JUSTIFICATION OF FUEL MIXTURE COMPOSITION OF PETROLEUM BASED DIESEL FUEL AND DIESEL BIOFUEL BASED ON PLANT OIL

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Abstract. The analysis of resource use shows the annual dynamics of increasing the use of fossil fuels. A special place in the structure of the use of motor fuels falls on diesel fuel of petroleum origin; the annual increase is about 5%. Today, European trends are aimed at reducing the use of diesel engines and diesel biofuels as sources of nitrogen oxide pollution. One way to reduce the pressure on the environment is to use biofuels, which by their nature are renewable resources. However, the use of diesel biofuel in its pure form requires significant changes in the design of the diesel engine and will require a significant increase in the area occupied by oilseeds. Many countries have a propensity to add about 5% of diesel biofuel to diesel fuel of petroleum origin. This approach does not significantly affect the environmental situation or reduce the amount of fossil fuels. The study and analysis of the fractional composition of diesel fuel of petroleum origin and diesel biofuel based on methyl esters of fatty acids of plant oil are performed. Diesel biofuel has significantly higher boiling points compared to diesel fuel. The obtained results indicate the possibility of adding 20% of diesel biofuel to diesel fuel of petroleum origin. When creating such a fuel mixture, it is advisable to replace part of the heavy fractions of diesel fuel of petroleum origin with diesel biofuel. Studies of physical and mechanical properties have shown the feasibility of using this method when creating a fuel mixture. The obtained results allow increasing the quantitative use of diesel biofuels and reducing the negative impact on the environment.

Keywords: petroleum, biofuel, diesel engine, fuel consumption, preheating.

Introduction

The ever-increasing dynamics of the use of fossil resources as fuel is exacerbating the problems associated with global warming [1; 2]. The only way that can significantly improve the situation and reduce greenhouse gas emissions is the use of reducing fuel as energy resources [2-4]. The implementation of the use of biomass as a fuel in the generation of thermal and electrical energy makes it possible to replace fossil fuels in stationary installations and processes [1; 5]. The situation is much worse with the use of renewable fuels for internal combustion engines [2; 6].

The widespread use of renewable fuels for internal combustion engines is associated with a number of technical and social problems [4]. The main social problem of the widespread introduction and use of bioethanol and biodiesel as reducing fuels is that food resources are used for their production [6; 7]. The main disadvantage of the production and use of bioethanol is the high energy consumption in the manufacturing process and the fact that during the fermentation process with the formation of 1 kg of alcohol, 1 kg of CO_2 is released, which is recognized as the main greenhouse gas [7]. Today, the production of biodiesel fuel from food production waste, namely, waste cooking fats, animal fats, as well as substandard raw materials that cannot be used for food purposes, has gained wide support [6; 8; 9].

Biodiesel is similar in properties to diesel fuel, but it has certain disadvantages, namely: higher kinematic viscosity, cloud point and pour point, and lower calorific value [3; 10; 11]. Most diesel engine fuel systems are designed with the properties of diesel fuel in mind, and therefore the use of pure biodiesel leads to deterioration in engine performance [12; 13]. The use of biodiesel in its pure form requires additional equipment of the diesel engine with a system for temperature treatment of fuels or the implementation of changes in its design [9; 13; 14].

Quite a lot of studies have been carried out on the use of mixtures with different concentrations of biodiesel in diesel fuel; the use of such fuel mixtures does not require changes in the design of the engine and its settings [12; 15]. The authors noted that the deterioration in operational performance is due to a decrease, primarily in the calorific value of the fuel mixture [6; 9; 15].

Analysis of the experience of using biodiesel indicates the need to substantiate the composition and methods of obtaining a fuel mixture of diesel fuel of petroleum origin and biodiesel [11; 12]. The optimal composition of the fuel mixture should reduce the negative effect of the properties of biodiesel on the efficient performance of the engine and increase the efficiency of using this type of biofuel.

Materials and methods

When determining the properties of biodiesel that affect its use as a fuel for diesel internal combustion engines, the kinematic viscosity of the fuel was determined in accordance with GOST 33-2016 [16], the fuel density in accordance with GOST 3900-85 [17]. For the possibility of adequate comparison of the data, determination of the indicators of the kinematic viscosity and density of biodiesel was carried out at a temperature of 20 ºC. Measurements of the kinematic viscosity were carried out using viscometers VPZhT-4 and a liquid thermostat TZh-TS-01, fuel density using hydrometers and a liquid thermostat TZh-TS-01 The determination of the cloud point and pour point of experimental biodiesel samples was carried out in accordance with DSTU ISO 3015:2012 [18] and GOST-20287-91 [19].

