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COMPARATIVE ANALYSIS OF FUEL CONSUMPTION, ENGINE POWER AND OPERATING COSTS OF PASSENGER CARS USING GASOLINE AND CNG

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Abstract: Abstract. The growing number of motor vehicles and the resulting increase in harmful emissions have intensified the need for environmentally friendly and economically efficient fuels. This study investigates the operational characteristics of passenger cars running on gasoline and compressed natural gas (CNG). Experimental studies were conducted at the laboratories of Andijan Avtotekhizmat LLC, Mukammal Avtoservis LLC and Andijan State Technical Institute. Three passenger car models widely used in Uzbekistan, namely Nexia R3, Gentra and Cobalt, were selected as research objects.

The main operational indicators, including fuel consumption, engine power and operating costs, were analyzed using brake dynamometer equipment. The results showed that the use of CNG significantly reduces fuel expenses compared to gasoline. Economic calculations revealed that the operating cost of vehicles running on CNG is approximately 71.4% lower than that of gasoline-powered vehicles under similar conditions. At the same time, a slight reduction in engine power was observed due to the physical properties of gaseous fuel.

The findings indicate that compressed natural gas is an economically viable and environmentally sustainable alternative fuel for passenger vehicles. The use of CNG contributes to lower fuel costs, reduced harmful emissions, extended engine service life and longer maintenance intervals. Despite the increased complexity of the fuel supply system and higher safety requirements, the overall advantages of CNG make it an effective substitute for conventional gasoline fuel.

Keywords: compressed natural gas, gasoline fuel, fuel consumption, engine power, vehicle operation, economic efficiency, environmental safety, passenger cars.

I. Introduction. The rapid development of the automotive industry has significantly improved the mobility of the population and contributed to economic growth. Following the independence of the Republic of Uzbekistan, large-scale reforms were implemented in the transport sector, resulting in the establishment of modern automobile manufacturing enterprises and a substantial increase in the number of vehicles operating throughout the country[1].

According to official statistical data, the number of passenger vehicles owned by the population has steadily increased in recent years. While the growth of motorization provides social and economic benefits, it also leads to increased environmental pollution caused by exhaust emissions from internal

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combustion engines. Harmful substances such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), particulate matter and greenhouse gases negatively affect both environmental quality and public health [2,4,5,7].

One of the most effective approaches to reducing vehicle emissions is the use of alternative fuels. In this regard, compressed natural gas (CNG) has attracted considerable attention due to its lower environmental impact, lower operating cost and wide availability in Uzbekistan. The country possesses significant natural gas reserves, creating favorable conditions for the widespread adoption of CNG as a motor fuel [3,6,13].

Previous studies have shown that the use of gas fuel can reduce harmful exhaust emissions, improve combustion quality and decrease vehicle operating costs. However, the transition from gasoline to compressed natural gas may also affect engine power characteristics and vehicle performance. Therefore, a comprehensive assessment of the technical and economic efficiency of vehicles operating on different fuel types is required [8,9,10,11,14,15].

The purpose of this study is to compare the fuel consumption, engine performance and economic efficiency of passenger cars operating on gasoline and compressed natural gas under operating conditions typical for Uzbekistan.

II. Methods. The experimental studies were carried out in the laboratories of Andijan Avtotekhizmat LLC, Mukammal Avtoservis LLC and Andijan State Technical Institute located in Andijan, Republic of Uzbekistan.

The research objects were three passenger car models widely operated in Uzbekistan: Nexia R3, Gentra and Cobalt. All vehicles were equipped with spark-ignition internal combustion engines with a displacement of 1.5 liters and were tested under comparable technical and operating conditions. The vehicles were operated on AI-92 gasoline and fourth-generation compressed natural gas (CNG) fuel systems.

The purpose of the experimental study was to compare the fuel consumption, engine power characteristics and economic efficiency of passenger cars operating on gasoline and compressed natural gas.

To determine the engine performance indicators, a brake dynamometer test stand was used. The brake dynamometer enables the measurement of effective engine power and torque under different operating conditions by applying a controlled load to the engine crankshaft. The measurement system consists of an electromagnetic load simulator, torque sensor and electronic data acquisition unit [4,12].

During testing, the engine was operated at different crankshaft rotational speeds ranging from idle speed to the rated operating mode. For each operating mode, engine power, torque and fuel consumption were recorded. The tests were conducted separately for gasoline and compressed natural gas while maintaining identical operating conditions.

The effective engine power was determined according to the following equation:

$$Ne = (Me \times n) / 9550 \quad (1)\ [4]$$

where:

Ne – effective engine power, kW;

Me – engine torque, N·m;

n – crankshaft rotational speed, rpm.

The comparative fuel consumption analysis was performed using the average fuel consumption per 100 km of vehicle travel. To compare the energy efficiency of gasoline and compressed natural gas, the equivalent fuel coefficient was determined based on the lower heating values of the fuels.

The conversion coefficient was calculated as:

$$k = Qg / Qcng \quad (2)\ [7,13]$$

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where:

k – fuel equivalence coefficient;

Qg – lower heating value of gasoline, kCal/l;

Qcng – lower heating value of compressed natural gas, kCal/m³.

Based on the obtained coefficient, the equivalent consumption of compressed natural gas corresponding to gasoline consumption was determined and used in the economic assessment.

The operating cost per 100 km was calculated according to the following relationship:

$$C = L \times P \quad (3)$$

where:

C – operating cost, UZS;

L – fuel consumption per 100 km;

P – unit fuel price.

The obtained experimental data were processed using comparative analysis methods. Fuel consumption, engine power and operating costs were compared for each vehicle model under gasoline and compressed natural gas operating conditions. The results were subsequently presented in graphical and tabular form to evaluate the technical, economic and environmental efficiency of both fuel types.

