biofuel, diesel fuel

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THE USE OF BIOFUEL ON THE RAILWAY TRANSPORT

Summary. The potential of biofuel application on rail transport for reducing the dependence on using the non-renewable diesel fuel and improving the environmental characteristics of the locomotive have been considered. The technique of comparative research concerning fuels on the rheostat and through operational tests has been offered. The methods of measuring harmful emissions with exhaust gases and the use of existing methods of controlling the fuel consumption have been developed. The conclusion about the prospects of using on diesel locomotives first the additives to the diesel fuel the biofuels of the first generation (biodiesel), and in future, the fuel of the second generation (synthetic biofuels) has been made.

ИСПОЛЬЗОВАНИЕ БИОТОПЛИВ НА ЖЕЛЕЗНОДОРОЖНОМ ТРАНСПОРТЕ

Аннотация. Рассмотрены возможности применения биотоплив на железнодорожном транспорте для уменьшения зависимости от использования невозобновляемого дизельного топлива и улучшения экологических показателей тепловоза. Предложена методика сравнительных исследований топлив на реостатных и эксплуатационных испытаниях. Разработаны способы замера вредных выбросов с отработавшими газами и использование существующих способов контроля расхода топлива. Делается вывод о перспективности использования на тепловозах вначале добавок в дизельное топливо биотоплив первого поколения (биодизеля), а в перспективе и второго поколения (синтетических биотоплив).

1. INTRODUCTION

At present much attention in the world is paid to the use of renewable energy. This is due to the steady rise in prices for fuels of fossil origin, which when burned increase the concentration of CO_2, and it leads to the increased greenhouse effect on the planet. The solution to this problem is the use of renewable biofuels. Currently, this can be the first generation fuels such as biodiesel, and in the future, after being improved and having a cheaper technology, the second-generation biofuels.

A significant consumption of diesel fuel is noticed on the rail transport and the replacement some of diesel oil for biofuels is an important task in the development of the industry.

The use of such fuels on rail transport affects the economic characteristics of diesel engine and reduces the exhaust gases in the environmental [1 - 3]. The use of these fuels requires the development of methods for determining the characteristics of diesel engine, both on the rheostat, and through operational tests.

2. THE PRODUCTION OF BIOFUELS

At present the biofuels can be implemented into the technological cycle of producing fuels, and further when the fossil fuels are depleted, they can replace them. (Fig. 1) [4].

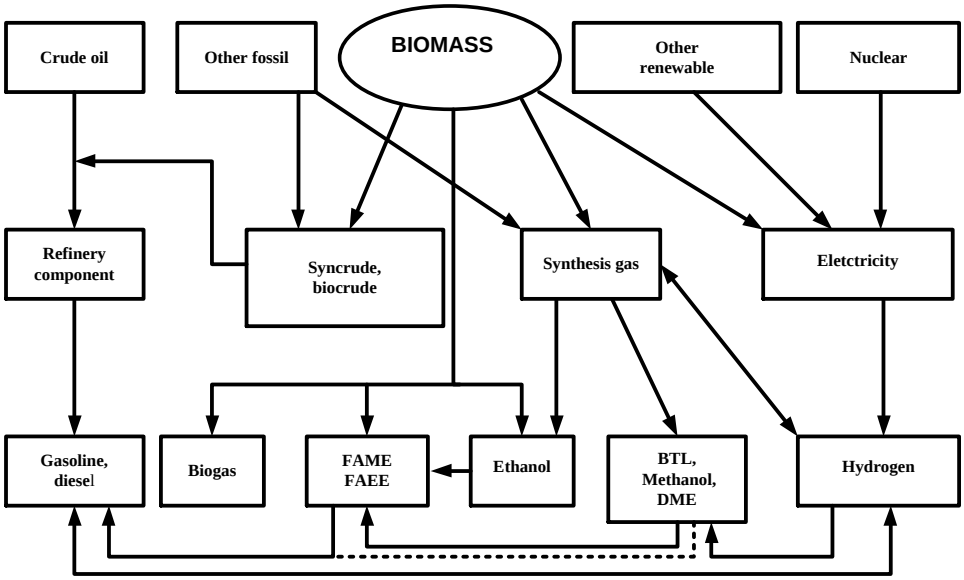


Fig. 1. Process chains for fuel production
Рис. 1. Структура производства топлив

The first-generation fuels from biomass include: biodiesel, vegetable oils, biogases, the second-generation fuels that are produced from the products of biomass CO and H_2 decomposition with the subsequent synthesis according to Fischer-Tropsch reaction.

