Studies of the influence of the emission of harmful substances into the atmosphere with using automated systems in a car

A V Cheremisin¹,², S S Makeev¹, S E Logunov¹ and A A Mozhayko¹

¹Peter the Great Saint Petersburg Polytechnic University, Saint Petersburg, 195251, Russia
²All Russian Research Institute of Phytopathology, Moscow Region 143050, Russia

E-mail: laksacher@yandex.ru

Abstract. The article considers the problem of increasing fuel economy and environmental friendliness of passenger cars. It was discovered that the effective ambient temperature, the color of the opaque body elements, the power of the internal combustion engine and the volume of the passenger compartment affect the fuel consumption and the amount of specific emissions of harmful substances with exhaust gases when using the "climate control" system. The results of experimental studies have established the dependence of fuel consumption and the share of reducing emissions of harmful substances with exhaust gases of cars with a "climate control" system on the coefficient of light reflection. It developed a method of reducing fuel consumption and the amount of specific emissions of harmful substances with exhaust gases of passenger cars with a "climate control" system. The use of this method makes it possible to reduce fuel consumption by 5.5-10.3% and the specific emission of harmful substances by 0.8-2.3%.

1. Introduction
The limited reserves of natural energy sources are driving up prices for all types of fuel [1-10]. High fuel consumption and extraction of raw materials cause great harm to the environment [11-20]. This necessitates improving the fuel efficiency of vehicles. Reducing fuel consumption leads to more sustainable vehicles [9, 10, 14, 16, 21-28]. The levels of carbon monoxide and hydrocarbons in the exhaust gases of cars are regulated, but they are difficult to control during the operation of the car. Reducing fuel consumption automatically reduces the specific emissions of harmful substances with exhaust gases. The control of gases and other harmful substances in the air and water is carried out by various methods [29-39].

When identifying the features of the operation of passenger cars at the present time, one should also take into account the effect of high temperatures. In the Russian Federation, the number of car-days in operation of passenger cars at temperatures above 20°C is more than 51%. Exceeding the effective ambient air temperature of the standard value of 20°C affects the amount of heat that enters the vehicle interior by changing the thermal state of its structural elements.

An automated climate control system which belongs to the auxiliary equipment of a passenger car is used to create the required microclimate in the cabin. Its inclusion in the work leads to an increase in the share of the engine power of the car, which is spent on the operation of auxiliary equipment, that it causes an increase in the consumption of fuel by the vehicle. The greatest influence is observed in the
absence of cooling structural elements of the body of air flows that occur when a car is moving, when a passenger car is idle with a running internal combustion engine.

In this case, an increase in the consumption of fuel consumed by a passenger car during idle time, the operation of the internal combustion engine and the inclusion in the operation of the "climate control" system, leads to an increase in the volume of exhaust gases. They are 95-98% composed of the products of complete combustion, unused oxygen and nitrogen of the air. They also consist 2-5% of several hundred components that determine the degree of the vehicle's harmful effect on the environment. However, the products of complete combustion also contain chemical compounds that have a negative effect on the ecological state of the atmosphere, for example, carbon dioxide, which contributes to the development of the greenhouse effect. Reducing the concentration of this compound in the exhaust gases can be achieved by decreasing the fuel consumption of passenger cars. Therefore, studies to improve the fuel efficiency and environmental friendliness of passenger cars when idle with a running internal combustion engine and the included "climate control" system is extremely important.

2. Research methodology and instruments

The environmental friendliness of the transport system can be described as the ability of vehicles to perform transport work or transport passengers with the lowest possible emissions of harmful substances under strictly defined conditions. Fuel consumption and the content of harmful substances in the exhaust gases of vehicles depend on many factors, in particular on the inclusion of auxiliary equipment in the operation and operating conditions.

An increase in the ambient air temperature increases the amount of heat entering the passenger compartment, therefore, the microclimate inside the vehicle changes.