To understand the course of evaporation and mixture formation, during the combustion of diesel fuel and biodiesel, the fractional composition of the fuel was determined according to the distillation temperature. According to the distillation temperature indicators one can distinguish the presence of heavy fuel fractions, which worsen mixture formation, induce the formation of carbon deposits and increase smoke. Measurements of the fractional composition according to the distillation temperature were carried out on an ARNS-1M apparatus.

Fig. 1. **Apparatus for frictional distillation of fuel**

Let us measure with a dry and clean measuring cylinder 100 cm^3 of the fuel under study (along the lower edge of the meniscus) and pour it into the flask of the ARNS-1M apparatus, pre-washed with gasoline and dried with air. Let us install the steam outlet tube of the flask, so that it fits into the tube of the refrigerator by 25-50 mm. Let us close the flask with a well-ground stopper with a temperature sensor, so that its working area is located at the level of the lower level of the flask steam pipes. The graduated cylinder, with which the fuel was measured, is placed, without drying, into the refrigerator tube and sealed with cotton wool.

Let us heat the flask with fuel, so that the time between the start of heating and the beginning of distillation (the first drop falls) is not less than 5 and not more than 10 minutes. Let us write down the temperature of the beginning of distillation and, by adjusting the heater, set the distillation rate to 4-5 cm^3·min^{-1}. Next, let us write down the temperature of 10, 20, 30, 40, 50, 60, 70, 80, 90, 96% of the distilled volume of fuel. For diesel fuels, the technical conditions provide for distillation to boil off 96% of the fuel.

The optimal composition of petroleum origin diesel and biodiesel mixture was determined. The above was performed by comparing the results of fractional distillation of diesel fuel of petroleum origin and biodiesel according to the distillation temperatures of the corresponding fuel fractions.

Results and discussion

Our research has shown that one of the main disadvantages of biodiesel fuel based on methyl esters of fatty acids is significantly worse low-temperature properties than diesel fuel of petroleum origin has (Table 1).

Table 1

Cloud point and pour point of biodiesel from various vegetable oils

Indicator	Biodiesel based on fatty acid methyl esters			Diesel fuel (summer)
	soybean oil	sunflower oil	rapeseed oil	
Cloud point, ºC	10.0	9.6	7.9	-5.0
Pour point, ºC	2.7	0.9	–0.8	-10.0

Analysis of the table shows that the low-temperature properties of biodiesel from various vegetable oils are quite close, the limiting ambient temperature, which allows the operation of diesel when using pure biodiesel, is about 10 ºC.

One of the important characteristics fuel affects is the characteristics of filtration and fuel delivery, as well as the atomization characteristics of the fuel during injection associated with the kinematic viscosity of the fuel. Comparative studies of changes in the kinematic viscosity of a mixture of biodiesel with diesel fuel in different concentrations in order to determine the dependences of changes in kinematic viscosity on changes in ambient temperature are carried out (Table 2).

Table 2

Influence of fuel temperature on the kinematic viscosity of mixtures of biodiesel with diesel fuel, $mm^2 \cdot s^{-1}$

Fuel	Temperature, ºC				
	0	3	8	14	20
Biodiesel (RME)	17.45	13.51	10.97	9.12	7.64
70% RME + 30% DF	15.23	11.34	8.96	7.36	7.22
50% RME + 50% DF	14.83	10.83	8.29	6.94	6.02
30% RME + 70% ДDF	13.42	10.11	9.18	6.19	5.21
Diesel fuel (DF)	10.21	8.35	6.13	5.27	4.50

An analysis of the results obtained for the change in viscosity with temperature for mixtures with different concentrations of biodiesel indicates the advisability of using fuel mixtures with a biodiesel content of no more than 30% percent.

Analysis of studies [20; 21] indicates that biodiesel has a heavy molecular structure compared to diesel fuel of petroleum origin. Therefore, when the engine is running on biodiesel, the fuel ignition delay time and the combustion duration increase, requiring an increase in the fuel injection advance angle. Since diesel fuel consists of hydrocarbons of various molecular chain lengths, providing its properties, a comparative fractional acceleration of petroleum-based diesel fuel and biodiesel was performed (Fig. 2).

Analysis of the fractional distillation temperatures of the fuel indicates that biodiesel has a significantly higher distillation temperature than petroleum based diesel fuel. Therefore, it is precisely with this that the need to increase the fuel injection advance angle, a longer delay time for self-ignition and combustion with worse performance is associated.

Analysis of the temperatures of fractional distillation shows that it is necessary to carefully approach the preparation of fuel mixtures. By adding biodiesel to diesel fuel of petroleum origin, we change the content of heavy fractions in it, thus such a fuel mixture needs more time for mixture formation and combustion in the engine cylinder. Therefore, to improve the characteristics of the fuel mixture based on the temperature of the fractional composition, it is possible to make recommendations on the need to change the technology of diesel fuel production.