Another problem should be mentioned, that is the use of food products for biofuels. It is believed that the use of biofuels leads to higher food prices. But in the work [5] it was given that rice does not produce biofuel, but the world prices on rice are growing too. Therefore, the reason for rising the food prices is the synthesis of factors, and the fact that they are used for biofuels is not always the determining factor.

These processes are supposed to be looked at wider. At present the sources of energy are both hydrocarbon fuels and agricultural products which when needed can be used both as food and as fuel. The example of it is the burning of wheat in Sweden to produce heat [6].

In this case, one should be rational when using the energy resources of any origin. For example, Germany has almost completely exhausted their available arable lands, but there are countries that do not fully use their arable lands, for example, Ukraine [7]. Comparing with 1990, the country's acreage have decreased, which allows to redirect a part of agricultural production for biofuels. Arable areas of Ukraine in 1990 amounted to 382,440 km^2 with the total area of Ukraine - 603,700 km^2 (when compared to the whole area of Germany - 357,000 km^2). In Ukraine it is possible to get from one hectare when cultivating the oilseeds from 300 to 1000 kg of oil, equivalent to 282 ... 940 liters of diesel fuel. Compare that in Russia 20 million hectares (200000 km^2) of arable lands are not used [8].

When considering this problem as a complex one, it is necessary to select special methods of crop rotation when applying the technical oilseeds, which are not used for eating. For example, it is the rapeseed oil with high percentage of erucic acid. Thus, in the Ryazan region the linseed oil is planned to use for this purpose [9]. It is also possible to cultivate these crops on the lands where the mine dumps are used as fertilizer, and which have a high content of heavy metals [10].

Much research is being currently carried out in the world as for the use of biofuels with the evaluation of their effect on the economic and environmental characteristics of engines and the impact on the operational indicators, for example, the neutralization systems [11]. In this paper the work of

the engine using diesel fuel with ultra low sulfur percentage and the mixture of diesel fuel with 20 vol. % of biodiesel have been compared. Also the influence of fuels on the characteristics of selective neutralizer of the nitrogen oxides and nitrogen oxides adsorber restoration has been evaluated. When the engine was working on the fuel mixtures, some increase in emissions of NO_x has been reported. But at the same time, the efficiency of adsorption neutralizer was higher at work on the mixture, compared to the work on diesel fuel. For the selective neutralizer restoration no differences of these fuels have been revealed. Also no differences in wear and aging of catalysts have been noticed.

The use of biodiesel additives in diesel fuel has several advantages:

- the use of reproducible fuel that reduces CO_2 emissions into the atmosphere;
- the increased efficiency of the engine;
- the reduced opacity of the exhaust gases;
- the improved lubricating characteristics of fuel;
- the higher temperature of fuel flare, which reduces the possibility of fire, and is especially important in terms of rail transport;
- considering the fact that the diesel locomotive equipment is mostly worn-out, the increased viscosity of bioldiesel will allow to prolong its service life;
- biodiesel has a biological safety and has no harmful effect on the environment when spills (the decomposition occurs under natural conditions).

However, there is a growth in emissions of NO_x, which can be compensated by a decrease in fuel injection advance angle.

At present, it is most possible from all biofuels to use biodiesel on railway transport. In addition, there is a positive experience in using biodiesel on rail transport. [1 – 3, 12]

Thus in the U.S. (Texas) a mixture containing 80% of diesel fuel and 20% of biodiesel in diesel engines have been tested. It was seen that there was a decrease of harmful emissions and the reduction of power losses of the locomotive, which corresponds to the improved fuel economy. But for this region of the U.S., this additive proved to be economically insufficient.