An increase in the amount of heat gains causes an increase in the air temperature in the passenger compartment, to lower and maintain which within the values corresponding to comfortable conditions, the "climate control" system is used. The main characteristics of its operation, which affect the fuel consumption of a passenger car, are cooling capacity and power consumption. They depend not only on the amount of heat supplied to the passenger compartment, but also on its volume, an increase in which, along with an increase in the amount of heat input, causes an increase in the power required for the operation of the "climate control" system.

It has been established that the increase in fuel consumption by a passenger car when the climate control unit is turned on is determined by an increase in the share of power take-off of the car engine for the operation of this auxiliary equipment, which is characterized by the ratio of the cooled volume of the passenger compartment to the power of the car engine. This value is characterized by the specific climatic power parameter, which determines the share of the internal combustion engine power, which is required to cool a unit volume of the vehicle interior.

The effective ambient temperature, the color of the opaque body elements and the developed parameter of the specific climatic power (the ratio of the volume of the passenger compartment of a passenger car to the power of its engine) affect the fuel consumption of a passenger car during the idle and operation of the internal combustion engine and the climate control installation, which, in turn, affects the amount of specific emissions of harmful substances with exhaust gases. However, the effective ambient temperature is an uncontrollable factor, and the coefficient of light reflectance of opaque body elements is a controllable input value that can be quite easily changed by imparting a color characterized by the maximum coefficient of light reflectance. Thus, it is necessary to develop a method to reduce the increase in fuel consumption of a passenger car during the idle and operation of the internal engine and the "climate control" system.

The measurement of the coefficient of light reflection was carried out using a thermal imager. The illumination of the site was assessed using a light meter. Fuel consumption was measured using the BT-ECU CAN adapter. Gas analyzer GIAM-29M-1 and other optical methods were used to control the volumetric content of harmful substances in the exhaust gases of engines. [40-43].
3. Results of experimental studies and their discussion

As a result of experiments, it was found that the fuel consumption of passenger cars during idle and operation of the internal combustion engine and the "climate control" system depends on the effective ambient temperature, the power of the internal combustion engine, the volume of the passenger compartment and the color of the opaque body elements (coefficient of light reflection). Of the presented controllable factors, only the power of the car engine, the volume of the passenger compartment and the color of the opaque body elements are considered; however, it is difficult to change the first two factors. Thus, one of the ways to influence the fuel consumption of a passenger car during idle time and operation of the internal combustion engine and the "climate control" system is to impart a color characterized by the highest light reflectance (white). The influence of the coefficient of light reflection of opaque body elements on the increase in fuel consumption Δq by a car during idle and operation of the internal combustion engine and the "climate control" system is shown in fig. 1.

![Figure 1](image1.png)

**Figure 1.** Dependence of the influence of the coefficient of light reflection of opaque body elements on Δq during idle and operation of the internal combustion engine and climate control settings for various temperatures. Figures 1, 2 and 3 correspond to T(K): 293.2, 303.1, 310.3.

An increase in the effective ambient temperature causes an increase in fuel consumption of a passenger car during idle and operation of the internal combustion engine and the "climate control" installation. A similar dependence is observed when the color of the opaque body elements changes from a light shade to a dark one, characterized by a lower value of the light reflectance coefficient K. This leads to an increase in the specific emissions of harmful substances with exhaust gases into the atmosphere, which is shown in fig. 2 and 3.

![Figure 2](image2.png)

**Figure 2.** Dependence of the reduction in specific emissions of carbon monoxide with exhaust gases of the passenger car during idle and operation of the internal combustion engine and the "climate
control" system from the K coefficient for various ambient temperatures. Figures 1, 2 and 3 correspond to T(K): 293.2, 303.1, 310.3.

An increase in the K factor leads to a decrease in the specific emissions of carbon monoxide and hydrocarbons with exhaust gases. Thus, to reduce the fuel consumption and specific emissions of harmful substances with exhaust gases, it is necessary to paint opaque body elements in colors characterized by a high coefficient of light reflectance. However, the amount of heat entering the passenger car interior is also influenced by the internal structure of the opaque body elements. The structure of the arrangement of the inner layers of the opaque body wall is shown in fig. 2.

