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Ways To Reduce The Negative Impact Of Vehicles On The Environment In Low-Temperature Operating Conditions.

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ABSTRACT

At present, more than half of the population is concentrated in the cities, which causes a high centralization of vehicles and industrial enterprises. This leads to an increase in the number of harmful substance emissions up to 75% into the atmosphere. According to the United Nations, nine out of ten city dwellers breathe air not complying with the maximum permissible concentrations. Therefore, programs to increase the number of vehicles with zero emissions are actively developed and implemented, in particular, electric transport is a evolving mode of transport. However, in the Russian Federation, the development of this area lags behind the world market by 7-8 years, which necessitates a search for alternative ways to improve the fuel economy and environmental friendliness of transport. In low-temperature operating conditions, which are typical for the Russian Federation, it is the improvement of methods and devices that increase the adaptability of vehicles and motor fuels. At present, the heating of process fluids using microwave radiation can be attributed to these methods. The article presents an analysis of the effect of microwave radiation on changes in the physicochemical characteristics and performance of an internal combustion engine. As a result, the positive effect of the developed method of heating on winter diesel fuel has been revealed.

Keywords: vehicles, winter diesel fuel, adaptability, low temperature conditions, process fluids

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INTRODUCTION

Modern cities occupy only 3% of the land area, while their population is about 55%, due to the peculiarity of their formation around large industrial centers. According to the UN, carbon emissions are 75% in cities. These emissions cause not only an increase in the average global air temperature, and, consequently, climate change and the occurrence of natural disasters, but also an adverse impact on the population. At present, nine out of ten city dwellers breathe air that does not meet the standards of maximum permissible concentrations. This leads to a decrease in life expectancy and an increase in the number of congenital and acquired chronic diseases. Such development trends are characteristic of the population living in cities in the territory of the Russian Federation. Therefore, at present, the program of sustainable cities, which is aimed at creating comfortable, safe and ecological clean areas, has been actively developed. This program considers the use of alternative energy sources as energy supply methods, the construction of energy efficient houses to reduce the amount of energy consumed, as well as the number of population movements and the introduction of vehicles with zero emissions, as road transport is one of the main sources of air pollution in the city. One type of vehicle with zero emissions is electric transport. In the Russian Federation, its development lags behind the world market by 7-8 years and its implementation causes a number of difficulties associated with the national mentality, lack of understanding of the state's own goals for its development, and, therefore, in the absence of government incentives, as well as the lack of infrastructure, special service centers and spare parts. Therefore, one of the current ways to reduce emissions of harmful substances into the atmosphere from road transport is to increase its fuel efficiency, which in particular depends on the adaptability of vehicles to operating conditions [1,2]. The most variable parameter of operating conditions is the ambient temperature. Its increase leads to a rise in engine temperature, as well as the need to turn on the climate system, which causes an increase in fuel consumption. Especially clearly this situation is observed at extremely low air temperatures, which are typical for the territory of Russia. A decrease in temperature causes an increase in the viscosity of the fuel and technical liquids, hence their consumption, or leads to engine malfunction as a result of the crystallization processes of the components, this is especially characteristic of diesel fuel.

Features of the location of the Russian Federation, namely the length along the northern latitudes and the vastness of the territory, which has a long winter period, necessitate the adaptation of fuels or vehicles for use in low-temperature conditions.

In road transport, the main areas of research related to improving the efficiency of vehicle operation in low-temperature conditions are optimization of the rolling stock structure and improvement of the design of both vehicles and subassemblies [3,4,5,6]. In low-temperature operating conditions, it is possible to achieve an increase in the efficiency of diesel fuel application by using devices that preheat fuel and technical fluids to operating temperature [7,8,9]. However, at present, their use is not great. In the course of research, the use of these devices, namely, pre-start, tape heaters, the heat of electric heaters is common. One of the modern methods of heating, which has not been studied enough in the course of research, is heating up by ultra-high frequency currents [10,11,12,13,14]. At the present time, the possibility of its use is being studied in pipeline and rail transport. In road transport, it is considered as a promising way to adapt vehicles to low temperature conditions. However, preliminary tests aimed at studying the characteristics of the effect of ultra-high frequency currents on the physicochemical parameters of fuels and process fluids are necessary to create an industrial design. Therefore, the purpose of this study is to identify patterns of influence of process parameters on the physicochemical parameters of diesel fuel.

