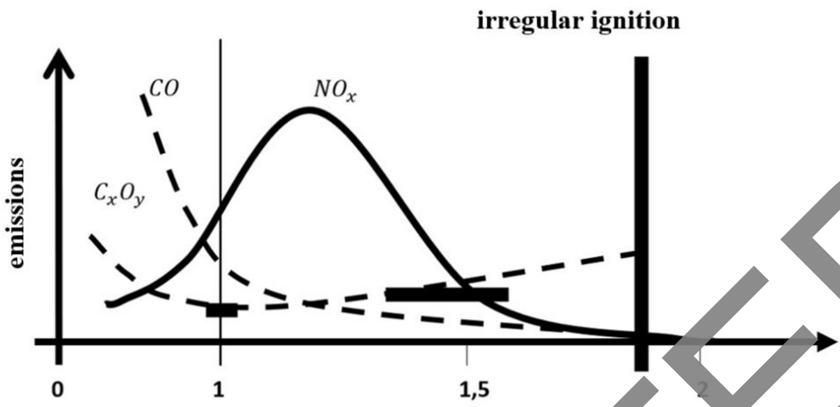

Fig. 5. Effect of excess air ratio on the amount of ICE emissions.

Quantitative analysis shows that as the value of excess air ratio increases within the range of 1.05÷1.35 the specific weight of carbon monoxide CO decreases, and on the contrary the specific weight of nitrogen oxide NOx increases, up to the value of excess air ratio 1.25 after which NOx begins to decrease. Some fundamental research by Y.B. Zeldovich describes it [10].

In general, in the theory of gas combustion and thermal propagation of laminar flame, the author [10-12] proved that nitrogen oxidation occurs at high temperatures and a number of nitrogen oxides are formed depending on it (NO_x).

According to NAMI (Scientific Research Experimental Centre for Automotive Vehicle Testing and Refinement of the Russian Federation), emissions when ICEs run on gasoline, liquefied petroleum gas, compressed natural gas are (see Table 1).

Table 1. Quantitative composition of vehicle emissions.

Type of fuel	Emissions g/km (V_H-2.4)			
	CO	C_XH_y	NO_X	CO_2
AI 93 gasoline	10.3	2.17	2.25	2.1
LPG	4.7	1.19	2.15	2.0
Compressed natural gas	2.1	1.11	9.1	1.9
Methanol	6.92	1.34	1.03	0.35

As follows from the table, the largest amount of CO is emitted during combustion of gasoline, followed by liquefied gas and the smallest amount during combustion of compressed natural gas, the main composition of which is methane CH_4-92 % ÷ 98 %.

5 Results and discussions

Analyzing the practical results of operation of automobile ICE on natural and liquefied gas and according to our laboratory research we can confidently state the fact that the use of altitude controller provides stable and uniform engine operation, and the fractional composition of exhaust gases changes towards the improvement of the environmental component. Fig. 6 shows a diagram of changes in the fractional composition of exhaust gases of the engine with a working volume of 2.8 liters (ZMZ-406) at different altitudes.