The results of the tests of Group of Companies "Oil product" and JSC „Russian Railways" conducted in 2006 - 2007 on the basis of South-Eastern Railway, confirmed the feasibility of using biodiesel for diesel engines [13]. During testing, RME was used on diesel locomotives ЧМЭ3 from the depot Voronezh - Kursk. From the four locomotives having been tested, the three ones worked on biodiesel with concentration of 5, 10 and 20 vol. % respectively, and the fourth locomotive as controlling one and used a regular diesel fuel. The results obtained showed that biodiesel according to its technical characteristics is almost equal to the conventional fuel, and even by some indicators improves its characteristics. For example, the oxygen content in biodiesel improved the fuel combustion process, and the opacity in the exhaust gases was reduced in some cases up to 60%.

Our research of biofuels [14] indicates that the engine parameters strongly depend on the quality of biodiesel, namely they are to conform to the standards of Ukraine [15], which fully meets the European standard EN 14214. Therefore, the characteristics of the biodiesel tested should maximum approach these standards.

3. THE RHEOSTAT TESTS OF THE LOCOMOTIVE

Considering our experience of investigating the characteristics of diesel locomotives by means of rheostat tests, we propose the following method of testing fuels.

It is recommended to test locomotives with the addition of biodiesel 5, 15 and 30 vol. % in comparison with the work of the locomotive using diesel fuel.

It is necessary to conduct tests on locomotives equipped with the fuel flowmeters of the type БИС Р. In this case, it will be possible to fix the changes in fuel consumption according to the positions of the controller driver. It should be also taken into account, that the combustion heat of the diesel fuel and the fuels with biodiesel additive is different. Therefore it is necessary to determine the efficiency of the engine as follows:

$$\eta_e^{fm} = \frac{3600}{g_e^{fm} \cdot Q_l^{fm}}, \quad (1)$$

Where:

g_e^{fm} – the efficient use of the fuel mixture;

Q_l^{fm} – the lowest heat of combustion of a fuel mixture consisting of a mixture of biodiesel and diesel fuel, which is calculated according to the formula:

$$Q_l^{fm} = N_{bio} \cdot Q_l^{bio} + (1 - N_{bio}) \cdot Q_l^{df}, \text{ kJ/kg}, \quad (2)$$

Where:

N_{bio} – the mass share of biodiesel in the fuel mixture;

Q_l^{bio} – the lowest heat of combustion of biodiesel, kJ/kg;

Q_l^{df} – the lowest heat of combustion of diesel fuel, kJ/kg.

Another important component of the research is the determination of the toxicity of the exhaust gases, which include NOx, opacity, CO and CH.

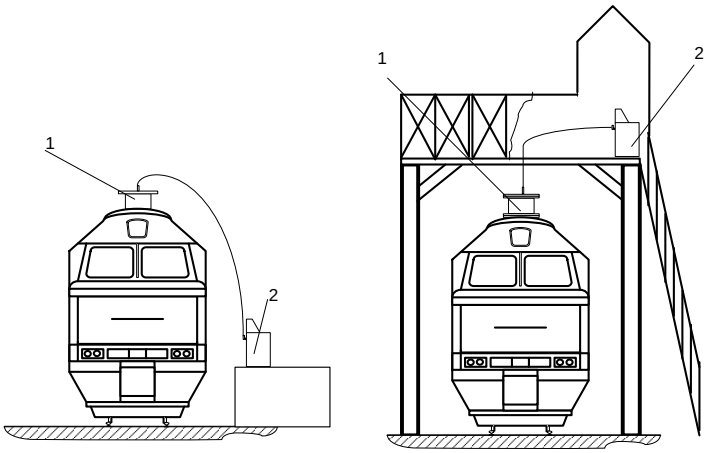
A preferred method of gauging the nitrogen oxides, CO and CH, is to locate on the rheostat the chromatographs with the direct supply of the exhaust gases to be analyzed. The chromatographic method allows determining also the content of CO_2 (a greenhouse gas, which standardization will be introduced in the EU since 2012). But the equipment and the operation of such a measuring system are associated with quite considerable financial costs and it is justified only in case of providing a constant control over the composition of the exhaust gases of the diesel locomotives.