METHODOLOGY

A detailed analysis of the vehicle adaptability to various operating conditions, including low-temperature variables, was performed in the researches of Reznik L.G., Petrov A.I., Karnaukhov V.N., Manyashin A.V., Chaynikov D.A. Abakumov G.V., Havaev A.S., Corberan J. M., Gonzalez-Gil A., Bjurling F., Palancin R., Torregrosa-Jaime B. and others. This line of study develops at present. In practice, improving the adaptability of vehicles to low-temperature conditions is accompanied by the development of devices aimed at heating its components and assemblies. At the same time, the evolution of the automotive industry determines the introduction of intelligent control systems for heating devices to achieve its full autonomy. Therefore, the neural system for controlling the heating and maintaining the required temperature of the process fluids is an actual solution to the problem under consideration. The development of this system is due to the emergence of components that can instantly be included in the work and perform uniform heating of the process fluid by volume. Magnetron emitting microwave radiation is a given component. Features of heating this type in technical systems, in particular in the transport industry, are considered in the studies of Anfinogenov V. I., Garayev T. K., Semenov V. A., Arkhangelsky Yu. S., Dotsenko A. V., Smolin A. A, Granat K., Nowak D., Suhajda K and others. The authors confirm the competitiveness and efficiency of maintaining the temperature of process fluids using this method, but they do not consider the impact of the processes causing changes in the physicochemical properties and, accordingly, the performance of the internal combustion engine such as starting qualities, fuel consumption and emissions of harmful substances. Although the feature of exposure to microwave radiation is the ability to change the molecular and atomic structure of hydrocarbons as a result of the process, which causes a change in the physicochemical properties. Therefore, this work is aimed at studying the characteristics of the effect of microwave radiation on the change of physicochemical parameters when the process fluid is heated.

The study is based on the use of microwave radiation as a source of heating diesel fuel. This type of heating was chosen because it has the rapidity of heating a liquid, the absence of thermal inertia and minimal energy expenditure. However, the effect of microwave radiation causes a change in the physicochemical properties of the process fluid, which is due to the peculiarities of the processes that occur, namely the polarization of the dielectric molecules, their mechanical oscillations and their further transformation into thermal energy. A feature of microwave radiation is also the creation of an electromagnetic field with a frequency range selected in accordance with the volume, temperature difference, physicochemical properties of the process fluid and the size of the heated compartment. A prerequisite for the application of this heating is the creation of such a frequency of oscillation that its function, this is the wavelength, is less than the geometrical dimensions of the compartment and can be repeatedly reflected from the walls, passing through the entire volume of liquid. Therefore, the preliminary stage of the research is to study the effect of microwave radiation on the change in the physicochemical parameters of the process fluid. However, the effect of microwave radiation on the performance of the internal combustion engine must be studied to assess the effectiveness of the developed system application. At the same time, we have to analyze the obtained results and create conceptual approaches about the applicability or impossibility of using this method for heating and maintaining the optimum temperature of the process fluid in vehicles.

The optimum temperature of process fluids is one of the main indicators that determine the efficiency of the equipment, including the internal combustion engine, as it reduces the wear of parts, increases the fuel economy of the vehicle, and, consequently, reduces emissions of harmful substances. At the same time, this temperature has different values for each process fluid and, accordingly, allows to improve the characteristics of the process depending on the place of its application. So the oil used in the internal combustion engine and the gearbox causes a decrease in wear of parts, as a result of improved lubricity and penetration into the gap between the friction parts when it has an optimum temperature. When the hydraulic oil used in the hydraulic system, hydraulic cylinders and shock absorbers reaches the optimum temperature, it has the viscosity necessary for working under high pressure. In an internal combustion engine, the coolant contributes to an increase in the quality of mixture formation with air and the complete combustion of fuel. Also, the improvement of mixture formation and completeness of combustion is achieved when the fuel has an optimum temperature. This contributes to reduce fuel consumption and emissions of harmful substances with exhaust gases.