III. Results and Discussion. The increasing number of vehicles operating in Uzbekistan necessitates the selection of economically efficient and environmentally friendly fuels. In this study, the fuel consumption, engine power characteristics and operating costs of Nexia R3, Cobalt and Gentra passenger cars operating on gasoline and compressed natural gas (CNG) were comparatively analyzed.

The experimental results demonstrated that the transition from gasoline to compressed natural gas significantly affects vehicle operating indicators. Figures 1–3 present the comparative fuel consumption characteristics of the investigated vehicles operating on gasoline and CNG.

Analysis of the obtained results showed that the use of compressed natural gas reduced fuel costs while maintaining acceptable vehicle performance. The lower operating cost of CNG is primarily associated with its lower market price and favorable energy characteristics [12].

For the Nexia R3 vehicle, the average gasoline consumption under urban operating conditions was 8.6 L/100 km. Considering the calorific value equivalence between gasoline and compressed natural gas, the corresponding CNG consumption was determined to be approximately 6.64 m³/100 km. Similar trends were observed for the Gentra and Cobalt vehicles.

The experimental data indicate that compressed natural gas provides sufficient energy to ensure stable engine operation while reducing overall operating expenses. However, due to the lower volumetric energy density of gaseous fuel and changes in the combustion process, a slight decrease in engine power was observed.

Figures 4–6 illustrate the variation of engine power for the tested vehicles operating on gasoline and compressed natural gas. The results reveal that engine power decreased by approximately 10–15% when operating on CNG. This reduction can be explained by the displacement of intake air by gaseous fuel and the resulting decrease in volumetric efficiency.

Despite the reduction in power output, the vehicles maintained satisfactory dynamic performance under normal urban driving conditions. Therefore, the observed decrease in power does not significantly affect the practical operation of passenger vehicles.

To evaluate the economic efficiency of fuel substitution, a detailed calculation was performed using the Nexia R3 vehicle as a representative example. The lower heating values of gasoline and compressed natural gas were taken as 7800 kCal/L and 9400 kCal/m³, respectively.

The fuel equivalence coefficient was determined using Equation (2):

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$$k = 7800 / 9400 = 0.83$$

This result indicates that approximately 0.83 m³ of compressed natural gas provides an energy equivalent to one liter of gasoline.

Based on the measured gasoline consumption of 8.6 L/100 km, the equivalent compressed natural gas consumption was calculated as:

$$LCNG = 0.83 \times 8.0 = 6.64 \text{ m}^3/100 \text{ km}$$

At the time of the study, the average retail fuel prices were:

Gasoline (AI-92) = 10,700 UZS/L;

Compressed natural gas = 3,950 UZS/m³.

Consequently, the operating costs per 100 km were determined as follows:

Gasoline:

$$Cgasoline = 8.6 \times 10{,}700 = 92{,}020 \text{ UZS}$$

Compressed natural gas:

$$CCNG = 6.64 \times 3{,}950 = 26{,}228 \text{ UZS}$$

The results show that the operating cost of the vehicle running on compressed natural gas is substantially lower than that of the gasoline-powered vehicle.

The percentage reduction in fuel expenditure was calculated according to:

$$\eta = ((92{,}020 - 26{,}228) / 92{,}020) \times 100$$

$$\eta = 71.4\%$$

Thus, the transition from gasoline to compressed natural gas reduces fuel expenses by approximately 71.4%.

In addition to economic benefits, the use of compressed natural gas contributes to environmental protection. More complete combustion of methane fuel results in lower emissions of carbon monoxide, unburned hydrocarbons and particulate matter compared to conventional gasoline fuel. Furthermore, the absence of liquid fuel washing effects on cylinder walls reduces engine wear and contributes to longer engine service life.

Overall, the obtained results confirm that compressed natural gas represents an economically advantageous and environmentally sustainable alternative fuel for passenger vehicles widely used in Uzbekistan.

IV. Conclusions. Based on the experimental and analytical studies conducted on Nexia R3, Gentra and Cobalt passenger cars operating on gasoline and compressed natural gas, the following conclusions were obtained:

1. The comparative analysis demonstrated that compressed natural gas can effectively replace gasoline fuel in passenger vehicles while maintaining stable engine operation and acceptable performance characteristics.

2. The equivalent consumption of compressed natural gas for the Nexia R3 vehicle was determined to be approximately 6.64 m³ per 100 km, corresponding to a gasoline consumption of 8.6 L per 100 km under urban driving conditions.

3. Economic calculations showed that the operating cost of a vehicle running on compressed natural gas is significantly lower than that of a gasoline-powered vehicle. The fuel expenditure per 100 km decreased from 92,020 UZS to 26,228 UZS, resulting in a cost reduction of approximately 71.4%.

4. Experimental results indicated that engine power decreases by approximately 10–15% when operating on compressed natural gas due to the characteristics of gaseous fuel and reduced volumetric efficiency. However, this reduction does not significantly affect normal vehicle operation.

5. The use of compressed natural gas contributes to environmental protection by reducing the emission of harmful exhaust components and improving fuel combustion efficiency.

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6. The absence of gasoline dilution effects in the lubrication system reduces engine wear, extends engine service life and increases engine oil replacement intervals.

7. Considering current fuel prices in Uzbekistan, the installation cost of a fourth-generation compressed natural gas system can be recovered within a relatively short operating period, making the conversion economically feasible for vehicle owners.

The obtained results confirm that compressed natural gas is an economically efficient and environmentally sustainable alternative fuel for passenger vehicles and can contribute to reducing fuel costs and harmful emissions in the transport sector of Uzbekistan.

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