![Graph](image)

**Figure 3.** Dependence of the reduction of specific emissions of hydrocarbons with exhaust gases of the passenger car during idle and operation of the internal combustion engine and the "climate control" system from K of the body on the ambient temperature. Figures 1, 2 and 3 correspond to T(K): 293.2, 303.1, 310.3.

The largest amount of heat enters the cabin through the roof due to the peculiarities of its internal structure, which consists in the absence of two additional layers. Thus, a reduction in fuel consumption and specific emissions of harmful substances with exhaust gases of a passenger car when using the "climate control" system can be achieved by making the roof of a passenger car white.

Application of the developed method made it possible to reduce the fuel consumption of a passenger car when using the "climate control" system by 5.5-10.3%. Giving a white roof to a silver car resulted in the fuel consumption similar to that of a white car.

The reducing fuel consumption by the passenger car during the implementation of the developed method made it possible to reduce the amount of the specific emissions of the carbon monoxide by 0.37-1.13% and the hydrocarbons by 0.47-1.08% with exhaust gases.

Thus, giving a white color to the roof of a vehicle will reduce the fuel consumption of a passenger car by 5.5–10.3% and reduce the total amount of specific emissions of harmful substances with exhaust gases by 0.8–2.3%.

4. **Conclusion**

In the course of experimental studies, it was found that when the color of the opaque body elements changes from light to dark (a decrease in the light reflectance coefficient), the fuel consumption and the concentration of carbon monoxide and hydrocarbons in the exhaust gases of cars increase when using the "climate control" installation.

The area of the opaque body elements and their internal structure are analyzed. This made it possible to reveal that the greatest amount of heat enters the cabin through the roof due to the peculiarities of its internal structure. Optimization of the parameters of this element of the car will reduce fuel consumption and, consequently, the emission of harmful gases into the atmosphere.
 References

[1] Yushkova V, Kostin G, Davydov R, Dudkin V and Valiullin L 2019 *IOP Conference Series: Earth and Environmental Science* 390(1) 012016

[2] Petrichenko M, Vatin N, Nemova D, Kharkov N and Staritcyna A 2014 *Applied Mechanics and Materials* 627 297-303

[3] Van S, Cheremisin A, Davydov R and Yushkova V 2019 E3S Web of Conferences 140 09008

[4] Van S, Cheremisin A, Chusov A, Switala F and Davydov R 2019 *IOP Conference Series: Earth and Environmental Science* 390(1) 012011

[5] Davydov V, Nikolaev D, Bukharov G and Pavlova Z 2020 *Proceedings of the 2020 IEEE International Conference on Electrical Engineering and Photonics, EExPolytech 2020* 9243948 227–229

[6] Murgul V, Vatin N and Zayats I 2015 *Procedia Engineering* 117(1) 819–824

[7] Vatin N, Petrichenko M and Nemova D 2014 *Applied Mechanics and Materials* 633-634 1007–1012

[8] Davydov R, Antonov V and Kalinin N 2015 *Journal of Physics: Conference Series* 643(1) 012107

[9] Nikolaev D, Chetiy V and Dudkin V 2020 *IOP Conference Series: Earth and Environmental Science* 578(1) 012052

[10] Sergeev V, Vatin N, Kotov E, Nemova D and Khorobrov S 2020 *Applied Sciences* (Switzerland) 10(23) 1–16 8739

[11] Lukashev N 2019 *Journal of Physics: Conference Series* 1236(1) 012068

[12] Valov A, Davydov R, Rud V and Grevtseva A 2019 *Journal of Physics: Conference Series* 1326(1) 012040

[13] Davydov R and Antonov V 2016 *Journal of Physics: Conference Series* 769(1) 012060

[14] Davydov V, Dudkin V and Karseev A 2013 *Optical Memory and Neural Networks (Information Optics)* 22(2) 112–117

[15] Davydov V, Dudkin V and Karseev A 2014 *Optical Memory and Neural Networks (Information Optics)* 23(4) 259–264