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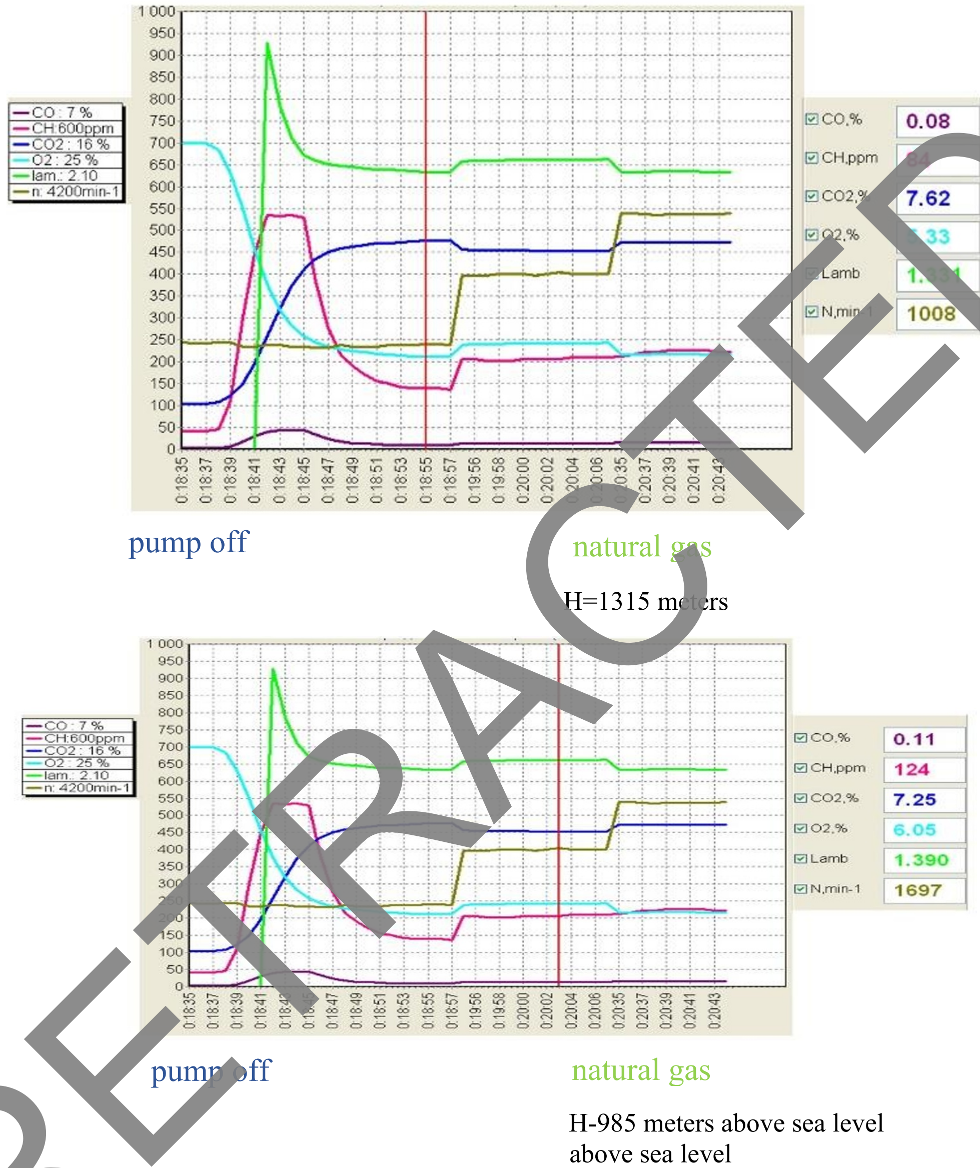

Fig. 6. Diagram of changes in the fractional composition of exhaust gases of an engine with a working volume of 2.8 liters. AH=985 m, BH=1315 m.

As can be seen from the diagram, when applying the altitude controller at the altitude of 985 meters and 1315 meters above sea level, the excess air ratio practically does not change (1.33 and 1.34), which indicates the effectiveness of the altitude controller. At the same time, the fractional composition of exhaust gases underwent a significant change in the direction of reducing the amount of CO and also, C_XH_Y is the main cause of the greenhouse effect. Experimental research conducted at the level of the laboratory of the Agrarian University (H=985) and at the parking lot of the northern bus station (H=1315 meter).

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Measurement of fractional composition of exhaust gases was carried out using gas analyzer "Infrakar" (Fig. 7).

Fig 7. Infrakar I-MI gas analyzer.

The air temperature in the exact measurements was 24 ºC (Agrarian University) and 20.5 ºC (northern bus terminal). Quantitative and qualitative (fractional) composition of exhaust gases is shown in Table 2, the engine was running on natural gas.

Table 2. Fractional composition of exhaust gases.

N	Measurement location	H (m)	T ºC	P rpm	CO	CO_2	C_XH_Y	O_2	α
1	Agrarian University	985	24 ºC	Idle run	0.08	7.62	84	5.33	1.331
				Av.rev	0.12	7.57	134	5.23	1.339
2	North bus terminal site	1315	20.3 ºC	Idle run	0.09	7.57	95	5.29	1.310
				Av.rev	0.13	7.51	146	5.16	1.309

6 Methodology for modeling the size of the lumen diameter of an altitude controller

The diameter of the adjustable clearance of the altitude controller is determined by modeling the velocity and air pressure loss in the inlet manifold using the following formula (11, 12)

$$d_g = 1.88\sqrt{\frac{P_0 V_{CH}}{(P_0 - \Delta P_a - \Delta P_b) W_{bH}}},$$

here d_g - adjustable lumen diameter, corrector
P - air pressure,

W_{bH}- average air velocity in the smallest cross-section,

V_{CH}- air volume flow rate at a given altitude,

P_0- velocity in the collector section,

ΔP_a- pressure loss due to air resistance,

ΔP_b- pressure loss in the inlet manifold.

As can be seen from the above formula, the diameter of the adjustable lumen of the altitude controller depends on the main losses of air velocity in the collector.

7 Conclusions

1. The application of the developed altitude controller to gas-fueled vehicles equipped with altitude controllers will not only improve environmental performance, but also ensure gas fuel economy.
2. With the use of modern information technologies, it is necessary to conduct a large-scale experiment on the whole territory of the republic, which will allow to ensure the economy of NGV fuel, to compensate the engine power loss, to increase the car performance, as well as to improve the environmental performance of the engine.

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