The optimum temperature of the process fluid is provided by heating the nodes, units and systems to the required values. In this case, in low-temperature operating conditions, the greatest difficulty is associated with the heating of the internal combustion engine, which causes correspondingly the difficulty of starting it. Therefore, at present, the heating systems of the internal combustion engine, as well as its components and assemblies, have become widespread. The heaters used in practice are based on the general principle; they transfer heat from the heated body to the process fluid. However, these methods are characterized by high inertia, which causes the inability to maintain the working temperature constant, have a high metal consumption, are not reliable in operation, which leads to an increase in additional costs for restoring their efficiency. Therefore, in the course of this study, a method and device that provides rapid heating of a liquid to operating temperature and supports it was developed to study the effect of microwave radiation on the physicochemical properties of process fluids.

Research Methodology

The experiment consisted of several stages. The effect of microwave radiation on changes in the physicochemical parameters of the process fluid, which was used as winter diesel fuel with a volume of 2 liters, was estimated at the first stage. It was divided into 20 samples, each of which had a volume of 100 ml. Next, the obtained samples were processed by microwave radiation for different periods of time. Baseline data asked during the first stage of the experiment are presented in Table 1.

Table 1. Settings for the magnetron.

Sample number	Processing time, s.	Magnetron power, W	Wave frequency, Hz.
1	0	850	2.4
2	180	850	2.4
3	300	850	2.4
4	480	850	2.4

According to the approved standards of the Russian Federation, the processed samples were studied by physical and chemical parameters, namely, kinematic viscosity, density and flash point in a closed crucible. Kinematic viscosity was determined according to GOST 33-2000 “Oil products. Transparent and opaque liquids. Determination of kinematic viscosity and calculation of dynamic viscosity ". The purpose of determining this indicator is the ability of the fuel to expire from a vessel of a specified volume, through a special capillary for a certain length of time. This physical and chemical indicator characterizes the atomization of the fuel and the uniformity of the working mixture.

The density of diesel fuel was determined to establish compliance with the brand of diesel fuel and energy. The measurement of this indicator was carried out in accordance with GOST 3900-85 “Oil and petroleum products. Methods for determining the density of oil and oil products using a hydrometer for oil”. In this case, the hydrometer was used as the main equipment. It was immersed in the test product, after which the readings on the scale of the hydrometer at the temperature of determination were removed. The results were recalculated for the density of the product at a temperature of 20°C.

The flash point in a closed crucible made it possible to estimate the fractional composition of the fuel and its fire safety. The determination was performed in accordance with GOST 6356-75 “Oil products. Method for determining the flash point in a closed crucible”. The fuel was placed in a closed crucible, which was heated at a constant rate with continuous stirring. During the test, researchers evaluated the possibility of ignition of vapors formed above the surface of the fuel at intervals as indicated in the regulatory document. The minimum temperature at which the resulting mixture of vapors and gases with air above the fuel surface ignited was chosen as the result.

The second stage of testing included the study of the influence of the processing of winter diesel fuel by microwave radiation on engine performance. The SDMO T9KM diesel generator set, equipped with a Mitsubishi S3L2 diesel engine, was used as equipment. Its technical characteristics are presented in Table 2.

Table 2. Technical characteristics of diesel generator set.

Technical characteristic	Value of technical characteristic
Power, W	8.6
Nominal crankshaft speed, rpm	1500
Fuel consumption, l/h	2.4
Noise level, dB	60.4

The following values were established by the conditions of the experiment: fuel temperature equal to + 20 ° C, air temperature equal to + 20 ° C, atmospheric pressure equal to 750 mm Hg, engine load equal to 70% of the nominal power and crankshaft rotation frequency 1500 rpm. The hourly fuel consumption, which was displayed on the instrument panel of the installation, as well as the content of nitrogen oxides, measured using a gas analyzer, and the opacity of the exhaust gases, determined using a smoke meter, were determined during this phase of the study.