[16] Davydov V, Dudkin V and Karseev A 2014 *Optical Memory and Neural Networks (Information Optics)* 23(3) 170–176

[17] Smirnova S and Nikolaev D 2020 *Journal of Physics: Conference Series* 1695(1) 012136

[18] Natorkhin M, Bobyl A, Cheremisin A and Sokolov M 2019 *Journal of Physics: Conference Series* 1236(1) 012011

[19] Davydov V 1999 *Russian Physics Journal* 42(9) 822–825

[20] Davydov R, Antonov V, Molodtsov D and Trebukhin A 2018 *Advances in Intelligent Systems and Computing* 692 915–920

[21] Davydov V, Fadeenko V, Popovskiy N and Rud V 2019 E3S Web of Conferences 140 07006

[22] Myazin N, Davydov V, Yushkova V and Rud V 2019 *Environmental Research, Engineering and Management* 75(2) 28–35

[23] Davydov V, Cheremiskina A, Velichko E and Karseev A 2014 *Journal of Physics: Conference Series* 541(1) 012006

[24] Davydov V, Dudkin V and Karseev A 2015 *Journal of Applied Spectroscopy* 82(5) 794–800

[25] Davydov V, Dudkin V, Myazin N and Rud V 2018 *Instruments and Experimental Techniques* 61(1) 140–147

[26] Davydov V, Velichko E, Myazin N and Rud V 2018 *Instruments and Experimental Techniques* 61(1) 116–122

[27] Davydov V, Velichko E, Dudkin V and Karseev A 2015 *Instruments and Experimental Techniques* 58(2) 234–238

[28] Davydov V, Velichko E, Dudkin V and Karseev A 2014 *Measurement Techniques* 57(6), 684–689
[29] Moroz A, Malanin K, Krasnov A and Rud V 2019 *Journal of Physics: Conference Series* **1400**(4) 044009
[30] Moroz A 2019 *Journal of Physics: Conference Series* **1368**(2) 022024
[31] Podstrigaev A, Smolyakov A and Grebenikova N 2019 *Lecture Notes in Computer Science* (including subseries *Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics*) **11660** LNCS 525–533
[32] Moroz A 2019 *Lecture Notes in Computer Science* (including subseries *Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics*) **11660** LNCS 710–718
[33] Moroz A, Malanin K and Krasnov A 2019 *Proceedings of the 2019 Antennas Design and Measurement International Conference, ADMInC 2019* 8969090 114–116
[34] Davydov V, Dudkin V and Karseev A 2015 *Technical Physics* **60**(3) 456–460
[35] Gryznova E, Grebenikova N, Ivanov D and Bykov V 2019 *IOP Conference Series: Earth and Environmental Science* **390**(1) 012044
[36] Myazin N, Dudkin V, Grebenikova N, Rud V and Podstrigaev A 2019 *Lecture Notes in Computer Science* (including subseries *Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics*) **11660** LNCS 744–756
[37] Davydov V, Nikolaev D, Moroz A, Dmitrieva D and Pilipova V 2020 *AIP Conference Proceedings* **2308** 060005
[38] Moroz A 2019 *Journal of Physics: Conference Series* **1410**(1) 012212
[39] Myazin N, Yushkova V, Taranda N and Rud V 2019 *Journal of Physics: Conference Series* **1410**(1) 012130
[40] Smirnov K, Glagolev S and Tushavin G 2018 *Journal Physics: Conference Series* **1124**(1) 022014
[41] Sachenko A, Kostylov V, Sokolovskiy I, Bobyl A, Terukov E and Shvarts M 2017 *Technical Physics Letters* **43**(2) 152-155
[42] Smirnov K, Medzakovskiy V, Vysochzyk V and Glagolev S 2017 *Journal of Physics: Conference Series* **917**(6) 062019
[43] Smirnov K, Glagolev S, Rodygina N and Ivanova N 2018 *Journal of Physics: Conference Series* **1038**(1) 012102