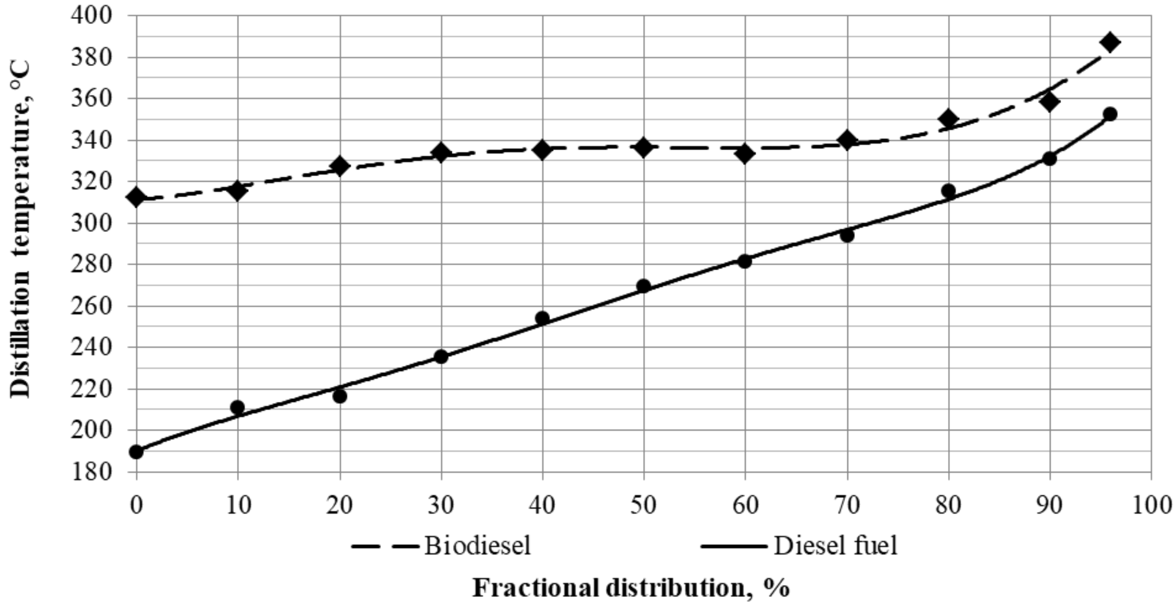

Fig. 2. **Dependence of temperatures of fractional distillation of fuel**

At the same time, when the fuel mixture must contain at least 80% of diesel fuel with a distillation temperature in the range from 190 to 300 C, 20% of the composition falls on the heavy fraction must be compensated for by biodiesel. Such a composition, first of all, will allow minimizing the impact on the combustion process of fuel in the engine cylinder and improving the environmental performance of the combustion of such a fuel mixture. At the same time, this approach will make it possible to send 20% of the heavy fraction of diesel fuel to additional cracking with the formation of a larger amount of light fractions of oil products from oil refining. Considering that the density of biodiesel is higher on average up to 10% of the density of diesel fuel of petroleum origin, this will partially compensate for the decrease in the calorific value of the volume dose of the injected fuel. The use of a gas composition does not require additional regulation of the parameters of the fuel supply by the fuel equipment.

It is planned for future research to produce fuel mixtures that will contain 75...85% of diesel fuel with a fractional distillation temperature up to 300 °C and 25...15% of biodiesel based on methyl esters of fatty acids, respectively. To substantiate the most appropriate fuel composition, it was decided to perform a series of multifactorial experiments to determine the main physical and mechanical characteristics of these fuel mixtures and to conduct comparative studies of operational and environmental indicators of diesel engines.

Conclusions

1. As a result of comparative studies of the physical and mechanical properties of diesel fuel of petroleum origin and biodiesel, as well as studies of the fractional distillation temperature, the most expedient composition of the fuel mixture, consisting of 80% of oil fuel and 20% of biodiesel based on methyl esters of fatty acids, is justified.
2. Based on the results obtained, it is most expedient to use a fuel mixture in the composition of 80% of the fraction of diesel fuel with a distillation temperature of up to 300ºC and 20% of biodiesel as a fuel for diesel internal combustion engines. This fuel composition will have viscosity characteristics and low-temperature properties close to those of summer diesel fuel. Due to the higher density of biodiesel, a fuel mixture containing 20% biodiesel will have almost the same calorific value as diesel fuel of petroleum origin and will not require additional adjustment of the injection cycle volume in modern diesel engines.

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