The used gas analyzer GIAM-29M-3 is usually used to monitor and estimate emissions of harmful substances into the atmosphere with the exhaust gases of internal combustion engines, including diesel engines, according to GOS R 51249-99 and GOS 52408-2005. Technical characteristics of the gas analyzer used are presented in Table 3.

Table 3. Technical characteristics of gas analyzer.

Technical characteristic	Value of technical characteristic
Operating principle	electrochemical
NOx measuring range, % vol.	0-0.5
Limit of the allowed main reduced error NO, %	10
Temperature of environment, °C	0…+45

Exhaust gas opacity was estimated using a META 01MP 0.1 LTK smoke meter, the technical characteristics of which are presented in Table 4.

Table 4. Technical characteristics of smoke meter.

Technical characteristic	Value of technical characteristic
Smoke measurement range in terms of absorption coefficient, not less than, m^{-1}	0…∞
Smoke measurement range in terms of attenuation, %	0-100
The limit of permissible absolute error with an absorption coefficient of 1.6 - 1.8 m^{-1}, not more than, m^{-1}	±0.05
The nominal value of the lowest discharge unit for the absorption coefficient, m^{-1}	0.01
Photometric base, m	0.01

The obtained results allowed to evaluate the possibility of using the developed method of heating process fluids, in particular, winter diesel fuel.

RESULTS AND DISCUSSION

During the first stage of the study, the physicochemical parameters of the treated diesel fuel, which represent samples 2,3,4, and the control raw sample 1, are determined. The data obtained from the experiment are shown in table 5.

Table 5. Physical indicators of the processed and not processed samples.

Indicators	Sample number			
	1	2	3	4
Kinematic viscosity, mm^2/s	3.21	3.16	3.13	3.04
Density, kg/m^3	824	821	820	815
Flash point in closed crucible, °C	36	33	30	30

The increase in the duration of the impact of the magnetron reduces all physico-chemical indicators. This is due to the decrease in the number of high-molecular hydrocarbons in the fuel, namely the number of naphthenic and aromatic rings, the length of their radical and the chain of paraffinic hydrocarbons. These changes caused a decrease in viscosity, including flash point in a closed crucible, as it depends on the concentration of light hydrocarbons. Increasing the number of compound this type leads to a decrease in flash point in a closed crucible.

The increase in the concentration of light hydrocarbons also causes changes in the performance of the internal combustion engine. The results of the second stage of testing are presented in table 6.

Table 6. The performance of the internal combustion engine.

Indicators	Sample number			
	1	2	3	4
Fuel consumption, l/h	2.38	2.31	2.24	2.21
NOx content in exhaust gases, %	0.03	0.03	0.026	0.023
Exhaust smoke, %	60	58	55	52

As a result, the increase in the duration of exposure to microwave radiation on diesel fuel reduces the opacity of the exhaust gases by 15%, which is associated with an increase in the quality of mixture formation and the absence of oxygen deficiency zones. These changes are caused by a decrease in viscosity and density of winter diesel fuel. Also during the second stage of the experiment, the reduction of nitrogen oxide emissions occurs by 30%, which is associated with a decrease in the flash point of the fuel in a closed crucible. This causes a decrease in auto-ignition temperature and contributes to a more uniform process of combustion of fuel with no temperature peaks. The increase in the quality of mixing and complete combustion of the fuel, as well as the uniformity of the process leads to a decrease in fuel consumption by 7%. The reason for this observation is also an increase in the concentration of light hydrocarbons.

Thus, the heating of winter diesel fuel using microwave radiation is possible. Within the considered limits of exposure time, it leads to positive results, namely, reduction of fuel consumption, nitrogen oxides and exhaust smoke, which is associated with an increase in the concentration of light hydrocarbons in this process fluid.

CONCLUSION

Low temperatures are an essential condition for the operation of vehicles in the Russian Federation, which necessitates the development of special devices or chemical compounds that facilitate their unimpeded use. In this article, an analysis of ways to improve the adaptability of process fluids and vehicles to low-temperature operating conditions is presented.