The gauging of opacity is conducted by means of opacimeters. The particular operation of opacimeters of different types should also be taken into account. The existing opacimeters of Hartridge type do not have built-in inducers of the exhaust gases and the flow into opacimeter is accomplished by providing the backpressure on the exhaust. For locomotives it is in most cases, are not acceptable because of the restrictions on backpressure in the exhaust system of the locomotive. This can lead to a change in fuel consumption and other indicators, in particular, to the increase in opacity. It is necessary to use opacimeters with the consumption inducers. The East-Ukrainian National University named after V. Dahl having the order from JSC „Luganskteplovoz" has developed such an opacimeter of ИДС type, which has been successfully used during the rheostat tests [16].

Some words should be said about the consultations, provided by the firm «Hartridge» according to the methods of gauging the opacity of the locomotive's diesels during the rheostat tests. The two ways of opacimeters location have been considered: on the viaduct and on the farm (Fig. 2).

When placing the opacimeter on a viaduct in long gas supplying tubes, especially in cold season, occurs the condensation, which could cause errors when gauging or even block the flow of the exhaust gas into the instrument.

When placing the opacimeter at the farm this disadvantage is eliminated, but there is a problem of calibrating the opacimeter by clean air. According to the representatives of «Hartridge» in the area where clean air is taken away, there may be an increased content of soot particles and when entered the calibration channel they will produce error in the measurements. Based on these consultations, it was proposed to use a special hose for the clean air supply into opacimeter ИДС-3С.



1 - exhaust branch; 2- opacimeter

Fig. 2. The installation schemes of opacimeter for gauging the opacity (on the viaduct-left, on a farm-right)
Рис. 2. Схемы установки дымомер для замера дымности (на эстакаде-слева, на ферме -справа)

4. THE OPERATIONAL TESTS OF THE LOCOMOTIVE

In 2007 having the order from "Ukrzaliznitsya" a schedule of experimental verification of the possibility of using domestically produced biodiesel for diesel engines of Donetsk railway station in the railway depot Kondrashevskaya-Novaya has been made[17]. This work included the following steps: searching for the domestic manufacturer of high-quality biodiesel, poster tests of biodiesel and its mixtures with diesel fuel, and the testing of locomotives. The first two phases have been fully completed.

To perform the third phase of the research the two shunting locomotives ЧМЭ3 equipped with fuel meters БИС-Р were selected, that allowed to record the fuel consumption both during operation and on the individual positions of the controller driver.

Different versions of testing the locomotive with the same load on the same track section have been worked out. Thus, the exhaust gases must be selected after the turbine engine through the existing connection in the aspirating flasks with the subsequent delivery and analysis in the chromatographic laboratory.

To measure the opacity it is necessary to use previously developed portable opacimeter where the opacity is taken away to the filters with the further analysis of the reflected light from the filter, according to the type of opacimeter produced by the company «Bosch». Taking into account the fact that the biodiesel may get into the lubricating oil, it is recommended for a laboratory depot to control its composition not later than after 2 - 3 days of testing.

5. CONCLUSIONS

One of the promising ways to use the renewable fuels is the use of biodiesel on rail transport. It is rational to use it as an additive to diesel fuel in, and in future as an independent fuel. In the first stage it is recommended to use as an additive to diesel fuel, and in the future as an independent fuel. This is a transition to the use of renewable fuels the second generation, in particular, synthetic fuels.

The use of biodiesel fuel that meets European standards, resulting in improved environmental performance: to reduce the opacity, to reduce emissions of nitrogen oxides after appropriate adjustments. At the same time also improving engine efficiency, which is a very urgent task at this time. The use of biofuels, until the new requirements will reduce the payment for environmental damage, given that in Ukraine it is rated for fuel consumption of petroleum origin. Developed requirements instrumentation for such studies. Should be applied in the locomotive built in flow of

fuel. It is recommended to use the smoke meter with built-in facialiator flow of exhaust gas so as not to interfere with operation of diesel. At the same time as the calibration gas must be used without air particulate impurities.

The described technique of conducting this research, designed with the account of the tests of locomotives on the rheostat may be recommended as useful for locomotive plant, and in the future and performance tests.

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