In the course of experimental studies, the possibility of using microwave radiation for heating and maintaining the temperature of the process fluid, in particular, winter diesel fuel, has been evaluated. An increase in the duration of exposure to winter diesel fuel causes a decrease in physicochemical parameters, namely, kinematic viscosity, density, and flash point in a closed crucible. This leads to a reduction in emissions of nitrogen oxides and exhaust smoke, as well as improved fuel efficiency. Therefore, the introduction of microwave heating technologies for winter diesel fuel has a positive effect, which leads to the need for further development of a neural network system for maintaining the temperature of diesel fuel in a vehicle.

REFERENCES

[1] Karnaukhov N, Reznik L, Holyavko V, “Toxicity automobile exhaust gases at subzero ambient temperature”, Advances in Transport, vol. 6, pp. 439-443, 2000.

[2] Anisimov I A, Gorbunova A D, Burakova L N, Burakova O D, “Evaluation of the effectiveness of the adaptive traffic management system for its development and interaction with electric transport”, IOP Conference Series: Earth and Environmental Science, vol. 177, 012013, 2018

[3] Anisimov I, Ivanov A, Chikishev E, Chainikov D, Reznik L, “ Assessment of gas cylinder vehicles adaptability for operation at low ambient temperature conditions”, WIT Transactions on Ecology and the Environment, vol. 190(1), pp.658-695, 2014.

[4] Ertman J A, Ertman S A, Anisimov I A, Chainikov D A, Chikishev Y M, “Complex characteristic estimation of vehicle adaptability for low temperature operation conditions”, Research Journal of Pharmaceutical, Biological and Chemical Sciences, vol. 6(1), pp. 1761-1770, 2015.

[5] Anisimov I, Ivanov A, Chikishev E, etc. "Assessment of adaptability of natural gas vehicles by the constructive analogy method", International Journal of Sustainable Devlopment and Planning, vol.12, pp.1006-1017, 2017

[6] Chikishev E, Chikisheva A, Chainikov D, etc. "Natural gas use in minibuses, engaged in the cariiage of Passengers and baggage on the regular routes, as a measure for decrease in harmful environment effects", IOP Conference Series: Earth and Environmental Science, vol. 50, 012008, 2017

[7] Torregrosa-Jaime B, Bjurling F, Corberan J M, Sciullo F Di, Paya J, "Transient thermal model of a vehicle's cabin validated under ambient conditions", Applied Thermal Engineering, vol. 75, pp. 45-53, 2015.

[8] Bauer C, Hofer J, Althaus H J, Del Duce A, Simons A, "The environmental performance of current and future passenger vehicles: Life cycle assessment based on a novel scenario analysis framework", Applied Energy, vol.157, pp. 871-883, 2015.

[9] Roskilly A P, Palacin R, Yan J, "Novel technologies and strategies for clean transport systems", Applied Energy, vol. 157, pp. 563-566, 2015.

[10] Novothy M, Suhajda K, Sobotka J, Gintar J, "Use of EMW Radiation in the Building Industry", Advanced Materials Reserch, vol. 1041, pp. 297-302, 2014.

[11] Nowak D, Stachowicz M, Granat K, Pigiel M, "Microwave Adsorption by Used Moulding and Core Sands", Versita, vol. 12, pp. 87-90, 2012.

[12] Granat K, Opyd B, Nowak D, Stachowicz M, Jaworski G, "Determination of electrical properties of materials used in microwave heating of foundry moulds and cores", Metalurgija – Sisak then Zagreb, vol. 54, pp. 347-349, 2015.

[13] Arshanitsa A, Akishin Y, Zile E, Solodovnik V, Telysheva G, "Microwave treatment combined with conventional heating of plant biomass pellets in a rotated reactor as a high rate process for solid biofuel manufacture", Renewable Energy, vol.91, pp. 386-396, 2016.

[14] Habash, Riadh W Y, "Electromagnetic fields and radiation: human bioeffects and safety". – New York: Marcel Dekker, 2002.